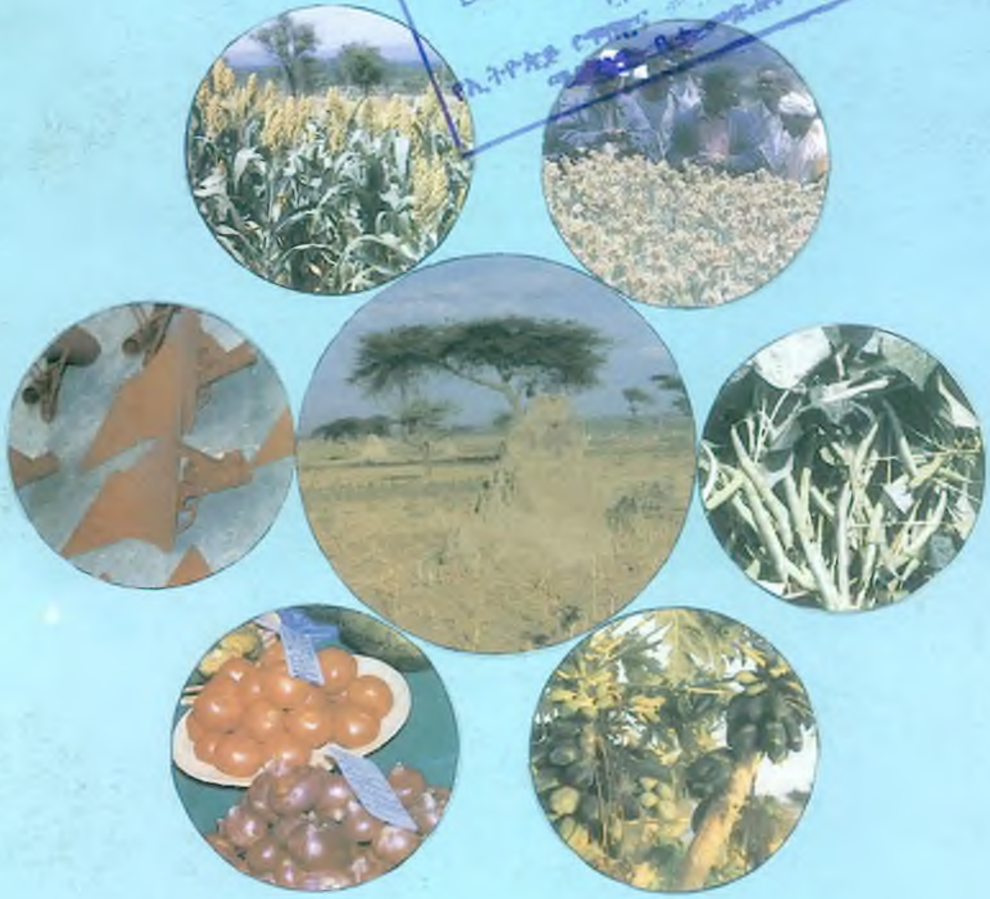
25 Years of Research Experience in Lowland Crops



Proceedings of 25th Anniversary of Nazareth Research Center

22-23 September 1995
Melkassa, Ethiopia

25 Years of Research Experience in Lowland Crops

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Session VI- Technology Transfer

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of the

25th Anniversary Conference of Nazareth Agricultural Research Center: 25 Years of Experience in Lowland Crops Research

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Nazareth/Melkassa, Ethiopia

Sponsored by:

Institute of Agricultural Research
SG 2000 – Ethiopia
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Institute of Agricultural Research
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Content

OPEENING SESSION

FOREWARD

A comprehensive review of 25 years of research and development in lowland crops was presented in a workshop held in Nazareth Research Center, Melkassa between 20-23 September 1995. The theme chosen for the workshop reflected the main objective of the anniversary:25 years of experience in lowland crops research. We work in the area of high soil degradation high soil erosion and erratic rainfall pattern. Technologies have been developed in the area of yield improvement, crop and soil management, moisture conservation, disease and pest management and farm implements. Our experience in the last 25 years were highlighted in this 3 days workshop. Lowland crops such as sorghum, maize, lowland pulses, tef, citrus, grapes, tomato, onion, papayas and sweet potato were emphasized. A very good discussion was made after presentation of individual papers. The discussions focussed on our past achievements and frustrations and the center's future research directions.

We believed at the outset that we would learn better by inviting a wider audience. We were extremely successful in this aspect and more than 100 participants coming from different research and development institutions attended the conference.

The conference highlighted the problems and challenges focused by the Nazareth Agricultural Research Center. The papers that are published here inorder in which they were presented will hopefully, provide a very useful contribution to improvement of the Ethiopian Agriculture. We sincerely believe we all have learned a great deal from the presentations and discussions and these proceedings will serve a useful tool to our future endeavor to better focus and target our clients.

Aberra Deressa (PhD)
Center Manager

ACKNOWLEDGEMENT

The Nazareth Agricultural Research Center would like to thank Dr. Habtu Assefa for compiling and editing these proceedings. Thanks are also extended to Dr. Tsedeke Abate, Dr. Aberra Debelo, Dr. Aberra Deressa, Dr. Lemma Desalgne, Ato Girma Tegegne, Ato Araya Kebede and Ato Melesse Temesgen for assisting in reviewing and editing one or more articles published in this proceedings. The center is very grateful to W/t Aynalem Terefe for typing most of the manuscripts and to W/t Masresha Adafire for making final corrections and type setting. We would like to thank all chairmen and rappoteurs of the various sections and also those who presented papers. The conference could not have been realized without the generous financial contribution of the Institute of Agricultural Research, SG 2000, PGRC/E and Ethiopian Seed Enterprise.

WELCOME ADDRESS

Aberra Deressa (PhD)
Center Manager, Melkassa Research Center

Your Excellency, Dr. Teketel Forsido,
Minister of Agriculture and Board Chairman of the Institute of Agricultural Research !
Invited Guests and Colleagues!
Ladies and Gentlemen!

The objective of this gathering is to officially and communally celebrate the 25th anniversary of the Nazareth Agricultural Research Center. On behalf of the center`s community and myself, I would like to welcome you all, upon your presence on this very commemoration of the center`s birthday.

The center was born on 17th of June 1969, with the objective of coordinating varietal improvement Programme on horticultural crops, which formerly was underway at Melka-Werer. Koka and Bako research Stations in a fragmented manner. The center was established by 5 expatriates sent from the Food and Agricultural Organization (FAO) of the United Nations and 30 non-qualified national staff whom most were contractual workers.

The Nazareth Research Center of the Institute of Agricultural Research (IAR) is located at 117 Km east of Addis, in the Central Rift Valley of the country. The region is a classical representative of the Semi- Arid Areas, where sustained and increased agricultural production is hampered by many natural constraints. Of these, short and unpredictable rainy season, intensive rainfall interspersed with sudden droughts, soil with low infiltration capacity, and thus greater erosion hazard and high evapotranspiration rate during the growing season are prominent.

This is the environment in which we were charged 25 years back, to challenge the rigor of these predicaments through research and technological changes. After 6 years of exclusive research on horticultural crops, a switch over to new strategic scenarios and programmes were made which was implemented when 160 hectares of land from Melkassa was annexed to the center in early 1976.

The current objective of the center are;

1. Generation of improved agricultural technologies, such as drought tolerant crop varieties with acceptable yield and quality, crop management practices including soil and water conservation and soil fertility management.
2. Development of integrated pest and diseases management systems.
3. Development of agricultural implements suitable for various environments.
4. Identifying constraints to agricultural development in the semi arid environment and assess means of alleviating them through technological changes.
5. Popularizing and communicating workable crop production technologies in cooperation with National and Regional level Agricultural Bureaus , to the intended users.

To fulfill these objectives currently the center undertakes its research activities under 8 **divisions. These are; Horticultural Crops Improvement,** Field Crops Improvement, Agronomy/ Crop Physiology, Agricultural Economics, Farm Implements, Crops Protection, Food Science, and Research-Extension. Agrometeorology and Farm Management as the technical service offering units, have also long been recognized. In addition, the center is also a national coordinating center for two commodities; sorghum and Agricultural Implements Improvement Programmes, Currently our mandate crops include; Sorghum, tef and maize (from cereals), haricot bean and cowpea (from lowland pulses), tomato, pepper, onion, and green beans (from vegetables),sweet potato and Irish potato (from root crops) ,citrus, banana, papaya, mango, and other tropical and sub tropical fruits (from fruits). Over the years, the center demonstrated a linear organizational accretion, in terms of critical mass development of both human and physical resources. During its inception, the center had no qualified researchers and had only 30 staff, most of whom were supporting staff and had only 5 hectares of land on which to conduct research in the town of Nazareth. But today we have grown to 286 staff members including 5 PhDs, 19 MScs, 23 BScs, 41 Diploma holders and 198 supporting staff.

The budget allocated for the center has increased from an average of Birr 139470 per year for the first 6 years to 3.5 million during the 1994/95 fiscal year. Similarly, the land area for research and other construction purposes has increased from about 10 ha at the inception to the current 200 ha. Of this land area, about 90 ha is for research purpose and 100 ha for construction purposes.

Concerted effort is being underway, to maintain the rational integration among our objectives, programmes and the existing human and physical resources in terms of priorities, possibilities and opportunities.

Your Excellencies!
Dear Participants!

Let us recall once again that, our work is in an environment of soil degradation, as caused by water and wind erosion, intensive and erratic rainfall and high evapotranspiration, resulting in poor crop harvest by substance farmers. Therefore, farmers are in short of cash and hence short of agricultural inputs.

We researchers, need to respond within the limit to the needs of these subsistent farmers. Though we believe that more should be done, modest achievements have been recorded in terms of improved agricultural technologies.

Among these; onion variety Adama Red, sorghum varieties such as 76-T1# 23, Gambella 1107, Dinkmash, Seredo, Birmash IS 9302; farm implements like tie ridgers, planter, mould board plough, weeder, donkey cart, haricot bean varieties like Roba-1, and Awash-1 ; crop management practices such as moisture conservation techniques ,crop protection practices and others have been identified.

Moreover, 19888 quintals of basic seeds of improved sorghum varieties, 2793 quintals of maize, 1948 quintals of haricot bean varieties were multiplied and disseminated to various users directly and/or through the Ethiopian Seed Corporation, Ministry of Agriculture and other governmental and non-governmental organizations. 3700 seedlings of fruits, 294, 250 cuttings of root crops, 13.2 kg of vegetables seeds have also been distributed. Besides, 6

Donkey Carts, 20 Mould boards, and 100 Tie-ridgers were multiplied and distributed. Furthermore, our Research-Extension experts in cooperation with Regional Agricultural Office Staff, put relentless effort to popularize generated technologies through training and demonstration.

When I talk of the center`s achievements and contributions to the Ethiopian Agriculture in last 25 years, I don`t mean that the road has been without problems. Like any of its sister research centers, this center has been facing several constraints: inadequate facilities such as vehicles, irrigation facilities, laboratory and office equipment, lack of consistent and sustained training programm at all levels, high staff turnover, lack of incentives, and so on. Most importantly, the center was confronted with one-time extremely destructive looting during the May 1991 political unrest, the time when we were deprived of all properties with the exception of the walls and roofs of the buildings. But thanks to the Ethiopian Government and the generous support of the international organizations, UNDP and FAO in particular, we were able to restore this center at least to the level it was before 1991.

Your excellencies,
Dear colleagues

We are very much pleased to celebrate this 25th birth day of our center at a time when the Government of the Federal Republic of Ethiopia is taking great steps towards improving Ethiopian agriculture.

Beyond any doubt, agriculture remains to be the spring board for the whole range of economic development in Ethiopia. The need for Agricultural Research towards boosting the out put from the agricultural and other sectors is therefore vital.

There is no time for us (Researchers) for complacency. We intellectually and consciously understand that there is a need to revitalize our commitments and manoeuver our mental and available physical resources to keep on generating suitable technologies tailored to the needs of various client.

To this end, our future direction will focus on impact assessment of what we have done in the past for redirecting our efforts to farmers needs, sponsoring workshops, seminars, imparting training to farmers and others to contribute to the sustainable and increased productivity in the semi arid areas of the country. Since ,maize and tef are absorbing greater interest from our users side , research on these food crops will be strengthened. Issues dominating the real farmers biological and socioeconomic circumstances, such as variability in rainfall and soil fertility, integrated pest and diseases management , the use of low cost farm machineries and livestock research will be emphasized. In general , appreciation of the farmers indigenous knowledge and their participation in research designing and implementation will be mission critical to us, to enable them cope with the existing complex farming systems problems. The need for capability building in terms of qualified manpower and office and field facilities is therefore so vital.

At this juncture, I would like to acknowledge with gratitude, the sustained understanding and budget the allocation of the government of Ethiopia for this costly venture. We are also thankful to UNDP, FAO, World Bank, CIAT, CIMMYT and other donor organizations for their unreserved financial and material assistance to rehabilitate the center.

My deepest appreciation also goes to the Institute of Agricultural Research and other organizations such as PGRC/E, SG 2000 and Ethiopian Seed Enterprise without whose support this anniversary would have not possible. Last but not least, I am thankful to my colleagues who did their best to make this anniversary a success story.

Finally, in this workshop, some 35 technical papers assessing the past achievements, shortfalls and future research direction of the Nazareth Research Center and policy matters related issues will be presented. I am sure this deliberation will stimulate discussion and draw the most rewarding future research areas related to our mission.

I thank you all, for honoring our invitation and we wish you a nice stay at this modest and enjoyable town of Nazareth.

Thank you!

OPENING ADDRESS

Your Excellencies,
Distinguished Guests,
Ladies and Gentlemen!

It is an honor and great pleasure for me to participate in the opening of the 25th Anniversary of the Nazareth Research Center at Melkassa of the Institute of Agricultural Research (IAR). At the outset, I would like to congratulate the management and staff of the Center for taking the initiative to organize this workshop, and the exhibition and the field day that will follow the workshop. It is only through such fora that we as researchers can get feedback from users of our technologies and evaluate ourselves so that we can get satisfaction from and feel good about our contributions to the well being of Ethiopian agriculture on one hand, and learn lessons from our past efforts on technology generation and dissemination on the other, so that we can redirect our efforts towards the current and future needs of the country. I hope that other sister research centers in the IAR will take similar initiatives.

Your Excellencies,
Distinguished Guests,
Ladies and Gentlemen!

As most of you very well know, our country, Ethiopia, is endowed with a great agro-ecological diversity, with corresponding diversity in climate, and with a wide variety of plant and animal life, and as such is the original home of many plants and animals. In spite of this blessing from nature, we have been faced with the perennial problems of increasing land degradation, declines in crop yields, food shortages, malnutrition, etc., etc. IAR was established in 1966 to address these problems by generating appropriate technologies to alleviate them. Have we (IAR) lived up to the expectations of the beneficiaries of our technologies? I will not dare to answer this question, but leave it to the workshop participants to tackle it at the end of the workshop. Please tell us your candid opions about our research results.

It is a gratifying coincidence that this workshop is being launched at a time when the Government of Federal Democratic Republic of Ethiopia is taking giant steps towards agricultural development in the following five years.

Nazareth Research Center was established 25 years ago with staff large enough to fit in one residence building, one Volkswagen van and with the land area for research not exceeding 10 hectares, located at Koka and Melkassa; today we are very happy to see it grow to its present capacity of 45 research staff with fairly well equipped office and laboratory facilities and more than 200 hectares of land for research and seed multiplication purposes. The Center was originally intended to be the national horticultural center; over the last twenty years or so, however, it has been also the national or coordinating center for research on Lowland Pulses, Sorghum, Agricultural Implements, and Dryland Agronomy/Physiology. Research staff in each one of these sections have tried their best to accomplish whatever they could, given the objective conditions that existed in the country in general and in IAR in particular. I hope they will keep up their exemplary efforts in the future.

Your Excellencies,
Distinguished Guests,
Ladies and Gentlemen!

You may be wondering what the contributions of this research to the Ethiopian agriculture have been. As I stated earlier, the purpose of this workshop is not to brag about our achievements, but to get feedback from users and potential users of our technologies. I do not want to go into details of what you will be deliberating over the next three days but I think it is in order for me to give you a generalized view on this issue. I am sure most of you who are familiar with IAR and this research center in particular are aware of the various technologies generated by this center: the various crop varieties such Adama Red (onion); Dinkmash, Birmash, Gambella 1057 (sorghum); Roba I, Awash 1 (haricot bean); etc. Crop varieties resistant to pests and diseases; crop management practices; tied ridges to conserve moisture in moisture deficit areas; and various farm implements. But above all, it is very satisfying to see the human resource development of this center; today we are blessed to witness the improvement in staff situation of this center not only in terms of quantity but in quality as well. I am not exaggerating if I said that we are proud to have among most highly qualified, experienced and regarded researchers at the Nazareth Research Center. It is my hope that these scientists and their younger colleagues are well equipped to take on the challenges of improved agricultural production, nutrition, food self-sufficiency and sustainability of our agricultural systems.

Your Excellencies,
Distinguished Guests,
Ladies and Gentlemen!

When I talked about the achievements of this center above I do not mean that the road on 25 years has been without problems. Like many of its sister research centers this center has been faced with several constraints: inadequate facilities and equipment (vehicles, irrigation facilities, laboratory and office equipment, etc.), lack of consistent and sustained training program at all levels, high staff turnover, lack of incentive, and so on. Most importantly, this center was looted and ransacked during the May 1991 disturbances during the EPRDF takeover of the government; we lost almost everything with the exception of the walls and roofs of the buildings. But thanks to the generous support of the international organizations, UNDP and FAO in particular, we were able to replace lost equipment and facilities and bring back Nazareth Research Center at least to the level it was before 1991. The Transitional Government of Ethiopia also has been doing its level best to boost the morale of our staff through countrywide salary increaments and promotions. Currently we are in the process of getting the career structure approved by the government and I have every reason to believe that it will be given a positive review. This, I hope, will further make the working environment for our scientists reasonably more conducive.

Once again may I take this opportunity to thank the Melkassa Research Center staff, in particular the center management and organizing committee for taking their time to organize this timely event. I would also like to thank all participants of this workshop for their participation and contribution. My deepest appreciations are extended to all organizations and individuals whose contributions have made it possible for this workshop to come to pass.

Finally, I declare this workshop open and wish you all the best in your deliberations.

I thank you!

SESSION I
Breeding and Selection

Chair: Dr. Getinet Gebeyehu
Rapporteur: Ato Eshetu Dejene

REVIEW OF FRUIT BREEDING AND AGRONOMY RESEARCH IN THE LAST TWO AND HALF DECADES

Seifu Gebre-Mariam; Nazareth Research Center, PO Box 436, Nazareth, Ethiopia.

Abstract

Many of the fruits are new to Ethiopian agriculture. Cultural practices and importance of fruits in the diet were not understood by the public. Now the trend is changing and very encouraging signs are observed both by producers and consumers. IAR's responsibilities will be to play a crucial role by identifying and finding solutions for existing and expected problems in the field. Research on fruits started at Melka Werer; coordination of fruit research including planning, planting material propagation, supervision and report writing was done from the then National Horticultural Research Center, the present Nazareth Agriculture Research Center. At the early stage, researchers introduced all sorts of fruits to study their adaptability. Later on they prioritized and concentrated on few fruit crops; and specialization of research centers was introduced. As a result several improved varieties were recommended to fruit growers. Besides, studies on major cultural practices including plant protection, spacing, fertilization and irrigation were initiated. It is only recently that individuals and organizations showed interest in fruits. To help this trend Nazareth Research Center launched extension program to reach all potential users. Strong activities in training of SMSs, DAs and farmers and distribution of planting materials to farmers and urban dwellers started. In the future, strengthening of various disciplines will continue and attempt will be made to disseminate existing technologies to users to assist fruit industry development in the country.

Introduction

Statistical information on horticultural crops in general and fruits in particulars are not available in Ethiopia. As a result it is difficult to indicate the actual production, productivity, per capita consumption, and export of major fruits. But the importance of fruits in the country's economy as source of vitamin and minerals to balance cereal diet, row materials for local industries, as saver and earner of foreign currency through import substitute and export is evident. Though the country has great potential to produce various fruits, the sector's role in the country's socio economy life was minimum.

In 1971, National Horticulture Center of the Institute of Agriculture Research (IAR) was established to coordinate researches on horticultural crops. Research on fruits was a major section and concentrated its research on citrus, banana, grapes, mango, avocado, pineapple and temperate fruits. Quite a lot of varieties were introduced and intensive screening were made in the major IAR research centers and interested state farms. Once good varieties are identified appropriate cultural practices that improve yield and quality were studied. Due to the nature of the crops and the land holding system of the country in the last two decades the major beneficiaries of research output were state sectors.

Planting materials are vehicles to transfer technologies developed by research centers to users. One reason for slow development of fruit industry in the country is the absence of government or private nurseries that propagate and distribute quality and true to name fruit trees. In many cases inferior and unnamed varieties, mostly seedlings, are grown because of lack of improved planting materials. As a result yield and quality of most fruits are considerably low.

To minimize the growing demand of planting materials by users the IAR in collaboration with regional and zonal agricultural offices and non government organizations (NGOS) established fruit nurseries to propagate and distribute fruit trees in respective regions and zones.

In spite of the existing potential, per capita production and consumption is one of the least among developing countries. In recent years demand for fruit and fruit products is increasing at alarming rate. This is an encouraging sign as well as a challenge to researches to develop technologies in the field of breeding, agronomy, plant protection, utilization packaging transportation, storage and processing.

Citrus

Variety Observation Trials

Melka Werer

The first experimental citrus orchard was planted at Melka Werer Research Center in 1967. Twenty combinations of seventeen scions and six rootstocks entered in the first lot. In the second lot, 58 combinations were made in 1974 (6). In general the quality of orange fruits at Melka Werer was not high. Fruits have an excessive high sugar/acid ratio, high fiber content and remain greenish yellow. Granulation, a physiological disorder causing drying of juice sacs, is very common particularly for Washington Naval (3). Keeping quality of grape fruit has been exceptionally good but that of lemons and mandarins is less so. Keeping quality for the latter can be improved by harvesting relatively early and carefully handling fruits at harvest and there after (4).

Campbell Valencia on Troyer Citrange, Frost Valencia on Sweet Orange and Jaffa on Trifoliate gave higher mean yield in one lot at Melka Werer. On the other lot, Olinda Valencia and Ruby Blood on Troyer Citrange and Jaffa on Macrophyla become the best yielders among 19 scion/stock combinations. Parent Washington Navel performed poorly at Melka Werer in terms of yield and quality. Hence, it is recommended only in relatively cool climate. Dancy on different rootstocks stood first in yield from lots followed by Fair child. Satsuma produced puffy fruits (13). Red Blush on Troyer Citrange gave highest yield among grape fruit varieties followed by Reed on Troyer Citrange in the first lot. Reed, Red Blush and JBC Marsh remained high yielders.

Cook Eureka and Alen Eureka on Macrophylla gave good yield at Melka Werer in both lots. Frost Lisbon on Troyer Citrange showed much more severe symptoms of boron toxicity. Lemons were observed to be the most susceptible to boron toxicity injury. Bears was the only lime variety tested and gave highest fruit yield on rough lemon.

Unmarketability was extremely high for all citrus species at later stage and yield decreased drastically. The loss was high for lemon. The real reason for the decline is unknown.

Unsuitability of Middle Awash for commercial citrus production was reported as early as 1970 due to high temperature, soil problems, disease and insect complex (10). Temperatures at Melka Werer are too high for the production of high quality orange and mandarin (11). At Melka Werer considerable losses have occurred from a brown rot 'stylar end rot' which is reported to be a physiological disorder (8). Problems of minor element deficiency and/or toxicity was observed at early stage (IAR, 1971). Salt and Boron in the soil is at toxic level and deficiency symptoms of zinc and manganese were observed on trees. Viruses, foot rot gummosis and insects exacerbated the problem (1). Due to these complex problems citrus activities at Melka Werer were reduced substantially.

Troyer Citrange found to be unsuitable at Melka Werer but Macrophylla was much better. Parent Washington and Satsuma performed poor. Trifoliate and its hybrids are not suitable for Melka Werer area. Sour orange for orange, mandarin and grapefruit, Macrophylla for lemon and lime are suggested. It was observed that Melka Werer is suitable for the production of grapefruit, lime and lemon and is less suitable for orange and mandarin (3). Grapefruit, lemon, lime and late orange and mandarin cultivars may be tried in the area. Till adequate information is obtained commercial citrus production is not recommended in the Middle Awash.

Koka

Koka is not a representative site of the region. A better result was expected in the region with fertile soil and adequate irrigation water. The soil is poor and the desiccating wind is hostile for fruit trees. In some cases stones were dug out and replaced by soil and manure before planting the trees. Tall pigeon pea trees were inter-planted to provide shelter (6).

At Koka an experimental citrus orchard comprising of 30 stock/scion combinations was established starting 1972. Bud wood was taken exclusively from the trees at Melka Werer, which were imported as virus indexed material from California (4, 11, 12).

Oranges in general perform well at Koka compared with Melka Werer. Internal quality of fruits fall within the range of world standard of first quality. The fiber or 'rag' content is acceptably low, develop typical orange skin color. Olinda Valencia on Troyer Citrange, Frost Valencia on Rough Lemon and Jaffa on Sour Orange were the first three top yielders among 18 orange scion/stock combinations. Ruby Blood, Parent Washington Naval and Campbell Valencia on Troyer Citrange ranked 4th to 6th in yield. Their quality is good and exceptionally high for Parent Washington Naval (7).

Among mandarin combinations tested, Dancy on Troyer Citrange and Fairchild on Troyer Citrange and on Cleopatra Mandarin out yielded other combinations. Quality is generally good but fruits were highly attacked by birds (7). Grape fruit cultivars were not doing well as in Melka Werer. Red Blush did not develop the pink color. Fruit drop was very common and acceptance of grapefruit by consumers was low (7). Reed and Red Blush on Troyer Citrange yielded better than the other combinations.

At early stage lemon did will compared with other citrus species tested. Over the years it declined and many trees died due to a complex problem of diseases and insects. Frost Lisbon on Troyer Citrange gave the highest marketable yield followed by Allen Eureka on Rangpur Lime and Cook Eureka on Troyer Citrange. Bears was the only lime variety tested and gave high yield on Troyer Citrange followed by on Macrophylla and on Rough lemon. Valencias (Olinda and Frost on Troyer Citrange) Jaffa on Sour Orange and Macrophylla, Parent Washington Naval on Troyer Dancy and Fair Child on Troyer Citrange are tentatively recommended for the area.

Attempt was made to establish citrus observational plots at Bako, Gambella, Gode, Holetta and Jima. These plots were abandoned later due to various reasons.

Bako

In 1972, variety observation trial was established at Bako Research Center. However, the site was not representative of the area (heavy clay and had water logging problem). Many plants died and others were stunted. A new experimental orchard was established in 1976 in areas which was believed to be representative of the region (7). Jaffa and Campbell Valencia on Troyer Citrange (Orange), Freemont on Troyer Citrange (Mandarin), Allen Eureka on Troyer Citrange and Frost Lisbon on Macrophylla (lemon), Bears on Troyer Citrange (lime) performed better than the other combinations (6,7).

Gambella

In cooperation with EPID of MOA, citrus variety observation trial was established at Gambella in 1977 on upland soil. After a year, trees were severely pruned unnecessarily. Flooding and grass fire destroyed many of the citrus plants established at Gambella (6,7,13).

Gode

A citrus collection consisting of 36 scion/rootstock combinations was imported from U.S.A by Alemaya College of Agriculture and planted early in 1970 at Gode (3). Due to security problem in the region full attention was not given to the orchard. The trial was abandoned later on.

Holetta

As expected citrus trees planted at Holetta made unsatisfactory growth. Holetta is too cold for testing citrus species and varieties (13).

Jima

Trial Orchard comprising of 136 trees was established at Jima (4). Lack of vigor, chlorosis, heavy and premature leaf fall, dropping of fruit before maturity, and very poor fruit quality were some of the symptoms observed. 'Greening' and high ground water level were observed to be the major causes for the decline of the orchard. As a result the trial was discontinued (13).

Irrigation

From irrigation frequency trial comprising of six citrus varieties on different rootstocks at Melka Werer it was concluded that irrigation at intervals of 1, 2, 3, and 4 weeks have no effect on fruit yield and qualities. Based on climate and plant-soil-water relationship for Melka Werer growing condition, irrigation once in three week in August-May and once in two weeks in June-July, 10 cm per application and a total of 19 irrigation per year is recommended.

Fertilizer

No fertilizer trial was conducted on citrus. All recommendations are from literature.

Spacing

The spacing 7m X 7m was found to be narrow for grape fruit and lemon at Melka Werer. At Melka Werer, 9m X 9m spacings are recommended for grapefruit, lime and lemon. For Upper

Awash and similar areas, 7m X 7m is adequate. In areas where fertility is low smaller spacings can be used (8, 13).

Propagation

In the early 1970s, there were citrus orchards of various sizes throughout the country. Most of these orchards were of unknown origin, started from seedlings or scions budded on unknown rootstocks Their performance was unsatisfactory due to complex problems of diseases, insects and other factors. To alleviate these problems, propagation of citrus from imported, known origin and materials free from known diseases started at Melka Werer, Nazareth and Jima.

These nurseries were intended to produce budded trees for research purposes. Due to lack of commercial nurseries in the country some trees were provided to Ministry of Agriculture, farmers, schools urban dwellers and commercial producers. Propagation and distribution of promising cultivars will continue till reliable commercial nurseries are established.

Propagation of citrus at Jima faced problems of transporting and preserving bud wood from Melka Werer. Earlier, due to fast growth of both rootstock and scion it was decided to concentrate citrus propagation at Melka Werer (3). This decision was reversed later on and Melkassa became and still is the major propagation center in the IAR.

One problem in nursery activity is lack of virus indexing program to make sure that the mother trees are free from diseases. To propagate healthy planting materials for distribution one must be sure that mother trees that are going to be used for propagation are free from major diseases. Though disease free materials were imported originally no one knows for sure that the materials are free from diseases now. The attempt made to establish a citrus virus indexing program in the IAR was not successful. To have a sound base for citrus industry in the country virus indexing program is essential (8).

Citrus Foundation Blocks

Initially all seeds and bud woods for research and development were imported and that was found to be expensive and inconvenient. To minimize these problems rootstock foundation blocks from known sources were established at Melkassa and Melka Werer Agricultural Research Centers. The rootstock foundation block at Melkassa comprised of ten rootstocks and five virus indicator cultivars.

Citrus scion foundation blocks were established at Melkassa, Melka Werer and Merti to serve as reliable sources of materials for citrus research and development in the country. Merti state farm is now successful in producing its own seeds (6, 7). In the new block 8 groups of citrus namely orange (17), Mandarin (13), tangor (1), tangelo (2), Grapefruit (4), lime (1) and lemon (3) a total of 41 cultivars each budded on three rootstocks entered. It is progressing well. The scion and rootstock foundation blocks can provide the needed seed and bud woods for the country's citrus industry.

Rootstocks

Trifoliate

Except at Jima on the acid soil, Trifoliate rootstock performed poorly at Melka Werer and Nazareth nursery sites. It is probably sensitive to alkalinity and thus not recommended in the Awash Valley (4).

Troyer citrange (Trifoliate hybrid) and *Carizo Citrange*

Troyer citrange is resistant to tristeza, not tolerant to alkalinity and high pH, and difficult to establish in the nursery. It is recommended for orange, mandarin and grapefruit where the soil pH is not higher than 6.5. It is not doing well at Melka Werer and similar areas (11).

Sour orange

Sour orange is a commonly used rootstock in Ethiopia. It is susceptible to tristeza, resistant to root rot, produces good fruit quality of the scion, relatively tolerant to alkalinity and easy to produce in the nursery. It is recommended for orange, mandarin and grape fruit where the soil pH exceeds 6.5.

Rough lemon

Rough lemon is common in Nazareth and Billate area. It is susceptible to root rot and gummosis. Fruit quality in the scion is not high but it is easy to grow in the nursery.

Macrophylla

Appears to be tolerant to alkalinity, reduce the intake of boron, easy to produce in the nursery, recommended for lemon and lime in the Middle Awash (11).

Rangpur Lime

It is a fast growing stock in the nursery and early growth of scions is good.

Sweet orange

Susceptible to root rot.

Ongoing Research and Development Activities

Scion and rootstock foundation blocks

The scion foundation block at Melkassa is serving as an observational trial as well as source of bud sticks for propagation.

Preliminary evaluation of the existing citrus

From a preliminary evaluation of the existing citrus scion/rootstock combinations at Nura Era state farm, interesting information are being collected for the last few years. This is expected to give some hints on the performance of the combinations at Upper Awash growing condition.

Effect of selected rootstocks on selected Orange and Mandarin scions.
Use of different rootstocks for different scion cultivars and varied number of trees per treatment hindered proper evaluation of scions, rootstocks and their interaction (6). Use of rootstock is very common practice in citrus industry for various reasons. Budding bear fruits earlier compared with seedlings. Rootstocks are developed to tolerate soil hazards such as elemental toxicity, salinity and soil-borne diseases. Such rootstocks enable the sensitive desirable scions to be produced in problematic areas. Some rootstocks have desirable effect on scions such as dwarfing, yield and quality of fruits.

To study the effect of five rootstocks on growth, yield and quality, five orange and three mandarin varieties were established in 1989 at Melkassa. The two trials are progressing well. Vegetative and yield data are taken for the last few years. They will be continued till adequate information are collected.

Small scale citrus propagation for research and development both at the center, MOA and NGO nurseries

Demonstrations on farmers fields, schools, and individual gardens

Problems

- Absence of virus indexing facilities in the country is limiting production of virus-free, certified citrus planting materials.
- Absence of government or non-government nurseries limits the use of available commercial citrus cultivars.
- Lack of proper studies on viruses and other diseases-citrus greening disease and its vector, Trioza erytreae, tristeza complex and the vectors, psorosis virus, exocortis viroid, cachexia (xyloporosis), 'greening', etc.
- Lack of systematic and continuous studies on the major insects and diseases and developing appropriate control measures-False codling moth, Mediterranean fruit fly, scale insects etc. Phytophthora foot rot/Brown rot gummosis
- Lack of nutritional requirement studies of citrus including deficiency and toxicity of minor elements.

Insufficient information on the optimum and frequency of irrigation.

- *Acute shortage of trained manpower to work in variety development, plant protection, soil* nutrition, irrigation, weed control, quality analysis, post harvest handling etc.

Lack of field and laboratory facilities to conduct meaningful research

Banana

In 1971 Poyo from Eritrea and two varieties Muraro and Uganda Red from kenya were obtained and planted at Melka Werer. In 1972, after multiplication, these varieties were established in

Jima, Bako, Melkassa and Gambella. A second lot was introduced from Kenya and planted at Jima in 1972 (4, 11).

From an observational trial at Gambella, Dwarf Cavendish gave higher fruit yield followed by Poyo (7). From variety trial conducted in 1972-1978, Ducasse Hybrid, Mattuke and Gititi were found to be adapted to Melko growing conditions. Among the six cultivars tested at Melka werer, Ducasse Hybrid gave significantly high yield followed by Plantain. Uganda Red was the least yielder. Poyo, Muraro and Giant Cavendish were intermediate (7). Ducasse hybrid commonly refereed as 'Kenya' performs relatively well under poor management and is relatively tolerant to growing hazards such as frost, drought and wind. Its yield is comparable with commercial varieties (Poyo and Giant Cavendish) and has a better keeping quality. But it gives small sized fruits that are inferior in flavor. Hence, it is recommended for marginal areas and under farmers conditions.

Dwarf Cavendish is highly susceptible to burrowing nematode in the Middle Awash and infected by cigar end rot in Melko. It is also susceptible to frost and wind damage. It has fingers of acceptable size but hands are closely spaced on the stalk which create difficulty in preparation. It is also reported that fruits fail to color under relatively cool weather and has short shelf life compared with Poyo and Giant Cavendish. Considering the above points the variety is not recommended (8, 12). Among commercial varieties Poyo and Giant Cavendish are the best in yield and quality of fruits.

In 1989, banana nursery was started at Melkassa by establishing varieties available in the Research Center and collected locally. In 1990, five more collections were added. In 1991, 32 cultivars in test tubes were received from Belgium.

Ducasse hybrid, Giant cavendish, Gititi, Dwarf Cavendish, Poyo and Wondo Genet I from the first lot, Pisang Raja, William I and II, Dwarf Cavendish and Robusta from the second lot were promising cultivars under Nazareth/Melkassa condition. Melkassa is marginal area for commercial banana production due to its relatively low temperature. Hence, research activities on banana was reduced to maintenance and propagation of planting materials for distribution.

Varieties at Melkassa were evaluated for general performance. Those cultivars that performed best under Nazareth condition are multiplied and distributed to users around Nazareth and places that have similar growing conditions. Most of these materials are established at Melka Werer, Jima, Awassa/Areka and Upper Awash for further evaluation. Indicative results are coming up from Melka Werer observation trial.

In cooperation with state farms, clump management and fertilizer (N&K) trials were conducted at Melka Sedi and Awara Melka state farms. Very promising indications were obtained from these trials but not continued due to civil unrest in the region. Leaving four or five suckers per hill at a time and application of potassium have positive effect on yield and quality of banana. Considering the importance of the practice in banana yield and quality, Upper Awash Agriculture Enterprise reestablished the trials at Awara Melka farm. The optimum irrigation regime recommended for banana in the Middle Awash is an application of 10 cm given at frequency of once in two weeks (7). 2.5 m X 2.5 m spacings are suggested for commercial banana production.

Promising cultivars are being demonstrated on farmers fields and MOA nursery sites. These cultivars are propagated in the research centers, MOA and NGO nurseries.

Deciduous fruits

Deciduous fruits comprising apple, pear, plum, peach, almond, quince, pomegranate, nectarine, apricot, fig and persimmon imported from California in 1971 were planted at Nazareth. Then they were transferred to Koka, Jima, Holetta, Melka Werer and Bako (11). In 1976 new cultivars were planted at Koka and Holetta, and a new trial was established at Chencha (14).

Due to their chilling requirement, diseases and other problems plum and fig performance was very poor at Jima. Hence the observation trials were terminated (4, 6). From screening trial of deciduous fruits the apple variety 'Winter Banana' produced fruit of good quality at Koka and Holetta. At Holetta the peach variety Ventura and the nectarine variety Penamint produced excellent quality. Among plum varieties Beauty, Santa Rosa and Frontier produced the best growth (12). At Holetta Satsuma is late while Beauty and Frontier are early maturing varieties (13, 14). Beauty is a dessert variety of good quality whilst Frontier and Satsuma are more suitable for jam making and canning.

Almond cultivars at Holetta have made good growth but observed to be very light bearers. Walnut and quince are considered to be sufficiently well adapted to Holetta. Currant and gooseberry were found to be unadaptable both at Koka and Holetta condition (14).

An observational trial of deciduous fruits was established at Bekoji in 1979. Fruiting was impressive but land was taken and the trees were abandoned (7).

At Kulumsa an observational trial of temperate fruits comprising of apple (five cultivars), plum (10 cultivar), peach (10 cultivars) were established in June 1976. The apple and plum cultivars were found to be unadaptable to Kulumsa growing conditions. Varieties 13/27, Florida Red and Florida Bell gave fruits in 1978. Though the trial was terminated years back some trees are still surviving to date.

Dormant buds are not breaking uniformly which is expected to be due to insufficient chilling in the Ethiopian condition, particularly in warmer areas. This resulted in poor yield. Though care was taken to import varieties which have a small chilling requirement, it was not possible to get uniform bud break. An attempt was made to break dormancy artificially by spraying tar oil distillate at 5 % and 10 % strength in September at Koka and Holetta (4). Based on dormancy score (the extent of prolonged dormancy delayed opening of buds) a good number of cultivars were discarded at Koka. This includes almost all quince, almond, nectarine and peach varieties.

Propagation

Rootstock seed of plum and peach, imported from California, were planted out for budding at Nazareth and Koka (11). Myrobolan plum was the major rootstock used. It made an excellent growth at Koka. Seedlings at Jima were infected with crown gall and decided not to plant them in the field (4). Demand by individuals cannot be met due to lack of deciduous fruit nursery (6)

Grapes

Many of the varieties in commercial vineyards and home garden are unnamed (7). Five grape cultivars were planted at Melka werer in 1971. In December 1972 Rubier, Thompson Seedless, Perlette and Golden Muscat gave some fruits. Powdery mildew attack was very severe even after introducing a strict routine spray at 10 days interval. Bird damage was another problem in the station (4, 11).

At Koka 15 varieties were established in 1972 as national collection to serve as source of reliable planting material for future use in the country (4). But due to desiccating wind and poor soil development, the result was not satisfactory (12). Small collections were also established at Holetta, Jima, and Bako. The Melka Werer variety observation trial was abandoned due to poor adaptation and difficulty in controlling diseases and birds(13). Perlette and Golden Muscat are not well adapted to Koka. Tibier, Rubired, Beauty Seedless, Muscat of Humberg, Barlinka and Royality appear to be will adapted at Koka (14).Trial at Bako was established on unsuitable site (14). At Holetta growth has been extremely slow.

At Jima 9 grape cultivars were established to study their adaptability. It is only Golden Muscat that gave some berries. Jima-Melko is not an ideal area for grapes due to its humidity which favors powdery mildew development. As a result the trial was discontinued (6).

A variety screening trial comprising of 25 imported and locally collected varieties was established in June 1982 at Melkassa. Muscat of Alexandria was identified to be high yielder and relatively resistant to mildew. Gold, Chenin Blanc, French Colombard, Ruby Red, Royality, 'Kei Dube', Golden Muscat, Barlinka, Ruby Cabrnet, Gamay and Ruby Cabrnet are better than other cultivars in the trial. At Koka Golden Muscat and Perlette are not well adapted. Powdery mildew, downy mildew and birds are the major problems in grape production. Many of the trials proposed on grapes discontinued at Melkassa due to bird damage.

Some 116 cultivars were entered in the National Grape Collection. Out of these 70 are wine grapes (41 white and 29 red), 21 are table grapes and the remaining yet to be identified. These materials are going to serve as source for future research and development. Similar collection is established at Merti. Staking and crop intensity trials are superimposed on UAAIE grape orchards. A variety observational trial was established at Guder. Many trials were started on grapes but suspended letter on due to acute shortage of staff in the section.

Papaya

The available papaya cultivars are highly heterozygous and fruits produced form these materials are different in size, shape, color, flavor and their reactions to diseases. Unproductive male plants are very common due to use of monoecious types. As a result, *Solo*, a bisexual type which contain female or hermaphrodite flowers in a single plant was introduced. Another one called, *Coorg Honey*, a dioecious type was also imported from India. All Solo plants are productive. There is no need to plant many seeds or plants at a point to get enough fruit bearing female trees (8). Solo produces small (350 gm), oblong and high quality fruits. It has fairly good keeping property, suitable for fresh consumption and fresh-by-air export. Unfortunately, acceptance of the type by local consumers was low due to its small size. Coorg Honey produces large, oval fruits (900 gm) of high quality, and is suitable for juice making (11).

An observational trial using Coorg Honey and Solo varieties was established at Melka werer. In 1971, about 100 q/ha/yr fruit yield was obtained. Cropping started 10 and 11 months after planting and continued for 15 months. Economic life of papaya in the Middle Awash is estimated to be 2-3 years from time of planting. This increases as altitude decreases (13). In 1972, an observation plot of Solo was established at Jima (3). The attempt to produce papaya seed at Melko failed due to diseases and luck of irrigation at the station. At Melkassa a trial plot was established using Solo seed produced at Melka Werer. But, the seed was reported to be not pure Solo type (13, 14). Attempt to produce papaya vegetatively was not successful (14).

A yield of 13 and 20 tons/year/hectare was reported at Melkassa for monoecious solo and female plants, respectively (8). Seed of Solo was successfully produced at Melka Werer two times and those were distributed to research stations, farmers through EPID of MOA, state farms and individuals. The material deteriorated through time and the activity was discontinued (7).

Passion fruit

Observational trials using purple and yellow fruited types were made at Melkassa, Jima, Melka Werer, Awassa, and Kulumsa. The yellow fruited type is more vigorous and bear larger fruits. The juice color is deep orange, very acid and of excellent flavor. Juice of the purple type on the other hand is much paler in color, and is less acid but has good flavor (5, 13). The purple type performed best at Jima, Kulumsa and Awassa. The yellow type on the other hand performed better at Nazareth and Melka Werer. A juice extraction trial at Melkassa gave 290 and 440 liters per ton of fruit, respectively.

Pineapple

Smooth Cayenne and Puerto Rico were imported from Kenya and established at Melko. Due to its finely serrated leaf margin and very low multiplication rate the latter was not intensively used. Smooth Cayenne was multiplied at Melko and distributed to research stations, state farms and interested growers. Agronomic trials were initiated and conducted at Melko and Gojeb state farm. Spacing trial to determine optimum spacings between rows and between plants that is convenient for cultural practices and that give high yield and quality fruits had started at Melko and Gojeb state farm in 1977 and 1978.

Performance of pineapple was much better at Gojeb than at Melko. In fruit yield 90 cm X 60 cm X 40 cm was superior in yield in both locations but the difference was not significant at Melko. This spacing was also convenient for routine cultural practices such as weeding and harvesting. From effect of size of slip trials, slip size of 30 cm and 40 cm gave relatively higher fruit yield than smaller and larger sizes.

Multiplication rate of pineapple is very low. It is the major limiting factor in the expansion of pineapple production. Three types of planting materials namely crowns, slips and suckers were compared. No significant difference was observed among treatments but crowns gave larger fruits (9). Considering availability of uniform planting materials, growing and harvesting seasons slips are recommended as planting material.

Mealy bug which reduce pineapple population drastically both at Gojeb and Melko is considered the major problem (7).

Strawberry

The following varieties Cambridge Favorite, Cambridge Vigor, Cambridge Prize Winner Fresno, Gorella, Hummi Gento, Hummi grande, Hummi Triscana, Lavo, Pocohontas, Primella, Rabunda, Red Gountlet, Royal Sovereign, Sagita, Senga Segana, Talisman, Tioga and Vola were evaluated in the screening trial at Melkassa. Royal Sovereign and Cambridge Prize Winner did not adapt well under Melkassa Condition (4, 13).

The spacing used were 30 cm X 60 cm between plants and rows respectively. Plants are deflowered at early stage for about four months to get reasonable vegetative growth before fruiting (3). At Melkassa Cambridge Favorite stood first in yield (148 q/ha) followed by Red Gauntlet and Gorella giving 134 and 93 q/ha yield, respectively (13). The German Hummi varieties produce too many runners when grown at Melkassa and consequently bear little fruits.

In Jima fourteen cultivars were tested. Cambridge Favorite gave the highest fruit yield but Cambridge Vigor was the best in overall quality (shape, size, color, texture and flavor) among the tested cultivars (4). Another set of varieties obtained from Natural Resource Center were assessed at Melko condition. Again Cambridge Favorite stood first followed by Red Gauntlet, Hummi and Triscana. Senga Sengana, Cambridge Vigor and Gorella were low yielders (4). From planting date trial it was observed that May and July plantings were found to be the best for Melkassa (13).

The major problem of strawberry production is shortage of planting materials. This is particularly true for those varieties that are not producing runners. Establishment of young plant, reduced flowering during dry period and crop losses due to insect and bird attack were found to be the problems in the production of strawberry.

Other Topical and Sub-Tropical Fruits

Different tropical and sub-tropical fruit trees were established at Koka and Jima. In most cases materials were of unknown origin and started mostly from seedlings (14). The Jima collection includes oyster nut, guava, mango, Brazil cherry, avocado, bullock's heart, kei apple, jack fruit, passion fruit, cheremoya, carob bean, rose apple, manzanilla, mulberry, macadamia nut and loquat. Mango, avocado, guava and others gave some fruits and found to be well adopted to the growing conditions (7).

At Koka, guava, macadamia nut, loquat, carob bean, mulberry, casamiroa, avocado and mango were established. This collection was replaced later on by Melkassa collection. In Melkassa collection of mango, avocado, casamiroa, jackfruit, date palm, and bullock's heart were included. Except bullock's heart, jack fruit and date palm performed well under Melkassa condition. Since seedlings were used, variation within a collection in terms of tree height and spread, fruit size, shape, color and flavor was great.

For future trials it was decided to use only scions of selected trees budded or grafted on selected rootstocks. Some trees were selected to provide rootstock seed and others to provide scions. A new collection is being established from selected and known planting materials. In this collection imported cultivars of mango and avocado from UAAIE farms are included. There is a plan to expand this activity by collecting and importing more materials. Since avocado is performing well in Jima area, improved avocado varieties are provided to Jima Research Center for further evaluation.

Conclusion

Citrus and deciduous fruit trees propagated at Koka, Melka Werer and Melkassa nurseries were distributed to experiment stations, MOA nurseries and commercial growers starting 1972. Similarly strawberry plants, asparagus crowns, passion fruit, papaya seed and banana corms have been distributed from Nazareth (12). Research results from Koka and Melka Werer had helped UAAIE to establish modern citrus orchards. NARC researchers are advising state farms and individuals on fruit production. The center is also giving training to MOA, NGO and farmers in the field. Currently the staff in the center are working very closely with state farms and MOA staff in identifying problems and conducting researches on their farms and nurseries. Through Research and Extension Division of the center technologies developed in the center are demonstrated on farmers fields. Farmers are reached through MOA of Eastern Shoa Zone, Arsi Zone, Region III and World Vision.

Fruit trees serve as shade and give fruits. Hence, they are popular among urban dwellers. The center has program to work with schools and hospitals to introduce improved varieties of the major fruits with accompanying technologies. Planting materials are also distributed to individuals and organization with minimum charge. At present there is no governmental or private nursery that propagate and distribute known fruit cultivars to users. The demand for fruit planting material from all over the country is tremendous. Beside expanding its own nursery, the center is working with MOA and NGOs to propagate and distribute these planting materials. This activity will continue till commercial nurseries are established in the country.

We wish you a healthy life by adding fruits in your diet!

Acknowledgment

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RESEARCH REVIEW AND FUTURE STRATEGIES ON VEGETABLE CROPS

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Abstract

Vegetables are grown in different agro-ecological zones of Ethiopia in multi-cropping system through out the year under rainfed and irrigated conditions. The production systems vary; from the cultivation of few plants in the backyard to home consumption to large scale intensive commercial production for marketing, processing and export. Increased production and improved handling of vegetables have great potential to enhance the nutrition of the urban and rural poor as well as to increase the income and provide opportunity for employment. There are different vegetables produced in the country. However, research have been exclusively concentrated on the nationally important vegetables. The main focus of research for the past 20 years has been on varietal development, agronomic studies and seed production techniques. Research effort made in this period has released some techniques which have contributed to commercial and small scale production of vegetables. The results of different experimental investigations for the past two and half decades are discussed.

Introduction

Different-types of leafy, bulb and fruit vegetables are produced by small farmers and commercial growers in Ethiopia. Of these tomatoes, onion and *Capsicum* are the dominant once.

Tomatoes, both fresh and processing types, are popular vegetable crops produced in the country. The bulk of fresh market tomatoes is produced by small farmers scattered along river banks and lakes mainly in the central, eastern and northern Ethiopia. Processed tomato products like paste, catchup, and juices are produced in the Upper Awash Merti processing plant for local markets and export (4).

Besides tomato, onion/shallot is an important spices and condiment to traditional dishes. Onion is extensively propagated by the state farms and is preferred to shallot for its ease of propagation by seeds and for its high export potential. As compared to shallot, onion is a recent introduction and can be conveniently propagated by using only about 4 kg ha^{-1} of true seed, on the other hand, shallot is propagated by using bulb and it requires about 20 q ha^{-1} of bulb seed (4).

Capsicum (hot pepper and birds-eye chili) are also the major vegetable and spice crops in the country. Hot pepper is an important cash crop to farmers of Shoa, Gojam, Wellega, etc. where it is particularly produced by small farmers. The farmers produce different types of local hot peppers, including standard cultivars, Bako Local and Mareko Fana. Most of the produce is used for flavoring the traditional sauces, whilst it is also an important row material for the processing industry (5).

In addition to varietal differences, the production of tomato, onion and *Capsicum* is found to be influenced by various factors, among which, growing environments and cultural practices are the predominant ones. Various studies have indicated that cultural practices like spacing and plant density, fertilizer and growing seasons affect the yield and quality of these crops. Today, farmers and commercial producers grow their crops under improved as well as traditional management practices in different parts of the country (4). This paper will review the experimental results of the last two and half decades.

REVIEW OF PAST RESEARCH WORKS

Varietal Development

A varietal evaluation and selection programs were launched to identify superior varieties of tomatoes, onion and capsicum to meet the demands of the growers and to overcome the various production constraints like low yield low quality and susceptibility to various pests/diseases.

Tomato

Over the years, a number of nursery screening and variety trials were conducted at Melkasa Research Center on different tomato cultivars introduced form international institutions like Asian Vegetable Research and Development Center (AVRDC) and Food and Agriculture Organization (FAO).

Fresh-market and processing tomatoes have been identified for home gardeners and processors from the introduced germplasm materials. Three fresh-market cultivars, Marglobe Improved, Marglobe and Money maker and two processing types, Roma VF and Napoli VF which are high in percentage of TSS were recommended for production (4).

Attempts were also made to identify fresh market and processing cultivars that are suitable to different production seasons, especially those acceptable to commercial and small farmers for immediate use and for further improvement. Different materials from AVRDC and FAO were tested under normal growing conditions without any staking/training or control measures against diseases and pests. Among the determinate processing types, high stand establishment and survival rate were observed in both the dry and rainy seasons (Table 1). Most cultivars were found better as compared to the standard check, Roma VF. There were differences in the fruit set, vegetative growth, and fruit quality among the cultivars and between the growing seasons.

In 1992 and 1993 yield trials were conducted on processing tomato cultivars at Melkasa and Zeway to select high yielder cultivar(s) than the existing varieties. Two cultivars, Serio and Red Pear gave higher marketable fruit yield as compared to the standard check Roma VF (Table 2). A yield trial was also conducted on fresh market tomatoes at two locations in 1993 to identify the high yielder cultivars. Cultivars CL-5915-206-D4-2-5-0 and Oval Red gave the highest marketable yield of 676 and 674 q ha^{-1} respectively as compared to the standard check which gave 596 q ha^{-1} (Table 3).

Table 1. Yield (Q ha^{-1}) of tomato cultivars in rainy and dry seasons.

Cultivars	Seasons	
	Rainy	Dry
CL - 1131 - 0 - 7- 2 - 0 - 9	209	380
CL - 1131 - 0 - 0 - 38 - 4 – 0	177	397
CL - 8d - 0 - 7 - 1	188	532
CL - 5915 - 93 - D4 - 1 - 0	148	634
CL - 9 - 0 - 0 - 1 - 3	180	377
CL - 5915 - 206 - D4 - 2 - 5	157	478
Roma VF	188	398
Marglobe	205	412

Source: Lemma and Herath, 1994.

Table 2. Fruit yield and some horticultural data of tomato processing cultivars at Melkasa and Ziway, 1992 and 1993.

Cultivars	Av. fruit wt(g)	No. of fruits/ cluster	Marktable yield q ha-1	Quality		Marketable yield q/ha
				Skin crack resistance	% of Juice	
Nova 70 A	46	6	296 C	V. good	88.6	322 D
Inter Peel	60	5	323 C	Good	77.3	382 ABCD
Serio	35	6	628 A	Good	79.4	401 ABC
Roma VF	50	5	487 B	Good	81.5	327 CD
M-22	62	5	478 B	V. good	86.9	333 BCD
Oval Red	75	5	520 B	V. good	83.8	410 A
Red Ball	83	5	517 B	V. good	87.3	364 ABC
Royal Ball	69	5	557 AB	Good	91.2	347 ABCD
Red Pear	58	5	619 A	Fair	85.3	411 A
Maremma sel.						
Jago	58	5	384 C	Good	84.5	405 AB

Means followed by the same letter(s) are not significantly different at P=0.05.
Source: Progress Report, 1993.

Table 3. Marketable fruit yield (q/ha) and average number of fruits per cluster of fresh market tomatoes, 1993.

Cultivars	Melkasa		Ziway	
	Fruit number	Fruit yield	Fruit number	Fruit yield
UC 204 A	4.9 C	317 F	6.7	315.9 E
Royal Ball	4.4 C	513 D	9.0	589.8 AB
H-2543	4.4 C	348 EF	9.7	550.8 AB
VFN-138	5.1 C	636 AB	10.0	742.7 A
Floradade	4.8 C	610 ABC	8.3	371.5 CDE
CL-5915-206-D4-3-0	6.6 A	654 AB	8.7	435.0 BCDE
CL-1131-0-0-43-10-1	6.9 A	415 E	10.0	474.4 BCDE
Heinz 1350 sel.	5.0 C	550 CD	8.7	531.2 BCD
CL-5915-206-D4-2-5-0	6.7 A	676 A	8.0	496.8 BCDE
Homestead 61	4.8 C	557 CD	9.3	335.6 DE
Oval Red	6.1 AB	674 A	8.7	542.8 BCD
Marglobe	5.2 BC	596 CD	10.0	430.3 BCDE

Means followed by the same letters are statistically similar at 0.05 level.
Source: Progress Report, 1993.

Onion

Several screening and varietal trials were conducted on a number of onion cultivars introduced from AVRDC, FAO etc at Melkasa Research Center with the objective of identifying the most adaptable types interms of high bulb yield and pest/disease tolerance/resistance.

Three onion fresh-market cultivars, namely Adama Red, Red Creole, and Bombay Red and one processing type known as Mermiru Brown were released so far. Adama Red is the only cultivar that is extensively grown in the state farms for bulb as well as export flowers production. Red Creole is less popular because of its poor bolting characteristics and poor seed set under the existing growing conditions (4). In recent experiments, two cultivars Pusa Red and N-53 gave the highest total dry matter and dry bulb yields. N-53 was found to be better in storage quality because of its high dry matter content. Both cultivars will be verified for release. In addition, cultivars with high potential for their bulb yield and quality have been identified and preliminary studies for bulb and seed (open-pollinated seed) production are in progress.

Table 4. Bulb yield (Q ha^{-1}) of onion cultivars in three locations (1990 - 1991).

Cultivars	Melkasa		Merti		Ziway	
	Market	Total	Market	Total	Market	Total
Adama Red	175bc	203bc	142bc	158b	155	165
Red Creole	165c	169c	157bc	169b	147	168
Pusa Red	234a	244a	197a	253a	139	150
N-53	217ab	277a	130ab	209ab	146	173
M. Brown	206ab	218ab	160ab	210ab	141	162

Means followed by the same letter(s) are not significantly different at 5% level.
Source: Lemma and Herath, 1994.

Capsicum

Capsicum (Bell pepper, Chili and Hot pepper) is produced in different parts of the country where hot pepper is a popular crop among the farmers. Hot pepper is one of the important parts of the daily diet of most Ethiopians, whilst it is also an important row material for the processing plants.

Two cultivars, Mareko Fana and Bako Local have been selected at Bako research center and are being extensively produced in the state farms and the peasant sectors. Mareko Fana is a large-poded, pungent, with a high oleoresin content and is highly preferred by farmers and consumers. It had good pod characteristics and color but poor yield and was found to be susceptible to diseases and pests; where as Bako Local was a good yielder though it lacked good pod characteristics and color but was also susceptible to diseases and pests like Mareko Fana (4). To identify the most adaptable lines(s) with high yielding and disease and insect resistance/tolerance, 115 lines were introduced from AVRDC, Sirilanka and other sources in 1990/91 and 1991/92. Of the introduced lines, six AVRDC cultivars PBC 376, PBC 151, PBC 233, PBC 207, PBC 076 and PBC 067 were identified for their high yield potential. PBC 151 was also found to be free from powdery mildew under field conditions. Laboratory analysis results showed that PBC 270, PBC 377 and PBC 510 gave high color intensity, which was in excess of 90,000 I.C.U (4). The cultivars will be evaluated at Multi-locations for their yield and quality.

Agronomic Studies

Tomato

Sowing Date. Tomato is adapted to a wide range of soil and climatic conditions, though for optimum production it requires warm conditions, clean and dry weather and moderately uniform temperature to produce high quality yield (8). To identify the optimum production period and to find out the main production constraints in the potential tomato growing areas, sowing date studies were conducted from 1984-89 with the fresh market (Money maker) and processing (Napoli VF) cultivars. According to this study, the August-November cool season sowing and the September-March field growing period gave the highest yield (Table 5).

Table 5. Effect of sowing date on yield and gross returns of tomatoes (1984-1986).

Sowing date (1st week)	Optimum Harvesting Month	TSS %		Marketable		Total		Revenue (ETB)
		MM	NVF	MM	NVF	MM	NVF	
January	May	4.4	5.3	46	96	153	205	3910
February	June	4.7	5.0	26	24	90	109	4160
March	July	4.5	4.5	13	12	45	41	2210
April	August	5.1	4.9	14	18	42	43	1190
May	September	4.4	5.4	13	5	63	27	1105
June	October	5.6	5.1	24	21	83	78	2040
July	November	5.0	5.0	42	57	157	166	3570
August	December	5.4	4.8	140	133	314	348	11900
September	January	4.9	5.1	133	173	303	369	13300
October	February	5.3	5.1	127	158	341	328	10795
November	March	4.2	4.0	141	152	310	282	11305
December	April	4.5	4.6	110	124	248	221	9350

Key: MM = Money maker, NVF = Napoli VF
Source: Lemma *et al.*, 1994.

Spacing. One of the management practices that greatly influenced tomato fruit yield is plant population and spacing, because it influences plant structure, vine types, soil fertility and purpose of production (7).

In 1984-87 inter row spacings of 100, 120, 130 and 140 cm and intra-row spacings of 10, 20, and 30 cm with a ranges of 21,000-100,000 plant ha^{-1} were tested on two fresh market varieties with different growth habits; namely, tall-growing (Marglobe) and short-set (Heinz 1350). These were tested under ground culture and low inputs (5). The inter-row spacings of 100-120 cm and intra-row spacings of 10 - 20 cm with 42,000-100,000 plants ha^{-1} gave high fruit yield for both determinate (Heinz 1350) and indeterminate (Marglobe) cultivars (Table 6).

Table 6. Effect of spacing on fruit yield of fresh market tomatoes.

Spacing(cm)	Population/ha. ('000)	Av. fruit wt (g)		Total yield (q/ha.)	
		HZ	ML	HZ	ML
100 x 10	100	88	79	212	255
100 x 20	50	91	86	211	179
100 x 30	33	108	86	199	260
120 x 10	83	88	94	229	254
120 x 20	42	91	90	207	198
120 x 30	28	102	94	209	205
140 x 10	71	85	80	201	215
140 x 20	30	91	94	198	198
140 x 30	24	95	82	185	187
160 x 10	63	115	82	195	217
160 x 20	51	89	82	172	156
160 x 30	21	98	87	174	173
Mean		95	79	199	208

Key: HZ = Heinz 1350, ML = Marglobe
Source: Lemma *et al.*, 1994

Population Density. The population density of tomatoes depends on conditions like plant structure, vine type, soil fertility, and purpose of production (1). Currently, determinate processing types are produced either under direct seeding or transplanting under higher density to improve fruit yield per unit area of land, which is an important requirement of processing tomatoes.

In plant density study, direct seeded processing tomato, Roma VF, gave the highest yield when 2-3 plants were left at 30-40 cm spacing between plants and 100 cm between rows (50,000 to 100,000 plants ha^{-1}). This plant density could be used for small-scale processing tomato production (6).

Fertilizer Application. Nitrogen and Phosphorus fertilizers trial was conducted at Melkasa to determine the optimum fertilizer rate for tomato production (4). Significant yield differences were observed both among nitrogen and phosphorus levels in marketable yield (Table 7). An increase in phosphorus level increased the mean fruit yield.

Table 7. Fruit yield (q ha^{-1}) of tomato as affected by type and rate of fertilizers.

Phosphorus (P_2O_5) (Kg ha^{-1})	Nitrogen in Kg ha^{-1}				Mean eff. of P
	0	46	98	184	
0	104.9	85.9	120.7	61.0	98.1 ab
46	105.4	100.9	102.9	107.9	104.1 ab
92	172.3	131.7	131.4	81.3	129.2 a
184	121.6	82.7	166.3	139.7	127.6 a
Mean of N	126.0a	100.3b	130.2a	97.5b	

In the column and row means followed by the same letter(s) are non significant at 5% level
Source: Vegetable Team Progress Report (IAR), 1987.

Onion

Sowing Date. Even though onion can be produced through out the year in Ethiopia, the yield and quality of dry bulbs seems to vary from seasons to season, owing to the diverse agro-climatic conditions prevailing in production areas. During 1984-1988 sowing date studies were conducted at Melkasa in a monthly interval to determine the optimum sowing date for onion bulb production and to assess growers' problems in the region under low-input conditions (without agro-chemicals) using the two standard cultivars, Adàma Red and Red Creole (7).

Sowing date affected dry bulb yield, bulb quality (splits and thick necked) and flower stalk development. The cultivar Adama Red produced significantly high marketable and total bulb yield from July-September sowing i.e in the cooler growing season (September-March), where as Red Creole was found to adapt better in the March and April sowing, i.e. in the March to November growing season, when there is high rainfall and disease incidence. Highest percentage of splits, thick necked, bolting, as well as larger bulbs were produced in the cooler season.

Bulb Production. Onion is produced either by direct seeding, seedling transplanting, or from dry sets depending on specific growing conditions. Different-sized sets less than 1.5, 1.6-2.0, 2.1-2.5, 2.6-3.0 and 3.1-4.0 cm diameter of Adama Red and Red Creole cultivars were tested for three years (1984-1987) to identify optimum set size for high yield and quality bulb. In both cultivars it was found that the larger the set size, the higher was the total bulb yield. The larger the bulb size the higher was also the number of bolters and flower stalks, which affects the quality of marketable bulbs. For high standard bulb yield smaller sets could be used but using larger sets could only be justifiable when the cultivar has non-splitting characteristics; using small sets and or transplanting is advisable otherwise (6).

Fertilizer Application. Experimental investigations were conducted from 1988-1992 to determine the optimum fertilizer levels for high bulb yield and quality at the Upper Awash, Melkassa Research Center and Nura-Era state farm using equal levels of N and P_2O_5 (0, 46, 92, and 138 kg ha^{-1}). Significant differences were found between N levels but there was no marked responses to P and N combinations in all the parameters considered (Table 8).

Table 8. Effect of NP fertilizers on dry bulb yield (q ha^{-1}) of Adama Red cultivar, (1986-1991).

Fertilizer ($Kg\ ha^{-1}$)	Marketable		Total	
N	MLKS	NE	MLKS	NE
0	233 c	241 c	256 c	262 d
46	248 b	272 b	275 b	292 c
92	263 a	299 a	289 a	320 a
138	248 b	284 ab	272 b	303 b
Mean	248	274	273	294
P				
0	240 b	275	267	294
46	241 b	272	268	292
92	252 b	273	276	291
138	260 a	277	282	299
Mean	248	274	273	294

Means followed by the same letter(s) are not significantly different at 5% level.
Key: MLKS = Melkasa, NE = Nura Era
Source: Lemma and Herath., 1994.

Capsicum

Harvesting Stage. The main quality determining properties of *Capsicum* are pungency, initial color, and color retention capacity. They are affected by variety, harvesting stage of the pods, and post harvest handling. Experiments were conducted at Bako and Didesa from 1987-1989 to evaluate the effect of different harvesting stages on yield and quality of hot pepper. Results obtained indicated that delay harvesting until the pods are dry and partially shrivelled on the plant gives higher oleoresin content (4).

Spacing. To determine the optimum plant density per unit are for Mareko Fana cultivar, experiments were conduced at Bako and Didesa during 1984-1986. Spacings of 70, 80, and 90 cm between rows and 20, 30, and 40 cm between plants were studied. The highest total pod yields were obtained from 70 cm between rows and 20 cm between plants at both locations (4).

Future Research Strategies (Based on Vegetable Research Strategy, IAR, 1993).

Tomato

- Development of high yielding fresh market and processing cultivars with high quality and resistant/tolerant to the major pests and diseases.
- Selection and development of stress (high temperature, low moisture, acidity, salinity, etc.) tolerant fresh market and processing cultivars.
- Development of hybrid fresh market and processing varieties for high yield and quality.
- Development of cultural practices for different agro-ecological regions, development of techniques for mechanized production and improvement of low fruit set of tomatoes which contribute to high fruit yield.
- Improvement of shelf life of fresh market tomatoes through varietal screening and improved storage conditions.

Onion

- Identification of cultivars with dark red color, very pungent, high dry bulb yield and widely adapted under rainfed and irrigated conditions.
- Development of high dry matter white brown colored and high dry bulb yield cultivars for processing and export.
- Development of cultivars adaptable under stress conditions (shot growing season and salinity).
- Development of production practices for onion for different growing seasons for small farmers and mechanized production under rainfed and irrigation and identification of high yield and quality seed production areas in the country with appropriate seed production practices.
- Improvement of shelf life of the existing varieties through curing methods and selection of cultivars with longer shelf life.

Capsicum

- Development of high yielding and widely adaptable varieties with desirable characteristics for home use, export and processing industries.
- Development of cultural practices for different agro-ecologies for rainfed and irrigated productions both for home garden and mechanized production system. Identification of cultivars for stress conditions (low rain fall, salinity, etc.) and development of seed production practices for small farmers and commercial growers.
- Development of proper post harvest technologies such as harvesting, curing, drying, and storing practices.

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germplasm evaluated have been used in the grouping work and classigied as early, medium and late maturing types (Table 2).

Table 1. Area, production and Yield of Sweet potato by zone during the 1993/1994 (1986 E.C) Meher season private holdings.

Production area	Area (Ha)	Production (tons)	Productivity (tons/ha)
Kilil 1	***0.64***	***0.74***	***1.15***
Central	0.01	0.04	5.42
Eastern	0.54	0.68	1.26
Southern	0.09	0.01	0.13
Kilil 3	***12.60***	***202.00***	***16.03***
West Gojam	4.00	30.00	7.50
South Wollo	8.60	172.00	20.00
Kilil 4	***17357.73***	***115268.10***	***6.64***
Aris	1517.00	7597.00	5.01
Bale	170.00	510.00	3.00
East Shoa	3.00	60.00	20.00
West Shoa	81.00	450.00	5.56
West Hararghe	6120.00	21174.49	3.46
East Hararghe	7985.50	73605.30	9.22
Illubabor	354.13	2478.91	7.00
Jima	516.60	1271.40	2.46
East Wollega	603.50	7845.50	13.00
NoerthWest Shoa	7.000	69.00	9.86
South Ethiopia	***30936.33***	***224487.10***	***7.26***
Sidama	259.00	725.20	2.80
North Omo	19477.75	194952.10	10.00
South Omo	700.00	10500.00	15.00
Keficho	8400.00	840.00	0.10
Bench	58.75	1380.00	23.49
~~Gedio~~	~~198.50~~	~~128.47~~	~~0.65~~
Kembata	809.00	9708.00	12.00
Hadiya	1000.00	6200.00	6.20
Burji	20.00		
Janjaro	7.00	42.00	6.00
Harari	***300.00***	***3000.00***	***10.00***
Dire Dawa	***389.40***	***615.27***	***1.58***

Source: Central Statistics Aurhority Report 1993/1994

Table 2. Sweet potato germplasm collected and introduced upto 1992 and grouped as early, medium and late maturing types.

Early maturing cultivars	Medium maturing cultivars	Late maturing cultivars
Alemaya	Koka 26	Koka 14
408	375	311
Abosto	377	394
402	Koka 25	397
Koka 3	381	366
364	388	390
409	365	407
TIB 11 (02)	CN - 1108 - 13	Melkassa 2
TIS 2498	AIS - 35 - 2	389
Arbaminch 2	Arbaminch - 1	315
CN 941 - 32	Koka 10	378
401	Arbaminch - 3	Koka 9A
EPID	380	382
Arbaminch - Mile	403	Arergota
393	392	386
CN - 1219 - 1	TIB 9 (62)	405
404	384	374
319	Baracuty	396
TIB 10 (3)	368	406
I - 444	Wondogenet	398
Koka 9B	Wolayita - 1	383
TIS - 1499	Koka 28	387
385	399	Melkassa 1
TIS 3017 (2)	400	376
TIS 1487 (20)	371	Bekule/Kersa - 1/
Cemsa	AJAC - 1	Wonago - 1
TIB 8441	Gura-low-low	Rutambur
CN-1032-16	AJAC - 3	TIS 30534

Koka 18	Bekule/Guradima/	Bekule/Kersa-2/
Wonago -3	373	Wonago -2
Guraminijar	TIS 80-637	Guganza
AJAC -2	AJAC -4	TIS 83/38
TIB 1-11-02	TIS 10683	TIB - 8401
TIB 16-3982	Carales	Mugandia
Bucaraso	Koka 6	Rusengo
TIS 9265		TIB 3261
Gurachire		K-51-3261
Wadada		Awassa -1

Variety Trial

Following the introduction, collection and classification work into maturity groups, variety trials have been conducted with those.different maturity period groups, in different locations (Awasa, Bako, Areka, Zeway and Melkassa). The early maturing sweet potato variety trial consists of the following varieties (I-444, Koka 9B, TIS 3017 (2), Cemsa, CN-1032-16, Koka 18, TIB-16-3982, Bucaraso, Wadada, 393, TIS 1499 and TIS 2498) (9, 10). This experiment was conducted at Awasa, Areka, Zeway and Melkassa (Table 3).

The medium maturing sweet potato variety trial consists of the following varieties (375, 368, AJAC-1, Koka 26, 377, Gura-low-low, Bekule/Guradima/, Carales, CN-1108-13, AIS-35-2, Baracuty and Koka 6) (9, 10). This experiment was conducted at Awasa, Areka, and Bako (Table 4). The late maturing sweet potato variety trial consists of the following varieties (Koka-14, 311, Eregota, 405, 374, Awasa-1, and local) (10). The early and medium maturing sweet potato variety trials were conducted with eleven and twelve varieties each, respectively starting from 1993. There are three promising early maturing varieties (I-444, TIS-1499 and TIS-3017 (2) (Table 5) (9, 10). There are also three promissing medium maturing varieties (AJAC-1, Gura-low-low and 375) (9, 10). (Table 4). These are candidates from both groups for release. The late maturing sweet potato variety trial was conducted with seven varieties starting 1994 (10).

Table 3. Early maturing sweet potato variety trial conducted at Areka, Awassa, Melkassa and Zeway in 1993, total root yield in tons per hectare.

Varieties	Areka	Awasa	Melkassa	Zeway	Across location mean
I 444	8.30	38.28	16.00	12.30	18.72*
Koka 9B	3.50	8.13	7.00	3.20	5.50
TIS 3017 (2)	9.70	32.93	20.67	14.10	19.35*
Cemesa	14.30	19.58	17.67	8.10	14.92
CN-1032-16	3.50	9.65	4.83	4.70	5.67
Koka 18	16.50	29.73	22.50	10.70	19.86*
Bucaraso	2.80	6.20	7.50	3.90	5.10
Wadada	3.50	12.93	9.50	11.60	9.40
393	8.50	18.50	15.67	9.20	13.00
TIS 1499	11.60	39.90	22.50	14.60	22.15*
TIS 2498	9.50	13.60	5.33	3.20	7.91
Mean	8.33	20.60	13.50	8.80	12.87

Table 4. Medium maturing sweet potato variety trial conducted for two years at Awasa and Areka in1993 and 1994, total yield in tons per hectare.

Varieties	1993	1994	Awasa Mean	1993	1994	Areka Mean	Across location Mean
375	55.5	55.40	55.50	12.70	24.07	18.40	37.00
368	23.90	8.30	16.10	9.24	6.37	7.81	12.00
AJAC-1	69.50	71.20	70.40	23.44	21.71	22.60	46.50
Koka 26	29.10	27.90	28.50	11.59	11.69	11.64	20.10
377	24.20	2.70	13.50	12.90	2.96	7.93	10.72
Gura-low-low	60.40	57.40	60.00	24.09	15.05	19.60	40.00
Bekule (gura dima)	18.40	12.50	15.50	16.93	10.19	13.60	14.60
Carales	18.90	16.50	17.70	7.68	9.33	8.51	13.11
CN-1108-13	17.00	13.90	15.50	14.84	6.37	10.61	13.10
AIS-35-2	22.80	22.70	22.80	9.44	9.49	9.50	16.15
Baracuty	6.40	5.60	6.00	9.24	4.81	7.03	6.52
Koka 6	60.20	51.90	56.10	21.10	15.16	18.13	37.12

Table 5. Early maturing sweet potato variety trial conducted for two years at Awasa and at Areka in 1993 and 1994, total yield in tons per hectare.

Varieties	1993	1994	Awasa Mean	1993	1994	Areka Mean	Across location Mean
I 444	38.28	26.90	32.60	8.30	23.54	15.92	24.26
Koka 9B	8.13	2.80	5.50	3.50	4.91	6.00	5.75
TIS 3017 (2)	32.39	20.20	26.30	9.70	8.15	8.93	17.62
Cemsa	19.58	18.70	19.14	14.33	8.38	11.36	15.25
CN-1032-16	9.65	2.30	6.00	3.50	2.13	2.82	4.41
Koka 18	29.75	16.70	23.23	16.50	10.58	13.54	18.40
Bucaraso	6.20	2.20	4.20	2.80	1.23	2.02	3.11
Wadada	12.93	4.10	8.52	3.50	3.08	3.25	5.90
393	18.50	20.20	19.35	8.50	9.42	9.00	14.20
TIS 1499	39.90	29.80	34.85	11.60	23.01	17.31	26.10
TIS 2498	13.60	10.10	11.85	9.50	6.83	8.17	10.01

Crop Protection

Sweet potato plants are subject to a large number of insect pests, weeds and diseases at all growing stages of the crop. Some of the pests are widely distributed and almost threatening the production of the crop in some parts of the country, and are considered to be economically important, while others are not so widely spread and have less economic importance. Each year, a significant amount of sweet potato crop has been and is being lost in the southern region due to sweet potato butterfly and other pests in the field. Therefore, the need for appropriate control measures of such a large number of insect pests, diseases and weeds are indispensable. These has to include: determination of causes of losses (pests, diseases and weeds), establishing economic importance of major pests, weeds and diseases on the crop and finally generate information on control measures (cultural, biological, varietal resistance, chemical etc.) There are three major disciplines (Entomology, pathology and weed science) which are involved in conducting research to generate appropriate control measures against the most important pests, diseases and weeds of sweet potato.

Insects. Insect pests are one of the most threatening factors of sweet potato production in most growing areas particularly in the southern region. Sweet potato butterfly (*Acraea acerata* (hew.)

And sweet potato weevil, *Cylas* spp. are the major ones.

Sweet potato butterfly has been reported to cause extensive damage to sweet potato in several locations in North Omo zone. The problem of sweet potato butterfly was first observed in 1986 in the previous Gofa *awraja*. Today the pest is spreading widely in Wolita, Kembata, Gofa, Gamo, Hadiya, and other near by *awrajas* also causing heave damage to the crop.The caterpillars feed on sweet potato gregariously in a very large number per leaf beneath a silken web. Heavy attacks can result in a complete defoliation of the leaf. Six insecticides were tested against sweet potato butterfly at Areka in 1991 and 1992. Endosulfan 35% EC applied at a rate of 500gm a.i. per hectare was found very effective in controlling the insect pest. The rate and frequency of this insecticide is not determined experimentally (10).

In the survey, collection and identification of natural enemies of sweet potato butterfly, larvae of sweet potato butterfly were collected from North Omo Administrative region. The larvae was kept in the rearing cage in the laboratory. After several days the observation indicated that it was only *Charops* sp. that emerged from the larvae of sweet potato butterfly. It can be concluded that the conservation of this natural enemy of sweet potato butterfly should be considered as part of the control of this pest (4,5).

Sweet potato Weevil is a universally occurring insect pest of sweet potato. It is a very serious pest causing extensive damage to sweet potato in almost all growing areas of Ethiopia. The larvae cause considerable damage to tubers and stems. The faeces of the insect is deposited within the tunneles, so that the tuber is rendered unfit for human consumption (12). The tunneled stems are also inferior in quality to serve as planting material. Survey on the major insect pest of sweet potato indicated that the infestation by the weevil varies with season. Therefore, the effect of planting date on sweet potato weevil was conducted at Awasa and Areka in 1994. The result of both locations indicated that a delay in planting has significantly increased the attack of this insect pest (15).

Insecticidal screening trial conducted against sweet potato weevil in 1989 and 1990 at both Areka and Awasa research centres indicated that cypermethrin and primiphos-methyl gave a better control (7). However, the rate and frequency of these insecticides need to be experimentally determined to make the use of these chemicals economical. A number of field and laboratory experiments were conducted with a number of varieties at Areka and Awasa in 1989 and 1990. The result of both locations indicated that there is a good chance of getting sweet potato varieties resistant to sweet potato weevil. However, a continues screening program with a considerable number of varieties is indispensable (4,5,6).

Weeds. Weed competition during the early growth stage of any crop can affect stand, vigor and the final yield. Losses in yield due to weed competition and the critical stage when the competition is most severe varies. Therefore, the removal of weeds manually and through some cultural means has been essential part of most crop cultivation by smal' farmers. Weeds are problems in sweet potato only during thr first two months of growth (12). After this period, vigorous growth of the vines causes rapid and effective coverage of the ground surface and smothers the weeds present. For this reason most traditional farmers do not weed sweet potato plots at all. But several annual broad leaved weeds have been recorded on the crop and the crop was found to be most susceptible to weed competition during the first third of its life.

The most predominant weeds of sweet potato identified during the early growing stage include: *Nicandra-physallodes, Datura-stramonium, Calinsoga parviflora, Tagates minuta.* Mid-season weeds include *Anagallis arvensis, Amaranthus hybridus, Bidense pilosa, Gynandropsis cynardra, Capsella rubensa and Guizotia scabra* (5).

Table 6. Major weeds of sweet potato in different altitude growing areas of the southern region.

Location	Altitude (masl)	Weeds identified
Chanodorga	1250 Low elevation	Commelina beinghalensis, portu acea oleracea, Cyperus rötundus.
Sawla	1360 low elevation	Convolvulacea sp., Guizotia scabra, Euphorbia hirta.
Awasa	1700 Inter-mediate elevation	Nicandra physalodes, Commelina benghalensis, Tagates minuta, Portulacea oleracea, Amaranthus hybridus, Solanum nigrum, Anagallis arvensis, Oxalis sp.
Gardula	2050 High elevation	Datura stramonium, Bidens pilosa, Commelina benghalensis, Tagates minuta.
Boditi	2350 High elevation	Guizotia scabra, Commelina benghalensis, Gynand ropsis gynandra, Galinsoga parviflora.

Removing the weeds twice in the cropping season at 45 and 75 days after planting was found to be most suitable for successful production of sweet potato in the Awasa and Areka areas. The crop did not benefit from one early weeding either at 20 days or 45 days after planting.

Agronomy Research

The part of the country where root crops ingeneral and sweet potato inparticular are important in the diet are precisely that part where population growth is highest and the land holding is the least, and threat of large scale starvation is ever-present. It has therefore become of urgent importance, to improve the quantity and quality of those crops which the people already consume. In Ethiopia sweet potato is predominantly cultivated under rainfed conditions. In the traditional culture, the crop is grown on the marginal soil in pure stand. No fertilizer or manure is used, and weeding is often done vary late. Under these crude methods of cultivation the national average yields of sweet potato are very low (8 tons/ha).

Over the last one decade several sweet potato trials have been conducted with the objective of developing appropriate cultural practices such as planting and plant establishment techniques, and planting materials management techniques.

Evaluation and characterization of sweet potato germplasm

This experiment was conducted in collaboration with the International potato centre (CIP) of the East Africa Region (Region 3). Minimum discription for morphologic characterization of 122 introduced and locally collected cultivars was made. The morphologic characterization was made on twenty two different parameters. The minimum discriptors for morphologic characterization in of *Ipomoea batatas* include: twining, plant type, internode length, internode diameter, vine pigmentation, vine tip pubescence, leaf lobig, number of lobes, shape central lobe, mature leaf size, leaf vine Collor on the lower surface foliage Collor, mature leaf Collor, imature leaf Collor, petiole length, petiole Color, storage root shape, storage root defects, cortex thickness, storage root skin Collor, storage root flesh Collor, and storage root formation (7).

Planting Date

The planting date experiment is designed to determine the most favourable period of environmental conditions for successful growth and production of sweet potato. The experiment conducted at Awasa Research Centre showed that late planting resulted in a considerable amount of loss in root yield. In Awasa and similar areas the optimum planting date for sweet potato is at the onset of the rain (between mid-May and early June) (5).

Seed bed preparation

This experiment was designed to investigate the optimum method of land preparation for establishment, growth and yield of sweet potato. The experiments conducted at Areka and Awasa demonstrated that there was no significant response to different methods of land preparation. In Areka and similar areas where the rain fall is higher and the water holding capacity of the soil is good and in Awasa and other similar areas where the amount of rainfall is sufficient for growth and the soil is more of sand, flat planting method can be considered optimum (4, 5, 6,). But generally in moisture stress areas tied ridges are the most universally recommended methods of growing sweet potato.

Spacing on sweet potato planting material production

This experiment was designed to determine the optimum plant spacing for successful production of sweet potato planting materials. The experiment consists of the following treatments 40, 60, 80, 100, and 120 cm row spacing and 10, 20, 30, 40 and 50 cm of between plant spacing. The experiment conducted at Awasa and Areka demonstrated that 40 cm by 30 cm gave the highest number of cuttings for planting material, and it was calculated that vine cuttings which can cover about 16 hectares of land was obtained from one hectare of land (6).

Different parts of the vine cuttings as planting material

Sweet potato will grow adequately if propagated by means of vine cuttings. This experiment was conducted to compare and evaluate the stand percent and yield performance of different parts of the sweet potato vine used as planting material (top, middle and basal parts). The experiment conducted at Areka and Awasa showed that the top cutting gave higher total yield compared to the middle and basal portion vine cuttings although the yields did not show statistically significant differences (5).

Pre-rooting of sweet potato vine cuttings

The pre-rooting sweet potato experiment is designed to determine weather allowing the cuttings to pre-root will create favourable conditions for establishment and yield. The experiment conducted at Awasa Research Centre showed that the different parts of the cuttings (top, middle and basal) and the length of days for pre rooting had no statistical significant effect on yield. However, the top cuttings pre-rooted for nine days gave the highest yield. On the other hand the experiment at Areka indicated that the parts of the cuttings and the length of the days for pre-rooting had statistical significant effect on the plant establishment. The top cuttings pre-rooted for six days gave the highest stand percent per hectare (7).

Planting position

The placement of sweet potato vine cuttings differ according to the different methods of ploughing. In hoe ploughing the vine is inserted into the soil at an angle or vertical, while in oxen ploughing the vine is burried in the furrow horizontally. Therefore this experiment was designed to investigate the best planting position of sweet potato vine cuttings. The experiments conducted at Areka and Awasa demonstrated that the vertical planting position resulted in higher root yield followed by the U shape planting position, the lowest root yield was obtained from the horizontal planting position (4, 5, 6).

Storage of the vine cuttings

The experiment on the storage of the vine cutting is designed to compare the establishment and root yield of sweet potato obtained from vine cuttings which are stored under shade for differnt length of time. The experiment conducted at Awasa indicated that storage of the vine cuttings for different length of time (0, 2,4,6,8 and 10 days) had no statistical significant difference on total root yield. However, the highest total root yield was obtained from the cuttings which were stored for six days. At Areka the result of the experiment indicated that there was statistically significant root yield difference. The highest total root yield was obtained from the cuttings which were stored for six and ten days (7).

NP Fertilizers

NP fertilizer trial conducted at Awasa Research Centre indicated that the application of different rates of NP fertilizers had no statistical significant effect on total root yield, green top and stem length of sweet potato. However, 46/44, 46/0 and 138/0 kg/ha of N/P205 gave the highest root yield, green top yield and the highest sweet potato stem length of 454 qt/ha, 21.3qt/ha and 102.3cm, respectively (5). Soil types seemed to influence the response of sweet potato varieties to fertilizer application. To come up with meaningful results, therefore, soil fertility experiments need to be conducted at several testing sites representing the major soil types where sweet potato is produced.

Fertilizer exhaustion trial on sweet potato

NPK fertilizer exhaustion trial on sweet potato conducted at Areka indicated that there was no significant response of sweet potato variety (Koka 6) to fertilizers applied at different rates. However, 69/42, 40.5/42 and 69/40.5/42 kg/ha of N/K, P/K and N/P/K, respectively gave more than double root yield and green top yield when compared with the check (5).

Harvesting Time

The harvesting time experiment was designed to compare the storability of sweet potato when kept in the field with and without vines after maturity to indicate the appropriate storage length in the field. The experiment conducted at Awasa and Areka Research Centres showed that late harvesting resulted in a substantial decrease in marketable root yield and a substantial increase in unmarketable root yield mainly due to insect damage (5,6,7).

The Future Direction of Sweet Potato Research Program

The Sweet Potato Improvement Program will continue the introduction, evaluation and mentenance of planting materials to broaden the genetic variability of the crop, screening early and medium maturing sweet potato varieties for different agro-ecological zones in the growing region, screening of sweet potato varieties against major insect pests such as sweet potato butterfly and sweet potato weevil, to investigate chemical control methods with their rates and frequencies against major insect pests, diseases and weeds, to investigate natural enemies of the major insect pests and their proper conservation method, to popularize different utilization aspects of the crop i.e. not only the tubers but the leaves and the tender shoots also, conducting suitable agronomic practices which can assist for successful production of the crop using the slandered cultivars which will be released in the future and s tudying to alleviate physical stresses on the production of sweet potato.. This will be done by refining, testing and evaluation procedures to be more responsive to user needs.

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LOWLAND PULSES IMPROVEMENT IN ETHIOPIA.

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Abstract

Since the establishment of the lowland pulse crops improvement at Nazareth Research Center considerable effort has been made to develop adapted, high yielding varieties of various lowland pulse crops. As a result of this effort, several pulse species which are suitable for the Central Rift valley of Ethiopia are identified and different varieties of these species are recommended/released for production. Particular effort has been made to improve the yield of haricot bean which is the most important pulse crop in the Central Rift Valley of Ethiopia. Improved varieties of haricot bean for both export market and local consumption are released in the past. Research highlights in this and achievements in other pulse crops are reviewed and suggestion for future research direction are given in this report.

Introduction

Ethiopia is primarily an agricultural country, the industry supporting the smallholder low-income rural farmer who represents about 85% of the countries population. The lowland areas of Ethiopia are climatically characterized by high temperature and insufficient amount of rainfall during the crop growing season. In most of these areas rainfall distribution is erratic and unreliable. Very short growing seasons are available for the crops grown in this part of the country. Consequently, only crop species which are adapted to such short growing seasons are essential. Those crops which are early maturing, drought tolerant and resistant to higher temperatures are of great interest to the farmers of the lowland areas of Ethiopia. Among the most important crops available to the lowland farmers especially in the Central Rift Valley, are lowland pulse crops.

These environmental background and various crop production constraints led to the establishment of the lowland pulse improvement program based at Nazareth Research Center in 1972. Since its establishment, the lowland pulses breeding program has been carrying extensive research work on lowland pulses in the past including haricot bean, cowpea, mung bean, pigeon pea, lima bean and adzuki bean. Earlier research work identified and recommended varieties of the aforementioned species suitable for areas from medium highland to semi-arid regions. However, because of the establishment of priorities among important lowland pulses, continuous breeding/selection work has been concentrated on haricot bean which is the major pulse crop in most of the lowland areas of Ethiopia. Therefore, relatively more information is available on this crop than other lowland pulses.

Besides varietal development activities, considerable achievements were made in developing the research capacity of the program through collaborative work with various International and regional programs. The most important advantages of such collaboration work have been exchanging research information and continuous exploitation of extensive genetic resource which are the prerequisite for the overall achievements of the program.

Research Highlights

Haricot bean (*Phaseolus vulgaris* L)

Haricot bean is the most important food and export pulse crop in Ethiopia and it is the source of protein and cash for poor farmers. Early maturity and double cropping often make beans the first food to become available after the annual " hungry gap" and sometimes the only food crop to mature in a short growing season (IAR, 1990). The current area under this crop is estimated at 300,000 ha. (IAR, 1990). The rift valley in Central Ethiopia is the main bean producing area contributing to about 60% of haricot bean production in the country (Alelign, 1990). The Western, Eastern and the Southern parts of Ethiopia are also the major areas for haricot ban production. Despite its role in the farming system and in supporting the national economy, yield has been low and stagnant for several years. There could be several reasons for this but the most important ones are lack of improved varieties with desirable agronomic traits, low yield potential of local varieties, diseases, low soil moisture and fertility. Other constraints can also be serious in particular zone(IAR, 1990)

Breeding/selection activity. The genetic solutions to the above production constraints lies on the provision of a range of improved cultivars that are adapted to local environments and have resistance to as many important diseases and pests as possible. To solve the many production constraints of haricot bean, efforts have been made in the past several years. One means through which this effort has been made was introduction of genetic variables, evaluation and selection from a large number of germ plasm each year. Genetic variation is the most important source for development of improved cultivars in any crop breeding program. Such variation could be made available from local collection or introduction from other countries. As haricot bean is not indigenous crop to Ethiopia, there are only few germ plasm collections in the country. As a result, at the start of the breeding program there was shortage of germ plasm for selection, and very few haricot bean lines were evaluated. Selections started with few land races collected from local markets plus few lines from new introductions.

In variety trials conducted between 1972 and 1982, at several locations and for many years, highest yields were obtained from local collections (Table 1).

Table 1. Percent of years in which the varieties were selected as high or next-high yielders during 1972-1982

Varieties	Black Dessie	15-R-52	Negro Mecntrau
High yielder	40	30	20
Next-high yielder	10	10	20

Although, insufficient genetic variation limited the possibility of selection for higher yield and other desirable traits, these varieties had relative good yield potential and disease resistance. Their yield were also consistent for many years (Table 2). Although, several years of varietal selection identified varieties which are high yielding with stable resistance to common diseases, their acceptance has been very low by the growers due to their undesirable grain color. In addition to these, other three white pea beans which are export types (Mexican-142, Tengeru-16 and Ethiopia 10) were developed and recommended for production. These varieties had fairly good resistance to bean rust and bacterial blight and gave high yield when infection pressure was not too severe (Ohlander, 1980)

Table 2. Haricot bean varieties selected for high yield during 1973-1982*

Variety	yield(q/ha)	seed color
Black Dessie	25	Black
15-R-52	26	,,
Negro mecentrau	24	,,
Mexican-142	23	White
Ethiopia 10	24	,,
Tengeru 16	25	,,

Source: IAR, 1990; Ohlander, 1980;
* year mean can be 4 or 5 years

Since 1983, the varietal selection program was refined by aiming at the development of improved varieties for both export market and local consumption (Teshome, 1990). Bean germ plasm are grouped in to export and food types and growers/consumers preferences are also given major emphasis in the varietal selection program. As a result, most of the best performing varieties in the different colored bean groups were given little consideration as possible releases because of their black seed color (Teshome, 1990).

During the later years, particularly since 1986, the number of germ plasm introductions were greatly increased and the chance of identifying improved varieties from diverse genetic variables was increased. Consequently, several promising lines for both export market and local consumption were selected and these materials showed substantial yield increase over earlier recommended varieties (Table 3).

From these promising lines, two varieties which have better export quality (Ex rico-23, named as Awash-1) and consumer acceptance (A-176, named as Roba) were released, and one variety from large seeded bean group proposed for release is provisionally accepted. These varieties showed significant yield increase over the control cultivars (Table 4).

Table 3. Mean yield of promising lines selected at several locations during 1987-1989

Group	Variety	(q/ha) Yield	% increase over the control
White Pea Beans	PAN 134	30	154
	PAN 112	27	140
	EMP 175	26	136
	Exrico-23	23	120
Medium seed size	A-265	31	131
	A-422	30	128
	A-455	30	129
	A-176	27	113
Large seeded Bean	A-262	29	144
	A-410	24	122
	ICA 15541	25	125

Source: Lowland pulses section Progress report

Currently several promising lines which are high yielding across locations (Table 5) or at specific bean production (Table 6) areas are available. Recently the variety improvement program is strengthened through initiation of crossing activities to generate genetic variations for selection.

Table 4. Yield of improved and local varieties on research center and farmers fields

Group	Variety	Yield (q/ha) RF	Yield (q/ha) FF	% yield increase RF	% yield increase FF
Export type	Awash-1	25	15	121	115
	Mexican-142 (check)	20	13	100	
Food type	Roba-1[b]	22	12	140	133
	Red wolaita (check)[b]	16	9	100	
	A-262[a]	27	12	138	120
	Brown speckled (check)[a]	20	10	100	

Source: Getachew Kassaye, 1990; Research-Extension Division, Nazareth
a : Medium seed size Bean; b : Large seed size Bean; RF = Research field; FF = Farmers field

Table 5. Yield of some promising haricot bean varieties across location (1990-1994)

Variety groups	Yield (q/ha)	% increase over the check
Export types		
EMP 175	26	104
PAC 29	26	104
Food types		
Mx 2500-19	30	111
Gx-1175-3	28	117
TY 3396-7	27	108

Table 6. High yielding varieties at specific production areas/environments (1990-1994)

Location	Variety	Yield(q/ha)	% increase over the check
Alemaya	PAC 29(W)	28	111
	TY-3396-8(MS)	35	135
	TY-3396-6(MS)	33	127
	GLP X-92(LS)	38	127
	G-2816(LS)	32	107
Awassa	PAC-29(W)	38	119
	PAN 150(W)	38	119
	PAC-19(W)	34	106
	MX-2500-19(LS)	39	105
	TY-3397-6(MD)	44	169
	TY-3396-16(MD)	40	154
Bako	EMP 175(W)	22	157
	PAN-112(W)	20	143
	MX-1309-3(MD)	23	115
	MX-2500-19(LS)	28	164
Jima	EMP 175(W)	30	125
	BAT 1198(W)	29	121
	A-422(MS)	37	158
	A-439(MS)	24	109
	ICA-15541(LS)	34	200
	G-2816	22	129
	MX-2500-19	21	124
Melkassa	PAC-29(W)	31	107
	HAL-5(W)	30	104
	GX-1175-3	35	140
	TY-3396-12(MS)	32	128
	A-195(LS)	37	103

Cowpea (*Vigna unguiculata*)

Nationally coordinated cowpea research has been under going in Ethiopia since 1972. Perhaps cowpea is the most promising crop for semi-arid rain fed areas mainly for the CRV and surrounding areas (Ohlander, 1974). Through many years of variety screening, four high yielding, disease resistant varieties are identified and are recommended for production (Table 7).

Mung Bean (*Vigna radiata*)

Mung bean has been found to perform well under hot irrigated conditions at Gode and Melka Werer. They have also been tried under rain fed conditions and has given promising results in the CRV and in the Northern Ethiopia. Four varieties of Mung Bean are recommended for the lowland areas of Ethiopia.

Pigeon Pea (*Cajanus cajan*)

It is used as a home garden crop in most parts of the country, especially below 2000 masl. Pigeon peas are drought tolerant and are therefore, suitable for areas of low and uncertain rainfall (Amare et al., 1989). Two varieties of pigeon pea are recommended in the past.

Lima Bean (*Phaseolus languidus*)

This crop is of special interest for the more humid south-western parts of Ethiopia. Through an earlier variety adaptation research two varieties of lima bean are recommended.

Table 7. Some of lowland pulse varieties recommended for production during the year(1972-1988)

Lowland pulses	Varieties	Altitude (masl)	Rain fall (mm)
Haricot bean	Mexican-142	600-1650	400-600
	Brown speckled	,,	,,
	Black Dessie	,,	,,
	Red Wolaita	,,	,,
Mung Bean	M 1134	1580-1700	,,
	M 409	,,	,,
	M 76	,,	,,
	M 109	,,	,,
Cowpea	Black Eye Bean	1150-1650	,,
	White Wonder Trailing	,,	,,
	TVU 1977-0D1	,,	,,
	Ex.Kenya	,,	,,
Lima Bean	Calico Pole	600-1700	700-800
	California Baby Lime Bean	,,	,,
Pigeon Pea	Tall Type Ex Florida	1100-1700	,,
	Short type C.M.E	,,	,,

Source :Lowland pulse improvement division

Conclusion

In the past 22 years very good effort have been made to improve the yield of haricot bean. Although, it was not so difficult to identify high yielding cultivars, varying consumers/growers preferences was the most challenging for the adoption of these cultivars. It is very difficult to combine all sets of preferences with high yield in a single genotype, however, efforts were made to reach at a compromising level. As a result varieties with acceptable level of yield combining the most important qualities are developed. These varieties showed a substantial yield progress over the original cultivars. Those genotypes with lower consumers acceptance, but high yield potential and other desired traits were selected to be used as parental materials in the hybridization program.

In the future, in addition to selection for yield and other agronomic characteristics strong emphasis should be given to some quality aspects as these can hinder the adoption of high yielding cultivars. A detailed survey and documentation of various farmers preferences are essential so that they can be included in the variety selection criteria. Inclusion of farmers in variety evaluation procedure is an important area to be given attention in the near future. This system can also facilitate generation of appropriate technology and faster adoption of a newly developed variety.

Initial screening work on other minor important lowland pulses also identified suitable pulse crops which have good potential in the country and thus several varieties are recommended. Further research work on these crops should be emphasized in the future to give farmers in the lowland areas with several alternatives for stressed production environments.

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PROGRESS AND PROSPECTS OF THE NATIONAL SORGHUM BREEDING PROGRAM

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Abstract

Sorghum occupies 726 000 to 1 026 000 hectares with annual production of 1 to 1.6 million tons of production annually. Sorghum is one of the major traditional food crops in Ethiopia, with wide uses. The tremendous range of genetic diversity existing in the indigenous germ plasm collections evidenced that it is native to Ethiopia. This genetic diversity also indicates the variability of sorghum growing environments in Ethiopia in terms of elevation, temperature, precipitation and length of growing period. Sorghum improvement research work has been initiated with the establishment of the then Alemaya college of Agriculture and dates back to the mid-fifties. To adequately address sorghum production constraints of the mid and low elevation areas, a National Ethiopian Sorghum Improvement Program has been established in 1977 with a coordinating center based at Melkassa. The overall objectives of the sorghum breeding program has been developing varieties and hybrids with high and dependable yield. Over the years, the sorghum breeding program has developed and released several varieties. Of these, six are on the current seed multiplication list of Ethiopian seed Corporation (ESC). Since 1985 over 3400 quintals of these improved seeds have been produced by Melkassa Research Center alone and distributed to governmental ESC, MOA and Non-governmental organizations. Other promising varieties for the dry and humid areas have been developed and proposed for release. The sorghum breeding program emphasis is on the development of varieties and/or hybrids with better tolerance to drought, good stand establishment, resistance to pests and diseases.

Introduction

Sorghum is one of the leading traditional food crops of Ethiopia occupying about 0.8 million hectares of land annually. It ranks third in the country following maize and tef in total production and second to tef in injera making quality.

The crop is utilized in different forms where the grain is used for human consumption and home made beverages, the leaves and stalks are commonly fed to animals. The hefty stalked sorghum is used for construction of houses and for fuel. The juicy stalks are commonly chewed like sugar cane (Brhane, 1979). Brhane (1979, referring Doggette) also stated that sorghum is first domesticated in the Vavilovian Abyssinian Center of Origin which covers the north eastern quadrant of Africa where both cultivated and wild sorghum are found in greatest variability.

In Ethiopia the crop is grown under a wide range of environmental conditions which has given rise to a wealth of genetic variability in terms of grain color, quality, plant height, disease resistance, adaptation to wide array of temperature and moisture regimes. Such highly variable genetic resource is found very useful for sorghum improvement program in Ethiopia in particular and for the world at large.

Obviously, as diverse are the sorghum growing environments so also the range of both biotic (Striga, diseases, insects, birds, etc) and abiotic (drought, soil fertility, frost, etc) sorghum production constraints. To alleviate these yield limiting factors and there by increase sorghum productivity, sorghum research work was initiated in the mid-fifties, with the establishment of the then Alemaya College of Agriculture. However, after critical evaluations, it was found inappropriate to address the problems of all production zones from Alemaya. For the purpose of sorghum improvement in Ethiopia four adaptation zones of sorghum are recognized. These are, highlands (>1900m) with about 800mm rainfall, intermediate (1600m -1900m) with high rainfall (>1000mm), lowlands (<1600m) with low rainfall (<600mm) and lowland (<1600m) with high rainfall (>800 mm) (Brhane, 1981). The national sorghum improvement program has representative locations in each of the ecological zones except the lowland with high rainfall areas. Each of the four distinct zones of adaptation needs different group of sorghum for the area. Which means different breeding program is necessary for each zone. However, because of shortage of high level trained man power and limitations of facilities, it has been found necessary to develop and run only one coordinated national breeding program at Melkassa Research Center, with the objective of developing sorghum varieties/hybrids with high yield potential which can contribute to the increased food production. The purpose of this paper is to review the progress and prospects of the national sorghum breeding program coordinated from Melkassa Research Center.

Manipulation of Genetic Stocks

The sorghum breeding program diversifies its germ plasm base from which superior types that can tolerate the various stress factors in the major sorghum production regions are identified through: acquisition and evaluation of germ plasm from indigenous and exotic sources, and generation of variability from planned hybridization.

Indigenous collection

Evaluation of available germ plasm based on needs and requirements of the breeding program aid in the better utilization of available resources. Ethiopia has provided a good base for the sorghum improvement program. Over 10,000 indigenous sorghum germ plasm accessions from the different sorghum producing regions of the country were evaluated for some agronomic and taxonomic characteristics by the Ethiopian Sorghum Improvement Program and Plant Genetic Resources Center/Ethiopia (PGRC/E). Selected accessions have been found very useful and used in various aspects of breeding program to transfer some of the valuable traits into otherwise high yielding varieties (Brhane, 1978). Selections possessing various desirable traits have made up 20-30% of the total number of parents used in the hybridization program. Yilma (1990) reported that pure line selections from indigenous materials have constituted close to 43% of the total number of entries included in the various variety trials.

Over the years, 12 varieties derived from indigenous collections have been recommended for release and five of these are on the current recommendation list. These include *Alemaya 70* and *ETS 2752* for high elevations, *Dedesa 1057* and *Asfaw White* for intermediate elevation and *Gambella 1107* for low-elevation areas (Abebe & Aberra, 1985).

Introduction of germplasm

In the low-elevation sorghum producing areas of Ethiopia, the growing season is short and rainfall is erratic and unreliable. In such areas, the late-maturing sorghum varieties grown by farmers are frequently exposed to moisture stress at critical phases of growth which results in either low yields or total crop failures. To stabilize and improve sorghum production in such areas, the requirement for early maturing genotypes that can match their critical stage of growth with favorable periods of the growing season are needed. Because of the limited number of early maturing genotypes of sorghum in the indigenous collections (Yilma & Abebe, 1989), it has become necessary to look for such materials from international (ICRISAT), regional (SAFGRAD, EARSAM), and national (USA, Uganda, Kenya, Tanzania) programs dealing with the improvement of these crops in order to promote active germ plasm exchange.

Since 1977, close to 10,723 exotic sorghum from international and national programs were received and evaluated mainly at testing sites representing moisture stress areas of the country and about 9% of these introductions were initially advanced for further testing. Some of these selections have been used as sources of desirable genes for yield, maturity, height, good grain quality and pest resistance. In any one year these selections constituted between 40% and 80% of the total number of parents used in the hybridization program .

Most of the selections from exotic sorghum have been purified and promoted to preliminary and national variety trials. Yilma (1990), stated that entries derived from exotic sorghum constituted 24 and 60% of the total number of entries included in the various intermediate and low elevation variety trials, respectively.

Several promising materials have been identified from the different introductions. Five early maturing and low elevation adapted varieties: *Kobomash 76*, *76T₁ #23*, *Melkamash 79*, *Seredo* and *Dinkmash* and three sorghum varieties of intermediate maturity, *Bakomash-80*, *IS 9302* and *IS 9323* were derived from various introductions.

Hybridization

A large number of crosses were made in order to enhance the probability of obtaining unique cross-combinations yielding recombinant of economic worth. The first crosses (F_1) have been sown in the off-season and the resulting F_2 seeds have been tested in the main seasons at the eventual areas of release. Selections from each generation grown at two or more testing sites representing a similar adaptation zone were pooled to form the planting materials for the following seasons. Selections from segregating generations constituted the bulk of the entries included in the low and intermediate elevation preliminary and national variety trials. Most of the selections possesses resistance traits for pest and diseases. On this line, a back-cross program aimed at transferring anthracnose (*Colletotricum graminicola*) resistance from selected lines in elite indigenous sorghum which are otherwise susceptible resulted in resistance lines (Abebe *et al.*, 1987) with good agronomic backgrounds (Table 1). So far, the results have been encouraging and one variety, *Birmash*, derived from this program has been released in 1990 for production and others have reached the verification stage (Tadesse *et al.*, 1995).

Performance tests

The hybrid breeding program which has been initiated in the mid seventies has made good progress. Over the years 500 A and B lines have been introduced from ICRISAT, Texas A & M and Purdue University and testing procedures for identifying promising hybrids have been developed (Brhane, 1980).

Table 1. Mean Grain yield (q/ha), days to flowering, plant height (cm) and disease score of backcross-derived progenies.

Selection	Grain yield	Days to flowering	Plant height	Disease score*
IS 158 x (ETS 2111)[4]	23	108	170	3.6
IS 2230 x (Awash 1050)[4]	41	106	198	6.8
IS 158 x (ETS 3235)[4]	51	112	171	4.5
NES 8827 x (ETS 3235)[4]	43	116	180	6.3
NES 8827 x (WB-77)[4]	39	114	185	4.8
ETS 2111	50	127	167	7.2
ETS 3235	48	134	240	7.6
WP-77	33	130	252	7.6

*/ A diseases score of 1 to 9 , were 1 represents no infection and 9 a 100% infection.

Parental lines (A & B) with good nicking ability have been identified and crosses have been made with advanced lines which have been included in the lowland national variety trials and the resulting hybrids were evaluated for their partial and complete fertility. Test crosses which have complete fertility with good agronomic backgrounds have passed through the initial, advanced and elite hybrid testing stages (Brhane, 1980). Considering adaptability, earliness, stability and yield advantage several hybrids have been identified (Table 2) for moisture stress environments.

To meet the demands of the diverse sorghum producing environments, different variety trials have been organized and evaluated in several sites representing each major adaptation zone. Since 1977, several variety trials consisting of promising materials derived from various sources have been evaluated at two or more testing sites. These trials have been organized based on height, maturity, yield potential and agronomic desirability. Over the years, several superior varieties identified from these trials have been recommended for release and some of them are on the current recommendation list. Agronomic characteristics of these varieties are given in Table 3.

Apart from these released varieties, there are a number of varieties that have reached the final stages of verification and are on the pipe line for possible release (Table 4).

Seed production and distribution

To meet the high demands of improved sorghum varieties, the Melkassa Research Center has produced over 3, 400 quintals of early maturing sorghum varieties since 1985. Seeds produced have been distributed to governmental (ESC, MOA) and non-governmental organizations.

Summary

The sorghum breeding program has been diversifying its germ plasm base through acquisition of materials from local and foreign sources and generation of variability from planned crosses. Materials derived from these sources have been evaluated for various desirable traits and promising lines with consistence performance over the years and locations have been released. The sorghum breeding program emphasizes on the development of varieties and/or hybrids with better tolerance to drought, good establishment, and resistance to pests and diseases.

Table 2. Mean grain yield (q/ha) days to flowering and plant height (cm) of hybrids in advanced yield trial tested at Melkassa, Miesso, Sirinka.

	Grain yield				Days to flowering				Plant height			
Identification	MK	MI	SR	Mean	MK	MI	SR	Mean	MK	MI	SR	Mean
ICSA-88001xICSR-18	37	58	69	55	64	67	80	70	151	173	157	160
" " 2	41	60	62	48	66	70	81	72	173	185	160	173
ICSA-5 x ICSR-14	38	57	67	54	64	70	79	71	173	175	178	176
ICSA-3 x ICSR-145	35	53	65	51	64	70	77	70	143	153	149	148
ICSA-5 x ICSR-63	40	47	64	50	60	64	76	67	172	170	195	179
ICSA-30 x ICSR-14	25	51	75	50	66	69	75	70	143	143	146	144
ICSA-3 x ICSR-161	27	55	66	49	60	63	77	67	145	156	141	147
ICSA-30 x ICSR-16	33	49	64	49	63	69	75	70	148	173	162	161
" " 50	37	48	60	48	64	70	79	71	167	173	157	166
ICSA-5 x ICSR-50	35	54	55	48	65	66	75	69	172	178	174	175
ICSA-88001 xICSR-14	32	49	62	48	66	81	85	74	165	187	141	164
ICSA-30 x ICSR-117	28	53	62	48	65	70	79	71	173	185	160	173
ICSA-30 x ICSR-2	30	50	62	47	66	70	78	71	145	157	148	150
Dinkmash (St. chk)	27	34	39	33	66	70	82	73	155	173	129	152
Mean	33	51	62		64	69	79		159	170	157	
L.S.D (.05)	12	11	21		1.5	2.2	1.7		22	42	17	
C.V (%)	22	13	20		1.4	2	2.8		8.2	15	6.5	

Table 3. Agronomic and other information on released/recommended sorghum varieties derived from indigenous and introduced materials (1976-1995)

Designation	Pedigree	Year of release	Days to flowering	Plant height	Yield range
High Elevation					
Alemaya	Indig. coll	1970	120-130	250-284	3.0-5.5
ETS 2752	"	1978	130-140	234-285	3.0-5.5
ETS 4946	"	1978	120-140	255-440	3.0-6.0
Intermediate elevation					
Bakomash 80	IS 9521	1981*	108-136	200-210	3.0-5.0
IS-9302	IS 9302	1983	87-120	100-180	3.0-6.0
Birmash	80 LPYT-1 x IS 9302	1990	84-121	131-233	3.1-6.9
Low elevation					
Gambella 1107	Indig. coll	1976	80-95	150-200	3.0-5.0
Melkamash	Diall.pop 7-8	1979*	70-80	109-140	3.0-4.5
Dinkmash	(SC108-3 x CS3541)	1986	63-90	103-107	2.0-5.0
Seredo	5Dx/35/13/1/3/1	1986	65-80	110-140	2.0-4.0
76 T^1 #23	954062 x 73pp9	1979	60-70	120-140	2.5-4.5
Kobomash 76	SC 108	1976*	77-88	109-140	2.5-3.5

*/ Not on current recommendation list

Table 4. Characteristics of Sorghum Varieties in the Pipe-line

Identification	Grain Yield (t/ha)	Days to flowering	Plant height (cm)
Highland			
IS 158 x (ETS 2113)[4]	6.8	130	195
IS 158 x (ETS 3235)[4]	5.9	127	195
ETS 3235	5.7	133	185
PGRC/E Inc. #202	4.9	139	230
PGRC/E Acc. #262	3.8	144	220
ETS 2752	5.2	142	220
Local check	4.4	140	310
Intermediate			
85 MW 5667	4.0	93	185
85 MW 5334	4.6	92	160
85 MW 5552	4.8	91	200
IS 9302	3.9	92	180
Lowland			
12x34/F4/3/E/1	2.3	61	170
M 36121	2.2	66	180
(148xE-35-1)-4-1XCS 3541			
derive-5-4-2-1	3.1	73	168
(148xE-35-1)XCS 3541	2.2	73	150
ICSV 83386	2.1	67	150
(148xE-35-1)X-4-1XCS	35	41	
derive-5-3-2	2.6	68	155
OZx26/F5/5/E/3	3.7	61	160
Dinkmash (check)	1.0	66	165

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REVIEW OF TEF RESEARCH IN THE MARGINAL RAINFALL AREAS OF ETHIOPIA: PAST AND FUTURE PROSPECTS

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Abstract

Tef [*Eragrostis tef* (zucc) Trotter] is one of the most important cereal food crops grown almost exclusively as a grain crop only in Ethiopia. The crop is cultivated almost entirely as a rain-fed crop by subsistence farmers. The production of tef is currently expanding to most of the drought affected areas. In these areas, in fact, tef production is replacing that of maize and sorghum. Similar to other cereals that are grown in the semi-arid areas of the country, tef encounters various production constraints. Despite the importance of the crop in the Ethiopian agriculture, there is a dearth of information on the improved production technologies of tef.This paper attempts to review the limited available research activities on tef including screening of drought tolerant cultivars, soil fertility management, improved cropping systems and cultural practices and also indicates future research needs.

Introduction

Tef [*Eragrostis tef* (Zucc) Trotter] is one of the most important cereal food crops grown almost exclusively as a grain crop only in Ethiopia. The crop is cultivated almost entirely as a rain-fed crop by subsistence farmers. Tef ranks first in importance both in area and total production (CSA 1988, 1989) amongst the food crops grown with an annual production of 1.3 mt, valued at over Birr 2.8 billion (Table 1). Its importance is based primarily on consumer preference for >injera= made from tef grain. Its agronomic versatility and reliability even under adverse conditions which suit it well to a country of contrasting and unpredictable environments where water logging, drought, pest and disease are all too common and bring repeated famine also makes this crop very important.

Tef is a genetically diverse species, adapted over a wide range of ecological zones than any other cereal. It grows from cold plateaux at up to 3000m often on water logging prone vertisols, down to hot dry regions below 1500m. In its current forms suitable areas of tef production lies at an elevation of 1700m-2500m, in Shoa, Gojam and Gonder administrative regions in the central high lands. The production of tef is currently expanding to most of the drought affected areas (Seifu, 1993). In these areas, in fact, tef production is replacing that of maize and sorghum. One of the best peculiarities of tef in moisture stress areas is the position it occupies in terms of crop calendar and to the relative position of its planting time in the probability of receiving enough rainfall (Tilahun and Teshome, 1987). Other advantages which contributed to the sustainability of tef includes:

1. Cattle prefers to feed on tef straw rather than any other cereal straw making tef straw an important source of feed during the dry season when feed shortage is acute.
2. Tef has higher market prices than the other cereals, for both its grain and straw.
3. It has got high acceptance in the national diet.

4. Unlike other cereals, tef grain is not attacked by weevils, which means that it has a reduced post harvest loss in storage and requires no pest-controlling storage chemicals (Seifu, 1988).

Table 1. Estimate of area (ha), production (qu) and yield of major cereal crops in Ethiopia in 1988 and 1989.

Crop	Area		Production		Yield q/h.	
	1988	1989	1988	1989	1988	1989
Tef	1461240	1226960	12177240	10461380	8.33	8.53
Barley	958470	912140	10181620	10630450	10.62	11.65
Wheat	647630	605070	7999360	7987510	12.35	13.20
Maize	1021100	1277690	16886860	20556360	16.54	16.09
Sorghum	627070	738250	8492120	9728050	13.54	13.18
Millet	132960	154770	1121900	1524550	8.44	9.85
Oats	42320	42430	476630	486930	11.26	11.48

Source: Central statistical Authority (1988 and 1989).

Production Constraints

Whilst tef yield is relatively reliable under variable environmental conditions, its yield is exceptionally lower than sorghum, maize, wheat, barley and many other crops grown in Ethiopia. The major contributory factors for its low yield depends on the soil type, cultural practices and availability of improved cultivars.

In the semi-arid areas of the country drought and poor soil fertility, high incidence of grass weeds and lack of drought tolerant high yielding cultivars are important constraints for low tef yield. The rainfall in these area can be characterized as, low in quantity, often high intensity, poorly distributed lacking in dependability. The soils in these areas have little or no organic matter content, their water retention capacity has decreased substantially, years of high soil erosion have left many of these soils with a shallow rooting depth. As a result their fertility is very low. Grass weeds, due to similar morphological characteristics with tef, are difficult to control even using hand weeding specially at early stage, thus reduce tef yield to a significant level.

Therefore, screening of genotypes, appropriate soil management technologies and improved cultural practices for sustainable tef production needed close research attention.

Past Research Activities

In spite of the importance of the crop, little attention has been given to the improved production of tef. It is only recently that a few agronomic research was started although there were a few collaboration work with tef improvement program to screen high yielding and drought tolerant cultivars.

Screening for drought tolerant cultivars

Drought stress during the growing season is the main factor for tef yield reduction in marginal rainfall areas of the country. A practical and economical solutions to this problem is to select or develop early maturing, high yielding and drought tolerant cultivars. Drought escape, achieved through short growth period, is an important means for reducing the hazard of exposure to stress. In an effort to address this problem of drought, a breeding program for drought resistance has been initiated by the national tef improvement program and has been able to release an early maturing (drought escaping) variety, DZ-CR-37. Plant phenology, an important attribute to be considered in the context of plant adaptation and its consequences for drought, has been evaluated using 12 different tef genotypes during 1993 and 1994 at Melkassa Research Center. Although the actual yield of the genotypes was not expressed due to severe bird damage, significant difference was observed between genotypes and moisture regimes for the different phenological, morphological and physiological data measured (Tables 2 & 3).

Days to heading under stress ranged among genotypes from 32 to 44 days after emergence (DAE) (Table 3). Mean days to heading and maturity for cultivar DZ-01-2089 occurred at 31 and 67 DAE respectively giving good potential to escape drought. On the other hand days to maturity for DZ-01-354 occurred at 80 DAE. From this date it was possible to see that the genotypes consisted of early, intermediate and late maturing types. The results also suggested that plant height and panicle length were significantly affected by the drought stress treatments. The mean plant height and panicle lengths ranged from 43 to 72 cm/plant and 19 to 33 cm/plant, respectively.

Crop production strategies are mainly designed to maximize light interception by achieving complete ground cover through promoting rapid leaf expansion and growth. Increased leaf area during vegetative growth is important in terms of optimizing dry matter production and is of value in estimating cultivar drought responses. In the above experiment leaf area index (LAI) and light interception were measured and the results indicated that significant difference was observed between genotypes and moisture regimes applied. LAI was reduced by the drought stress treatment in all cultivars and the highest percentage reduction in LAI occurred in DZ-01-2089 (62%) and DZ-01-354 (54%) whereas the lowest percentage reduction in LAI occurred in DZ-01-1662B (10%).

Light interception is a function of the size of the photosynthesis system which may be expressed in terms of LAI. Difference was also expressed between genotypes for the amount of light intercepted. The reduction in light interception in stressed plants ranged from 21 to 40 percent. The reduction in the LAI of the drought stressed plants in all the genotypes had caused a significant reduction in the light interception by the leaf surface.

Screening of 134 different tef genotypes is also under way using line source irrigation scheme for selection of cultivars for drought tolerance.

Table 2. Response of different tef genotypes under different moisture regimes in the off-season during 1994.

Genotypes	Days to heading			Days to maturity			Plant height (cm/plant)		
	St	NS	Mean	St	NS	Mean	St	NS	Mean
1. DZ-01-354	43	43	43	80	79	80	64	74	68
2. DZ-01-1292	39	38	38	76	76	76	63	71	67
3. DZ-01-296	39	38	38	79	76	77	60	75	68
4. DZ-01-481	44	44	44	75	75	75	62	66	64
5. DZ-01-530	42	44	43	77	76	77	71	70	70
6. DZ-01-2089	32	29	31	69	65	67	40	46	43
7. DZ-01-1015	45	43	44	79	75	77	60	67	64
8. DZ-01-1910	42	41	42	80	73	77	56	54	55
9. DZ-01-1662B	39	40	40	79	78	79	66	79	72
10. DZ-01-1020	39	38	39	79	77	78	63	71	67
11. DZ-01-1628B	38	39	39	79	77	78	57	67	62
12. DZ-01-1122	38	38	38	76	74	75	59	67	63

Source: Unpublished data
ST = > Stressed blocks; *NS* = > Non stressed blocks

Table 3. Response of different tef genotypes under different moisture regimes in the off-season during 1994.

Genotypes	Panicle length (cm/plant)			Leaf Area Index			Light interception (MO1)		
	St	NS	Mean	St	NS	Mean	St	NS	Mean
1. DZ-01-354	28	35	32	0.573	1.243	0.908	734	1077	906
2. DZ-01-1292	30	36	33	0.637	0.917	0.777	680	1047	864
3. DZ-01-296	31	35	33	0.563	0.800	0.682	697	1082	890
4. DZ-01-481	27	33	30	0.677	1.090	0.883	678	942	810
5. DZ-01-530	33	33	33	0.630	0.880	0.755	877	1109	993
6. DZ-01-2089	18	20	19	0.350	0.923	0.637	855	1069	962
7. DZ-01-1015	28	33	31	0.580	0.927	0.753	617	980	799
8. DZ-01-1910	29	26	28	0.553	0.783	0.668	679	1125	902
9. DZ-01-1662B	30	34	32	0.547	0.607	0.577	578	915	746
10. DZ-01-1020	31	34	32	0.600	0.787	0.693	728	975	852
11. DZ-01-1628B	25	31	28	0.517	0.690	0.603	826	1221	1023
12. DZ-01-1122	29	35	32	0.513	0.747	0.630	753	1050	902

Source: Unpublished data
ST => Stressed blocks; NS => Non stressed blocks

Soil fertility management

Poor soil fertility is one of the major production constraints in the semi-arid regions of Ethiopia. Many of the soils are deficient in essential nutrients. It is believed that the problem of poor soil fertility in this marginal rainfall areas needs to be addressed as a matter of urgency. In view of this, tef fertilizer response experiment, with and without moisture conservation practice, was conducted during 1993 and 1994 cropping season on farmers field around Nazareth (Welenchiti, Boffa and Wonji). The two years data indicated that there was no significant interaction between different levels of fertilizer applied and moisture conservation practices across locations and over the years. But, the mean grain yield was significantly affected by fertilizer treatments across locations and over years except at Wonji in 1993.

Application of 64 N, 46 P_2O_5 gave the highest yield at both Welenchiti and Wonji whilst application of 32 N, 23 P_2O_5 resulted the highest yield at Boffa and yield reduction was observed when fertilizer was applied beyond this level (Table 4). From this results it is not possible to reach at a specific recommendation and further investigation is needed to reach at a conclusive results.

Table 4. Fertilizer Response of Tef with and without moisture conservation practices at Three On-farm locations during 1993 and 1994 Cropping Seasons.

Treat	Grain yield (kg/ha)								
	Welenchiti			Boffa			Wonji		
	1993	1994	Mean	1993	1994	Mean	1993	1994	Mean
1.	1556	1028	1292	565	633	599	1432	417	924
2	1599	1197	1398	522	685	602	2405	445	1425
3	2175	1262	1719	837	823	830	2350	960	1655
4	2036	1333	1685	771	1121	946	2290	970	1630
5	2132	1702	1917	481	783	632	2040	963	1502
6	2481	1723	2102	655	859	757	2263	1049	1656
LSD (0.05)	400.3	309.9	242.5	77.1	139.5	76.35	NS	77.04	NS
CV (%)	13.3	14.96	14.09	8.01	11.31	15.34	23.59	6.39	25.74

Source: IAR, Nazareth Progress Report for 1994
NS-Non significant

Treatments

1. O N, 0 P_2O_5 - Tef on open furrow
2. O N, 0 P_2O_5 - Tef on tied furrow
3. 32 N, 23 P_2O_5 - Tef on tied furrow
4. 32 N, 23 P_2O_5 - Tef on open furrow
5. 64 N, 46 P_2O_5 - Tef on tied furrow
6. 64 N, 46 P_2O_5 - Tef on open furrow

Improved cropping systems

To minimize the risk of crop failure farmers inter-crop tef either as a major or second crop. Traditionally, tef is relay cropped in maize stands at about silking stage in Sidamo and Hararghe. It is also largely inter-cropped with rape seed and safflower in Gonder, Tigray, Gojjam and with sorghum in Wello. It is also mixed cropped with rape seed, safflower and amaranths species in the rift valley (Nigusse, 1994). Some work is on progress at Melkassa Research Center to study the compatibility that exists between tef and companion crops (amaranths, safflower, rape seed and mustard). Alley cropping of leguminous shrubs and tef was conducted at Sirinka in 1987-88 cropping seasons. The results of this trial (Table 5) indicated that sole cropping of tef gave 747 kg/ha while 716 kg/ha and 637 kg/ha yield was obtained when alley cropped with *Sesbania sesban* and *Leucenea leucocephala*, respectively suggesting that the possibility of producing both crops without significant yield reduction of the main crop. Besides, the leguminous shrubs produced substantial amount of dry matter which can be used for animal feed, green manure, mulch and fuel wood.

Table 5. Effect of alley cropping *Sesbania sesban* and *Leucaena leucosephala* on seed yield of tef at Sirinka, 1986/87

Treatments	Seed yield (kg/ha)	Stover yield (kg/ha)
Sole tef	747	2300
Tef + *Sesbania sesban*	716	2390
Tef + *Leucaena leucosephala*	637	2158

Source: Kidane et al (1988b)

Cultural practices

Improved and stable tef production in marginal rainfall areas of Ethiopia depends on the optimization of a crop management such as using proper seeding rates, reliable sowing dates and efficient weed control. In the past, a few and isolated cultural practice research activities were conducted at different research centers to address the major production constraints of the respective locations.

An experiment was conducted at Kobo research center to determine optimum plant population density per unit area and frequency of weeding for optimum growth and improved yield of tef during 1985 cropping season (Table 6). The result indicated that no significant yield difference was obtained for both seed rate and weeding frequency. However, some yield advantage was obtained by sowing at the rate of 25 kg/ha seed and weeding once, but yield reduction was observed when increasing the weeding frequency and plant density beyond this level. As a result using seed rate of 25 kg/ha and weeding once resulted in seed yield of 662 kg/ha and 627 kg/ha, respectively. When seed rate increased to 30 kg/ha, it resulted in 461 kg/ha and weeding twice and three times resulted 449 kg/ha and 536 kg/ha, respectively.

In arid and semi-arid regions, the choice of an appropriate sowing date may have a considerable effort on water use efficiency (in relation to economic yield) by ensuring that the pattern of growth of the crop is adjusted to the pattern of precipitation or to available soil moisture (Simpson, 1981). Sowing date trial was conducted at Mekele to determine optimum sowing time for tef in 1974-75 cropping season (Table 7). Three sowing times (early July, mid July and early August) and three varieties were used. The results obtained indicated that mid July sowing gave the highest yield irrespective of the variety used.

Table 6. Mean seed yield of tef as influenced by seed rate and weeding frequency at Kobo 1986.

Seeding rates	Seed yield (kg/ha)
20 kg/ha	530
25 "	662
30 "	461
LSD 0.05	NS
CV (%)	39.64
Weeding frequency	**Seed yield (kg/ha)**
No weeding	591
One weeding	627
Two weeding	449
Three weeding	536
LSD 0.05	NS
C.V. (%)	42.91

Source: IAR, Kobbo Research Center Progress Report 1986;
NS-Non significant

Table 7. Sowing date trial on tef at Mekele, 1974 and 1975 crop season

Variety	Grain yield (kg/ha)					
	1974			1975		
	Early July	Mid July	Early August	Early July	Mid July	Early August
Local	1031	885	582	1530	1664	1667
DZ-01-238	826	907	516	1269	1514	1369
White Dubie	-	-	-	1519	1706	1603
$LSD_{0.05}$						
Sowing date		336			NS	
Variety		NS			NS	
CV (%)		25			18.8	

Source: IAR, Mekele progress report 1974-75; NS - Not significant

Weeds has been identified as the major production constraints of tef around the central rift valley. To address this problem herbicide verification trial was carried out around Nazareth area during 1988 cropping season. Two herbicides were verified in comparison with two distinct hand weeding. The results revealed that most of the broad leaf weeds were controlled by herbicides however grassy weeds were able to survive after spraying (Table 8). The highest yield was obtained from two times hand weeding followed by 2,4-D and Mecoprop. The results also indicated that grass weeds are more important for yield reduction. Looking this issue an attempt is on progress to screen herbicides for the control of grass weeds and sedges for tef at Melkassa Research Center.

Future Research Needs

The future research on tef in marginal rainfall regions has to focus:-

- Establishing easy and efficient screening techniques for drought resistance.
- Continue screening of drought resistant genotypes on the basis of morphological and physiological traits.
- In-depth investigation of soil fertility management such as fertilizer requirement and method of application and their interaction with moisture conservation practices.
- Identification of low input and nutrient efficient tef cultivars.

- Establishing cropping systems techniques that minimize the effects of drought and increase water use efficiency and also permit intensification and diversification of production both in time and space so as to increase total crop yield and net cash return per unit area and time.
- Establishing appropriate cultural practices for improved water use efficiency and their interactions with other management factors.

Table 8. Grain yield (q/ha) of tef herbicides Vs hand weeding trial during 1988 cropping season.

	Locations						
Treatment	Bishola	Mermersa		Deki-Adi	Wele	Dabie	Mean
		1	2				
2, 4-D	8.6	10.16	12.5	19.14	11.86	12.5	12.46
Mecoprop	8.59	11.66	12.5	17.63	12.69	10.94	12.34
2XHW	8.6	11.72	13.67	19.92	13.28	13.11	13.38
1XHW	8.2	9.38	11.72	19.53	12.15	10.55	11.92
Mean	8.5	10.73	12.6	19.06	12.5	11.78	12.53
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS
$LSD_{0.10}$	NS	NS	NS	1.32	1.01	1.74	NS
CV (%)	6.28	15.14	10.95	7.39	4.5	3.63	8.85

Source: Steven et al 1988; NS - Non significant

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MAIZE BREEDING FOR DROUGHT STRESSED AREAS OF ETHIOPIA: A REVIEW

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Abstract

Drought stressed areas devoted to maize production occupy 38 to 42% of the total maize growing area but contribute only about 17% to the total maize production. Unreliable rains that are very poorly distributed during crop growth and non availability of suitable maize varieties are responsible for such significant yield reduction. To minimize the yield reduction and thereby reduce farmers risk of crop failure, germ plasm development work has been started by Awasa College of Agriculture in 1976 and Nazareth Maize Program in 1992. Since then several early maize varieties were developed by the College of which ACV-3 and ACV-6, drought tolerant materials, were identified from the screening and multi-site evaluation by Nazareth Maize Program.These promising materials have been directed to different breeding schemes for further evaluation. Although the major emphasis at present is placed on breeding for earliness, the future breeding strategy will focus on the development of drought tolerant maize varieties. Along with this, mechanism of drought tolerance will be studied.

Introduction

In the drought stressed areas which constitute about half (46%) of the total arable land (Reddy and Kidane, 1993), maize is one of the most widely grown and important food crop. Though the area under maize is large (400 000 ha) in these areas, the contribution to the total maize production is very low (269 000 tons) resulting mainly due to unreliable rains that are very poorly distributed during crop growth and non-availability of suitable maize varieties: early and/or drought tolerant (Mandefro, 1995).

Until 1976, germ plasm development was mainly for high rainfall areas. Maize breeding work for drought prone areas has been started in 1976 by Awasa College of agriculture (ACA) and recently in 1992 by Nazareth Maize Program (NMP). Since then many breeding activities have been carried out using standard breeding methods and as a result promising maize varieties were identified and developed. This paper summarizes the importance and scope of drought stress, germ plasm source, breeding methods used, varieties identified/developed by ACA and NMP, and the future plan of NMP.

Drought Stressed Areas of Ethiopia

Importance and distribution

Although there is no proper documentation before 1950 (Workneh, 1987), drought stresses of different intensities have occurred in different parts of the country, incurring losses of life and property. Since 1950s, there have been many notable drought stressed years, of which the 1973/74 and 1983/84 were the most catastrophic. Drought stress affects mainly along the Rift Valley,the Northern, Northeast, and Eastern parts of the country. There is a concern that drought stress occurs once in every ten years in the country as whole and four out of the five years in the drought stressed areas.

In terms of magnitude 46% of the total arable land and 40% of the maize growing area (Geremew, 1988) fall under drought stressed areas. Of the total population, 25% i.e 13.75 million people live in these areas.

In general, drought stressed areas are characterized by scanty and unreliable rains, annual precipitation of less than 800 mm, hot temperature, dry air, non availability of suitable maize varieties, poor soil fertility lack of appropriate technologies for soil and water management, low cash income that bring about limitation to use chemical inputs, and peak season labor shortage.

Categories of Drought Stressed Areas

Geremew (1988) categorized drought stressed areas into two based on altitude and rainfall distribution.

Low-altitude drought stressed areas

These areas are located between 500 and 1400 masl and has a uni-modal rainfall distribution with usually drought spell in between. In these zones there are also extremely marginal areas receiving a very high intensity of rainfall for a very short period of time and in such cases supplementary irrigation is required for successful maize production. Early maturing maize varieties with drought tolerance characters can be grown.

These areas are represented by the low lands of the south, southeast, southern Awash basin, Omo basin, Omo valley, and western low lands except Gambella.

Mid-altitude drought stressed areas

This zone is located between 1400 and 1800 masl and has a bi-modal rainfall distribution. The first rain (Belg) comes from mid-March to mid-April and the second rain (Kiremt) is from mid-June to September with usually drought spell in between. Drought tolerant maize varieties that are intermediate in maturity can be grown in this zone.

Regions that represent this zone are Central and Southern rift valley of Ethiopia, parts of the Shebelle basin, Northern Shewa, Wello and Tigrai.

Status of Maize in the Drought Stressed Areas

Maize production area has increased and become popular due to various reasons. The reasons for its popularity are many and include the following:

1. it gives the highest yield per unit area,
2. it provides nutrient in the compact form,
3. its husks give protection against birds and rain,
4. it is easy to harvest and shell, and does not shatter,
5. it can be harvested over a long period, and

6. consumers preference, many people prefer maize to other crops.

Although maize is one of the most widely grown cereal crops, it is subjected to periodic drought due to erratic rainfall and this unreliable rain causes a sizable reduction of maize grain yield. This is particularly true when the stress coincides with critical stages of development (early seedling, flowering, and early grain filling).

The major maize producing regions in the drought stressed areas include: Northern Shewa, Central and Southern Rift Valley, low lands of Bale, Southern parts of Awash basin, Shebele basin, and along the Blue Nile tributaries (Geremew, 1988). Total area under maize in Ethiopia in 1992 was 1 million hectares (Benti, 1993) and the total production in the same year was 1.7 million tons. By manipulating the above data, the total hectarage under maize, total production and the magnitude of grain affected by drought in these areas can be estimated:

1. area affected by drought, 40% x 1,000 000 ha = 400 000 ha
2. total production (at 1.7 t/ha) = 680 000 tons (expected)
3. total production (at 17%) = 269 000 tons (actual)
4. difference between expected and actual = 391 000 tons

Although maize is affected by drought stress farmers kept on growing maize. In the survey made around Nazareth, which is one of the drought prone areas in the Central Rift Valley, maize is grown by 95% of the sample farmers. According to this survey most farmers grow *Katumani* while some grow intermediate varieties like A511, *Sheye*, and *Harerghe*. *Katumani* was introduced from Kenya and being used in Ethiopia for more than 20 years. It has lost its genetic potential due to out crossing, becomes low yielder and susceptible to mid-season drought (Aleligne et al, 1992).

Maize Breeding for Drought Stressed Areas

Prior to 1976 major emphasis was given to the development of germ plasm for high rainfall areas of the country (Benti et al., 1993). In 1976, maize improvement program for drought stressed areas was initiated by ACA and recently in 1992 the Institute of Agricultural Research established maize breeding program at Nazareth Research Center.

Maize breeding activities of ACA

The ACA started maize improvement work with the main objective of developing early varieties that can escape drought stress periods. A brief review of the varietal development for the period 1976-91 were as follows.

The germ plasm for improvement were obtained from Alemaya University of Agriculture, Bako Research Center, PGRC/E, CIMMYT, IITA, and other African countries.

The College used S_1, Mass, Half-sib, and Unit selection to develop and improve the germ plasm.

Varieties developed by the College are: Alamura, Birkata Mirtchaye, Sheleko, Yellow bulk, Bulk from half-sib (BFH), composite of best families (CBF), and some lines.

1. Alamura: is a synthetic variety developed from eight inbreds and it was released in 1984 for Central Rift Valley Regions of Ethiopia. This variety did not attain wide distribution due to its yellow color.
2. Birkata: is an improved version of Katumani by mass selection. It is under verification for release.
3. Mirtchaye: is a topcross between Alamura white and an inbred (Kat.1.1/80-S3).
4. Sheleko: is also a topcross between Alamura early and inbred (TZ5R.1.1/81).
5. Yellow bulk: is developed by bulking elite families from the half-sibs.
6. Bulk from half-sib (BFH): is developed from elite half-sib families.
7. Composite of best families (CBF): is developed from elite half-sib families and it is also under verification for release (Table 1 & 2).

Nazareth maize program

To strengthen the maize improvement activities and hasten the achievement of the development of suitable maize varieties for drought stressed areas the NMP has started breeding work in 1992 at Nazareth. Since 1992, Several germ plasms were screened, few were evaluated across location and promising ones are promoted for further breeding and evaluation. The main breeding activities are summarized as follows.

Sources of germplasm

The germ plasm for improvement were obtained from the following sources: already developed varieties and families by ACA, materials identified and sent from CIMMYT Drought Network & FAO, varieties obtained from other African countries (Kenya, Zimbabwe, South Africa and Burkina Faso).

Current activities and promising materials identified

The initial improvement effort at Nazareth concentrated on identifying sources for earliness, drought tolerance, and resistant/tolerant to the major pests (Table 3). Therefore, germ plasm screening, multi-site evaluation of promising materials identified from the screening, topcross breeding (to categorize the germplasm into heterotic groups) and off-season evaluation of drought tolerant germ plasm are the major breeding activities of NMP. Promising materials identified during the last three years are shown in Table 4.

Future Plan of NMP

Nazareth Maize Program is supposed to concentrate on population improvement for the fact that hybrids are not economically feasible in such marginal areas. The drought escape mechanism that has aimed at shortening the life span of the crop may be performed on intermediate maturing maize varieties that may not be well adapted, but not on early varieties because in relation to yield, little progress is anticipated by further reducing maturity duration. In attempting to improve yields in the population improvement program, emphasis will be given to drought tolerant materials. Special emphasis will also be placed on studies to understand the female flowering behavior.

Development of extra-early maize varieties for extremely marginal areas, development of composites, grouping the promising available materials into heterotic groups and combining ability are going to be studied. Superior maize varieties will be released during the breeding process.

Table 1. Selection methods used, and the major outcome of maize breeding work of ACA.

Selection	period	materials used	source	outcome
1. S1	1976-83	47B/52	Germany	Alamura Y
2.		India	India	Alamura W
3.		Katumani	Kenya	Mirchaye & Sheleko
4.		Negelle (Col.)	Ethiopia	Inbred lines
5. MS	1983-88	Katumani	Kenya	Birkata
6. HS	1981-91	Introductions	Many	Yellow bulk composites
7. Unit S	1988-91	Collection	Ethiopia	Promising units

S_1 = first selfed generation, MS= mass selection, HS= half-sib selection, and unit S= unit selection

Table 2. Performance of varieties developed by ACA

Variety	yield (kg/ha)	Days to tassel	maturity	plht (cm)	endosperm color
1. Alamura Y	3410	48	106	157	yellow
2. Birkata	3540	49	111	158	white
3. Mirtchaye	4150	47	110	157	white
4. Sheleko	3440	47	109	161	yellow
5. Yellow bulk	3320	47	111	172	yellow
6. CBF	3540	48	111	178	white
7. BHS	3200	47	109	167	white
8. Katumani	3000	48	108	153	white

CBF = composite of best families, BHS = bulk from half-sib
Adapted from Benti and Ransom eds, 1993.

Table 3. Performance of promising early and drought tolerant maize germ plasm identified by NMP.

Variety	Days to		Yield
	tassel	silk	kg/ha)
A. Early			
1. Mung loc 8926	64	67	6700
2. Muneng 8926	61	64	6313
3. Ferke	66	70	5703
4. Pantanagar	56	57	5680
5. Suwan-2(5)C7	58	61	5640
6. Across 8931	61	62	5352
7. Poza Rica	57	60	5344
8. Poza Rica 8931	64	66	5040
9. 92 SEW-2	53	56	5040
10. 89C 28/TEW Pool	50	53	4800
11. 92 SEW-1	52	54	4733
12. 89/C27/dr HI	51	53	4654
13. C60 A/AC 8530	56	58	4653
14. Katumani	48	50	3352
B. Drought tolerant			
15. TEWD SR DT	55	55	5320
16. Pool 16 C20	57	58	4465
17. Pool 18 Seq.	55	56	4033
18. DTP-1 C5	60	62	3750

Source: Progress Report of the NMP, 1993-94

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SESSION II
Resource Management

Chair: Ato Getachew Alem
Rapporteur: Ato Million Abebe

AGRONOMY AND CROP PHYSIOLOGY RESEARCH: ACHIEVEMENTS, LIMITATIONS AND FUTURE PROSPECTS

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Synopsis

The agronomy and crop physiology research at Melkassa Research Center (MRC) started as a research activity in the then department of field crops research and currently grew into a strong research team with a national mandate: a coordinating body of the dryland farming research program of the Institute of Agricultural Research (IAR). Through the process of time and experience, research programs were increased from handling research on sorghum and lowland pulses to include the major farming enterprises in the area that includes maize, tef, testing of small farm implements and areas of crop-environment-livestock intervention such as research on multi-purpose trees and shrubs. Research orientation has also changed from on-station top-down approach to prudential systems perspective bottom-to-top approach taking the need of the farming community as a guide and target of service. Looking back to what the team has passed through, various achievements made by the team makes it the nations promontory in the field. In this paper, some of the contributions made in the field and future areas of research directions are indicated.

Historical Background

The agronomy and crop physiology research at Melkassa Research Center was established in 1982 with few staff and facilities, thus, at its inception the division was fairly weak both materially and in research capability. With time, this has changed in the extent and quality of research. Research orientation has changed from on-station top-down approach to prudential systems perspective bottom-to-top approach taking the farming community as a guide of and target of research service.

Before the establishment of the agronomy and crop physiology division at Melkassa most agronomic trials were handled by the respective improvement programs of each crop. After establishment of the research program the list of activities has increased gradually to include the major farming enterprises in the area including testing of small farm implements and areas of crop-environment-livestock intervention. With the assumption of national dryland farming research coordination, the major activities has grown significantly with many affiliating centers and testing sites such as Mekele, Kobo, and Sirinka and sub-centers such as Meiso, Welenchiti, and Zeway. With the current capability and anticipated national objective of addressing dry land farming crop management problems, the plan is to widen the areas of coverage to the south, south east and eastern parts of the country. By doing so more or less dryland areas of the country which account for 46% of the total arable land will be accounted for. These areas are estimated to contribute only to 10% of the total crop production (Getachew, 1986). Strengthening agricultural research in these areas have got substantial impact on the national food security efforts.

Major crops produced by small farmers in dryland areas includes maize, sorghum, tef, beans and some horticultural crops. Production is mainly for food and cash and the stover is used for animal feed, domestic fuel, and construction (Tilahun and Teshome, 1987). The farmers themselves are resource poor and have strong aversion to risk. Thus, the impulse is to generate and apply technologies uniquely suited to the environment as well as farmers circumstances (Teshome, 1990).

Major production constraints include:

- Moisture stress (early, mid or late season)
- Poor soil fertility
- Shortage of dry season animal feed
- High weed incidence
- Lack of appropriate and well planned cropping system
- Limited availability of improved and adaptive crop cultivars
- Soil crusting problem resulting in poor seedling emergence
- Week or insufficient draught power for farm operations
- Pest and disease problem such as Quelea and stalk borer
- Inefficient farm implements

The broad objectives of Agronomy and crop physiology research program are to strengthen research activities aimed at developing appropriate management practices and crop management options that conserves soil and soil moisture, improve soil fertility, design, and test cropping system options that increase yield and sustain biological efficiency, assist breeders in the development of drought tolerant cultivars, and develop farming systems appropriate to dryland farming targeting the following key components of the farming system: cropping system, livestock component, socio-economic circumstances and their interaction as they affect overall productivity.

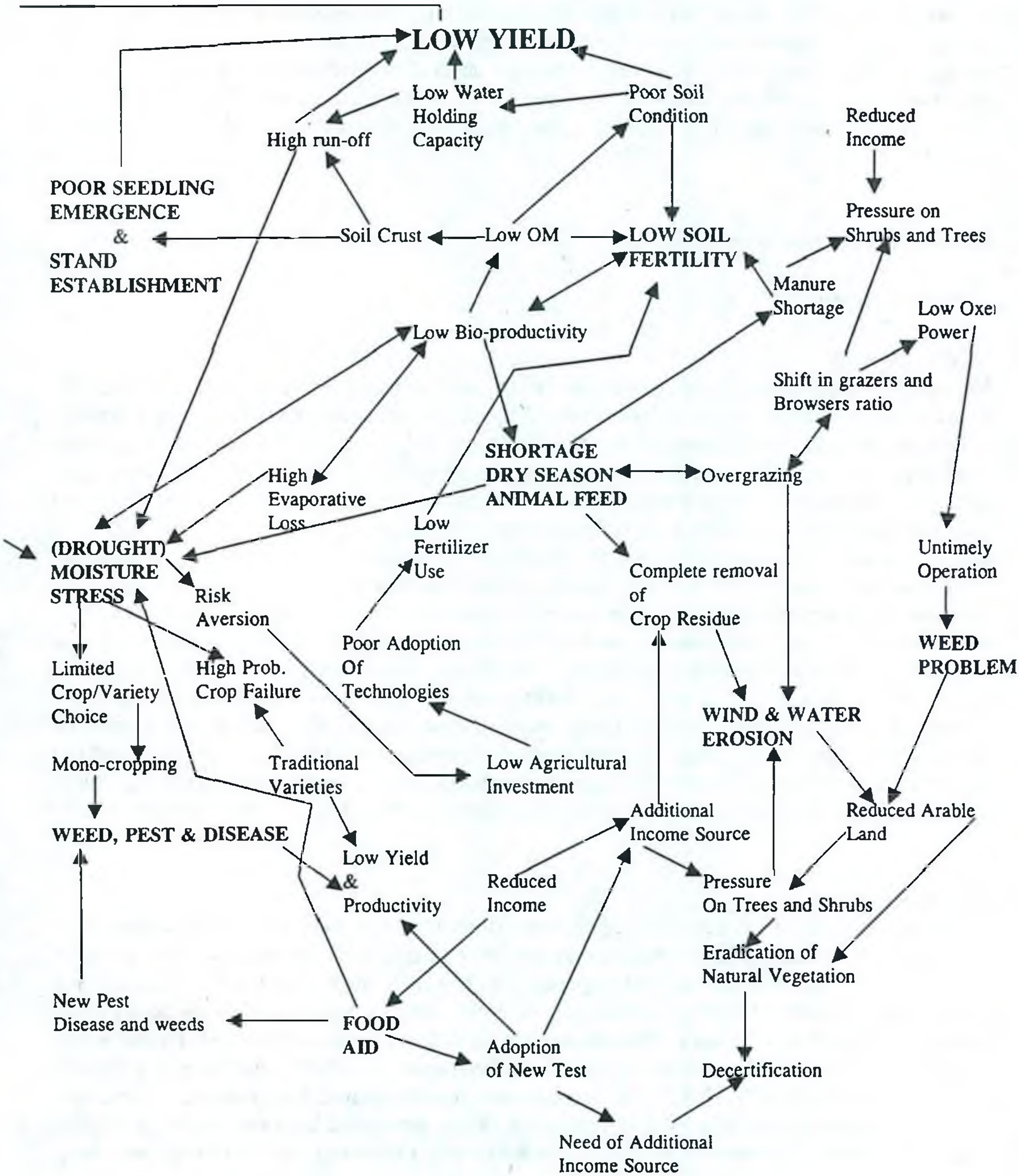
Research Approaches

In the process of addressing the production constraints, various approaches had been pursued, however, it is worth mentioning recent developments in which research orientation has changed from on-station top-down approach to prudential systems perspective bottom-to-top approach taking the farming community as a center of activity guidance and target of service. Research programs are developed incorporating farmers' circumstances and their resource base through information obtained from farming system surveys, feed-back information, observations during on-farm activities and informal discussions with farmers.

In efforts to improve the current production system the motto is to build up on existing farmers' production system. Farmer problems are more complex than a simple list of priority constraints elucidated by limited surveys. The complexity of production problems in a given production system can be seen from the environment-crop-livestock interaction scenario example shown in Figure 1 taking Adama-Boset woredas as an example. Due to the strive for life the farmer acts on the causes and effects changing the rate and direction of system development. When the rate and direction of change incurred by the action of the actor is in the deleterious direction intervention is required. For any intervention to be effective all possible interactions and its effect on overall systems sustainability should be evaluated critically. In such condition the most important step is to freeze or terminate negative system flows. To do so creating awareness of the overall actor, the human component through education about the gravity of the problem is the first step. Second, technologies and inputs such as seed, water and fertilizer, requiring moderate knowledge and capital which can be met

FIG 1. CAUSE AND EFFECT RELATIONSHIPS OF PROBLEMS IN ENVIRONMENT - CROP - LIVESTOCK INTERACTION SYSTEM

An Example



easily with some extra-efforts by the user, agricultural service sector and credit facility rendering institutions should be emphasized. Properly created awareness and available technologies related to seed, water and fertilizer can stabilize the system and fetch considerable confidence of the farmer. Thus, a planned and sectoral community based intervention on the whole production system in a step wise manner involving the human, physical and biological factors stabilizes and improves the whole systems and shifts the direction of system evolution to a desirable direction. To reach such a goal the farmer makes a good team with dedicated and visioned agricultural workers.

Review of Major Achievements

Cultural practice

Seed technology

Seed is an important and possibly one of the determinants in crop production as it determines the kind of plant population anticipated and finally the yield. As mentioned earlier, soil crust (sealing) affects proper field establishment of the major cereals mainly sorghum. Both seed characteristics (viability, size, source, coleoptile and radicle length etc.) and environmental factors (soil, moisture, temperature, crust strength, disease and pests etc.) affect seedling emergence and survival. In the lowlands, a field sown seed is at a disadvantage with respect to the challenges of soil temperature, soil crust and moisture. The ability of a plant to survive these environmental constraints and achieve good field emergence is both genetic and physiological with due role of agronomic management applied. Repeated investigations to evaluate sorghum genetic materials in the laboratory, screening nurseries and in the field confirmed the existence of genetic (Yilma and Abebe, 1986) and physiological (Kidane and Reddy, 1993) variation for such traits. These studies also reveled emergence not to be related to seed weight or stress. The studies also revealed, emergence to be positively correlated with seedling shoot length and seedling root length. To reduce the impact of soil sealing on sorghum seed emergence efforts were also made to evaluate field emergence by sowing pre-soacked seeds. Information obtained indicated potential importance of the practice. Such practice is traditionally used for maize by farmers in moisture stress areas.

Seed placement

The time and depth of sowing with respect to environmental variables such as soil temperature, soil moisture and others determines emergence. In semi-arid areas rainfall, possibly the most important determinant of success in crop production, is usually inadequate poorly distributed and short lived. Therefore, length of growing period of the varieties used should fit the periods with high probability of reasonable moisture and the sowing time should be adjusted so that critical crop growth stages fall in the relatively optimum environmental conditions. As there is very high variability of rainfall (CV 30-87%) both within and among seasons. For practical reasons, dry sowing of sorghum and maize when the on set of rain is anticipated with reasonable probability (starting from the first week of June) is recommended in addition to the use of improved early varieties that fit in the June to mid September growth period (Table 1). In dry sowing adjustments must be made for possible abortive germination and soil crust effect. Due to variation in seed size sorghum is at disadvantage with this respect compared to other big seeded crops. Bean is wet planted during relatively reliable rainfall periods in the season, thus the problem of seedling emergence is not acute. In dry sowing both crop seeds and weed seeds emerge at the same time. Hence, early stage weed competition is much severe on dry planted crop than those planted after one or two effective rain. In the latter case emerged weeds are destroyed by the plowing operation done for sowing.

Depth of sowing is another important cultural practices for reasonable stand establishment in dryland areas as it influences the effects of premature seed germination due to ineffective showers. Proper sowing depth was found to be 4-8 cm for maize and 2-4 cm for sorghum at Melkassa (Table 2).

Table. 1. Effect of planting date on grain yield of sorghum at Melkassa

Treatment	Sorghum grain yield (kg/ha)			
	1983	1984	1985	Mean
Varieties				
76 T1 23	1513	677	2172	1453
Gambella-1107	2704	640	2762	2005
Melkamash-79	2150	190	2194	1517
$LSD_{0.05}$	91	na	155	
Sowing Dates				
Dry Sowing	3455	611	2746	2268
After one effective rain	2466	618	2506	1771
After two effective rains	1530	463	2383	1407
After three effecteve rains	1041	319	1897	1086
$LSD_{0.05}$	131	na	113	

Source: Adjei -Twum et al. (1986)
na = not available

Table 2. Effect of planting depth on grain yield of sorghum at Melkassa.

Seeding depth (cm)	Sorghum grain yield (kg/ha)			
	1983	1984	1985	Mean
2	1138	406	2839	1471
4	2084	403	2921	1803
6	1510	406	2548	1455
8	1699	475	2199	1458
$LSD_{0.05}$	346	ns	361	

Source: Kidane (1985); ns = non significant

Plant population

Usually farmers use a higher plant population for all crops grown in semi-arid areas for various reasons such as moisture stress, method of sowing used, suppresion of weeds, traditional practices such as shilshallo and animal feed. Plant population of about 90,000 plants/ha, 66,667 plant/ha and 500,000 plants/ha were found to be optimum for sorghum, maize and beans, respectively. To achieve these population recommended seed rate of 8-10 kg/ha, 25 kg/ha, 100 kg/ha is respectively used for sorghum, maize and beans, at a spacing of 75 cm between rows of sorghum and maize and 40 cm between rows of bean with intra-row spacing of 15, 20 and 10 cm for sorghum, maize and beans. Depending on seasonal rainfall and the level of soil moisture conservation practice employed, sorghum plant population can be elevated to 133,333 plants and that of maize to 88,889 plants per hectare. Under worse moisture conditions lower plant population should be used. Under farmers condition seed rates are increased to 15-20 kg/ha for sorghum, 30 kg/ha for maize and 130 kg/ha for beans.

Plant population has a very strong interaction with variety and the cultural practice employed. A trial on the effect of sowing density, variety and conservation technique on maize yield was conducted in 1984 and showed increased seed yield by 23.8 %. There was significant difference in yield between plant densities.

Another trial conducted to see the effects of variety by inter- and intra-row spacing on haricot bean yield showed significant increase in yield as both intra- and inter-row spacings decreased. Population densities of 300,000-500,000 plants/ha (60-80 kg/ha) with spacings of 5-10 cm between plants and 40 cm between rows were found optimum for row sowing. Under broadcasting, a seed rate of 100-140 kg/ha suppressed weeds and produced higher grain yield.

Soil and Moisture Conservation

Moisture stress is the key problem of crop production in dryland areas. Therefore, any crop management should address or incorporate some aspects of this problem. Thus, most recommendation although cultural in the strictest sense are tuned to address soil and moisture conservation issues. Apart from moisture stress, dryland areas are characterized by high loss of soil due to wind erosion in the dry season and water erosion in the rainy season. High evaporative soil moisture loss of the limited available moisture is another loss dimension in dryland. Both wind and water erosion are responsible for soil loss while run-off and evaporation are responsible for moisture loss. Therefore, alternative soil moisture management options that could conserve soil and soil moisture in-situ must be sought.

Tillage

Proper tillage management with respect to timing, frequency and method has its contribution in soil and moisture conservation. Early plowing just after harvest of the previous crop helps in conserving off-season rain by increasing infiltration, which is lost by run-off, the tillage operation incorporates some left over crop residue that is essential for increasing soil organic matter and then improved soil water holding capacity. Belg rain contributes on average about 20% of the yearly rainfall for Melkassa which is a substantial amount. Conservation of this rain makes a big difference on seasonal soil water re-charge. A study at Welenchiti on maize showed two plowing (once plowing just after harvest of the previous crop (October) followed by once plowing in June)) using an improved Nazeret plow significantly increased (30%) grain yield over farmers implement and time. The improved plow resulted in a 12% yield advantage (Table 3).

Table 3. Effect of plow type, frequency of tillage and planting time on grain yield of maize at Wolenchiti in 1988.

Treatment	Grain yield (kg/ha)
Plow type	
Local plow (maresha)	2284
Improved Nazret plow	2552
$LSD_{0.05}$	154
Plowing frequency	
Once (mid-June)	2224
Twice (October + June)	2895
Three times (October + May + June)	2634
$LSD_{0.05}$	219
Sowing date	
Dry sowing	2826
Wet sowing	2410
$LSD_{0.05}$	203

Source: IAR, Nazret Research Center progress report, 1988.

Tie-ridging

Another widely used moisture conservation tillage practice else where and found to be effective in low rainfall areas of the country is tie-ridging. Besides serving for in-situ moisture conservation tie-ridges are effective in controlling run-off and soil erosion (Arnon, 1972). Evaluations made around Melkassa reveled highest grain yield from crops (sorghum and maize) planted in the furrows of tied ridges (Kidane and Reddy, 1993). However when valuated on farm high labor requirement (23-30 man days/ha) discouraged farmers from adoption (Teshome *et al.* 1993). Based on feed back information gained, the Agricultural Implements Research and Improvement Center (AIRC) of IAR has developed maresha attached simple tied-ridger which was tested and found to be agronomically sound for tie-ridging. The yield effect of tie-ridge is very high during below normal rainfall years as compared to average or above normal rainfall years especially when ridges are tied at shorter intervals (Figure 2). Tie-ridges has also showed significant interaction with fertilizer use on sorghum and maize. In below normal rainfall years and on-farm sites of acute moisture shortage fertilizer use without tie-ridging was found to be unprofitable. Modified tie-ridging done to suit tef production gave promising results in bad rainfall years although the practice needs further refinement.

Mulching

Mulching has proved effective in conserving soil moisture, decrease soil temperature, increase soil organic matter, in weed control, and maintaining favorable soil structure through enhanced biological activity (Lal, 1979). However, dry season feed shortage, complete removal of crop residue from crop field for other purpose and low environmental productivity to provide surplus biomass makes mulching impossible in the low lands. Earlier efforts made to use tef straw and scoria (red ash) as a mulching material was found to increase sorghum yield by 147% and 198% by using tef straw at the rate of 3 and 5 t/ha respectively; and 3 and 5 cm deep scoria mulch increased yield by 184% and 170% respectively. Unfortunately the tef straw is the main oxen feed during early land preparation and scoria mining and transport demands too much resource beyond what most farmers afford for cereal production. Searching for alternative intervention without affecting established flow directions of materials in the system and could supplement the over all stability of the system was sought. Multi-purpose fodder shrubs and trees were evaluated at Melkassa among which those showing good performance in adaptation were evaluated under alley cropping with major crops including projected introduction as farm-yard live-fence. The shrubs can also be pruned and used as a source of mulch despite other uses as dry season feed bank. The use of woody parts for domestic fuel is excepted to relieve some inputs to shift their traditional flow pattern. Increased availability of feed and domestic fuel relieves crop residue left on farm for mulching purpose. Thus, inclusion of multi-purple shrubs and trees in the cropping system not only increase the availability of mulching material by itself but also relieves other mulching materials in the system. Among the shrubs evaluated, alley cropping *Susbania susban* and *Cajanus cajan* with sorghum and other food crops produced a substantial amount of biomass (2-3 t/ha)(Table 4).

Table 4. Effect of alley cropping on grain yield of maize and biomass production of legume shrubs at Melkassa.

Treatment	Maize yield (kg/ha)			Biomass production (kg/ha)		
	1987	1988	mean	1987	1988	mean
Sole maize	4644	3597	4121	----	----	----
Sesbania	3944	4605	4275	2507	2198	2353
Leucaena	5799	4177	4988	----	778	778
Cajanus	5914	3419	4667	1639	3457	2548

Source: Kidane et al. (1989b)

Shilshallo

Shilshallo is a farmers' technology for various objectives. The limitation of traditional shilshallo was improper timing of operation. Re-evaluation established the proper time of doing shilshallo to be at 6 to 8 leaf stage for sorghum and 4 to 6 leaf stage for maize (Table 5). Another important attribute of shilshallo is that when tie ridging was not done at the time of sowing, shilshallo can be modified to serve the same purpose by manually tieing furrows made by shilshallo at the desired interval.

Table 5. Effect of time of shilshallo on grain yield(kg/ha) of sorghum and maize at Melkassa.

Time of Shilshallo	Sorghum				Maize			
	1987	1988	1989	Mean	1987	1988	1989	Mean
Shilshallo at								
4 leaf stage	-	-	-	-	943	3118	2304	2121
6 leaf stage	1702	2058	3593	2451	460	3012	1731	1734
8 leaf stage	1497	2040	4150	2562	411	2635	1954	1666
10 leaf stage	882	1444	3762	2029	336	2891	1651	1626
12 leaf stage	1105	1332	2214	2029	-	-	-	-
Tie-ridge	2261	3796	3941	3333	2939	4844	4480	3787
LSD (0.05)	184	722	969		59	905	526	
CV %	9	na	18		-	-	-	

Source: IAR, Melkassa Research Center progress reports for 1987,1988 and 1989.
na = not available.

Soil Fertility Management

Low soil fertility is a major limiting factor of crop production in the low lands. Here, soils have low inherent fertility and deficient both in N and P. The soils are also shallow with low organic matter. Prevailing wind and water erosion further aggravate the problem by removing the relatively fertile top soil, wide gap between crop yield obtained with and without proper soil fertility management clearly indicates that soil nutrient stress should be addressed as a priority possibly next to moisture stress. 3.3.1. Fertility maintenance

Low level of risk acceptance, limited resource and insufficient credit system forces most farmers in dryland areas to favor fertility maintenance intervention options than options that require external inputs such as commercial fertilizers.

Crop Rotation

Crop rotation is one of the cheapest methods used for fertility maintenance. Crop rotation also reduces weeds, insect pest and disease build up. Ideally sound crop rotation should include equal proportion of cereals and legumes. However, in practice, there are limited number of legumes in .lowland areas as compared to that of cereals. Even then, rotation is recommended as far as cereals of different nutritional habit and rooting behavior are rotated. For instance, tef followed by sorghum or maize may seem useless theoretically but in practice intense weeding done on tef leaves lower amount of weed'seed in the soil reducing weed infestation on sorghum or maize. Additionally, shallow rooting depth of tef leave the soil below the rooting depth in a state of un-acknowledged fallow which can be reached by deep rooted crops such as sorghum. A rotation system that used maize as a test crop, increased yield (60%) when maize followed bean or tef (Hailu and Kidane, 1988). Similar beneficial effect was also observed due to cereal rotation with alley cropping cereal/Sesbania or sole bean (Table 6).

Table 6. Development of appropriate crop rotation systems for semi-arid areas of Ethiopia

Cropping sequence			Grain yield (kg/ha)					
			1992		1993		1994	
1992	**1993**	**1994**	**F0**	**F1**	**F0**	**F1**	**F0**	**F1**
Maize	Maize	Maize	4387	5223	2163	4174	2305	3503
Beans	Maize	Beans	---	---	3215	4131	---	---
Maize\Bean	Maize	Maize\Bean	3308	3804	2841	3375	2065	2819
Maize\Sesbania	Maize\Sesbania	Maize\Sesbania	4594	5044	3460	3714	2542	3756
Maize\Sesbania	Bean\Sesbania	Maize\Sesbania	3342	5424	2175	2160	2440	3649
Tef	Maize	Tef	—	—	2635	3902	—	—

Green Manuring

The use of green manure is one of the options available for fertility maintenance in the lowlands. Green manuring can be introduced by growing green manure legumes during fallow years where there is no land shortage or by growing short-season leguminous crop early in the season. Currently neither of the two is used in Central Rift Valley and the practice of green manuring is practically nil for all crops. However, it is hoped that the current introduction of multi-purpose shrubs in the farming system could provide green manuring material. Encouraging results were shown form activities initiated at Melkassa with this respect
(Table 7).

Table 7. Effect of green manuring on yield response of maize during 1992 and 1993 cropping season.

Treatment	Straw weight (kg/ha)			Grain yield (kg/ha)		
	1992	1993	Mean	1992	1993	Mean
1. Without mulch	3175	2627	2899	2049	1440	1745
2. *Cajanus cajan*	3649	5298	4474	2235	3204	2720
3. *Sesbania sesban*	4526	5405	4966	3135	3318	3237
$LSD_{0.05}$	440	732	586	697	420	559
CV (%)	7.19	9.53	8.36	17.86	9.14	13.5

Inter-cropping

Inter-cropping, as far as one crop is a legume, is an important system of fertility maintenance. Additionally, subsistence farmers tend to intercrop to minimize risk, diversify crop grown and spreading labor peaks. Even if intercroping is considered a common practice in marginal rainfall areas, the practice is nearly nil in Nazret area. Nevertheless, studies were made at Melkassa and on-farm sites to determine the feasibility and best intercroping options. The studies reveled that a yield advantage of 74%, 37% and 31% were obtained when sorghum was intercropped with mungbean, haricot bean and cowpea respectively as compared to the sole crop (Table 8) which can be partially accounted for improved fertility by the legume.

Table 8. Land equivalent ratio as influenced by population density in sorghum-pulse intercropping at Melkassa.

Population density (plants/ha)	*Mean Land Equivalent Ratio* Sorghum+Mungbean	Sorghum+Haricot bean	Sorghum+Cowpea
102,188	2.00	1.53	1.34
85,248	1.55	1.55	1.13
71,116	2.22	1.26	1.61
59,325	1.70	1.14	1.32
49,489	1.59	1.42	1.19
41,284	1.44	1.53	1.22
34,441	1.66	1.13	1.39
Mean	1.74	1.37	1.31
Cropping system $LSD_{0.05}$	0.10	0.02	0.07
Population Density $LSD_{0.05}$	0.31	0.02	0.07

Use of commercial fertilizes

The use of commercial fertilizers has got its own blessings and limitations. When used properly commercial fertilizers increase yield dramatically. According to FAO (1974) in Ethiopia for each kg of applied nutrient there is an output of 16.3 kg of sorghum which is very far from the current yield level attained by most farmers. To determine the optimum rate and time of fertilizer application several N & P response studies were carried out in the past at Melkassa. However, most observed trends in responses were not consistent and significant for maize and sorghum. This could have been possibly attributed to confounding effect of inconsistent rainfall and stress of crop at one or two critical growth stages. Testing selected fertilizer rate treatments including those that showed better response at Melkassa center on farmers fields in the Central Rift Valley with additional treatment of soil moisture conservation practice, showed 100 kg/ha DAP and 50 kg/ha urea to increase sorghum and maize yield significantly. Without moisture conservation response to fertilizer was very low for most on-farm sites. The fertilizer with significant response to the time of application is nitrogen fertilizers. With this respect the available information shows N to be efficient most when applied half at sowing and half at boot stage (knee height). Splitting the rate has an additional advantages of withholding the second half in case of poor crop establishment which is common in moisture stress areas.

Development of Improved Production Packages

Knowledge and farmers' awareness about the relative importance of each package component to overall crop yield could give farmers optional flexibility for step wise adoption of technology, according to their conditions and resources. It could also cause some of the adoption problems by splitting package into relative ranking. and then facilitating better communication between the farmer and the extension agent. It also allows the farmer to have different options in case of contingencies.

Selected package components and their combinations that are agronomically critical and/or do not require a major shift in the current maize production method in terms of resource allocation and operational know how are included for simplicity despite the availability of various recommended packages. Recommended fertilizer of 100 kg DAP and 50 kg Urea per hectare (F), early weeding once at three weeks after emergence (W), row sowing with recommended plant spacing and population (P), and sowing in the furrow of ridges tied at 6 meter interval (C) were evaluated by adding on the farmers practice of maize production (FP). Addition of each package component has increased maize yield as compared to the farmers practice. About 89% increase in yield over the farmers practice was obtained when all the production packages appeared together. Individually fertilizer showed consistent increase in yield with at least 16% increase over the farmers practice. In pairs, recommended weeding and tie ridging are the package components with highest impact on yield with 71% increase over the control. However, there is a confounding effect of row sowing and optimum population as tie ridging forces unconditional use of row sowing. The third best yield was obtained by applying recommended fertilizer on a row planted maize with a 47% increase over the farmers practice. Thus, farmers can increase maize yield at least by about 441 kg/ha just by adopting one package component (fertilizer) which can be further increased by a range of about 787 to 1951 kg/ha (29% to 71%) simply by taking two of the package components.

Similarly, sorghum packages i.e. Sowing in the furrow of ridges tied at 6 m interval (C), row sowing with recommended plant population (P), timely weeding at 20-25 days after emergence (W) were evaluated against the farmers practice (FP) using local variety. Tie ridging alone increased grain yield by 6% while row sowing and optimum plant population increased yield by 32% when compared to farmers practice. When row sowing and recommended time of weeding were added on farmers practice the increase in sorghum yield was 48%. When row sowing, timely weeding and tie ridging were used together, about 55% yield increase over the control was attained. Of special interest here is the response observed due to tie ridging. More yield response of the local variety to weeding and sowing method packages as compared to tie ridging when they appeared individually may suggest better adaptation of the local variety to moisture conditions of the area. For improved variety, tie ridging was the most important single package component followed by timely weeding. Yield improvement over the farmers practice was by about 3% and 11% for timely weeding and tie riding, respectively. The highest yield increase 14% was obtained when sowing in the furrow of ridges tied at 6 m interval and weeding at the recommended time were used.

Gaps Identified and Future Research Needs

- Describe, demarcate and characterize dryland areas for their common and specific production constraints.
- Biotechnology and dry land crop improvement
- Biochemical responses to water deficit and their implication for drought tolerance
- Physiological traits associated with drought tolerance should be evaluated at early stage of varietal development
- Alternate land use system in dryland such as water shade management
- Alternate in-situ moisture conservation practices other than tie-ridging should be explored
- Further work on off-season and early tillage practices
- Fertilizer recommendation based on soil test values and prediction of yield based on soil test values as influenced by varying rainfall.
- Fertilizer management specific to agro-ecology, soil type, cropping system and state of other soil management practices
- Interaction effect of fertilizer with moisture, genotype, weed management, and other cultural practices need further evaluation
- Management of secondary and micro-nutrients in dryland cropping systems for critical limits and possible interaction with macro-nutrients
- Energy management in dryland agriculture and system energy flow
- Statistical modelling and optimization techniques in resource use with respect to crop response

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CROPPING SYSTEMS RESEARCH STATUS AND FUTURE TRENDS IN THE RIFT VALLEY: I. INTER-CROPPING

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Abstract

Farmers with limited land resources and high population pressure have traditionally increased the cropping intensity of their lands to maintain sustainable yield over the years. However, the importance of intensive cropping has not been well understood by most farmers in the rift valley. Hence, with the view to increase crop productivity per unit area per season, several Inter-cropping experiments were carried out to evaluate the relationship that exists between crop species and to identify cropping systems that can give sustainable yield and economic returns under different edaphic and climatic situations. Results revealed that lowland pulses, namely mung bean and haricot bean are compatible crops to inter-crop with maize and sorghum under the rift valley climatic conditions. A follow-up experiments conducted under on-station and on-farm conditions indicated that significant differences were observed between treatments and their interactions for stover yield and grain yield of maize, straw yield and grain yield of beans within and across locations. Besides, considerably higher combined land equivalent ratios and net returns were obtained from simultaneous inter-crops when planted in 2 maize/1 bean row patterns. Comparing among bean genotypes, Awash-1 planted simultaneously with maize in 2 maize/1 bean row patterns gave significantly higher yield advantage ranging from 33 to 49% with sustainable economic benefit across locations. The results of the experiments so far reviewed indicated that sustainable biological yield and economic returns could be possibly obtained by maintaining 100% maize population and 50% bean population It is worth, therefore, mentioning that early maturing bean varieties planted simultaneously with maize in 2 maize/1 bean inter-crop pattern can give sustainable yield and income advantage in the rift valley. Thus, it can be recommended that Inter-cropping of lowland pulse with maize and sorghum in 2 maize or sorghum/1 pulse row patterns can give sustainable yield and economic returns by avoiding risk resulting from poor distribution and erratic nature of rainfall, in addition to reducing weed, pest and disease incidence in the rift valley of Ethiopia.

Introduction

Inter-cropping is the planting of two or more crops on the same land in the same season where there is a significant amount of inter-crop competition. Inter-cropping may lessen the yield of each component crop but it optimizes overall stability. This greater stability in inter-cropping is achieved by compensatory effects among crops; reduced incidence of pests and diseases as a result of greater vegetative diversity; and more complete and earlier soil cover due to varying stages of growth of the component crops, which reduces the incidence of weeds. Farmers with limited land resources have traditionally inter-cropped their land to minimize risk by diversity; to spread income by a range of crop maturity; and to provide a more balanced diet. Inter-cropping can also be considered socially stable because it can be used by farmers at all levels of productivity and technology (Adjei-twum *et al.* 1986).

In many parts of Ethiopia, farmers harvest only once in a year and on sole crop basis even in high rainfall areas. Such traditional farming do not ensure the production of adequate food for a family, especially under conditions where average land holding is very small. The continued use of cereal mono cropping does not augur well with soil fertility maintenance. It is true that there are farmers in some parts of the country who optimize land use intensity through inter-cropping, relay cropping and even double cropping. But such examples are few and far between. These are not common practices in the major crop (cereal) production zones of the country, particularly in the rift valley (Niguse, 1994).

In the past much efforts have been directed towards improving technology for sole cropping. However, sole cropping is neither practical nor acceptable to many small farmers, and recent research indicates that inter-cropping systems can actually give more efficient total resource exploitation and greater overall production than sole crops. As a result, most farmers in the Southern, Northern and Eastern part of Ethiopia (Reddy et al. 1994) base food production on inter-crop systems.

In the central rift valley farmers practice sole cropping and variation in yield is observed from year to year and hence farmers are not sure of the outcome of their crops in a given cropping season (Tilahun and Teshome, 1987). Consequently, the vast majority of the farmers are resource poor and are averse to risk taking. This would call for crop management techniques that at least would not further degrade the environment and optimize input/output relations (Niguse, 1994). To that effect, therefore, experiments were conducted at Nazareth Research Center and on-farm sites to identify crops that can increase sustainable yields and to assess the advantages of these cropping systems in minimizing crop failure due to drought and the incidence of weeds, pests and diseases.

Review of Results in Inter-cropping Experiments

Crop compatibility trials

Preliminary experiment were conducted at Melkassa during the 1983-1985 cropping seasons to study the influence of maize/sorghum/ pulses (cowpea, haricot bean, and mung bean) associations on the yield of respective companion crops. Table 1 and 2 indicate the effect of inter-cropping maize and sorghum with different lowland pulses on grain yield of component crops at Melkassa in 1983-1985, respectively. The results revealed that higher grain yield of maize and sorghum was obtained when inter-cropped with mung bean and haricot bean, compared to respective sole crops in 1983. In 1984, all inter-crops yielded better than sole maize due to minimized evaporation and facilitate favorable microclimate for crop growth and development in this drought prone year. However, a total crop failure occurred in this year due to late maturing sorghum variety (Melkamash-79). In 1985, sole maize and sorghum gave better yield than inter-crops with haricot bean and cowpea, but less than inter-crops with mung bean. This might be resulted due to variation of crop species in competition for nutrients, water and other growth resources. In general, maize inter-cropped with mung bean and haricot bean gave a three years mean yield advantage of 108 and 99% of sole maize, respectively. On the other hand, yield of inter-cropped pulses was significantly less than respective sole cultures. The three years mean indicates that 65, 44 and 47% of sole haricot bean, cowpea and mung bean was obtained from respective inter-crops with maize, respectively. Moreover, about 69, 54 and 71% of sole haricot bean, cowpea and mung bean was obtained from respective inter-crops with sorghum.

Table 1. Effect of maize/pulses Inter-cropping on grain yield of component crops at Melkassa.

Cropping systems	Grain yield (kg/ha)			
	1983	1984	1985	Mean
a. Maize				
Sole Maize	1330	417	3175	1641
Maize/Haricotbean	1444	989	2409	1614
Maize/Cowpea	1330	620	2304	1418
Maize/Mungbean	1628	776	3386	1930
LSD (0.05)	162	NA*	88	
b. Pulses				
Sole Haricotbean	1479	401	1514	1131
Intercropped haricotbean	931	301	960	731
LSD (0.05)	527	NS	26	
Sole Cowpea	1585	642	1930	1386
Intercropped Cowpea	902	274	634	603
LSD (0.05)	475	229	109	
Sole Mungbean	422	282	519	408
Intercropped Mungbean	367	40	163	190
LSD (0.05)	NS	158	25	

* NA => Not Analyzed

Table 2. Effect of sorghum/pulses inter-cropping on grain yield of component crops at Melkassa.

	Grain yield (kg/ha		
Cropping systems	1983	1985	mean
a. Sorghum			
Sole Sorghum	2009	2275	2142
Sorghum/Haricotbean	2471	2027	1637
Sorghum/Cowpea	1157	1417	1287
Sorghum/Mungbean	1697	2364	2031
LSD (0.05)	77	104	
b. Pulses			
Sole Haricotbean	2040	2254	2147
Intercropped Haricotbean	1568	1407	1488
LSD (0.05	130		
Sole Cowpea	2127	2679	2403
Intercropped Cowpea	1229	1382	1306
LSD (0.05)	216		
Sole Mungbean	633	666	650
Intercropped Mungbean	551	372	462
LSD (0.05)	NS		

Land use efficiency of the different cropping systems indicated that about 73, 46 and 81% and 38, 2 and 50% advantage was occurred due to inter-cropping of maize with haricot bean, cowpea and mung bean in 1983 and 1985, respectively, compared to sole cultures (Table 3). Similarly, land use efficiency of the different cropping systems indicated that about 39, 16 and 72% and 51, 12 and 60% advantage was occurred due to inter-cropping of sorghum with haricot bean, cowpea and mung bean in 1983 and 1985, respectively, compared to sole cultures (Table 3). As observed from the results, haricot bean and mung bean are more compatible to inter-crop with maize in the dryland areas of Ethiopia and further research should be carried out with these compatible crop species.

Table 3. Effect of maize/pulses and sorghum/pulses inter-cropping on land use efficiency (LER) at Melkassa during 1983 and 1985.

Cropping systems	Land Equivalent Ratios		
	1983	1985	mean
a. Maize/Pulses			
Sole Crops	1.00	1.00	1.00
Maize/Haricotbean	1.73	1.38	1.56
Maize/Cowpea	1.46	1.02	1.24
Maize/Mungbean	1.81	1.50	1.65
LSD (0.05)	0.04	0.03	
b. Sorghum/Pulses			
Sole Crops	*1.00*	*1.00*	*1.00*
Sorghum/Haricotbean	1.39	1.51	1.45
Sorghum/Cowpea	1.16	1.12	1.14
Sorghum/Mungbean	1.72	1.60	1.66
LSD (0.05)	0.07	0.10	

Impact of Inter-cropping on Component Economic yield:

An experiment was executed to evaluate the relationship that exists between maize and beans subjected to different planting patterns and planting schedules of bean varieties that would effectively suppress weeds and reduce pest and disease incidence; and to identify cropping systems that can give sustainable yields and economic returns under low and medium rainfall situations. The results revealed that sole Awash-1 gave higher bean grain yield and net returns than sole Mexican-142, but both bean varieties gave higher net returns than sole maize at both locations (Table 4). This increase in net return occurred due to higher field price of beans than maize. Though there was no significant difference between bean varieties, inter-crops with Awash-1 gave higher maize grain yield and net returns than inter-crops with Mexican-142 at both locations. Land use efficiency was higher by 25 and 31% and 21 and 8% due to inter-cropping maize with Awash-1 and Mexican-142 at Melkassa and Awassa, respectively, compared to sole crops.

Table 4. Effect of bean varieties, planting pattern and planting schedule of beans on component yield, land equivalent ratio and net returns at Melkassa and Awassa.

	Melkassa				Awassa			
Treatment	BY	MY	LER	NR	BY	MY	LER	NR
Sole Maize	----	3823	1.00	2247	----	3460	1.00	1937
Sole Awash-1	3014	----	1.00	2955	3345	----	1.00	3942
Sole M-142	2748	----	1.00	2338	3232	----	1.00	3796
Intercrop/Awash-1	1142	3123	1.25	3070	994	3126	1.21	2850
Intercrops/M-142	1142	3072	1.31	3028	977	2720	1.08	2410
2 Maize/1 Bean intercrop	1168	3560	1.41	3527	1128	3193	1.27	3154
Both mixed in same row	1152	3280	1.33	3273	1168	3062	1.25	3056
Maize row/Bean broadcast	1194	2944	1.26	2945	842	2760	1.06	2318
Maize/Bean both broadcast	1055	2607	1.13	2457	807	2677	1.00	2019
Simultaneous intercrops	1382	2913	1.34	3225	1106	2828	1.15	2748
Relay intercrops	902	3277	1.23	2873	828	3018	1.12	2518
LSD (0.05)	52.67	113	0.04	165.8	75.67	124.2	0.05	152.0
CV (%)*	4.5	6.38	2.21	8.19	13.52	6.24	1.89	3.36

Note:- BF => Bean yield (kg/ha), MY => Maize yield (kg/ha), LER => Land equivalent ratio, NR => Net returns (Birr/ha)

Planting patterns differed significantly in grain yields of maize and beans, LER and net returns. The result revealed that 2 rows maize/1 row bean pattern gave 41 and 93%; and 34 and 92% of sole beans and sole maize, respectively; and this resulted in 42 and 27% land use advantage and net returns of 3527 and 3154 Birr/ha at Melkassa and Awassa, respectively. Moreover, staggered planting of bean varieties have significantly affected the biological yield efficiency and net returns. Simultaneous inter-crops gave 48 and 76% of sole bean and sole maize yield, respectively, whilst 31 and 86% of sole beans and sole maize, respectively were obtained from relay inter-crops at Melkassa. At Awassa, simultaneous inter-crops gave 33 and 82% of sole bean and sole maize yield, respectively, whilst 25 and 87% of sole beans and sole maize, respectively were obtained from relay inter-crops.

On-Farm Testing

On-farm testing of maize based inter-cropping systems was conducted during 1992-93 to examine the relative benefits of inter-cropping systems at four on-farm locations namely, Boffa, Wonji, Welenchiti and Melkassa. Farmers were involved in executing the trial along with the researchers.

The mean of four locations over two years indicate that 2 rows maize/1 row bean inter-cropping gave 1623 and 660 kg/ha grain yields of maize and bean, respectively (Table 5). This combination gave the highest advantage of land use efficiency (57%) and net benefit of 1887 Birr/ha in addition to reasonable weed suppression. On the other hand, highest maize yield of 1821 and 174 kg/ha, respectively, and lowest bean yield of 174 and 319 kg/ha, respectively were obtained from maize/bean both broadcast with bean relay planted treatment. However, this treatment gave the lowest land use efficiency, net benefit and weed suppression. The results also indicated that about 48-68% and 57-90% of sole bean and maize yields, respectively, were obtained from simultaneous and relay inter-crops. Similarly, about 13-23% and 90-100% of sole bean and maize yields, respectively, were obtained from relay inter-crops. Moreover, incidence of weeds was generally low in inter-cropped treatments as opposed to sole crops. It was also observed that inter-cropping treatments where both crops were planted simultaneously, weed incidence was relatively lower than in relay planted treatments. About 44% advantage of weed suppression was recorded in maize/bean both broadcast planted simultaneously, compared to sole cultures.

The results revealed that improved biological productivity and economic returns are possible from improved maize based inter-cropping systems by maintaining 100 % maize population and an additional 50% bean population in all inter-cropping systems. In addition to this, planting both crops simultaneously in late June is more beneficial as compared to sole cultures and relay inter-crops. However, relay planting of beans could be beneficial when poor stand establishment of maize occurred due to undependable rainfall situations and used as gap filling.

Table 5. On farm testing of maize based Inter-cropping systems around Nazareth area

Treatment	Grain yield(kg/ha)		Land Equivalent Ratio (LER)			Net benefit (Birr/ha)	Weed DM (G/m2)
	Maize	Bean	LERm	LERb	LERt		
Sole maize	1800	-	1.00	-	1.00	1355	48
Sole Bean	-	1367	-	1.00	1.00	1440	51
M/b both broad p1	1258	884	0.69	0.80	1.50	1851	28
M row/b broad p1	1026	866	0.57	0.68	1.25	1607	33
M/b mixed in row p1	1227	715	0.64	0.55	1.19	1576	41
2 row M/1 row B p1	1623	660	0.92	0.65	1.57	1887	39
M/b both broad p2	1821	174	1.03	0.15	1.18	1441	47
M row/b broad p2	1728	319	0.98	0.27	1.25	1454	43
LSD (0.05)	206	91	0.09	0.06	0.12		

(Mean of three on-farm locations around Nazareth, 1992 and 1993 crop seasons)
Note:- M/b => Maize/Bean Inter-cropping P1 => Simultaneously planted in late June
Broad => broadcast P2 => bean relay planted after "shilshalo".
Weed DM => Weed Dry matter

Future Trends

Although much has been written about traditional agriculture, there is a paucity of studies that have investigated the agronomic and socioeconomic validity of inter-cropping systems in Ethiopia. In the present trials, however, cropping systems are identified in which greater complementarity occurred and in which greater competition reduced cereals and pulses yield. Consequently, a detailed understanding of present production processes and decision behavior in the small-scale farming sector of the rift valley can be of paramount agronomic and socioeconomic importance.

Thus, agronomic research in inter-cropping in the rift valley of Ethiopia should focus on understanding and improving of the existing traditional inter-cropping systems being practiced by subsistence farmers. Therefore, the future research should focus on:

Studies that should be mounted to determine the relevance, practicality, and potential success of improved inter-cropping systems and management designed to optimize maize and bean yields.

Information, which should be collected on the utilization of available resources to effect, an optimum combination of crop variety, costs of inputs and returns from output, as well as information on the marketing structure required for the various crops.

Select crops that are compatible in mixtures with minimum changes in sole crop plant population and planting arrangement for optimum performance.

Predict to what extent relay or simultaneous inter-cropping, spatial arrangements, and use of crop plants possessing certain canopy structures and other characteristics can enhance efficiency of production in inter-cropping.

Study on yield stability in inter-cropping systems under different agro-ecological conditions versus sole crops;

Study weed population and growth, insect pest infestation and disease infection dynamics under inter-cropping versus sole cropping under different environmental conditions.

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ROPPING SYSTEMS RESEARCH STATUS AND FUTURE TRENDS IN THE RIFT VALLEY. II. WEEDS, INSECT PESTS AND DISEASES

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Abstract

Maize/Bean Cropping systems experiments were conducted at Melkassa and Awassa during 1992 cropping season. Two early bean varieties with different growth habits were planted simultaneously with maize and relay planted one month after maize planting in different planting patterns in a randomized complete block design. The objectives of the experiments were, to evaluate the relationship that exists between maize and beans subjected to different planting patterns and planting schedules of bean varieties in reducing disease incidence, insect pest and weed, and give sustainable yields under low and medium rainfall situations. The results indicate that higher plant population maintained by component crops were effective in suppressing weed growth. The contribution to weed suppression was more evident with the intimacy of crop species in each pattern. The effect of planting patterns indicated that an advantage of 42 to 53% and 35 to 47% reduction in weed incidence could be maintained at Melkassa and at Awassa, respectively compared to sole maize. Lower weed population and weed dry matter was found in maize/bean both broadcast and maize in rows/bean broadcast planting patterns. On the other hand, sole maize and 2 rows maize/1 row bean inter-crops were having highest weed population/m2 and weed dry matter. Planting schedule of beans has significantly affected weed growth at both locations. The results also revealed that inter-crops were effective in controlling the incidence of insect pests namely different array of cob worms, stalk borers, pod borers and bean fly. The insect pest incidence in both maize and beans was higher in relay inter-crops than simultaneous inter-crops. Significantly higher pest incidence was observe at Awassa compared to Melkassa. Much difference was not observed in pest attack between bean varieties. Maize/bean inter-cropping significantly reduced the incidence of bean rust at Awassa by inhibiting the spread of spores and due to wider spacing between bean plants in 2 maize/1 bean inter-crop and maize/bean mixed in the same row patterns. Contrary to this, incidence of anthracnose was higher in inter-crops compared to sole beans. Both bean varieties planted simultaneously with maize in 2 rows maize/1 row bean inter-crop pattern gave significantly higher yield advantage at both locations. Thus, planting lowland pulses and maize and sorghum in 2-row cereal/1 row pulse is recommended for the rift valley of Ethiopia.

Introduction

Subsistence farmers of the dryland areas spend more time and energy on weed control than on any other aspect of crop production. Weed management for any cropping system can involve the use of many kinds of biological, physical, and chemical techniques to promote crop dominance over weeds. Inter-cropping has potential as a means of weed control because it offers the possibility of mixture of crops capturing a greater share of available resources than in mono-cropping, preempting their use by weeds (Akobundu, 1986). In maize-based inter-crop systems, Altieri and Liebman, (1986) found that mung bean was more weed-suppressive than peanut and ascribed this to its more rapid early growth and more uniform canopy structure.

Inter-cropping is widely practiced by subsistence farmers in the tropics for several purposes, one of which is reductions in insect pest numbers, diseases and weeds, and hence reductions in crop damage and yield losses. Cropping systems can affect population dynamics of insect pests by interfering with the colonization of the crop, the development of pest populations, dispersal of the pest, or by influencing the abundance of natural enemies (Hasse and Litsinger, 1981). Intensive cropping systems may hamper colonization of crops by insects through their influence on the visual and olfactory stimuli of the pest, and through the action of some crops as diversionary host plants. Visual cues are important in the colonization of crops by insects.

Rapid population build-up is favored where pests find all their food, shelter and oviposition requirements within the crop. Changes of microclimate, confusing visual and olfactory stimuli received from host and non-host plants in diverse environments may disrupt normal behavior of the pest. In addition to these, the dispersal of both adults and larval stages of pests may be impeded where host and non-host plants are growing together (Altieri, 1984).

Epidemics are favored by morphologically and genetically uniform crops grown on large area of land. In contrast, a combination of genetically different crops grown together in the same field doesn't provide the uniform substrate needed by pests and pathogens to multiply rapidly and acquire epidemic proportions. The incidence of insect pests and diseases therefore, may be reduced in inter-cropping, relative to sole cropping, but this is not invariably the case. Much depends on factors such as host range of the insect species concerned and the relative sowing times and spatial arrangements of the associated crops. Certain pests or pathogens colonize one particular crop in a given ecosystems, which then serves as a diversionary host, protecting other more susceptible or economically valuable crop from severe damage. On the other hand, some pathogens and insect pests can attack and feed on several plant species and can move from one host to another when one of the host plants matures. It is critical, therefore, to select the correct plant diversity before a given micro-climatic, biotic and inter-crop situation; a specific diversity in the same system can be beneficial in one region but harmful in another (Bhatnagar and Davis, 1981).

The dryland areas in Ethiopia are generally mono cropped or sometimes mixed cropped with very low cropping intensity. However, there are possibilities to increase cropping intensity through inter-cropping or relay cropping thereby increase crop productivity per unit area per season depending upon environmental resources. Nevertheless, the ever-increasing human population on the one hand and the progressively shrinking per capita availability of agricultural land on the other warrant the temporal and spatial intensification of cropping systems (Niguse, 1994). The experiments were, therefore, conducted to identify crops and combinations that can increase yields on-sustainable basis and to investigate the effect of maize/bean inter-cropping on the incidence of diseases, insect pests and weeds under low and medium rainfall situation

Review of Results

Major Weeds and their abundance in inter-cropping

The most abundant weed species observed in the subsequent measurements at Melkassa and Awassa are shown in Table 1. *Galinsoga parviflora, Nicandra physalodes, Setaria verticillata, Amaranths* spp., *Brassica* spp., *Tagetes minuta, Eragrostis* spp., *Portulaca olorancea, Cyperus* spp., *Commelina* spp., *Solanum nigrum, sorghum* spp., were observed in high populations at both locations. *Convolvulus* spp., *Launea cornuta, Tribulus terrestris, Datura stramonium,* and *Argemone mexicana* were restricted to Melkassa only while *Trifolium rueppthanium, Anagallis arvensis and Ageratum conyzoides were observed only at Awassa.* The differences in the quantity of weed species that existed in the planting patterns of component crops in both planting schedules of bean may have influenced the nature of competition in the present study.

Table 1. Major weeds and their abundance in subsequent measurements at Melkassa and Awassa.

Name of weed	Days after emergence					
	Melkassa			Awassa		
	22	55	120	22	55	145
Galinsoga parviflora	3	3	2	103	84	75
Nicandra *physalodes*	4	2	3	33	29	25
Setaria verticillata	17	5	3	8	2	-
Amaranths spp.	10	2	-	48	2	-
Brassica spp.	11	3	-	4	1	-
Tagetes minuta	-	1	1	3	2	2
Eragrostis spp.	60	17	8	7	35	87
Portulaca olorancea	1	2	5	6	2	-
Cyprus spp.	2	2	4	6	3	2
Commelina spp.	3	1	1	1	-	-
Solanum nigrum	30	1	5	21	11	9
Sorghum spp.	11	3	2	-	3	6
Trifolium rueppthanium	-	-	-	5	2	-
Anagalli arvensis	-	-	-	1	1	1
Ageratum conyzoides	-	-	-	-	4	204
Plantago lanceolata	-	-	-	-	-	1
Coryza banariensis	-	-	-	-	1	5
Convolvulus spp.	11	3	2	-	-	-
Launea cornuta	2	1	1	-	-	-
Tribulus terrestris	9	2	1	-	-	-
Datura stramonium	2	1	-	-	-	-
Argemone mexicana	19	5	1	-	-	-

In general, grass weed incidence in maize/bean inter-cropping at Melkassa revealed that there was a decreasing trend in grassy weeds incidence in subsequent sampling in all planting patterns with both bean varieties. Comparing the bean varieties the erect type, Awash-1 was effective to control grass weeds than the semi-prostrate bean variety (Mexican-142), whilst the reverse was true for broadleaf-weeds.

Highest number of both grassy and broad leaf weeds were recorded at Awassa than at Melkassa. In all subsequent measurements, sole maize was weak while sole beans were effective in suppression of weed growth. This might be due to the early canopy cover obtained from the early maturing bean varieties and low canopy growth during early seedling stage of maize. The wider row arrangement in sole maize, maize/bean mixed in the same row and 2 maize/1 bean inter-crops allowed light to penetrate and favor germination of weeds. Contrary to this, maize/bean both broadcast and maize in rows/bean broadcast had closer inter-row and intra-row space thereby limiting penetration of light and resulted in low weed incidence. Moreover, there was an increase in weed incidence with time at Awassa while there was a decrease in weed incidence with time at Melkassa. The mean of weed counts taken at 22, 52 and 120 DAE indicated that there were 98, 56 and 20 grass weeds/m2 and 81, 39 and 14 broad leaf weeds/m2 at Melkassa, respectively. Contrary to this, 30, 67 and 93-grass weeds/m2 and 143, 159 and 202 broad leaf weeds/m2 were found at 22, 52 and 145 DAE at Awassa, respectively. These results indicated that a total weed population of 179, 95 and 34 weeds/m2 were observed at 22, 52 and 120 DAE, respectively at Melkassa, whereas a total weed population of 173, 226 and 295 weeds/m2 were observed at 22, 52 and 145 DAE, respectively at Awassa. The increasing trend in weed population might be due to longer duration and high rainfall that occurred at Awassa while that of decreasing trend at Melkassa might be attributed to the low and shorter duration of rainfall.

Weed dry matter at harvest in maize/bean inter-cropping

There was significant difference among planting schedules and planting patterns, and higher weed dry matter was observed in row planted inter-cropped maize with both bean varieties in either planting schedules(Table 2). The results indicated that the extent of weed infestation was related to the amount of ground cover and crop canopy development. In sole maize and relay inter-crops, canopy development occurred much later, and weed growth was not effectively suppressed until much later. However, weed suppression was most pronounced in plots with relay planted beans compared to simultaneous inter-crops and sole maize at harvest due to extended ground cover of relay planted beans. Simultaneous inter-crops suppressed weeds less than relay inter-crops either broadcast or row patterns. Similarly, weed dry matter in row inter-crops was significantly higher than broadcast patterns either simultaneously planted with maize or relay planted. Planting patterns with M-142 were significantly lower in weed dry matter than patterns with Awash-1 in either planting schedules. Moreover, planting patterns with relay planted beans gave lower weed dry matter than with simultaneously planted beans.

The results indicate that higher plant population maintained by component crops was effective in suppressing weed growth. The contribution to weed suppression was more evident with the intimacy of crop species in each pattern. Lower weed population was found in broadcast planting patterns while row inter-crops were having highest weed biomass and weed population/m2. Hence, maize/bean inter-crops were efficient in weed-suppression than sole maize. This indicates that beans were more weed-suppressive than maize ascribed to its more rapid early growth and more uniform canopy structure. Thus, maize/bean inter-cropping is small farmers' first line of defense in reducing and countering crop losses due to weed interference and are of critical importance in the design of effective weed management strategies based on planting patterns. Inter-cropping systems make excellent biological systems for reduction of pests and disease damage, to suppress weeds. Weed dry matter at harvest accounted for 36, 15 and 19 g/m2 in sole maize, Awash-1 and M-142, respectively, but only 20 g/m2 in maize/bean inter-crops at Melkassa; while 378, 183 and 217 g/m2 in sole maize, sole Awash-1 and M-142, respectively but 220 g/m2 in maize/bean inter-crops at Awassa; implying that combinations of crops captured a greater share of available resources, thereby preempting their use by weeds. Weed counts were higher in sole maize followed by inter-crops and sole beans at both locations. Moreover, weed shift in different planting patterns had been investigated. These investigations on weed counts and weed shifts in different planting patterns has indicated possible changes in weed control strategy in which inter-crops may be specially designed to minimize weed infestation and attendant losses.

Table 2. Effect of planting pattern, bean varieties and planting schedule of beans on weed Dry matter (g/m^2) at harvest in maize/bean inter-cropping at Melkassa and Awassa.

Planting Pattern/	Planting Schedule					
	Melkassa			Awassa		
Bean Varieties	Simul-taneous	Relay bean	Mean	Simul-taneous	Relay bean	Mean
Sole Maize	35.56	---	35.56	377.78	---	377.78
Sole Awash-1	15.60	---	15.60	183.33	---	183.33
Sole M-142	18.67	---	18.67	216.67	---	216.67
2 Maize/1 Bean Intercrop, Awash-1	23. 83	16.93	20.38	294.44	222.22	258.33
2 Maize/1 Bean Intercrop, M-142	27.94	13.43	20.69	244.44	213.89	229.17
Maize/Bean mixed in same row, Awash-1	33.90	12.18	23.04	272.22	211.11	241.67
Maize/Bean mixed in same row, M-142	27.24	11.99	19.62	205.56	191.67	198.62
Maize row/Bean broadcast, Awash-1	28.08	15.87	21.98	230.56	158.33	194.70
Maize row/Bean broadcast, M-142	17.98	20.21	19.10	233.33	175.00	204.17
Maize/Bean both broadcast, Awash-1	18.30	7.13	12.72	188.89	269.44	229.17
Maize/Bean both broadcast, M-142	27.18	14.18	20.68	180.56	236.11	208.34
Mean	24.93	13.99	20.33	238.89	209.72	226.61
CV (%)			8. 3			2.96
LSD (0.05)			1.26			11.68

		Melkassa	Awassa
LSD (0.05) Interaction effects	Planting Pattern x Planting Schedule	0.76	7.68
	Planting Pattern x Bean Varieties	0.76	7.68
	Planting schedule x Bean Varieties	0.54	5.43
	P. Pattern x P. Schedule x B. Varieties	1.10	10.86

Insect pest and disease incidence

Significantly higher incidence of stalk borer and cob worms was observed from sole maize compared to inter-cropped treatments (Table 3). No significant difference was observed between bean varieties either in sole culture or in inter-crops. Moreover, due to variation in spatial arrangements of planting the component crops, higher incidence of maize and bean pests were observed in row patterns compared to broadcast patterns. Significantly higher maize pest incidence occurred in simultaneously planted maize, whereas higher pest incidence in beans was observed in relay planted beans. This might be attributed to synchrony of prevalence of the pests that incidence increased with delay planting of beans whereas the reverse was true for maize pests.

Table 3. Effect of bean varieties, planting pattern and planting schedule of beans on insect pest and disease incidence at Melkassa.

Cropping systems	Bean Pests		Maize Pests	
	BF	PB	SB	CW
Sole Maize	---	---	20.0	8.2
Scle Awash-1	4.0	30.8	---	---
Sole M-142	4.7	31.3	---	---
Intercrop/Awash-1	12.2	8.7	12.0	3.4
Intercrops/M-142	9.2	13.5	12.0	2.4
2 Maize/1 Bean intercrop	12.6	11.5	11.0	3.5
Both mixed in same row	12.5	11.8	13.5	2.8
Maize row/Bean broadcast	9.4	10.7	11.5	2.3
Maize/Bean both broadcast	8.3	10.5	11.5	3.4
Simultaneous intercrops	3.0	4.2	15.5	2.5
Relay intercrops	18.4	18.1	9.0	3.3
LSD (0.05)	1.50	1.70	2.45	0.62
CV (%)*	8.61	8.78	8.95	11.73

Note:- BF = > Beanfly incidence PB = > Pod borer
SB = > Stalk borer incidence CW = > Cob worm incidence

Table 4 illustrates the effect of bean varieties, planting patterns and planting schedule of beans on disease and insect pest incidence (%) at Awassa. The result showed that there was no significant difference within inter-crops while there was significant difference between sole beans and inter-crops in rust incidence. Like the effects in sole crops, there was significantly higher incidence in patterns planted with M-142. The incidence of rust in sole crops was two times higher than the inter-crops of both varieties. There was no significant difference between simultaneous and relay planted beans. Sole culture and inter-cropped Awash-1 was infected by about 8 and 2%, respectively. Similarly, sole culture and inter-cropped Mexican 142 was infected by about 20 and 5%, respectively. This indicated that Mexican 142 was significantly susceptible to rust than Awash-1. The presence of maize in different planting patterns might have acted as a physical barrier to the free spread of the fungus propagules. In addition to the wider spacing between bean rows, shade and other micro-climatic effects, Inter-cropping could also have effect on reducing the infection and development efficiency of the pathogen, which are in line with what was reported by Allen (1990). Thus, maize/bean inter-crops buffer against rust incidence by delaying the disease or reducing spore dissemination

Table 4. Effect of bean varieties, planting pattern and planting schedule of beans on insect pest and disease incidence at Awassa.

Cropping systems	Beans				Maize Pests	
	Diseases		Pests			
	Rust	Ant	BF	PB	SB	CW
Sole Maize	---	---	---	---	85.0	92.2
Sole Awash-1	8.0	3.0	3.7	12.4	---	---
Sole M-142	20.0	5.0	3.3	36.6	---	---
Intercrop/Awash-1	2.0	15.8	13.3	21.9	75.0	72.2
Intercrops/M-142	5.3	22.5	13.6	12.3	79.0	69.2
2 Maize/1 Bean intercrop	3.5	10. 0	17.2	18.0	73.5	69.0
Both mixed in same row	3.0	25.0	15.5	21.9	81.0	70.4
Maize row/Bean broadcast	4.5	15.0	11.4	14.5	78.0	71.1
Maize/Bean both broadcast	3.0	25.0	10.0	14.0	74.5	72.5
Simultaneous intercrops	2.0	15.0	2.3	2.2	80.0	67.6
Relay intercrops	3.5	25.0	24.6	32.0	73.5	73.9
LSD (0.05)	0.31	0.78	1.75	4.22	8.0	11.68
CV (%)*	4.5	6.38	8.19	13.52	6.24	6.08

Note:- Ant => Anthracnose incidence BF => Beanfly incidence PB => Pod borer SB => Stalk borer incidence CW => Cob worm incidence

The result indicated that the severity of anthracnose on bean varieties was significantly higher in beans inter-cropped with maize than sole beans. Like the difference in sole crops, the other planting patterns with Awash-1 showed less incidence than Mexican 142. Sole culture and inter-cropped Awash-1 was infected by about 3 and 15.8%, respectively. Sole culture and inter-cropped Mexican 142 was infected by about 5 and 22.5%, respectively. Nevertheless, higher infestation of 25% was observed in beans planted in maize/bean mixed in the same row and maize/bean both broadcast patterns. But when beans were planted in 2 rows maize/1 row bean the incidence was low (10%). The higher anthracnose incidence in inter-cropped beans could be a result of micro-climate modifications imposed by maize crop; increase in relative humidity and shade which may favor the incidence of the disease. However, 2 maize/1 bean inter-crop and maize in rows/bean broadcast planting patterns consistently had lower incidence and these patterns minimized the negative impact of the disease as a result of micro-climate alteration.

Future Trends in Inter-cropping Research

There is a paucity of studies that have investigated the agronomic and socioeconomic validity of inter-cropping systems in the rift valley. In the present trials, however, cropping systems were identified in which greater complementarity occurred and in which greater competition reduced maize yields. Therefore, the future research should address to:

understand clearly and determine farmers' criteria for practicing inter-cropping systems in some parts of Ethiopia and why not in the rift valley.

Studying in detail the various cropping systems such as inter-cropping, alley cropping and cropping sequence to reduce weed incidence and to improve total biological productivity.

Studying the application of agro-climatic information in relation to weed abundance and shift, which can assist in the process of planning improved crops, cropping patterns and land use systems for different agro-climatic zones.

Doing an on-farm research to verify promising research findings in farmers' fields and finding out the acceptability and economic feasibility of various inter-cropping systems.

There is a need to develop guideline for determining economic threshold levels for weed infestation in inter-cropping systems under different agro-climatic situations .

Investigations on type of crop, sowing dates, proportions and spatial arrangements of component crops, soil fertility, tillage and moisture conservation techniques are required to determine the inherent competitive ability of component crops against weeds.

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CROPPING SYSTEMS RESEARCH STATUS AND FUTURE TRENDS IN THE RIFT VALLEY. III. ALLEY CROPPING AND CROP ROTATION

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Abstract

The low total agricultural production and land productivity, coupled with a high rate of population growth and an alarming state of land degradation in the country, requires a strategy that will lead both to an increase in agricultural production and control of land degradation. Increasing cropping intensity through alley cropping systems is one of the ways to increase agricultural production in the marginal farming situations. Alley cropping is basically a land use strategy that integrates crop production and growing of trees and/or shrubs to maintain and increase the sustainability of farming systems, production of fuel wood, animal fodder and cash products, and diversification of agricultural products. The results revealed that a substantial amount of biomass can be produced from the alley cropped leguminous shrubs without any reduction in crop production. The possibility to add green manure from the alley cropped shrubs is one way of increasing soil fertility, thereby increase biological and economic yields per unit area per year. The research themes so far tackled include species comparison, adaptation of perennial leguminous shrubs and their compatibility with food crops in an alley cropping, and potential of green manuring from alley cropped shrubs. However, much needs to be known about local farming systems and their individual components in different dryland farming areas of the country.

Another way of increasing crop production is through an appropriate crop rotation scheme. Haphazard succession of crops mainly dependable on cereal - cereal rotation is the usual practice in the rift valley. This practice contributes to decline in soil fertility and build-up of weed, insect pest and disease incidence and occurrence. To alleviate these production constraints some crop rotation experiments were conducted at Nazareth Research Center. The results indicated that sowing pulses preceding to cereals (maize-haricot bean rotation) gave sustainable yield of the test crop. Besides, the result revealed that inclusion of inter-crops of maize and bean in a rotation considerably increase grain yield in addition to having a bonus yield of beans. Application of green manure from alley cropped legume shrubs also gave 70-100% yield increase compared to maize-maize rotation. It is worthy, therefore, to realize that crop rotation experiments can be conducted within an alley cropped shrubs and obtain sustainable grain yield, substantial biomass from legume shrubs, improve soil fertility and minimize weed, insect pest and disease incidence under the rift valley climatic condition.

Introduction

The loss of soil fertility because of low vegetative cover, mono cropping and overgrazing in the dryland areas of Ethiopia is a serious problem. Besides, the impact of high-intensity raindrops on the bare soil surface coupled with low organic matter content of the soil often results in severely degraded soil with poor physical and chemical properties. Consequently, crop yields are usually low and shortage of animal feed is a major constraints in the dryland areas (Tilahun and Teshome, 1987). The shortage is especially acute during the end of the dry season when most of the plowing has to be done. Thus, the draft power is limited and is at its weakest point.

Alley cropping of leguminous shrubs can supply most of the basic feed requirements. The inclusion of leguminous shrubs in the land use system offers the advantage of maintaining soil fertility through nitrogen fixation and nutrient recycling, maintaining adequate levels of soil organic matter, supplying mulch material for protecting the soil and regulating water infiltration, runoff and erosion; supplying fuel wood; limiting fallow to narrow strips, consequently saving land and making possible continuous farming with or without short fallow periods (Reddy *et al.* 1994).

Alley cropping is the result of long-term efforts in integrating traditional and modern or emerging technologies. It involves growing annual food crops between rows of selected leguminous perennial species. Substantial evidence indicates that alley cropping results in higher biological productivity and better control of the environment and safeguard against unfavorable condition (Kang *et al.*, 1981).

Traditionally, farmers grow tree species in a haphazard manner in the rift valley. In general, *Acacia* species, *Cordia abyssynica*, *Olea* species, etc. are left in the field for multipurpose uses such as farm implement, firewood, fencing, shade for livestock during sunny days and increasing soil fertility. They maintain *Acacia* species, particularly *Acacia albida* that is a high N fixer and potential supplemental feed for goats and sheep when the pods are matured. Besides, after the crops are sown the branches are pruned and used for fencing their fields. These pruned branches are further used for firewood after the crop is harvested (Reddy and Kidane, 1993).

Besides, other problems encountered in the rift valley include unfavorable environment to crop growth, limited choice of crops and varieties, low cropping intensity; and unavailability of appropriate crop rotations and successions that lead to low and unstable productivity. Cereal dominated crop rotation systems are practiced in the rift valley depending upon the on-set of rain. The major crops are maize, tef and haricot bean. This limited crop enterprises that is under practice limit the choice of specific crop rotation and succession for a specific location in the rift valley. As a result prevalence of diseases and insect pests as well as propagation and dissemination of weeds in farm lands are becoming common occurrence which could be alleviated by using appropriate crop rotations (Reddy *et al.* 1994; Tilahun and Teshome, 1987) .

The traditional haphazard succession of crops usually results in declining soil fertility and in increased weed, pest and disease infestation. Legumes in the crop rotation supply some N to subsequent crops and thereby reduce N fertilizer requirements. In a crop sequence where a pulse crop is followed by a cereal, P application benefits the pulse crop and it appreciably economizes the need for N for the following crop (Reddy and Kidane 1993). Although highly recommended to include a legume crop in a rotation cycle, it is not widely practiced in dryland farming in Ethiopia.

Much has bean said about traditional intensification of cropping such as alley cropping and cropping successions. But, the scientific information on the relative benefits of these practices are very limited in the rift valley. Conducting fundamental research that evaluate the principal factors influencing the nature and productivity of alley cropping of food crops with leguminous shrubs and crop rotation appeared to be paramount importance. Thus, experiments were conducted at Nazareth Research Center to identify crops that can increase sustainable yields, to assess feasibility and potential productivity of biomass of the alley cropped shrubs in the rift valley and to assess the advantages of alley cropping leguminous shrubs in the cropping sequences of the major crops in the rift valley.

Review of Results

Alley cropping

Suitability of multipurpose shrubs with field crops

Preliminary studies were conducted to determine the adoption of selected leguminous shrubs (*Sesbania sesban, leucaena leucocephala* and *Cajanus cajan*) and their suitability for alley cropping with food crops (sorghum, maize and haricot bean) at Melkassa during the 1987-1988 crop seasons. Food crops were grown in an alley spaced 10 meters apart and spacing between shrubs was 50 cm apart. The results indicated that *Sesbania sesban* and *Cajanus cajan* were promising and could be adapted to the dryland areas of Ethiopia (Table 1). Grain yield increased as much as 4, 19 and 13% and 36, 25 and 8% when maize and sorghum were alley cropped with *Sesbania sesban, leucaena leucocephala* and *Cajanus cajan,* compared to sole maize and sorghum, respectively. In addition, the legume trees, especially *S. sesban* and *C. cajan* produced 2353 and 2548, 2357 and 2474, and 3075 and 2101 kg/ha, biomass when alley cropped with maize, sorghum and haricot bean, respectively. These biomass yield can be used for animal feed or fuel wood or as green manure or mulch to improve soil fertility.

Table 1. Effect of alley cropping on grain yield of maize, sorghum and haricot bean; and biomass production of legume shrubs at Melkassa.

Treatment	Grain yield (kg/ha)								
	Maize			Sorghum			Bean		
	1987	1988	mean	1987	1988	mean	1987	1988	mean
Sole maize	4644	3597	4121	2500	2332	2416	1299	2754	2027
Sesbania	3944	4605	4275	2541	4034	3288	1232	2298	1765
Leucaena	5799	4177	4988	2809	3243	3026	1371	2902	2137
Cajanu	5914	3419	4667	3048	2174	2611	1694	2048	1871
	Biomass production (kg/ha)								
Sesbania	2507	2507	2353	2265	2448	2357	1942	4208	3075
Leucaena	—	778	778	—	656	656	—	554	554
Cajanus	1639	3457	2548	1760	3188	2474	1942	2260	2101

Source: Kidane *et al.* (1989)

Use of green manure from alley cropped shrubs

Based on the preliminary alley cropping trial results, a follow-up experiment was conducted at Melkassa during 1993-1994 to assess the effect of green manuring on soil nutrients and yield response of maize from alley cropped *Cajanu cajan* and *Sesbania sesban*. Green manure sources were established during the rainy season in the hedgerows. The shrubs were pruned in December, March and June before planting maize in late June. Each time the pruned material were weighed and incorporated in the soil of each plot. Totally 3 tons/ha fresh green manure was used for incorporation.

Results revealed that statistically significant differences were observed among treatments (Table 2). In 1993, an advantage of 15% and 43% in straw yield and 9% and 53% in grain yield were obtained from green manure application of *C. cajan* and *S. sesban*, respectively, compared to without green manuring (check). In 1994, straw yield advantage of 102% and 106%, and grain yield advantage of 123% and 130% occurred due to application of *C. cajan* and *S. sesban* green manure, respectively, compared to check treatment. Means of the two years indicated that straw yield increased by 54% and 71%, and grain yield increased by 39% and 86% when green manure of *C. cajan* and *S. sesban* were applied, respectively, compared to farmer=s practice. The results revealed that biological yield of maize considerably increased due to application of green manure from the alley cropped leguminous shrubs, *C. cajan* and *S. sesban*, by protecting the soil and regulating water infiltration, runoff and erosion in drought prone areas of Ethiopia.

Table 2. Effect of green manuring on straw and grain yield of maize at Melkassa.

	Straw weight (kg/ha)			Grain yield(kg/ha)		
Treatment	1993	1994	Mean	1993	1994	Mean
Without mulch	3175	2627	2899	2049	1440	1745
Cajanus cajan	3649	5298	4474	2235	3204	2720
Sesbania sesban	4526	5405	4966	3135	3318	3237
LSD (0.05)	440	732	586	697	420	559
CV (%)	7.19	9.53	8.36	17.86	9.14	13.5

Crop rotation

A trial was conducted at Melkassa during the 1986 and 1987 crop seasons to evaluate the relative benefit of crop rotation and succession. In 1986, seven precursor crops (maize, sorghum, tef, haricot bean, safflower, *Dolchos lablab* and sweet potato) were grown at two different fertilizer levels (0 and 100 kg/ha) of DAP (18-46 N-P2O5). In 1987, a test crop of maize was grown to examine the effect of different precursor crops on the succeeding crop.

Yields of different precursor crops in 1986 and of the test crop (maize) grown in 1987 are presented in Table 3. The results showed that the seed yield significantly increased compared with maize after cereals (maize, sorghum and tef) when maize was planted after haricot bean. This may have been owing to the improvement in soil fertility levels because of N fixation by haricot beans compared with maize after cereals.

Table 3. Effect of crop sequence on grain yield of maize at Melkassa, 1986 and 1987.

Cropping system		1986 *crop yields* (kg/ha)		1987 maize yield (kg/ha)
1986	1987	1986	1987	
Maize	Maize	2489	2295	3036
Sorghum	Maize	2017	2241	2595
Tef	Maize	1045	1286	2877
Haricot bean	Maize	816	930	4233
Safflower	Maize	695	632	3263
Dolichos lablab	Maize	*3764	3496	3187
Sweet potato	Maize	**9583	10815	2544
LSD (0.05)		---	---	445

* *Drymatter weight (kg/ha)*

** Fresh tuber weight (kg/ha)

Another experiment was carried out to develop an appropriate crop rotation systems for maize production during 1993-1994. The results presented in Table 4 indicate that maize yield decreased by 100 % as a result of continuous mono cropping without the application of fertilizer in the second year of rotation. Even after applying the recommended fertilizer rate the grain yield dropped by 10 Q/ha. Similar tendency was observed in the following year. Tef and beans got less benefit from the alley cropped *Sesbania sesban* compared to maize. There was considerable difference between with and without fertilizer applications in all crops. The advantage of maize/*Sesbania sesban* followed by maize/*Sesbania sesban rotation* exceeded other treatments in terms of increasing grain yield across all seasons in both fertilizer levels. The increase in production was very clear since the second year where about 13 Q/ha yield advantages was recorded in plots without fertilizer, compared to cereal after cereal sequence. The same trend was observed in 1994 cropping season. Incorporation of *Sesbania sesban* into the soil was as good as recommended commercial fertilizer. 12-13 Q/ha yield advantages was observed both as a result of fertilizer application and incorporation of *Sesbania sesban*. The results indicate that there is a possibility to increase crop production with biological fertilizer that needs very little cost of production in addition to alleviating natural resource degradation.

STRIGA RESEARCH IN ETHIOPIA - ACHIEVEMENTS AND FUTURE PROSPECTS

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Abstract

Most of the damaging species of *Striga* namely *Striga hermonthica*, *Striga asiatica*, *S. latericia*, *S. aspera*, *S. gesnerioides*, and *S. forbesii* are known to occur in Ethiopia. Among those, *Striga hermonthica* is the most wide spread and devastating, attacking important food crops such as sorghum, maize, and finger millet. More recently, it is becoming increasingly important on tef, *Eragrostis tef* trotter, the main staple cereal food crop in the country. A large number of sorghum genotypes both indigenous and introduced were evaluated by the programme. Varieties that have showed relatively consistent and high level of resistance were SAR-24, ICSV-1007, ICSV-1006, N-13, Framida and SRN-39. Work on identifying resistance sources in maize was not so successful. However, considerable variation between varieties was observed in terms of susceptibility to *Striga*. A promising line, B37 91-952-1 (from Purdue University, USA) was found to be low stimulant producer in recent laboratory tests. Some more tropical lines from CIMMYT have also appeared to be very low haustorium factor producers. Pearl millet has so far proved immune to Ethiopian populations of *Striga hermonthica*. Results of other *Striga* control investigations have revealed that late season hand pulling (flowering *Striga*) requires 2 to 4 fold less labour compared to early pulling (farmers' practice). Nitrogen has decreased infestation and the effect was more apparent on some selected improved varieties such as ICSV-1006, and ICSV-1007 and under conditions of improved moisture availability. Inter-cropping of sorghum with legume crops was found to be effective in minimizing *Striga* incidence and improving yield per unit area. None of the herbicides tested could arrest subterranean development of *Striga* but 2,4-D, glufosinate and oxiflourfen were suitable for post emergence use to prevent seed setting. Integrated control trials have revealed that *Striga* can be more effectively controlled through the combined use of improved management practices involving relatively more resistant cultivars, row planting, fertilizer and hand pulling (flowering *Striga*) or 2,4-D (1 l product/ha.). The national strategy is to develop a more holistic approach to address the complex of all associated factors with *Striga*. Currently, special emphasis is being given to developing cropping systems and agroforestry interventions to improve soil fertility and control *Striga*.

Introduction

Striga was first recorded in Ethiopia over 100 years ago (Richard et al., 1847-1851). But, it has received increased research attention following Parker's report in 1970. The major species occurring in the country in order of importance are: *Striga hermonthica*, *Striga asiatica*, *Striga latericea*, *Striga aspera*, *Striga gesnerioides* and *Striga forbesii*. *Striga hermonthica* is wide spread and most devastating, attacking a whole range of crops.

In the early 1970, research activities were launched with the primary objective of finding control options. Initial laboratory studies were undertaken and large number of crop genotypes were screened for low *Striga* germination stimulant exudation. Field experiments were also carried out at two sites, Humera and Kobo. However, inaccessibility of research sites, loss of trials to drought, un-evenness of *Striga* infestation, among others, have hindered accumulation of sound information. Field activities were interrupted in the late 1970s and early 1980s mainly due to security reasons, particularly in Humera, until they were reinitiated in 1986 at Kobo and two other state farm sites in north western part of the country, Lower Bir and Beles. Later, Sirinka Research Center was also included as the main site for *Striga* research. These are new sites with more reliable climatic conditions, particularly rainfall. Some modifications of field designs were introduced to alleviate the non-uniformity problem in *Striga* infestation. Laboratory techniques were also developed, which facilitated further studies on *Striga* germination biology and crop genotype screening. Thus, making use of the improved conditions some progress has been made lately and encouraging results were achieved. In this paper an attempt is made to briefly describe the *Striga* research activities carried out in Ethiopia to date.

Survey

Survey activities, although fragmented and far from comprehensive, were carried out to determine the extent of *Striga* problem in different regions in the country. One such activity was designed to investigate the distribution of *Striga* in relation to soil factors and previous cropping history (Parker, 1988). About 100 fields were surveyed in Tigrai and Welo regions and soil samples collected from the 0-15 cm depth for PH and mechanical analysis. The range of PH recorded was from 5.7 to 8.1 and high infestations of *Striga hermonthica* occurred through out almost this whole range. Generally neither PH nor soil type appeared to be at all critical for the occurrence of severe *Striga*.

In 1987 a survey, in the form of interview questionnaire, was undertaken again in Welo region. The survey was administered by extension staff to 100 farmers in six districts. Only farmers growing sorghum and having *Striga* infestations were interviewed. Summary of farmers' responses have indicated that *Striga* was present in the majority of the areas for over 20 years (Van Delft and Stroud, 1988). About 85% of the farmers estimated severe damage to their sorghum and 43% had severe damage on their maize. Within adjacent areas, there was a large variation in the intensity of *Striga* infestation. The study tried to relate this variation to possible differences in farming practices.

Striga is known to be a major constraint in the predominantly sorghum growing state farms in the western and north western parts of the country. Earlier reports indicated that large acreage of land was abandoned due to *Striga* and a survey was initiated in 1987 to determine the magnitude of the problem. Six state farms namely Fincha, Beles, Ayehu, Upper Bir, Lower Bir and Humera were included in the survey (Wondimu W/Hanna and Rezene Fessehaie, 1988). Fields infested with *Striga* were randomly selected and data were collected at a distance of 100 m from edge of each field. *Striga* counts were taken using $1m^2$ iron quadrats from 782 sample points. *Striga hermonthica* was wide spread and commonly occurring species in most of the surveyed state farms. At Fincha, however, *Striga aspera* was far more common. At Humera, where the *Striga* infestation was the worst, *Striga* density ranged from 60 to 217 shoots/m^2. At Beles, *Striga hermonthica* infestation was severe but sporadic. At Upper Bir, although 46% of the sample area was infested, infestation intensity was rather low. Generally infestation was so heavy in those state farms often leading to enormous crop loss. *Striga* has been the main cause for abandoning sorghum production in 17,249 ha of land in Humera and 6000 ha in the rest of the farms.

Another set of information, gathered through a questionnaire, has also confirmed that many damaging parasitic weed species do occur in Ethiopia (Fasil Reda and Parker, 1991). The dominant among them appears to be *Striga*, particularly the species - *Striga hermonthica*. *Striga asiatica* was reported from many other places, where it was not known to have existed before, including Bale, Sidamo, Welega, Shewa and Gojam in the South and South-western parts of the country. *Striga gesnerioides* was found causing considerable damage on sweet potato in Gambella settlement area. Sporadic infestations of *Striga aspera* on maize was recorded from south Gojam and bordering parts of Welega.

Varietal Studies

Sorghum

In 1970, 24 sorghum varieties were compared for their root exudate stimulant activity and for their susceptibility in a pot experiment. Root exudate activity from 4 day old seedlings varied from 1.6 % to 49% germination, whereas, emergence of *Striga* in pots, from 0.5 to 6 plants per host. There was no apparent correlation between the two parameters (IAR, 1971). The following year, 90 varieties were tested for stimulant production in the laboratory and 55 of these were found to be promising (IAR, 1972). After a long interruption, laboratory activities commenced in the late 80s. The main laboratory technique used involved growing host seedlings in plastic cups for four days at 32^{0}c. Root tips (1.5 cm long) were then cut and incubated in distilled water equivalent to 0.5 mm per tip at the same temperature. The solution with the root tips was used after 24 hours for the stimulation test on preconditioned *Striga* seeds. Reading on induced germination was taken after 48 hours. Using the described technique a large number of sorghum genotypes were screened. A number of genotypes including SAR-24, ICSV-1006, ICSV-1007 and some of their crosses were found to be low stimulant producers. Those varieties have maintained high level of resistance when they were exposed to a wide range of *Striga hermonthica* populations under glass house conditions (Fasil Reda, 1991).

Field testing of sorghum genotypes for resistance was the main component of the *Striga* research program for a long period of time. In 1972, 110 varieties were planted in Setit-Humera and scored visually for *Striga* attack. Twelve of these exhibited some level of resistance (Alemaya No 87, 60, 1105, 54, 33, 55, 29, 785, 322, 56, 137 and 39) (IAR, 1973). In 1973, Dobbs and Framida were compared with Wadi-aker and Feterita at Humera, but all were severely damaged and produced no yield under heavy infestation (IAR, 1975). In 1974, at Kobo five varieties showed nil emergence: N-13, IS 1562, 37-2-13, GC 373 and IS 6492 (ESIP, 1978). In 1978, of those included in 1977, SRN 4841 (= Framida) showed reasonably low counts in all replicates (ESIP, 1979). In 1979, interesting results were obtained on the relative susceptibility of varieties. Sorghum varieties, IS 8686 (=Framida) was significantly less attacked than the standard CK 60B. N-13 was also less attacked but the difference was not significant (ESIP, 1980). In 1980, N-13, SPV-103 and IS-8686 gave low *Striga* counts but no statistical analysis was possible because of missing plots.

In 1981, *Striga* emergence per m^2 varied from 2.3 for N-13 to 84 for Melkamash 79, but erratic distribution and missing plots precluded statistical analysis. Results of another preliminary yield trial have showed that SPV-103 with 12.4 *Striga* per m^2 was appreciably lower than Gambella-1107 with 85 counts per m^2, but differences were not significant. In 1982, three varieties showed significantly lower count than the checks, namely N-13, 81-ESIP-44 and 81-ESIP-38. In

1984, at Beles *Striga* emergence was relatively low but a little less erratic and most of the entries recorded significantly lower counts than the checks. Among those with lowest counts (less than 0.5 *Striga* / sorghum plant) were N-13, IS-8686, S-587, P-967059, M-90362, S-4553 and *Striga* trial entry no-28 of 1980. Tetron was found to be highly tolerant, growing inspite of heavy infestation. In 1985, *Striga* counts showed the usual erratic behaviour, and although some varieties had very low infestation, including 148 x Framida and (Framida x SPV 329)-2-1 (means of 16 and 10 per plot compared with 85 and 243 for Melka mash and Gambella respectively), these differences were not significant. In 1986, varieties showing lowest counts included SAR-24, IS-9568, S-4652, S-4678 and ICSV-1007 HV (=148x Framida). In another location, Beles, counts were a little less erratic and SAR lines 8,12, 19 and 24, (Framida x SPV 329)-2-1, IS-9568 and S-4641 were significantly more resistant than varieties E35-1 and S-4620. SAR-24 has showed good resistance at Lower Bir. In 1987-88 seasons, early assessment made at Beles revealed that entries ICSV-1006 and 81-ESIP-57 had less than 20% of *Striga* intensity recorded in the adjucent checks. Framida, N-13, ICSV-1007, ICSV-1049, Tetron, 81-ESIP-55, 85-MW-5340,88-MW - 5031, 88-MW-5056, 88-MW-5220 and Dinkmash -86 sustained less than 40%. In the second assessment only ICSV-1006 showed less than 40% infestation. At Beles the highest and lowest grain yields were obtained from Framida and 84-MW-4143, respectively. At Lower Bir entries 88-MW-5056 and 84-MW-4143 gave the highest and lowest yields respectively (Babiker, A.G.T. and Fasil , 1991)

Maize

In 1979, most of the tested varieties were very susceptible, but variety D-771 was significantly less attacked, showing that useful variation in susceptibility can occur also in this crop (Parker, 1988). In 1988, four maize varieties including 8322-13 and 8221-18 from IITA (Nigeria) were tested in pots and all supported heavy *Striga* pressure (Fasil and Parker, 1988). The two indicated varieties have displayed considerable tolerance to *Striga* in field tests. In 1992, 112 maize genotypes were screened in the laboratory using the agar gel method. One line, B-37 91-952-1, has proved to be low stimulant producer. It was also interesting that some tropical lines from CIMMYT, including PR 91A 496-45, PR 91B 5323 33x34, PR 91A 496-17 and PR 91B 5353 41x42 were very low haustorium factor producers (Fasil et al., 1993).

Pearl millet

Results with pearl millet varieties confirmed the almost complete immunity of this crop to *Striga hermonthica*, at least at Kobo (Northern Welo) (Parker, 1988). The crop has also proved immune to different *Striga hermonthica* populations in subsequent glass-house experiments (Fasil, 1991).

Chemical control

In 1971, prynachlor 2 kg a.i/ha was superior and gave 60% reduction in infestation. In 1972, medinoterb granules applied 65 days after planting gave at least 90% control but only for few weeks. In 1975, the fumigant, methyl bromide was tested for its ability to clear *Striga* infested land for purpose of experiment. Application at a standard rate to moist soil in July, under plastic covers left in place for 48 hours, gave 100% control of *Striga hermonthica* in the sorghum planted

15 days later. A synthetic strigol analogue (GR7) was tested in a variety of ways and there was a mean 50% reduction in infestation, the best treatment giving 80% control (Parker, 1988). Herbicide trials were conducted at two locations, Beles and Lower Bir and showed that Oxyfluorfen, glufosinate and 2,4-D were of some potential. Glufosinate was effective early in the season, but it did not prevent late season infestation. 2,4-D applied 5 to 8 weeks after planting delayed *Striga* emergence and killed top growth but it did not affect late season infestation. Application of the product 19 weeks after planting displayed excellent activity at Lower Bir (82% control). Oxyfluorfen showed satisfactory activity at both locations (Babiker and Fasil, 1991).

Manual weeding

Early season hand pulling (farmers practice) was found to be significantly high labour demanding. The man days required were 2 to 4 fold more than needed for late season pulling (after flowering). This suggests that the practice can more effectivelly and economically be put to use later in the season. *Striga* removal, irrespective of stage of growth, did not improve grain yield.

Time of planting

A sowing date experiment at Humera showed highest yield from the earliest sowing on 18 July. Sowing late showed slightly lower yield and slightly higher *Striga* per sorghum plant. On the other hand, observation made hear Axum (Northern Ethiopia) suggested that, under a bimodal rainfall pattern, *Striga* was very much worse when sorghum was planted on the early (April) rains, which experienced a dry period in May, than when planted in June, immediately prior to more continuous rain (Parker, 1988). At Sirinka (Northern Welo), a long season local sorghum variety (Degalit), planted in April, suffered less *Striga* attack and gave superior yield compared to May and June planted short season varieties. Similarly, there was less *Striga* pressure on April (early) planted maize. Results obtained from the time of planting experiments have lacked consistency and more research needs to be done in this area in the future.

Fertility studies

The earlier experiments at Humera and Kobo were inconclusive, but showed at least some reduction of *Striga* infestation from application of nitrogen. Later, fertilizer trials at two other locations (Lower Bir and Sirinka) showed that nitrogen tended to decrease *Striga* infestation on Gambella-1107 and N-13, but its effect on ICSV-1006 and ICSV-1007 was more consistent.

Biological control studies

In 1972, the only serious pest of *Striga* at Setit Humera was found to be *Smicronyx* gall-forming weevil, but it was not common enough to be a significant control agent (IAR 1972, IAR 1973). Plans were developed to introduce other insects from East Africa and India. *Eulocastra argentisparsa* and the Indian weevil species *Smicronyx albovariegatus* were introduced from India (IAR 1977). In 1978, *Eulocastra* and *S. albovariegatus* were again introduced and released, this time at Kobo (Tadesse G/Medhin and Parker, 1989). One year later, *S. albovariegatus* was found but not the *Eulocastra*. No systematic surveys or collections are known to have been conducted in the areas of release since then, mainly due to security reasons. *Smicronyx umbrinus*, the African weevil, was reported from many places in the country although not as a serious pest of *Striga*.

Conclusion

Survey

The survey results showed that *Striga* is spreading at an alarming rate to infest new areas. Highly contributing to this unwelcome trend is lack of established quarantine procedures and hence free movement of farm machinery, farm produce etc. from infested to non-infested areas. Developing infestation maps of farms and then imposing strict quarantine restrictions, which prohibit movement of contaminated materials from infested sections of the farms, should be exercised to limit further spread.

Striga development appears to be less affected by PH or soil type and the problem is being aggravated by the continuous mono-cropping of susceptible host crops. In some state farms, continuous cultivation of susceptible crop cultivars has lead to excessive build up of *Striga* infestation and consequently abandonment of large acreages of land. Rotation into suitable trap crops or resistant varieties coupled with some other complementary control measures such as hand pulling and/or herbicides have to be employed to deplete seed reserve and then reduce the problem to a manageable level.

Striga hermonthica is the most serious and wide spread problem, but many other species, formerly of little or no significance vis. *Striga aspera* on maize and *Striga gesnerioides* on sweet potato are also gaining importance. The build up and spread of infestation of these species should be prevented through constant monitoring and use of measures to prevent seed setting.

Generally sorghum seems to be much more susceptible to Ethiopian population of *Striga hermonthica* compared to other crops. Pearl millet has so far proved immune, which makes it a potential break crop for *Striga* prone areas. The occurrence of *Striga* on tef is a recent development, but it appears to be a rapidly growing problem of major concern. The increased susceptibility of tef could be because of a new strain which is more adapted to the crop or a particularly virulent population attacking very susceptible cultivars. In either case, efforts have to be made to make farmers and development workers aware that seed setting has to be prevented and the production of susceptible tef cultivars should be discouraged whenever possible.

Varieties

Up to the early 1980s, large number of sorghum genotypes were tested without any promising results due to reasons such as drought, non-uniformity of *Striga* infestation. As of the late 1980s, considerable progress was made following use of new sites with more reliable rainfall conditions and some modified field designs. Among the large number of sorghum varieties tested N-13, SAR-24, ICSV-1006, ICSV-1007 and SRN-39 were superior with high level of resistance, although some inconsistency was noted in certain years and across locations, particularly in the state farm sites, Beles and Lower Bir. The *Striga* infestation in those farms was extremely high and less than ideal for variety testing.

Most of the resistant varieties were poor agronomically. Recent attempts to improve their agronomic background while preserving the resistance trait have given encouraging results. Host plant resistance is widely considered as the most feasible method of *Striga* control. Therefore, screening and evaluation of sorghum genotypes should continue with more emphasis on indigenous germ plasm.

Chemical control

Research efforts made for identifying systemic herbicides which could potentially prevent initial development of the parasite on the host crop were not successful. A range of products have, however, offered effective control of emerged *Striga* plants. These include oxyflourfen, glufosinate (directed application) and 2,4-D. Repeated application of these herbicides was required for better results. It should be noted here that there could only be a long term benefit from use of such chemicals through prevention of seed setting and gradual exhaustion of the seed bank in the soil. These herbicides may be applicable specially in big farms where employing labour could be highly expensive and impractical. More work on rates and time of application of new chemicals should continue with the primary objective of identifying effective chemicals, which have systemic property and a potential to arrest early development of the parasite.

Hand weeding

This is the most commonly used control practice by the farmer, but timing of the operation varies from place to place. Correct timing appears to be critical for this method to work effectively and it has been shown that 2-4 fold less time and labour was required for late pulling (during flowering) compared to early pulling. Furthermore, weeding of *Striga* plants has to be repeated at certain intervals and has to continue up to and beyond harvest for maximum effect. More experiments should be carried out to determine the optimum time interval for pulling without the risk of allowing *Striga* to shed seed. The practice should also be studied as part of an integrated control approach.

Time of planting

Results coming out of the time of planting experiments were usually controversial and never showed any clear trend. However, more research may be required to determine the effect of time of planting on *Striga* infestation in areas with mono-and bi-modal rainfall pattern.

Fertility studies

Nitrogen resulted in reduced *Striga* infestation. However, the effect of nitrogen was more pronounced on some varieties than others. Further studies have to be carried out on different forms, rates and time of application of nitrogen fertilizers. Attempts need to be made to determine the fertilizer type-cultivar-*Striga* interaction.

Biological control

The gall-forming weevil *Smicronyx* has been seen damaging *Striga* in Humera, and it was realized quite early that there could be scope for introduction of this and other insects from other parts of Africa and India. Two insects were subsequently introduced from India and released at Humera and Kobo, but political disturbances unfortunately prevented proper follow up. According to later observations it does not seem that the insects have successfully established at least in Kobo area, but more systematic surveys will be conducted to look for the introduced species and other beneficial insects and pathogens.

Recommendations

1. *Striga* exerts most of its damage in the small scale subsistence agriculture regions, being a severe problem in highly degraded areas with low fertility. Hence, emphasis should be given to developing low input technologies that would not only minimize *Striga* pressure but also sustain land productivity. More research is required on cropping systems to identify compatible legume species and planting arrangements that could fit into the existing farming systems. Legumes have to be introduced into the existing largely cereal based system which favoures *Striga* buildup.
2. Very little work has been done in the area of biological control which is receiving increased attention as a highly promising method elsewhere in the world. The potential of using indigenous insects and pathogens against the parasite need to be explored more. Effective species can be mass produced and used as part of an IPM to control *Striga* under localised conditions or at a large scale. Introduction of exotic bio-control agents could be considered in the long run.
3. There is so far no any single control method that is fully effective on *Striga*. Efforts should, therefore, continue to develop a variety of integrated *Striga* management systems. Different approaches may need to be formulated as a package taking the specific nature of the various farming systems and ecological conditions into consideration.

4. Despite encountered problems in the past, some useful research findings have been registered. The major setback has been the poor extension setup in and inaccessibility of the infested regions. A more intensified extension effort will be required to disseminate available research results.
5. Most farmers consider *Striga* as a curse from god. A lot can be gained by simply making farmers appreciate the importance of the prevention of seed setting. Many people who are directly or indirectly involved in agriculture are also hardly familiar with the basic aspects of *Striga* biology. All available means of communication (mass media, publications etc.) have to be used to relay highly relevant messages pertaining *Striga* reproduction, mechanisms of spread and the need for communal effort in the overall endeavour for *Striga* management.

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SESSION III
Disease and Pest Management

Chair: Dr. K. Ampofo
Rapporteur: Ato Ahmed M. Sherif

A REVIEW OF VEGETABLE AND FRUIT CROP DISEASES RESEARCH: ACHIEVEMENTS AND PROSPECTS.

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Summary

Vegetable diseases are the major production constraints throughout the country both under rain-fed and irrigation systems. They differ greatly in severity and frequency of occurrence, depending on the season. Diseases cause a considerable amount of yield and quality loses every year. The geographical distribution and relative importance of vegetable diseases were assessed in major production zones of the country, and accordingly 11 diseases on tomato, 27 diseases on pepper and 10 on onion have been identified. Research on fruit crop diseases has focused on survey. FAO experts in collaboration with IAR and state farm enterprise staff have made survey to assess factors limiting citrus production and related crops in different citrus production areas under irrigation. Virus and virus like-disease and fungal diseases of Citrus, leaf curl of peach , cigar-end rot and burrowing nematode of banana and downy and powdery mildews of grapes were reported as important diseases. Recently an extensive survey was made on farmers' fields in the rift valley in papaya growing areas, and reported that papaya production suffers due to anthracnose disease. However, frequent interruption in staff continuity and /or insufficient allocation of research time and gaps in knowledge on which area to focus have made progress rather slow in fruit diseases research. The other area of emphasis was chemical control of powdery and downy mildew of grapes. Effective fungicides and rate of application have been identified.

Introduction

Vegetables

Tomato, pepper and onion are the major vegetable crops cultivated in small holdings and in farm enterprises both under rain-fed and irrigation systems. Today people are consuming more fresh vegetable than before and the production of vegetable crops is one of the important farm enterprises in the country (Mengistu, 1992). Among the biotic stresses, diseases are the major ones affecting the production of vegetables.

Depending on environmental conditions and type of cultural practices used in different production systems, vegetable crops are frequently affected by various diseases. Several plant pathogens infect vegetable crops, among which late blight (*Phytophthora infestans*), Septoria leaf spot (*Septoria lycopersici*), powdery mildew (*Leveillula taurica*), root-knot nematode (*Meloidogyne spp.*) and viruses on tomato, powdery mildew (*L. taurica)*, viruses, stem blight (*Phytophthora spp.*), bacterial leaf spot (*Xanthomonas campestirs pv. vesicatoria*), pod bleaching on pepper, purple blotch (*Alternaria porri*), downy mildew (*Pernospora destructor*) on onion are of great economic importance. These diseases cause considerable amount of yield and quality losses every year (Tesfaye and Habtu, 1985).

In early days, different research activities including disease surveys, chemical control studies, cultural control, yield loss assessment and screening for disease resistance were carried out, and various control measures including effective fungicides with appropriate concentration, application frequencies and cultural control were identified and recommended against major vegetable diseases.

Fruits

Fruit crops production is becoming an important agricultural enterprise. It includes citrus (orange, mandarin, lemon, lime, grapefruit), banana, grapevine, papaya, mango, pineapple and others. Among these, citrus banana, grapevine and papaya are produced relatively in a large scale. Among the major disease problems in the production sector, foot rot (*Phytophthora nicotianna*), viruses and virus-like diseases such as psorosis, tristeza, and greening on citrus, powdery mildew and downy mildew on grapevine, burrowing nematode and cigar- end rot on banana, anthracnose and foot rot on papaya are of great economic importance. The major activities so far on fruit crop diseases were limited to surveys and identification, and attempts were made to know the geographical distribution of diseases.

The main objective of this review is to assess research findings which have been done so far, identify the gaps and plan future research priorities on major vegetables and fruit crops. Therefore, this paper deals with a brief summary of disease survey, highlighting different research findings obtained for the last 25 years, problems untouched and future research priorities on vegetable and fruit crops with major emphasis on tomato, pepper, onion, and citrus.

General Disease Surveys

Vegetable crop diseases.

Disease survey have been conducted in major vegetable production areas of the country. During the disease survey program attempts were made to know the geographical distribution and relative importance of major vegetable and fruit crop diseases. More than thirty sites in eight administrative regions (Shewa, Kefa, Gojam, Gonder, Wello, Hararghe, Wellega, and Illubabor) were visited and a total of 27 diseases on pepper, 11 on tomato, and 10 on onion were identified and recorded (Tesfaye and Habtu, 1985; Table.1).

Fruit crop diseases.

Regarding fruit crop, disease surveys have been made by various consultants and plant pathologists in the country on major citrus producing areas (state farms) since 1970. Viral diseases (tristeza, psorosis and exocortis), fungal diseases (foot rot) and mycoplasma-like diseases (greening) on citrus, burrowing nematodes and cigar-end rot on banana, powdery and downy mildew on grapevine were identified to be the major diseases (IAR, 1980). Recently an extensive disease survey was made on major papaya growing areas. As a result anthracnose disease caused by *Colletotrichum spp.* was found to be serious problem in almost all surveyed areas. The growers were advised to use spray broad spectrum fungicides to minimize the problem. A list of major diseases of fruit crops identified in the country is summarized in Table 2.

Table 1. Geographical distribution of major vegetable crop aiseases in Ethiopia.

Crops	Disease	Causal agent	Locations
Tomato	early blight	*Alternaria solani*	Melkassa, Ziway, Nuraera, Awassa
	late blight	*P. infestans*	Melkassa, Wonji, Nuraera, Ziway
	powdery mildew	*Leveillula taurica*	Wonji, Nuraera
	root-knot nematode	*Meloidogyne spp.*	Awassa, Merti, Ziway, Melkassa
	leaf spot	*Septoria lycoperici*	Melkassa, Nuraera, Wonji, Ziway
	viruses	TMV,PVY,PVX	Wonji,Ziway, Melkawere, Awassa, Melkassa.
Pepper	powdery mildew	*L. taurica*	Debrezeit, Melkassa, Ziway, Wonji, Erergota
	Stem blight	*Phytophthora spp.*	Melkassa, Nuraera,
	Bleaching of pods	complex	Bako, Didessa, Gibe, Angergutin,
	bacterial leaf spot	*X. vescatoria*	Melkassa,Awssa, Bako, Nuraera, Ambo
	viruses	PVX,TMV,CMV	Melkassa, Nuraera, Ziway, Awassa, Shewarobit,
Onion	Purple blotch	*Alternaria porri*	Awassa, Nuraera, Melkassa, ziway, Bako
	Downy mildew	*Peronospera destructor*	Alemaya

Table 2.Geographical distribution of major fruit crop diseases in Ethiopia.

Crop	disease	causal agent	Location
Citrus	Foot rot	*Phytophthora spp.*	Gibe, Sodere, Melkaoba, Urso, Melkawere, Wonji, Tibila, Erergota, Merti, Degaga
	Greening	Mycoplasma-like organism	Gibe, Nazret, Koka, Melkaoba, Wonji,Tibila, Abadir,Urso, Erergota, Awaramelka,Diredawa, Ziway
	Tristeza	Virus	Gibe, Melkawere, Urso, Erergota. Bilate, Wonji,
	Psorosis	Virus	Diredawa, Urso, Erergota, Arbaminch, Abadir, Awaremelka, Gibe, Tibila,Dagaga
	Anthracnose	*Colletotrichum spp.*	Jimma, Koka, Bilate, Abadir,
Banana	cigar end rot	*Verticillum spp.*	Shewarobit, Melkassa
	nematode	*Radophilus similus*	Melkawere, Melkasedi
Grapevine	powdery mildew	*Uncinula necator*	General
	downy mildew	*Plasmopora viticola*	General
Mango	powdery mildew	*Oidium mangiferae*	Hararghe, Shewa
Peach	leaf curl	*Taphrina deformans*	General
	scab	*C. coropophilum*	Hararghe
Guava	fruit rot	*Pestalotic psidii*	Kefa

Source: Tesfaye and Habtu (1985), Lemma (1992).

Control Strategies

Vegetable diseases

Diseases of tomato.

Tomato is known to be infected by a number of diseases in Ethiopia (Mengistu, 1992). The most important are: damping off caused by various fungal pathogens, late blight (*Phytophthora* *infestans*), septoria leaf spot (*Septoria lycopersici*), early blight (*Alternaria solani*), viruses and root-knot nematode (*Meloidogyne sp.*). To combat these problems chemical and cultural control were studied.

Chemical and cultural control of foliar diseases. To control vegetable diseases in general, and tomato diseases in particular, chemical control was considered as an immediate solution. On this regard series of experiments were conducted to study the influence of fungicides against damping off and foliar diseases of tomato. Among the cultural control practices the effect of staking on foliar diseases was also determined. Treating tomato seeds with metalaxyl 5G at a rate of 100 g/kg of seed, increased the percentage of healthy plants by about 154 % over the control. No significant difference was observed among seed rates tested (Table 3). The incidence of septoria leaf spot was significantly reduced by spraying captafol 0.3 % alone and in combination with metalaxyl 0.27 % (Table 4). Metalaxyl alone and in combination with captafol was effective in reducing the incidence of late blight. There was a 91 and 95 % diseases control, when these fungicides were applied, respectively (Table 5). No statistically significant difference was recorded whether staking was practiced or not.

With regard to yield, the highest yield was obtained from captafol and captafol plus metalaxyl sprayed plots. The yield obtained was more than 52 and 66 t/ha, respectively which is about 127 and 190 % increase over the control (Table 6).

Table 3. Effect of seed treatment on damping off on tomato at Melkassa 1985.

Seed treatment	Rate g/kg seed	Percent of healthy plants: seed rates (gm) 6.5	4.5	3.5	Mean	In % of control
Control (flooding)	-	20.3	12.5	27.7	20.2	100
Watering with can	-	15.2	16.9	12.2	14.8	73.3
Vitavax 200	2	14.9	45.4	26.4	28.9	143.1
Thiram	3.25	26.0	32.6	22.9	27.2	134.7
Metalaxyl 5G	100	56.6	55.2	41.9	51.9	253.5
Vitavax 300	5	31.1	32.0	46.3	36.5	180.7
Apron 35-D	1.45	15.5	5.2	33.2	17.9	88.6
Mean		25.6	28.5	30.1		

Source: Girma (1987).

Table 4. Effect of fungicides and staking against septoria leaf spot on tomato 1985.

Treatments	Severity score(0-5 scale)			
	stakingnon	staking	mean*	in % of control
Control	1.40	1.40	1.40b	100
Water + Citowett	1.46	1.40	1.43b	102
Captafol 0.3 % +CW	0.66	0.60	0.63a	45.5
Metalaxyl 0.27 % + CW	1.46	1.26	1.36b	97.0
Captafol 0.3 % + Metalaxyl 0.27 %	0.46	0.46	0.46a	0.33
Mean	1.09	1.02		

* Three years average. Means within the column followed by the same letter (s) are not significantly different from each other at 5% (DMRT); Source: Tesfaye and Habtu (1985)

Table 5. Effect of fungicides on the incidence of late blight of tomato 1985

Treatments	Percent of late blight incidence			
	Staking	non staking	mean*	in % of control
Control	28.42	20.15	24.29 c	100.00
water + Citowett	17.03	20.42	17.73 c	73.00
Captafol 0.27 % +Citowett	10.36	10.03	10.26 b	42.00
Metalaxyl 0.27 % plus citowett	2.17	2.17	2.17 a	9.00
Captafol 0.3 % +Metalaxyl 0.27 %	0.18	2.11	1.15 a	5.00
Mean	11.63	10.98		

*Three years average. Means with in the column followed by the same letter (s) are not significantly different from each other at 5 % (DMRT); Source: Tesfaye and Habtu (1985).

Table 6. Effect of fungicides on the yield of tomato (1985)

Treatments	Yield in t/ha.			
	Staking	non staking	mean	in % of control
Control	24.3	21.6	23.0 c	100.00
water + Citowett	6.2	5.3	5.8 c	25.00
Captafol 0.27 % +Citowett	46.1	58.3	52.2ab	226.9
Metalaxyl 0.27 %plus citowett	33.6	26.2	29.9c	130.0
Captafol 0.3 % +Metalaxyl 0.27 %	60.0	73.2	66.6a	289.5
Mean	34.0	36.9		

Means with in the column followed by the same letter (s) are not significantly different from each other at 5 % (DMRT); Source: Tesfaye and Habtu (1985).

Diseases of onion.

Purple blotch, *Alternaria porri* and downy mildew, *Peronospora destructor* are the most important diseases which have been given due attention. These diseases are very serious and cause economic yield loses during rainy seasons in major onion producing areas of the country (Habtu, 1986). To alleviate the problem, series of chemical control experiments have been conducted.

Chemical control of purple blotch. Spray trials were conducted using different fungicides against purple blotch at Bako and Holleta starting 1974 to 1976. Captafol and mancozeb were found to be effective. It was also possible to get a 50 % yield increase by applying either of the fungicides. At Nazareth a trial was conducted using the best performed fungicide (Captafol) with different stickers and spreader agents (Tesfaye and Habtu, 1985). All treatments gave higher yield as compared to un sprayed check. The best was citowett which had a 73 % advantage over the check, and a 40 % advantage when fungicide alone was used (Table 7).

In follow up studies, the effect of captafol and mancozeb was compared with the newly introduced products, where three rates, each of captafol, fentinhyroxide and grandstand were tested at Melkassa. Captafol sprayed plots gave the highest yield (48 to 66 % higher than the control), although fentinhydroxide was relatively effective in controlling the disease (Table 8).

Table 7. Effect of captafol and different wetting- sticking agents on the incidence of purple blotch and yield of onion

Treatments	No of infected leaves/plot	yield q/ha	yield in % of control
Captafol	34.2	42.5 a	140
cptafol + Citowett	30.8	52.5 a	173
Captafol + additive	33.0	43.8 a	144
Captafol + biesterfiel	37.2	50.6 a	167
Captafol + Rino	53.4	45.5 a	150
Captafol + AA stickol	35.6	42.6 a	140
control	40.2	30 .3	100

Means with in the column followed by the same letter are not significantly different from each other at 5 % (DMRT); Source : Habtu (1986).

Table 8. Effect of different spray concentration of selected fungicides against purple blotch of onion.

Treatments	Rate	disease score (0-5 scale)	Marketable yield q/ha	yield in % of control
Control	-	5.0	41.3 c	100
Captafol 80 % WP	0.2%	4.5	61.1 a	148
Captafol 80 % WP	0.3%	3.5	68.7 a	166
captafol 80 % WP	0.4%	3.8	65.2 a	158
Fentinhyroxide 60 % WP	0.2%	2.5	51.0 ab	123
Fentinhyroxide 60 % WP	0.3%	3.0	40.0 c	97
Fentinhyroxide 60 % WP	0.4%	3.0	42.0 c	102
Grandstand	6 ml/10 L	4.5	27.9 d	68
Grandstand	8 ml/10 L	4.8	39.3 c	95
Grandstand	12 ml/10 L	4.8	32.8 c	79

Means with in the column followed by same letter(s) are not significantly different from each at 5 % (DMRT); Source : Tesfaye and Habtu (1985).

Diseases of pepper.

So far, several diseases have been identified on pepper, among which powdery mildew, viruses, stem blight, bacterial leaf spot, bleaching of pods and pod rotting are the most important ones. Control of these disease was focused on chemical and varietal screening.

Chemical control of powdery mildew. To control powdery mildew, about 10 fungicides were evaluated at different sites. Among the tested fungicides triadimefon (25 % WP), denmert (10 EC), kumulan 80 % WP, thiophanate methyl 70 % WP at the rates of 0.2 kg/ha, 0.5 lt/ha, 3 kg/ha, and 0.6 kg/ha, respectively were found effective in controlling the disease.

Varietal screening to powdery mildew. Attempts were made to identify resistant/tolerant varieties against powdery mildew, and about 70 accessions were tested and none of the tested materials were found resistant. However, the varieties designated as p-6635, p-700-s, C-746 and EP-21 were recorded below 2 using a 0 to 4 scoring scale.

Stem blight/wilt. Stem blight causes a considerable damage to pepper production. This disease occurred on pepper at Melkasedi state farm since 1977. In 1980 more than 70 hectare of pepper was devastated in this farm. Later on it was observed at various production fields in Upper Awash (Mengistu, 1992, Tesfaye, 1983). Pathogenicity test and chemical control studies have been carried out.

Pathogenicity test experiments on stem blight of pepper indicates that varieties of both sweet and hot pepper were very susceptible to this disease, and the symptom was clearly noticed after three days of inoculation (Tesfaye, 1983).

For chemical control of stem blight five fungicides (Cupric hydroxide, Grand stand, Mancozeb and Metalaxyl) were include. Mancozeb at 3.5 kg/ha was the most effective in reducing the disease incidence (Table 9). The highest yield was also obtained from Mancozeb sprayed plots.

Table 9. Effect of fungicides against stem blight on sweet pepper at Tibila.

Treatment	Spray Interval	Rate	% healthy plants* 1st	2nd	3rd	Yield kg/ha	In % of control
Control	-	-	79	36	23	1990	100
Cupric hydroxide	10 days	1.48g ai/lt	78	45	24	3646	191
Grand stand	10 days	120ml/100l	85	52	26	2257	118
Mancozeb	10 days	3.5 kg/ha	85	75	67	10243	536
Fentin hydroxide	10 days	0.4 kg/ha	78	54	38	7813	409
Metalaxyl	10 days	5kg/ha	84	58	58	8160	427
LSD			ns	24	21	1365	

* 1st, 2nd, and 3rd : counts of healthy plants; Source: Tesfaye and Habtu (1985).

Viral diseases. Viruses are one of the limiting factors of pepper production in Ethiopia. Surveys have been made in different pepper growing regions, and a number of viruses have been identified (Agranovsky, 1984). Potato virus Y (PVY) and tobacco mosaic virus (TMV) were recorded as major problems. Alfalfa mosaic and cucumber mosaic viruses were found in some locations (Tesfaye and Habtu, 1985). Seventy varieties were included for the screening program against the combined viral diseases at Melkassa. However, none of the varieties were free of the disease, but varieties cp-199, p-611-s, and p-706 showed relatively lower disease incidence (IAR, 1980).

Bleaching of pepper pods. Bleaching of pods is one of the problem that become very important in some of the production areas (Bako, Didessa, Gibe). Identification of the causes of pod bleaching indicated that fungal pathogens (*Phomopsis sp., Colletotrichum sp., Phoma sp., Leveillula taurica*), bacteria (*Xanthomonas vesicatoria*) and insect (*Heliothis armigera*) were found to be the major factors (Almaz, 1981, IAR, 1987, Tesfaye, 1984).

Fruit diseases

Disease of citrus.
Several diseases of citrus were identified by different consultants and plant pathologists, among which foot rot, virus and virus like diseases such as psorosis, tristeza, and greening were reported as the major ones (Tesfaye and Habtu, 1985).

Indexing for citrus diseases. Since 1977, attempts have been made on indexing of important citrus diseases at Holetta Research Station. Only indicative results were obtained on the presence of tristeza virus in some orchards. No clear symptoms of greening were observed, except vein yellowing.

Fungal diseases of citrus. Foot rot disease has been found distributed all over citrus growing regions, and identified to be caused by *Phytophthora nicotiannae*. Different recommendations such as use of resistant root stock (sour orange), basin irrigation followed by protective control and/or curative treatment with Ridomil 5G were suggested by various consultants (Tesfaye and Habtu, 1985).

Diseases of grapes.
Powdery mildew, *Uncinula necator* and downy mildew, *Plasmopara viticola* are the most destructive diseases that limit production of grapevine throughout the country (IAR, 1979).

Chemical control. Chemical control of powdery mildew was conducted at Koka, Holetta and Dukem by IAR and MSFD. Dinocap 0.05% and Benomyl 0.03% were found to be effective against powdery mildew (Lemma, 1992).

Diseases of banana.
Banana production is severely threatened by burrowing nematode (*Radopholus similis*). Nematicide screening studies conducted by MSFD indicated that Mocop 10G (32.5 g/mat), Furadan 5G (60 g/mat), Temic (15 g/mat) and Nemacur 10G (27 g/mat) showed 20-40% yield increase on poyo variety.

Conclusions

The control of plant diseases depend on an integrated approach, which include suppression of inoculum potential, sanitation, modification of environment, host resistance and use of effective chemicals. However, research activities in the past emphasized mainly on chemical control. Consequently, use of chemicals has let hazardous effect on the environment and human beings. Hence, research on disease management should focus on an integrated approach.

The incidence of most fungal diseases was very high during rainy seasons, due to this, small-scale farmers and commercial growers are producing vegetables under irrigation. However, recently other diseases (powdery mildew, root-knot nematode and viruses) are heavily attacking vegetable crops, especially tomato on irrigated fields. Despite their importance, research on the management of vegetable diseases has been insignificant.

Regarding fruit crops, the past research activities were limited only to surveys and identification. Very little work has been done on the management of diseases fruit crops. This is due to frequent interruption in staff continuity, lack of trained man power on fruit crops pathology and inadequate green house facilities.

Future Research Priorities.

In the future the following areas of research should be given high priority:

The general disease survey program should be strengthened to include the major vegetable and fruit growing areas of the country.

Varietal screening for disease resistance.

Some of the recommended fungicides are banned, and this suggests screening and evaluating new effective fungicides to control vegetable and fruit crop diseases.

Virus problems on vegetables and fruits.

Indexing of citrus for greening and virus diseases.

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DISEASE MANAGEMENT IN LOWLAND PULSES: PROGRESS AND POSSIBILITIES FOR AN INTEGRATED APPROACH

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Abstract

In the later part of 1970s there was a need to include research on diseases as part of the Lowland Pulses Improvement Programme. Studies have been made to identify and document all known diseases of pulses, understand their geographical distribution and relative importance, determine yield loss, set priority disease constraints and develop disease management strategies. Managing diseases utilizing different control strategies was adopted as a key strategy. In the early part of the research phase, the emphasis was on identification of disease causing agents and understanding their distribution. As the programme developed, the research focussed on identifying appropriate cultural practices, screening of effective fungicides, studying physiologic races, yield loss, development of damage-loss relationships and resistant varieties. Hot-spot sites, appropriate screening methodologies and selection procedures were identified. Attempts were made to integrate the pathology research with the breeding programme. The emphasis was on individual components, tackling each disease and each control strategy, following the *ceteris paribus* hypothesis, that is, in an experiment all things are equal except the one or two independent variables chosen for examination. A better understanding of the interrelated factors and their influence on disease development is required. To properly manage diseases of lowland pulses there is a need to integrate not only different components of disease control strategies but also all relevant disciplines (agronomists, breeders, economists, entomologists, pathologists). To also address the specific needs of different crop growing regions the programme needs to recognize major bean growing areas with different ecologies (differences in elevation, rainfall, temperature, production system, production constraints and objectives).

Introduction

Common bean (*Phaseolus vulgaris L.*) Suffers from a wide range of leaf, stem and root diseases, including common bacterial blight, rust, anthracnose, angular leaf spot, web blight and bean common mosaic virus. In Ethiopia, common bacterial blight, rust and anthracnose are most important and widely distributed while the rest, though important, are much more restricted in their distributions.

Among these numerous diseases of beans in Africa, rust caused by Uromyces appendiculatus (Pers.) Unger var. appendiculatus, merits close attention. A preliminary survey (Habtu, 1987a) conducted in Ethiopia indicated bean rust to be important in bean production but did not address the prevalence and intensity of bean rust under farmers' conditions and practices. Surveys need to be conducted at regular intervals to describe the geographic distribution of diseases (Zadoks, 1961; James, 1969; King, 1972), to monitor changes in their relative importance and elucidate their epidemiology.

Bean rust is a major cause of low average yields of common bean in Ethiopia, estimated to be about 600 kg/ha. Severe incidences of bean rust were reported in southern, south-western and mid altitude cooler regions (Habtu 1987a). A severe out break of rust resulted in nearly total yield loss in highly susceptible cultivars at Awassa (Habtu, 1987b). In Tanzania (Howland and Macartney, 1966), highly susceptible varieties were found completely defoliated by mid-flower, resulting in severe reductions of grain yield. Early work in eastern Africa suggested that severe infection by rust could decrease bean yields by 10% (Padwick, 1956). In Kenya (Singh and Musiyimi, 1981), 37% yield loss was reported.

Most of these conclusions were based on either visual observation or preliminary field work and few data exist on the relationship between disease reaction and yield loss. It is thus important to develop functions to relate damage to temporal and spatial injury with respect to crop growth and development.

Host plant resistance is a long-practised method of rust control. Evaluation of local germplasm and introduced materials have been conducted and Mexican 142, BlackDessie and Brown Speckled, were recommended for their resistance to diseases. Now, however, the widely cultivated Mexican 142 appears susceptible to most foliar diseases, particularly bean rust. Cutltivars with black seeds (Black Dessie and Negro Mecentral) continue to express excellent disease resistance but are not acceptable to farmers because of their seed color. Attempts to identify genotypes with stable resistance and acceptable seed type did not succeed, because those resistant at one location proved susceptible at others (Habtu, unpublished).

All genetic studies of rust resistance in beans to date indicate a monogenic mode of inheritance (Dias and da Costa, 1968; Grafton et al., 1985). Such resistance does not provide permanent protection because the fungus is highly variable in pathogenicity. Variation in the fungus has been reported from the U.S.A. (Stabely, 1984), Australia (Ballantine, 1978), South America (Augustin et al., 1972) and Tanzania (Mmbaga and Stavely, 1988). The pattern of races found in eastern Africa is not well understood.

Following review of the importance, distribution and control of rust, it was found necessary to study in detail its epidemiology and management. Thus a bean rust sub-project was proposed and approved by the Eastern Africa Regional Bean Project steering committee in 1987 with the following objectives:

1. Understand bean rust status under Ethiopia conditions;
2. Assess yield loss of dry bean due to bean rust;
3. Investigate the physiological races of the bean rust fungus and study patterns of race distribution; and
4. Strengthen the screening program in close collaboration with bean breeders and initiate a regional bean rust nursery.

Disease Survey and Identification

Extensive surveys of lowland pulse diseases have been made in most part of the lowland pulse growing area and a large number of mycological, bacterial, viral and nematode specimens have been collected and preserved at Nazareth Research center. Most of the pathogens associated with the diseases were identified and documented (Habtu, 1984).

Foliar diseases

Stewart and Dagnatchew () and Agechew ( ) listed more than 47 fungal, bacterial and viral diseases of lowland pulses (haricot bean, soybean, cowpea and mungbean) in Ethiopia. Of these reported diseases bean anthracnose, bean rust, angular leaf spot, floury leaf spot, web blight, common bacterial blight, halo blight and bean common mosaic virus in haricot bean, bacterial diseases and pyrenochaeta leaf spot in soybean, viruses and bacterial blight in cow pea and halo blight in mung bean were found important. In haricot bean, common bacterial blight, anthracnose and rust are widely distributed in the country while angular leaf spot, floury leaf spot, web blight and ascochyta leaf spot have limited distribution found mostly in the hot, humid regions of the country.

A very detailed survey of foliar diseases of haricot bean was conducted from 1990-1993. A summary of the disease survey data over a 4-year period (Table 1) indicate variation in disease severity with years and geographical areas. Bean rust (BR), anthracnose (BA) and bacterial blight (BB) were more widely distributed than angular leaf spot (AL) or floury leaf spot (FL) which were not found in some regions. In farmers' fields, disease severity was generally low and the overall mean severity did not exceed 7 %.

Table 1. Geographical distribution and severity (%) of bean diseases in Ethiopia (1990-1993). Disease severity measure as proportion of leaf area infected

Area	Year	BR[1]	BA	BB	AL	FL	DT
Central	1990	2.28	3.39	6.07	0.00	0.00	0.86
	1991	2.96	6.60	8.01	0.00	0.00	3.14
	1992	2.23	4.27	6.43	0.00	0.00	3.53
	1993	5.09	3.94	5.42	0.00	0.00	2.05
	Mean	3.14	4.30	6.48	0.00	0.00	2.39
South	1990	5.79	0.93	0.82	1.26	0.00	1.48
	1993	3.12	2.18	1.03	0.07	0.00	2.25
	Mean	4.45	1.55	0.92	0.66	0.00	1.86
West	1990	1.30	2.15	0.14	2.46	1.45	.-
	1992	1.99	2.37	3.32	4.63	3.17	0.49
	1993	2.95	3.68	3.14	10.26	8.20	0.00
	Mean	2.08	2.73	2.20	5.78	4.27	0.24

[1] BR = bean rust; BA = anthracnose; BB = common bacterial blight; AL = angular leaf spot; FL = floury leaf spot; DT = Dead tissue

There were differences in prevalence and severity of rust among regions and farming practices (Table 2). In the hot and dry areas of the Rift Valley, where rainfall is normally erratic and temperatures rather warm, rust prevalence and severity are low and, in some cases, non-existent. In these regions, the most prevalent disease is common bacterial blight. In Southern Ethiopia, where weather conditions are favourable, rust poses a serious threat to bean production. On research stations at Melkassa, Areka, Ambo, Debre Zeit and Awass, rust was prevalent but of varying intensity. Rust reactions recorded in 1988 were greater than those in 1987 and 1989. Comparison of rust prevalence on farmers' fields, state farms and research stations indicated that severity and prevalence are much on research stations, intermediate on state farms and slight in farmers' fields.

On research stations, intensive production of bean in concentrated areas has allowed gradual build-up of the pathogen, aggravated by the inclusion in trials of susceptible lines. State farms grow bean on very large areas. They also use a single cultivar - Mexican 142 - which is susceptible to rust. Disease increase is favoured by aggregation of host crops in space and time (Zadoks and Schein, 1979). Thus, bean rust has become endemic and severity has been increasing.

On farmers' fields, scattered occurrences of rust are observed, mainly along main roads, but severity is much less than on either research stations or state farms. There are many possible reasons. Farmers in Sidamo and Gamo Goffa grow many different cultivars, sometimes with seeds of mixed colour, size and shape. Farmers' bean fields are also rather scattered and in most cases associated with either maize, enset or coffee. The value of associated cropping in pest management is well-documented (van Rheenen et al., 1981; Moreno, 1985).

Rust is more prevalent and severe in the south, probably due to optimum temperature and rainfall conditions, while differences within the region are mostly due to cultural practices. Maximum rust severities are found associated with aggregation of farm practices, cultivation of susceptible cultivars concentrated in space and optimum temperatures and rainfall.

During the survey only limited fields were selected and other important foliar diseases were not considered. A study in this area in the future must address other components of bean production systems such as severities of other diseases, for example CBB, which has been found more widespread than previously suspected. We must also establish the place of bean rust as a component in the multiple phytosystem that now prevails in bean production.

Crop-Losses and Severity-Damage relationships

Assessment of losses was conducted for rust from 1988 to 1993 at Ambo, Awassa and Debre Zeit. Field experiments were conducted in split plot designs with five replications. Bean cultivars (Negro Mecentral, 6R-395-08, Red Wolaita, Mexican 142 and Nazret Small-03) were in main plots and fungicide treatments (unsprayed and systemic fungicide, oxycarbinoxin - Plantavaz at 0.1% concentration - at 5, 10, 15 and 20 day intervals until maturity) in sub-plots.

In 1987 and 1988, all entries were included. In 1989, Red Wolaita was omitted due to similarities in its rust reaction to Nazret Small-03; Negro Mecentral was also omitted because of its high resistance to rust. In 1990 to 1993 only Mexican 142 and 6-R-395 were used. In 1987 and

1988, susceptible varieties were severely damaged by anthracnose, complicating the interpretation of results. In 1989 to 1993, seeds were treated with benomyl in an attempt to control anthracnose. Diseases were monitored weekly, commencing with the first spray. Other data collected include pods/plant, seeds/pod, seed size and seed yield.

Critical Point Models

As Ambo and Awassa represent two different environments with different disease severities, the results are analyzed separately.

Ambo

No results are presented for 1987 as there was high incidence of anthracnose and most of the crop was completely destroyed. In 1988, natural infection of bean by rust in sprayed and unsprayed plots produced mean rust severities ranging between 3 and 5 (Table 3). Differences among treatments in rust reactions were not significant probably due to delays in spraying. Though there were differences among treatments in seed yields, there were no consistent trends.

In 1989, there was high incidence of rust and the three entries showed moderate to large rust reactions related to their levels of resistance. All spray schedules reduced disease reactions (Table 4), the least disease occuring with the most frequent sprays. The trend was consistent for all the three entries. Differences in seed yields were also observed.

Assigning an index of 100 to the dried seed yield at the lowest infection level, yield was reduced by 10-73% in Mexican 142, 8-67% in Nazreth Small-03 and 3-15% in 6R-395-08. Regressions of seed yield on rust reactions for the individual entries (Table 5) showed that yields of Mexican 142 were reduced by 203 g/plot (8.1%) for each unit increase in disease reaction. For Nazret Small-03, this was 127 g (6.5%), for Red Wolaita it was 132 g (5.4%), and for 6R-395-08, it was 82 g/plot (6.07%). For Negro Mecentral (resistant), there was no relationship between disease reaction and seed yield.

In 1989 (with Negro Mecentral and Red Wolaita omitted), the relationships between seed yields and rust reactions were highly significant accounting for 83-96% of the variation in seed yields. Per cent yield losses for every unit increase in disease reactions were 11.0% for Mexican 142, 8.7% for Nazret Small-03 and 3.9% for 6R-395-08. Rust caused very large reductions in yields of Mexican 142 in both seasons, followed by Nazareth Small-03 and 6R-395-08.

The r2 values were also higher for Mexican 142 and Nazareth Small-03 and slightly less for 6R-395-08.

Awassa

In 1988, rust reactions were rated several times during the growing period but only disease reactions at maturity were used to relate to yields, as in Ambo. There were significant differences in rust reactions among entries and spraying with fungicide significantly reduced the rust reactions of Mexican 142, Nazret Small-03, 6R-395-08 and Red Wolaita (Table 6) but not of Negro Mecentral, which is resistant to rust. The most frequent sprays consistently produced the least disease reactions and the largest yields (index = 100%). Yield losses were small for Negro Mecentral (0.3-4. 1%) and 6R-395-08 (0-5.3%), large for Nazret Small-03 (19.2-27.6% and intermediate for Mexican 142 (3.1-17.8%).

In 1989, the responses to application of fungicide were larger. Losses ranged between 4.1

and 23.3% in Mexican 142, 15.2 and 35.1% in Nazret Small-03 and 8.3 and 13.6% in 6R-395-08. (Table 7).

Regressions of seed yield on the rust reactions for the individual entries (Table 8) showed that yields of Mexican 142 were reduced by 4.4% for each unit increase in disease reaction. For Nazreth Small-03, this was 7.8%, for Red Wolaita it was 6.3% and for 6R-395-08, it was 3.9%. For Negro Mecentral (resistant), there was no relationship between disease reaction and seed yield. In 1989, the yields of Mexican 142 decreased by 3.2% for each unit increase in disease reaction, by 5.4% for Nazreth Small-03 and by 2.6% for 6R-395-08.

In 1989, as other diseases were practically unimportant and rust severities correlated well with yield, rust is most likely responsible for observed crop losses relative to the yields of the most frequently sprayed plots. Crop loss varied among entries, years and locations, which can be expected due to differences in disease resistance and variations in weather and their subsequent impact on rust initiation and development. Obviously, the relationships demonstrated are valid only within the limits of these experiments, but the more information of this sort that can be assembled, the greater will be the accuracy with which we can assess the yield losses due to rust and other diseases across environments.

Among other factors, final crop yields are influenced by the severities of the diseases that occur during crop growth, which are also related to the rates of disease progress. The apparent infection rate (van der Plank, 1963) plays an important role in establishing a prediction model for crop loss. The results presented here follow a critical point model. Critical poing models estimate yield losses for any level of disease at a time when a specified level of disease is reached (James and Teng, 1979). They assume that years, environments and cultivars are typical in terms of duration and time of onset of disease and stability of infection rate. This may not be so under natural conditions, so future experiments should examine the role of initial infection and its subsequent development in yield loss.

Moreover, more than a single disease can be present at any one time (for example, angular leaf spot and common bacterial blight at Awassa and anthracnose and ascochyta blight at Ambo) and their contribution to yield loss cannot be neglected in establish multiple point models by continuing field experiments, repeated both in time and space.

Table 2. Effect of Bean Rust on Disease Reactions and Seed Yields of Haricot Beans at Ambo in 1989.

Entries	Spray Interval (Days)	disease severity (1-9)	Seed Yield (g/Plot)	Index	Per cent change in yield
Mexican 142	5	1.8	1267	100	0
	10	3.3	1144	90.3	-9.7
	15	3.8	1108	87.5	- 12.5
	20	4.2	1071	84.5	- 15.5
	Control	6.8	341	26.9	- 73.1
Nazareth	5	1.6	1246	100.0	0
Small-03	10	3.2	1145	91.2	- 8.8
	15	4.0	1016	81.5	- 18.5
	20	4.6	1007	80.8	- 19.2
	Control	8.0	417	33.5	- 66.5
6R-395-08	5	1.4	1496	100.0	0
	10	2.8	1447	96.7	- 3.3
	15	3.2	1359	90.8	- 9.2
	20	3.8	1352	90.4	- 9.6
	Control	5.2	1271	85.0	- 15.0

Table 3. Coefficients of regressions of seed yields on Rust Reactions and percentage yield Losses due to Rust of Entries in Trials at Ambo in 1988 and 1989.

	1988			1989		
Entries	Regression Coefficient	r	% Loss	Regression coefficient	r	% Loss
Mexican 142	- 203.3	0.30	8.1	- 191.0	0.90	11.0
Nazareth Small-03	- 127.3	0.08	6.5	-133.5	0.96	9.7
6-R-395	- 131.7	0.65	5.4	- 60.7	0.83	3.9
Red Wolaita	- 82.5	0.40	6.1	NT	NT	NT
Negro Mecentral	+20.0	0.01	0	NT	NT	NT

Table 4. Effect of Bean Rust on Disease Reactions and Seed Yields of Haricot Beans at Awassa in 1988.

Entries	Spray Interval (Days)	Disease severity (1-9)	Seed yield (g/Plot)	Index	Per cent change in yield
Mexican 142	5	1.5	1339	100.0	0
	10	2.3	1297	96.9	-3.1
	15	3.8	1275	95.2	- 4.8
	20	4.5	1129	84.3	-15.7
	Control	5.3	1101	82.2	-17.8
Nazareth Small-03	5	1.7	1781	100.0	0
	10	2.8	1344	75.5	- 24.5
	15	4.0	1320	74.1	-25.0
	20	4.0	1440	80.8	- 19.2
	Control	5.5	1290	72.4	-27.6
6-R-395	5	2.5	2894	100.0	0
	10	1.7	2914	100.7	+ 0.7
	15	2.5	2741	94.7	- 5.3
	20	2.5	2902	100.3	+0.3
	Control	3.0	2743	94.7	- 5.3
Red Wolaita	5	1.5	1518	100.0	0
	10	2.8	1389	91.5	- 8.5
	15	2.7	1344	88.5	-11.5
	20	3.3	1239	81.6	-18.4
	Control	5.3	1117	73.6	-26.4
Negro Mecentral	5	1.5	2441	100.0	0
	10	1.5	2449	100.3	+0.3
	15	1.5	2341	95.9	-4.1
	20	1.7	2439	99.9	-0.1
	Control	2.5	2434	99.7	-0.3

Table 5. Effect of Bean Rust on Disease Reactions and Seed Yields of Haricot Bean at Awassa in 1989.

Entries	Spray Interval (days)	Disease Severity (1-9)	Seed Yield (g/plot)	Index	Percent change in yield
Mexican 142	5	1.0	1955	100.0	0
	10	1.6	1875	95.9	-4.1
	15	2.4	1550	79.3	-20.7
	20	3.2	1565	80.0	-20.0
	Control	5.4	1500	76.7	-23.3
Nazreth	5	2.0	1740	100.0	0
Small - 03	10	2.0	1760	101.1	+1.1
	15	3.8	1475	84.8	-15.2
	20	3.4	1360	78.2	-21.8
	Control	7.8	1130	64.9	-35.1
6-R-395	5	1.4	1990	100.0	0
	10	2.0	1825	91.7	-8.3
	15	2.0	1760	88.4	-11.6
	20	2.4	1825	91.7	-8.3
	Control	5.0	1720	86.4	-13.6

Table 6. Coefficients of Regressions of Seed Yields on Rest Reactions and Percentage Yield Loses due to Rust of in Entries in Trials at Awassa in 1988 and 1989 .

	1988			1989		
Entries	Regression Coefficient	r	% Loss	Regression Coefficient	r	% Loss
Mexican 142	-63.3	0.86	4.4	-101.2	0.68	5.2
Nazareth Small-03	-127.0	0.71	6.8	-102.7	0.85	5.5
6-R-395	-123.9	0.43	3.9	-51.7	0.50	2.6
Red Wolaita	-103.5	0.93	6.3	NT	NT	NT
Negro Mecentral	+22.4	0.00	0	NT	NT	NT

Multiple Regression Models

Multiple regression analyses (MRA) were conducted for several independent variables among which include LAI, rust intensity, severity of rust and other diseases, and dead tissue present during different growth stages and at different canopy layers. A number of equations were tested by combining several independent variables. The independent variables selected and the equations computed are given in Tables 7-10. Because of high cultivar by treatment interaction, models in this paper are presented separately for susceptible (SUS) and partially resistant (RES) cultivars.

Pods per plant (PP). To develop the model we used the combined results of three years for SUS and two years for RES. For SUS we tested 14 combinations of which models using data of growth stage R7B or a combination of R6 and R7B were slightly better than models based on stage R6 (Table 7). Models with LAI and severity of rust were slightly better than those with LAI and rust incidence. All models resulted in R^2 values explaining ≥ 90 % of the variation in PP. The best equations for PP contained two or three input variables at both R6 and R7B. When R6 and R7B were taken both, the combined use of LAI, rust incidence and severity of rust did not improve the R^2 value. For PP, middle and lower canopy layers were determinant since removal of the upper canopy layer did not change R^2. Generally, R^2 values were highest at stage R7B. For SUS the best models were models 1.1 - 1.4 (Table 8).

For RES, at R6 the use of incidence or severity variables did hardly affect R^2 values. When R6 and R7B were combined, models based on LAI and incidence showed a slight improvement. Models 2.1 - 2.4 (Table 8) were selected. Models 1.1, 1.2, 2.1 and 2.2 are single point models, with either R6 or R7B, while models 1.3, 1.4, 2.3, and 2.4 are two-point models.

Seed Yield (SY). For yield of SUS the best models were based on LAI and severity at two growth stages (Table 7), with R^2 values ≥ 85 % of the variation. Generally, models based on R7B or on a combination of R6 and R7B resulted in R^2 value ≥ 89 % of the variation (models 3.2 - 3.4; Table 8). Inclusion of incidence did not affect the relationship, but exclusion of severity at upper canopy reduced R^2 by 1-3 %. For SUS a combination of LAI and severity at growth stage R6 gave an acceptable model explaining 85 % of the variation (model 3.1). For a similar combination at R7B R^2 increased by 4 % (model 3.2). In these two cases addition of incidence variable did not improve the model. For RES the 14 models did not show substantial differences. For all practical purposes models 4.1 - 4.4 were considered satisfactory.

Table 7. Multiple regression equations and coefficients of determination (R^2) values for pods per plant (PP) and seed yield (SY)[1] in bean rust

Independent variables					Dependent variables			
		Severity			PP		SY	
LAI	IN	UC	MC	LC	SUS	RES	SUS	RES
R6	R6	R6	R6	R6	0.91	0.92	0.87	0.89
R6	R6		R6	R6	0.91	0.92	0.85	0.89
R6	R6				0.90	0.92	0.85	0.89
R6		R6	R6	R6	0.91	0.92	0.87	0.89
R6			R6	R6	0.91	0.92	0.85	0.89
R7B	R7B	R7B	R7B		0.92	0.93	0.89	0.89
R7B	R7B				0.92	0.93	0.88	0.89
R7B		R7B	R7B		0.92	0.92	0.89	0.89
R6-R7B	R6-R7B				0.92	0.93	0.89	0.89
R6-R7B		R6-R7B	R6-R7B	R6	0.92	0.93	0.90	0.89
R6-R7B		R6-R7B	R6-R7B		0.92	0.93	0.89	0.89
R6-R7B	R6-R7B		R6-R7B		0.92	0.93	0.89	0.89
R6-R7B	R6-R7B	R6-R7B	R6-R7B		0.92	0.93	0.89	0.89
R6-R7B	R6-R7B	R6-R7B	R6-R7B	R6	0.92	0.94	0.90	0.89

[1]LAI = leaf area index; IN = rust incidence; RS = rust severity; UC = upper canopy layer, MC = middle canopy layer, LC = lower canopy layer; PP = pods $plant^{-1}$; SY = seed yield in g m^{-2}; SUS = susceptible, Mexican 142; RES = partially resistant, 6-R-395.

Pathogenicity of Rust Isolates

Studies of the reactions of the 20 rust differentials to Ethiopian rust isolates began in 1988. In greenhouse tests at Melkassa, three isolates collected from Ambo, Arsi Negelle and Awassa were readily distinguished on the 20 differentials. The rust isolate from Ambo produced large pustules (500-800 microns in diameter) on Kentucky Wonder 780, Mountaineer and Olathe; medium-sized pustules (300-500 microns) on Kentucky Wonder 765 and Redlands Pioneer; small pustules (less than 300 microns) on US no. 3, CWS 643, Pinto 600, Early Gellatin, Brown Beauty and Aurora; and induced no reactions on Mexico 235 and 51051 (Table 9).

In nine of 20 cases the Ambo and Arsi Negelle isolates induced similar responses. However, the isolate from Arsi Negelle induced large pustules on Mountaineer, medium-sized pustules on US no. 3, Pinto 600 and Brown Beauty and no reaction on Mexico 235, Mexico 309, NEP 2, 51051 and CNC. These results and reactions on Golden Gate Wax indicate differences in pathogenicity between the two isolates.

In most cases, reactions to the isolate from Awassa were similar to either one or both of the isolates from Ambo or Arsi Negelle. Reactions differed on Golden Gate Wax, Ecuador 299 and Mexican 235-0n Golden Gate Wax, pustule size was between 300-500 microns, on Ecuador

299 less than 300 microns and on Mexico 235 only necrotic spots were produced.

Considering all three isolates, similar reactions were produced on CSW 643, Kentucky Wonder 765, Early Gellatin, Mountaineer, A x S 37 and 51051. 51051 was immune to all three isolates: A x S 37 induced only a necrotic response: CSW 643 and Early Gellatin gave small pustules: Kentucky Wonder 765 produced medium-sized pustules: and Mountaineer, large pustules for all isolates. However, the three isolates appear distinct: they not only differ one from the other, but there are indications of mixtures of isolates in each collection.

In the field studies: high incidences of rust occurred at Awassa and Ambo in 1988 and 1989; incidences were intermediate at Debre Zeit and slight at Melkassa in 1988; and rust was absent from Debre Zeit and Melkassa and only slight at Arsi Negelle in 1989. Table 10 summarizes the reactions of the 20 differentials to some Ethiopiuan rust populations at Ambo and Awassa in 1988 and 1989 and Debre Zeit and Melkassa in 1988 only.

The classification was based on a 1-9 scale, where 1-3 was considered resistant (R), 4-6 intermediate (I) and 7-9 susceptible (S). On this basis, at least ten different responses can be distinguished, indicating the occurrence of at least 8 different isolates. The most prominent interactions were recorded on the differentials, Golden Gate Wax, Olathe, Kentucky Wonder 780 and Pinto 600.

In the greenhouse and field studies, variability in rust reactions occurred among isolates, indicating the presence of more than one isolate of the pathogen. The frequent occurrence of several isolates in collections of *Uromyces appendiculatus* is common (Stavely, 1984), indicating the existence of a wide range of natural diversity. The isolates used here were not collected from individual plants, neither were they properly described during collection. For clear identification of physiologic races of bean rust, homogeneous isolates need to be used and the date, place and cultivar of their collection should be recorded. Moreover, local and improved cultivars must be included among the differential set to detect new, local rust genotypes that may not be distinguished by standard differentials alone.

Cultural Control

Cultural practices often studied to reduce bacterial blights include the use of pathogen-free seed, proper crop rotation, deep plowing, sowing dates, population densities and weeding practices. At Nazareth, the effect of plant densities and weeding practices were studied to determine their effect on common bacterial blight and halo blight both on haricot bean and mung bean. Though both practices seem to have a limited effect on the spread of CBB and Halo blight, high plan densities and weeding early in the morning when the leaves are still wet favoured the spread of the bacteria' diseases though the effect on yield was not significant.

Table Effect of population densities and weeding time on the development of CBB (1981-1983)

Spacing	Dry Weeding			Wet Weeding		
	5	10	20	5	10	20
20	7.0	6.5	6.0	6.6	5.1	5.2
40	6.3	6.0	5.1	7.0	5.5	5.6
60	6.1	5.5	4.8	6.3	6.3	4.6
Mean	6.3	6.0	5.3	6.6	5.6	4.9

Chemical Control

Various chemicals were tested both as seed treatment or foliage spray to control bean anthracnose, common bacterial blight and halo blight. For anthracnose, seed infections were controlled by benomyl seed treatments. Spraying protectant fungicides such as captafol and manozeb reduced the disease severity and increased bean yield. Seed treatments followed by spraying proved effective but the economics of this treatment may limit the use to only seed treatments. For CBB and HB, seed treatments with sodium hypochlorate, streptomycin, copper hydroxide and other copper derivatives did not prove effective. Though infection at early stage was reduced due to wind and splashing rain disease spread faster later on. Foliar protectant chemicals such as copper oxychloride, streptomycin did not appear to be effective either.

Varietal Resistance

Bean cultivars are known to vary in their reaction to all foliar diseases. The variation appear to be greatest for rust, anthracnose and halo blight where the programme has successfully identified highly resistant varieties. For CBB and web blight a high degree of resistance was difficult to find and most entries studied thus far fall under the intermediate category. Of the lines studies thus far Awash and Roba, recently released varieties were found resistant to rust, intermediate to CBB and susceptible to anthracnose. Those varieties that possess multiple disease resistance (CBB, rust and anthracnose) include A409, BAT 73, BAT 24, BAT 1629, BONITA NIGRA, EMP 87, EMP 110, HAL 5, PVAD 1022, PVA 1145, PAN 64, PAN 173, ICA 15541, ICA PIJAS, ROBA, Red Lands Pioneer, TY 3396-16, XAN 177, XAN 162, XAN 135, XAN 41 and ZAA 84057

Resistance in bean to diseases is not unique. Several sources of resistance to bean rust, anthracnose, common bacterial blight and bean common mosaic virus are reported (Coyne et al., 1973). The results reported here confirm these findings and also indicate that there is a good possibility of identifying genotypes with resistance to one or more diseases in Ethiopia. Entries such as Redlands Pioneer, Ecuador 299 and BAT 448 were also found resistant to rust in Uganda and other diseases in Zambia.

The Future

When one look ahead in the research of lowland pulse pathology there are a number of areas that still needs emphasis. These include, breeding for partial resistance especially for pathogens such as rust and CBB, cultivar mixtures that include optimum combination of resistant varieties and similarities in agronomic characteristics; species mixtures intercropping of beans with one or more other crops and their influence on disease development; cropping practices such as effect sowing date, plant densities under different cropping systems, effect of weedings and effect of available nutrients; patterns, migration and distribution of physiologic races or race variations for effective deployment of genes and possible gene rotation; multiple diseases and constraint resistance, integrated disease management with understanding and recognition of major bean growing areas with different ecologies which in the end will influence disease management techniques. It is becoming increasingly clear that the expectation of a simple solution to the problem of disease control is not likely to be realized. It is more likely that a stable solution to the disease problem will come through the continued balanced application of a range of disease control measures. The integration of various control tactics and their balance will depend on the particular host, pathogen system, control available, ease of application and the economic importance of the disease.

The research being undertaken thus far reflects a reductionistic outlook, an approach that tackles problems one at a time. The programme needs to reflect a holistic approach a gradual transition from disease control to integrated disease management to integrated crop management in a system perspective. The best match between the classical crop protection research and the newly emerging attitude IDM/ICM with its high expectations is the great challenge awaiting us. The researcher of today is trained to isolate a problem and study one aspect at a time. We the present plant pathologists need a new approach to change this attitude in a systems perspective. The ultimate aim of a plant pathologist is not to destroy destructive plant diseases but to learn how to manage them.

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SORGHUM DISEASES RESEARCH- PROGRESS AND ACHIEVEMENTS

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Summary

In the past, panicle diseases of sorghum such as grain mold, smut and ergot, and leaf diseases like sorghum anthracnose were recognized as major production constraints. Breeding program was initiated to incorporate anthracnose resistance traits to high elevation varieties derived from indigenous collections. Grain mold resistant Zerazera genotypes identified here are still in use as a donor parent to develop grain mold resistant varieties in India. Reliable screening techniques and resistant genotypes to grain mold, ergot and anthracnose diseases are identified. Efforts are underway to exploit the genetic potential of the resistant lines to develop mold resistant varieties and explore the possibility of developing ergot resistant male-sterile female parents (A-lines) that could be used in the hybrid sorghum seed production. Furthermore, the biological role of pollination and fertilization of ovary to reduce or delay ergot severity and, the histopathological evidence of *Collethothricum grminicola* in the deposition of spores, penetration, colonization and symptom expression could help the program to understand the functional mechanism of identified resistant lines. The variability of *C. graminicola* in Ethiopia limits the breeding progress to develop anthracnose resistant varieties that could be used across locations. Hence, the identified resistant materials need to be tested across locations before the deployment of resistance in crossing programs. Effective seed treatment chemicals to control smut disease have been identified. Future research fpcus is on understanding the mechanism of resistance and develop other cultural and chemical management options to control smut and downy mildew.

Introduction

Sorghum is subject to attack by several diseases that reduce grain yield and quality. The relative importance of these diseases, their potential effect on yield and their distribution between and within sorghum growing regions in Ethiopia was reported (8). However, there are few published accounts with regard to quantitative crop-loss data of sorghum diseases in farmers' fields.

Yield losses due to smut disease were estimated at Alemaya and the loss range from 0.3 to 3.4 q/ha. At Merhabete smut incidence was recorded up to 50% (11,12). Yield loss due to sorghum leaf anthracnose was estimated to be between 22 and 27%, if infection reaches 37% at hard dough stage(1). Other diseases could have similar effect on yield. Though empirical data is limited, panicle diseases such as grain mold, smut, ergot and leaf diseases such as sorghum anthracnose are considered as major diseases in Ethiopia (9). The sorghum improvement program, in its efforts to develop high yielding improved varieties, is using disease resistance as one criteria. To complement this effort and stabilize sorghum productivity in the production system, the sorghum pathology research program intends to develop resistant germplasm that could be used as genetic resources. Hence, sorghum pathology research has focused its effort in the area of developing field screening techniques and identification of resistant lines to anthracnose, grain mold and ergot diseases. Source of resistance and screening techniques for ergot and sorghum anthracnose diseases are now available(13).

Chemical control to reduce smut disease had also received priority attention in the research agenda in the past and few chemicals with appropriate rate were recommended (11).

Variability studies in sorghum anthracnose has confirmed the existence of variation in pathogen population in Ethiopia (14). But information on physiological races of *Colletotrichum* *graminicola* in Ethiopia is not yet available. Histological studies to detect the infection process of sorghum anthracnose pathogrn in the host cell has uncovered further studies to understand the functional mechanism of the host cell of resistant sorghum varieties (Girma, unpublished data). When inoculation and pollination were performed simultaneously to trace the progress of pollen tube and infection hyphae to determine if fertilized ovaries can be colonized, the result lead to further study to understand the contribution of floral mechanism to resist ergot disease (15).

This review presents information on the achievements gained in sorghum pathology research work in the past and identify important gaps that should receive research attention in the future in sorghum improvement program.

Achievements

Host plant resistance development

Identification of resistant lines against important diseases of sorghum has been one of the major strategies used to exploit the available genetic resources in the sorghum improvement program. Because Ethiopia is the center of origin of sorghum, the land races represent a vast and diverse resources containing all types of resistance to major foliar and panicle diseases In the past, anthracnose resistance donor parents were selected under field condition at Alemaya and a back crossing program has been initiated in an attempt to incorporate resistance characteristics to indigenous elite lines. Success has been achieved in restoring genes for resistance into selected lines. But the donor lines were not tested across the regions where different sorghum anthracnose pathotypes are supposed to occur. And in some cases, evaluation of germplasm under natural disease pressure in field condition especially for particular foliar disease is not reliable because other diseases would have confounding effect on the target disease. Furthermore, it was observed that the anthracnose syndrome at Alemaya was so complex that in the lesion bacterial ooze was found with few anthracnose conidia. The selected donor germplasm were screened under less virulence isolate and the improved varieties would lack the ability to resist sorghum anthracnose attack across locations.

To fill this gap, searching for resistance to sorghum anthracnose was carried out at Bako and Pawe using artificial inoculation. The study indicated that artificial inoculation using Sorghum Green Leaf Media (SGLM) produced enough inoculum. Inoculum application at 5-7 leaf stage provided maximum infection and produced high disease intensity and clear difference was observed among the test entries 10 days after inoculation. Using this method the confounding effects of other diseases were avoided. The identification of the resistance entries in both sites was significant and source of resistance have been identified among accessions of introduced and indigenous germplasms. The apparent infection rate of these germplasms were estimated and these were lower compared to the susceptible once (Table 1).

The lower apparent infection rates in the resistance germplasms indicate the delay of disease progress that was obviously caused by the reaction of host resistance. Furthermore, among the tested germplasms at both locations, few of them showed similar resistance response and this showed the potential of the germplasm to resist a wide array of isolates at both locations.

Research on resistance to ergot and developing screening technique had been also given high priority. Especial research program was set up to develop effective screening technique to

Table 1. The apparent infection rate in Ethiopian sorghum accessions found resistant to anthracnose in artificial screening Bako and Pawe in 1990

Genotypes	Apparent infection rate
Resistant	
ETS 4544	0.01
ETS 3530	0.01
ETS 3135	0.02
ETS 3286	0.02
87 HL4016	0.02
Susceptible	
ETS 2113	0.05
ETS 3753	0.04
No. of observation	23
Mean	0.028
SE	0.002

identify sources of resistance adapted to the high-altitude sorghum growing areas of Ethiopia in collaboration with ICRISAT during the 1989 and 1990 rainy seasons. Effective screening technique involving a single inoculation of non trimmed panicles with suspension of ergot conidia prepared from diluted honeydew when anthesis began in a panicle, followed by bagging had been developed (Table 4). The method helped to induce high disease pressure and found to be most appropriate inoculation technique with respect to biological significance. It restricted a rapid pollination of ovary that influence the nature of resistance and escape owing to efficient pollination.

With regard to resistance studies, of the 213 entries screened, six ergot resistant lines showed significantly lower infection incidence of spikeltes (< 20%) while the susceptible checks had more than 90% infected spikelets (Table 5). The resistant lines are adapted and have high yield potential in the highland areas of Ethiopia. It appears that this findings has raised an interest to look in to the possibility in the design of male-sterile lines for hybrid breeding in the future. In ICRISAT conversion program on this potential cultivars was initiated and in Zimbabwe an effort was made to explore whether the resistant lines posses physiological-based resistance mechanism. They consistently found low ergot severity despite artificial inoculation of the accessions identified here in Ethiopia. Among the tested materials, ETS 1446 failed to be infected even under heavy artificial infection (10). Host x environment x pathogen interaction was not analyzed as accurate weather data for Arsi Negele was not yet available. In general, it was believed that cool and wet weather condition during flowering favors disease development. There are, however, information gaps to understand like the inheritance and mechanism of resistance lines.

Table 2. Effect of panicle trimming, bagging, and inoculation on severity of ergot infection in resistant, susceptible and highly susceptible sorghum genotypes.

Treatments			Infected spiklets %				
			1988			1989	
Trimming	Bagging	No. of inoculations	ETS 3135	ETS 0223	Melka mash	ETS 3135	IS 9302
+	+	1	8.8	71.8	95.8	12.8	49.8
+	+	2	9.3	69.8	95.5	10.4	48.4
+	-	1	1.8	70.1	92.0	3.7	12.4
+	-	2	3.1	65.5	91.8	2.9	12.0
-	+	1	9.2	61.9	92.7	12.1	53.4
-	+	2	6.2	64.8	91.4	7.5	51.1
-	-	1	3.7	58.5	84.3	6.3	16.5
-	-	2	2.7	75.8	89.7	6.5	19.3

+=Treated,-=untreated

Grain mold is also one of the major disease concern for sorghum improvement in early-maturing sorghum varieties in areas where flowering and grain filling occur during periods of rain fall and high relative humidity. Varieties, Bakomash, IS 9302 and Birmash suitable to the mid altitude have been recommended but some of the identified mold resistant varieties become susceptible as a result of the existence of different fungi and/or high disease pressure in the region. Sources of grain molds resistance have been identified earlier from a local collection of sorghum. Gambella 1107, for example, has been found resistant to several diseases in the semi-arid tropics and in demonstration trials in West Africa where it is being used as a direct introduction.

Chemical control

Generally, four types of smuts have been recorded in Ethiopia. Virtually, only evaluation of fungicides for control of these fungi has been done over the past several years. Effective seed dressing chemicals including an organo mercurial compound (aldrex), agrosan 5W, dieldrex M, sulphur, carboxin, benomyl, thiram and captan were studied in different institutions. Sulphur and captan fungicides were found effective to control smut infection.

However, the incidence of covered and loss smut diseases in farmers field is increasing. This is because farmers use seed from previous harvests without cleaning and most often farmers are not using seed-dressing chemicals to control smut diseases. Recently, an effort was made at Merhabete to domensterate thriam treated seed. Obviously, farmers observed significant effect on plant vigor. Farmers have now appreciated the importance of the practices and around 90 farmers

Table 3. Ethiopian sorghum accessions resistant to ergot in the field screening at Arsi Negele, Ethiopia.

Genotype	Days to flowering	infected spikelets (%) 1987*	1988*	1989+
Resistant accessions.				
ETS 1446	133	2.7	2.7	8.7
ETS 2448	125	17.3	3.5	14.1
ETS 2465	133	6.5	-	7.0
ETS 3135	134	0.7	2.9	11.6
ETS 4457	141	6.0	-	13.2
ETS 4927	123	3.0	2.5	2.6
Susceptible controls				
ETS 4567	144	NA	NA	100.0
ETS 2113	144	NA	NA	99.5
Local cultivars				
85 PGRC/E Acc.No.137	135	92.5	NA	NA
ETS 0223	140	NA	77.2	NA
SE		1.46	0.95	1.43

NA=Data not available,*= Mean of five inoculated panicles, += mean of 20 inoculated panicle

in 1995 sow their field with treated seed of their own. It is foreseen that in the future more farmers will be practicing seed treatment as a major component. However, the major question regarding this practice is its' sustainability. The high cost of pesticides and their availability may limit the

use of seed treatment practices. Therefore, apart from chemical application, other cultural and traditional practices would be studied in the future. The value of traditional practices were not recognized. Early sowing, animal urine and water washed were used to manage smut diseases in traditional farming system (personal communication). These practices have been forgotten undocumented and lacking experimental evidence. The advantage of early planting in the control of smut is also considerably influenced by unreliable weather condition.

Table 4. Mean scores for grain mold resistance at Bako, Jimma, Pawe during 1990, 1992- 93

Cultivar	Year 1990	1992	1993	Mean yield(t/ha)	Germination rate in (%)
85 MW 5552	3.0	2.3	1.7	3.1	77
89 MW 5099	3.0	3.8	-	1.8	70
89 BK 4134	3.0	-	-	1.7	62
87 BK 4332	3.0	2.4	2.3	1.7	78
85 MW 5334	2.5	2.9	-	2.8	57
IS 10301	2.0	2.0	2.4		40
IS 13958	2.0	2.0	2.4		65
IS 10892	2.0	2.0	2.0		53
Check					
IS 9302	4.0	4.3	4.0	-	-
85 BK 6136	3.8	-	-	-	-
SE	0.098	0.108	0.108		

Basic studies

Pathogenicity test

There are few published accounts of the existence of different pathotypes in *C. graminicola* in Ethiopia. The existence of pathogen population in *C. graminicola* in the production areas at Jimma, Bako and Alemaya was observed and found out that the Jimma isolate was found more virulent followed by Bako and Alemaya (5). In view of this findings, further study to determine differences in virulence character of the isolates and their race composition on a set of host differentials is in progress in collaboration with (ICRISAT) International Crops Research Institute for the Semi-Arid Tropics and with Texas A & M University. Infected samples were sent to Texas, USA to investigate genetic variation, using genetic markers.

Host parasite relationship

Methods were developed to investigate sequences of events from spore deposition, penetration, colonization and symptom expression of *C. graminicola* through Fluorescence microscopy. Results indicated that conidia of *C. graminicola* form appressoria, develop infection peg, penetrate the host cell wall and colonize the host cells, within 2, 4, 6, 6-7 and 20-144 hrs of inoculation, respectively. Setae formation, the last stage and which produce second generation of conidia, appeared 168 hrs after inoculation in a susceptible variety (GirmaTegegne, Unpublished data). The method could be used in the future to understand the physiological basis of identified resistance genotypes.

Effect of pollination and fertilization in ergot severity

Flowering behavior of sorghum and the role of pollination in ergot severity in relation to environments was reported by many authors (10, 15, 16). It was also our great interest to know the most critical period of ergot infection and the concurrence of pollen tube and conidia in fertilized and unfertilized ovary. Results showed that pollen can germinate and pollen tube can fertilize ovaries within 24 h. In contrast, conidia require less than 24 h to germinate, 48 h to reach ovary and 72 h to colonize ovule and ovary. Ergot severity was 87-95% in spikelets pollinated 2-4 days after inoculation, 95% in spikelets pollinated 9 days after inoculation, 20% in spikelets inoculated at the time of pollination and 3-5% in spikelets pollinated 2-4 days before inoculation. It was also observed that both grain and fungal stroma developed together in 7.5% spikelets in which infection hyphae and pollen tube grew simultaneously in the pistil.

Table 5. Effect of inoculating spikelets at various periods before and after anthesis on ergot development.

Inoculation	Infected spikelets (%)	
	Infected	healthy
Hours after anthesis		
96	3.6+3.93	77.8+4.53
72	5.9+3.22	74.8+3.77
48	5.0+2.82	62.5+3.29
24	10.3+2.60	63.6+3.03
6	20.1+2.54	54.3+2.96
At anthesis	32.4+3.68	30.7+4.29
Hours before anthesis		
24	51.7+2.48	32.9 +2.89
48	87.1+2.42	2.3
72	92.2 +2.16	2.7+2.52
96	95.2 +2.16	2.1
120	89.5 +1.86	6.5+2.17

Future Needs/Gaps

There is a need to study the resistant mechanisms of the identified resistant genotypes of sorghum to ergot, anthracnose and grain mold. Confirmation of these characteristics would be most useful to device appropriate breeding strategy.

Epidemiological aspects of these diseases is not very well known. Hence, the importance of environmental variables and disease dynamics should be known.

There are measures that are traditionally accepted. Early planting is known to reduce smut infection. Cow urine seed treatment was also believed earlier as appropriate method in some locality to protect sorghum smut disease. Looking these aspects at some depth is important as treating seeds with chemicals at farm level might be expensive.

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PEST MANAGEMENT IN HORTICULTURAL CROPS: PROGRESS AND PROSPECTS

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Abstract

This paper reviews the status of entomological research on horticultural crops (citrus, vegetables, roots and tubers) in Ethiopia. Concerted research efforts on horticultural crop entomology in this country started in the early 1980s. Initial efforts concentrated on pest surveys, identification, economic importance and their geographical distribution. Scale insects, aphids (as virus vectors), and citrus psyllid on citrus; fruit worms on tomato; onion thrips on onions; and potato tuber worm on potato have been identified as the major pests that inflict heavy damage and cause considerable yield losses. Significant progress has been made in establishing and implementing IPM programmes against the major pests. Use of mineral oil sprays timed to coincide with the peak breeding period of the red scale (*Aonidiella aurantii*) has enabled to reduce the frequency of pesticide application from about a dozen to 2-3 sprays per year, thus conserving natural enemies that play a significant role in the IPM of this insect; some progress has also been made in understanding the significance of the natural enemy fauna in the natural biological control of important pests. Parasitoids introduced from abroad and released against scale insects on citrus did not get established. Seasonal changes in the population of fruit worms on tomato have been studied, and sources of host plant resistance have been identified; the critical period of damage has also been determined. Studies on the population dynamics of onion thrips have been carried out and peak periods of damage have been identified; the rate and frequency of insecticide application have been determined. Promising results have been obtained with botanical control of onion thrips. Future research will focus on an IPM approach with more emphasis on conservation of natural enemies, use of host plant resistance and natural products, wherever applicable.

Introduction

Well over 50 horticultural plant species (including fruits, roots and tubers, vegetables, and herbs) are known to grow in Ethiopia. Examples of these, along with important arthropod pests, are shown in Table 1.

Organized research on the management of pests of horticultural crops started with the establishment of the National Horticulture Research Center at Nazareth in 1970. Early efforts centered round survey, collection and documentation of pest species. Crop improvement research was reorganized in 1979 and four teams (including fruits and nuts, roots and tubers, vegetables, and herbs and spices) were formed; Nazareth Research Center served as a focal point for coordination of all horticultural crops research.

Research on horticulture entomology focussed on pest surveys, documentation, establishing the economic importance, and devising appropriate management measures for major pests on major horticultural crops in Ethiopia. Progress along this line has been reported in recent reviews (Abate, 1986a,b; Abate, 1994; Abate & Gashawbeza, 1994; Adhanom et al., 1986). This paper gives highlights of research on the various activities carried out on pests of horticultural crops over the last several years, and suggests future directions for further research.

Table 1. Important arthropd pests and total number of pest species recorded on selected horticultural crops in Ethiopia[1].

Crop	Important pest(s)	Records
FRUIT CROPS		
Citrus	armored scales, aphids, psyllid[2]	68
Grape	armored scales[3]	15
Mango	scale insects[3]	15
Palms	scale insects[3]	14
Peach	not established	11
Papaya	red mites[3]	10
Guava	fruit flies[3]	8
Apple	not established	7
Banana	none	6
Avocado	armored scales[3]	5
Strawberry	not established	4
Pineapple	pineapple mealybug[2]	1
VEGETABLES		
Cabbages	cabbage aphid, diamond back moth[3]	25
Tomato	fruit worms, tobacco whitefly[2]	23
Cucurbits	aphids, fruit flies[2]	22
Capsicum	ABW, TWF, termites[2]	20
Eggplant	not established	13
Okra	not established	11
Onions	onion thrips[2]	6
Lettuce	not established	4
Green beans	not established	3
ROOTS/TUBERS		
Sweet potato	butterfly, weevils, leafminer	41
Potato	PTM	23
Radish	not established	12
Carrots	not established	6
Yam	not established	4
Beet	not established	3
Enset	not established	3
Anchote	not known	0
Taro	not known	0
HERBS/SPICES		
Basil	not established	3
Chicory	not established	2
Dill	not established	2
Rhubarb	not established	2
Rhue	not established	2
Fennel	not established	1
Parsely	not established	1

[1]adapted from (Abate, 1988a); [2]major pest; [3]common but pest status not determined

The Pests and Their Economic Importance

Insect and mite pests attacking horticultural and related crops in various parts of Ethiopia are cataloged by Abate (1988a). Table 1 summarizes the importance and total number of arthropod pests recorded on selected crops in this country.

Although a large number of pests may be recorded on a particular crop, only a few of them may be of significant economic importance - i.e. need human intervention to avert crop loss. Some insects may occur in large numbers but their pest status is not known either because their incidence is seasonal and their populations are checked by natural control agents (parasitoids, predators, insect pathogens, abiotic factors) or the crop in question is not of high priority to warrant allocation of resources for full time research. For instance, outbreaks of the cottony cushion scale (*Icerya purchasi*), and to some extent of the soft brown scale (*Coccus hesperidum*) and the groundnut hopper (*Hilda patruelis*) occur on citrus and other perennials following the dry season but their populations usually drop to uneconomic levels with the advent of the rainy season. Several species of parasitoids and predators are considered to contribute to natural control of these pests; these include several species of *Metaphycus* (Hymenoptera: Encyrtidae) and *Rodolia* (Coleoptera: Coccinellidae) on cottony cushion scale, *Coccophagus* spp (Hymenoptera: Aphelinidae) on soft brown scale, and *Psyllecthrus oophagus* (Hymenoptera: Encyrtidae) on groundnut hopper (Abate 1991).

On the other hand, the economic importance of pests on certain crops has not been established, not because these crops are not important but because of negligence. For example, little work is done on enset, on which at least 20% of the Ethiopian population depends for food, fibre and other purposes; nothing has been done on anchote (*Coccinia abyssinica*) and taro (*Colocasia esculenta*), although these too are important in southern and southwestern parts of the country.

The economic importance of insect pests in herbs and spices listed in the table has not been established primarily because these crops are not grown on a large scale in Ethiopia.

It is interesting to note here that no insect pests of economic importance occur on banana in Ethiopia. The banana weevil (*Cosmopolites sordidus*) which is the limiting factor in banana production in Uganda and elsewhere does not occur in Ethiopia. Strengthening quarantine regulations against this and other pests that are important outside but do not occur in Ethiopia is the only economical means of controlling such pests.

Available data on estimates of pre-harvest crop losses due to insect pests are presented in Table 2. Data on post-harvest losses due to pests and diseases in horticultural crops are not available; Berga et al. (1989) reported that annual average losses of about 49, 28, 26, 20, 17, and 11 percent of guava, pineapple, mango, tomato, mandarin, melons, and onion, respectively, occur in the state farms. However, not all of the losses could be attributed to pests and diseases, as post-harvest losses in horticultural crops can also result from physical factors such as temperature, humidity, lack of oxygen, and physical damage.

The high loss figures suggest that significant savings can be made in terms of increased crop yields and thus in terms of increased farm income if appropriate methods of pest management are devised to prevent such losses.

All yield loss data presented in Table 2 were obtained from on-station experiments and caution must be taken in interpreting these estimates, especially for crops grown by subsistence farmers (such as sweet potato), as on-station experiments are usually conducted under artificially high pest pressure and do not take into account the normal farm practices of the small farmer. Figures for crops grown in large scale, commercial farming may not be very far from the reality. Although the sweet potato butterflies (*Acraea* spp) are very serious pests of sweet potato in southern Ethiopia, no data are available on actual losses caused by these insects and their control measures.

Table 2: Pre-harvest loss estimates due to insect pests in selected horticultural crops in Ethiopia

Crop	Pest(s)	Loss (%)	Reference(s)
Tomato	tobacco whitefly (TWF)	27-37	Abate 1986b
	fruitworms (PTM, ABW)	30-90	Emana 1985
Capsicum	African bollworm (ABW)	11-27	Abate 1986b
Onions	onion thrips	26-43	Abate 1983a
	shallot fly-mite complex	41	IAR 1983b
Citrus	scale insects	2-9 20-	Abate 1981
Sweet potato	sweet potato weevil	77	Emana 1987
	sweet potato leafminer	0-23	Abate 1985a

Studies On Management

Studies on the management of horticultural crop pests concentrated against pests of citrus, tomato, onions, capsicum (hot pepper), and sweet potato. Pest management strategies focussed on an integrated approach that included cultural, ecological, biological, host plant resistance, and insecticidal control methods. Progress in each of these aspects against various pests on each of the crops mentioned above is highlighted below.

Citrus IPM

A recent review of citrus IPM in Ethiopia can be found in Abate (1994). Scale insects are by far the most important pests of citrus in Ethiopia (Abate, 1981, 1983b, 1984, 1986a; Goossens et al., 1981). Among these, the red scale (*Aonidiella aurantii*) is the major pest. It was not uncommon to observe monthly or even fortnightly blanket applications of organophosphate (OP) insecticides such as methidathion against this and other insects in state farms orchards during the late 1970s.

IPM of these insects in Ethiopia centred round understanding of their population dynamics and of their the natural enemies, and selection of insecticides that are compatible with the IPM approach.

Studies on the population dynamics of red scale and its natural enemies were conducted between 1981 and 1983. Breeding peaks were reached following the rains, one in October-November and the other in March-April (Abate, 1984). A large number of parasitoids and predators were also recorded; native species of *Aphytis* were the most important parasitoids; the ladybirds in the genera *Chilochorus*, *Hyperaspis*, etc. were important predators and their abundance increased with the increase in pest numbers. Mineral oil (white oil) at the rate of 1.5-

2.0% a.i. (in conjunction with methidathion or alone) was found to give effective control of red scale (Abate, 1983b).

It has thus been recommended that a maximum of three sprays (1-2 in October-November, 1 in March-April) of white oil be applied per year (Abate, 1983b). These recommendations have been followed and at present the pest is no more a great threat to the citrus industry of Ethiopia. Significant savings must have been realized from reductions in the frequency of pesticide applications; savings in terms of environmental safety are of course obvious.

The parasitoids *Aphytis melinus* and *A. coheni* (against red scale) and *A. holoxanthus* (against purple scale) were introduced from California, reared in the laboratory at the Nazareth Research Centre and released in citrus orchards at Koka and Yerer in 1979 (IAR, 1983a) and in later years (Abate, 1986c), but these have not become established.

Heavy infestations of the leafminer *Phyllocnistis citrella* occur on flush growth but it appears that the pest is kept in check by parasitoids (*Cirrospilus* spp). Heavy parasitisation and predation are also responsible for the low level of several pest populations in citrus orchards; examples include *Coccus*, *Icerya*, *Toxoptera*, and *Trioza* (see Table 3).

Table 3. Number of known indigenous natural enemy species on selected insect pests of horticultural crops in Ethiopia*

Pest	Major pest on	Known enemies
HOMOPTERA		
Toxoptera aurantii	Citrus	18
Aonidiella aurantii	Citrus	13
Toxoptera citricidus	Citrus	12
Icerya purchasi	Citrus	12
Chrysomphalus aonidum	Citrus	11
Trioza erytreae	Citrus	10
Coccus hesperidum	Citrus	6
Bemisia tabaci	Tomato	2
DIPTERA		
Liriomyza trifolii	Vegetables	2
LEPIDOPTERA		
Helicoverpa armigera	Vegetables	11
Phyllocnistis citrella	Citrus	8
Phthorimaea operculella	tomato, potato	2

*adapted from Abate (1991).

Studies on the 'greening' disease (caused by *Trioza erytreae*), and 'tristeza' (caused by the aphids *Toxoptera* spp, and *Aphis gossypii*) on citrus have been conducted over several years and the geographical distribution, host range and natural enemy complex of these pests have been determined (Abate, 1988c). Natural enemies play an important role in regulating populations of these pests (Abate, 1991).

IPM of Fruit worms on Tomato

Two species of fruit worms are important on tomato in Ethiopia. These are the potato tuber moth (*Phthorimaea operculella*) and the African bollworm (*Helicoverpa armigera*). The former accounts for more than 95% of fruitworm damage on tomato around Melkassa (Gashawbeza & Abate, 1993). Damage by these insects may reach 100%. Studies towards the development of IPM of these pests focussed on seasonal changes in their populations, cultural practices, varietal resistance, and screening of selective insecticides.

Trials carried out at Melkassa during 1983 showed significant influence of inter-row spacing and sowing dates (IAR, 1986a,b); closer spacings tended to favour pest damage. Experiments conducted on the population dynamics of fruit worms also at Melkassa between 1991 and 1994 showed significant variations in pest numbers at different periods (Abate & Gashawabeza, unpublished).

Several species of parasitoids have been recorded on both species (Abate, 1991). The braconids *Chelonus* sp and *Diadegma molliplum* are important parasitoids of PTM (Adhanom, 1981); various stages of ABW are attacked by a wide range of hymenopterous and dipterous parasitoids in the genera *Charops*, *Trichogramma*, *Venturia*, *Linnaemya*, *Palexorista*, *Voria*, etc.

Progress has also been made in recent years towards identifying sources of resistance in tomato cultivars and hybrids; moderate to high levels of resistance have been observed (Abate & Gashawbeza, 1994; Gashawbeza & Abate, 1993). Replicated trials have shown that the genotypes 'Pusa Early Dwarf', 'Pusa Ruby', 'Seedathing' and 'Serio' are resistant and 'RV-44' and the commercial variety 'Money Maker' are moderately resistant. Another commercial variety, 'Marglobe' is susceptible. In addition 'Serio' is a high yielding variety (Abate & Gashawbeza, 1997). Attempts to replace organophosphate and synthetic pyrethroid insecticides have not succeeded in finding suitable substitutes; the bacterial preparation *Bacillus thuringiensis* did not give satisfactory control (Gashawbeza & Abate, 1993).

IPM of Onion Thrips

Studies on IPM of onion thrips (*Thrips tabaci*) consisted of population dynamics of the pest and its natural enemies, host range, screening of effective chemicals, determining the rate and frequency of insecticides, and testing the efficacy of botanicals as alternatives to pesticides.

Experiments on population dynamics conducted between 1981 and 1984 at Melkassa showed that thrips numbers vary significantly from month to month and from season to season. Highest peaks are reached between February and April whereas thrips counts are lowest during the wet months of June to August. These changes are significantly correlated with maximum temperature, relative humidity, and rainfall. Thrips numbers increase with the increase in maximum temperature, or with decreases in rainfall and relative humidity; minimum temperature does not influence thrips population.

Thrips tabaci has been recorded on many cultivated and wild plants in the upper and middle Awash areas. Some of these are tomato, hot pepper, cabbage, haricot bean, nut sedge (*Cyperus* spp), and wild sorghum. However, it causes direct damage only on onions in Ethiopia.

Ladybird beetles and minute pirate bugs are important predators of onion thrips in

Ethiopia. The ladybird beetle *Adonia variegata* is the most common predator that attacks onion thrips in the upper and middle Awash valley; its abundance increases with the increase in thrips numbers. At least two species of *Orius* (minute pirate bug) are found on onion thrips in this country. Neither natural enemy appears to give adequate control of onion thrips.

Effective control of onion thrips can be achieved with pyrethroids such as cypermethrin (Abate, 1983a) at the rate of 50-75 g a.i. ha^{-1} (Ferede & Abate, 1992) applied at the threshold level of 5 thrips per plant. However, we observed secondary outbreaks of red spider mite (*Tetranychus* sp) following continued use of pyrethroids. Efforts are currently under way to find alternatives to pyrethroids; preliminary results suggest that crude extracts of neem (*Azadirachta indica*), persian lilac (*Melia azadirach*) and pepper tree (*Schinus molle*) give promising levels of control to warrant further testing.

Studies on Pests of Hot Pepper

Hot pepper is attacked by a large number of insect and mite pests (Abate, 1986b, 1988b). Of these, the African bollworm (ABW), *Helicoverpa armigera*, is the most important. Trap cropping studies carried out at Bako demonstrated that strip cropping hot pepper with lupin (*Lupinus albus*) gives good protection against ABW (Abate, 1985b, 1988a).

The tomato erinose mite, *Aceri lycopersici*, also commonly occurs in the Rift valley and in the upper Awash areas. Its attack causes the characteristic hairiness on growing buds of hot pepper and tomato. No work has been initiated against this pest so far.

Studies on Pests of Sweet Potato

More than 40 species of arthropod pests have been recorded on sweet potato in Ethiopia (Abate, 1988b; Emana & Adhanom, 1989). The sweet potato butterfly, *Acraea acerata*, is perhaps the most important pest of sweet potato in southern Ethiopia. The larvae of this insect skeletonize the leaves, sometimes resulting in a total defoliation of the crop. It is suggested that the larvae be hand collected and destroyed mechanically. This can be done conveniently during the early larval stage of the pest where it is gregarious and therefore easy to collect. Routine monitoring will be necessary to ensure that infestation is spotted in good time.

The sweet potato weevils, *Cylas* spp, occur in many parts of the country. Chemical control trials have been carried out but chemical control is not practical in pest management in small scale production systems. Pest damage is known to increase if harvesting is delayed (Emana, 1990); timely harvesting is therefore recommended against sweet potato weevils.

Sporadic outbreaks of the sweet potato leafminer, *Bedellia somnulentella*, occurs in southwestern Ethiopia (Abate, 1985a, 1988b) but no control measures are necessary. Tortoise beetles of the genera *Aspidomorpha* and *Conchyloctenia*, and larvae of sphinx moths such as *Hippotion celerio* and *Hyles lineata* also attack sweet potato in the Melkassa and Melkawerer areas but do not require control measures.

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PROGRESS IN SORGHUM INSECT PESTS MANAGEMENT RESEARCH

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Abstract

Progress made in sorghum insect pests management research at Nazareth Research Center of the Institute of Agricultural Research is reviewed. About 52 insect pests whose status ranging from unknown to major have been recorded. Area of emphasis has been on the integrated management of stalk borers, *Chilo partellus* (Swinhoe) and *Busseola fusca* (Fuller). Studies on biology, loss assessment, critical period of attack, and control methods including cultural, varietal and chemical have been made in one or both species. Preliminary survey on sorghum midge, *Contarinia sorghicola* (Coq.) has also been carried out. From laboratory biology study at Melkassa, the number of eggs laid by adult female of *C. partellus,* fertility of the eggs and the duration of the different stages of the insect have been reported. Preliminary data on the effect of inter-cropping sorghum with legumes on stalk borers incidence, early sowings, genotype resistance, effective insecticidal control and horizontal placement of sorghum stalks in the sun at different lengths of time to reduce the survival rate of diapausing larvae of stalk borers suggested that they can be good components in the integrated management of the insects. Sorghum midge was reported to be the cause of sterility in some parts of the country. In this paper major findings are reviewed and priorities for future research are suggested.

Introduction

Sorghum is one of the major cereal crops in Ethiopia accounting for 16 - 20% of the total cereal production. Current production is estimated at 1-1.6 million tones in 726 000 to 1 026 000 hectares of land. It is predominantly produced in low lands where drought and poor harvest are common occurrence (Brhane, 1977). Yield in peasant farms are low ranging from 1-1.2 tons/ha compared with higher than 3 tons in experimental fields (Gashawbeza & Melaku 1995a). It has been observed that any factor hindering normal development of a crop tends to intensify pest damage (Harris, 1962). As this crop is mainly produced in marginal areas, insect pests hold key position as yield reducing factors. Research on sorghum entomology at Melkassa Research Center began in 1986. Area of emphasis during this period has been on the integrated management of stalk borers, *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) and *Busseola fusca* (Fuller) (LepidopteraiNoctuidae). Experiments on the biology, critical period of attack, loss assessment, and control methods including cultural, varietal and chemical have been made in one or both of the species. Preliminary survey on infestation of sorghum by the sorghum midge, *Contarinia sorghicola* (Coquillett) (Diptera: Ceddomyidae) has also been carried out. In this paper major findings are reviewed and priorities for future research are suggested.

Survey

To date about 52 insect pests have been recorded on sorghum in Ethiopia. Thirty eight of them were earlier reported by Adhanom and Abrham (1986). Eight of the 16 species (Table 1) are records of survey made in latter years; the remaining 8 species had been reported by others. These include major insects such as *Chilo partellus* and *Contarinia sorghicola*; and *Dysdercus* sp., *Longuiguis sachari, Schizaphis graminum* and *Spodoptera exigua* (Tessema, 1982; Seshu and Omolo, 1985). Generally the major insect pests in sorghum are stalk borers, *Ckilopartellus* and

Busseola fusca, and shoot fly, *Athregona soccata* as regularly occurring and the sorghum chaffer, *Pachnoda interrupta* as a sporadic pest in the field and various species of weevils, *Sitophilus spp.* in the store. Sorghum midge and the sorghum head lygus, *Taylorilygus* spp. have also been recognized as important pests in recent years. Sorghum midge had been regarded as minor pest (Tessema, 1982) in previous years. Its importance as pest of sorghum in Ethiopia was known after a survey was made to identify the cause of sterility of sorghum seeds in 1989. Details are presented in latter part of this report.

Table 1. New species of insect pests recorded on sorghum in Ethiopia: 1986 - 1995

Scientific name	Common name	Status	Ref.
Agrotis spp.	cut worm	unknown	2
Campyloma spp.	head bug	unknown	14
Diopsis thoracica	stalk eyed fly	unknown	2
Lampyridae	fire flies	minor	2
Locris spp.	-	minor	
Nematocerus spp.	Shiny cereal weevil	unknown	2
S. pandurus	Lygus bug	minor	2
Systates spp.	Systates weevil	minor	2

Studies on Stalk borers

Biology of *Chilo partellus*

Although detailed studies were not made, the following information on the biology of *C. partellus* was reported (IAR, 1990) using larvae collected from field and reared in cages in the entomology laboratory at Melkassa Research Center in 1990. Adult female of the insect laid 379 eggs on the average. The mean durations of the different stages of the insect, egg, larva, pupa and adult were 7, 35, 14 and 4 (for female) and 5 (for male), respectively. Completed life cycle lasted 42 to 68 days. Oviposition started on the first day of adult emergence in the night; the peak oviposition was on the first day of emergence and declined over time. About 83 % of the eggs were hatched in to larvae.

Yield Losses and Critical Period of Attack

A yield loss of 64.4% (2.09 t/ha) (Table 2) was reported using natural infestation at Ziway (alt. 1650) in 1993 where mixed populations of *Chilo partellus* and *Busseola fusca* occur (Gashawbeza and Melaku, 1995a). However, the loss was reported to vary with location and season; for example, in experiment conducted at Adami Tulu Research center (alt. 1650) in 1992, the loss due to these pests was only 23.4% (0.4 t/ha). The composition of the two species of stalk borers vary from year to year in the same location as observed in experimental sites. For example, the composition of *Chilo partellus* and *Busseola fusca* at Ziway in 1990 was 60 and 40%, respectively (Melaku and Gashawbeza, 1993b) where as in 1993 *B. fusca* accounted for 95% of the two species (Gashawbeza and Melaku, 1995b).

Protecting the crop at 15 days after emergence from attack through insecticide application was reported to minimize extent of leaf infestation (Melaku and Gashawbeza, 1993a). However, significantly lower damage in the late growing period and higher yield were reported when the crop was protected at 45 days after emergence than it was at 15 or 30 days after emergence (Table 2). Insecticidal control at 45 days after emergence was generally reported to be advantageous to minimize damage and loss due to stalk borers (Gashawbeza and Melaku, 1995a).

Table 2. Effect of cyhalothrin applied at different period of sorghum growth on stalk borers, *C. partellus* and *B. fusca*, infestation and damage at Ziway, 1993.

Applied (DAE)	Leaf yield damage 60 DAE	Leaf feeding score 60 DAE	% chaffy head	% harvested head	Yield (Kg/ha)
15	40.0	1.5	26.6	73.9	1495
30	39.7	1.4	25.4	74.6	1736
45	47.3	1.4	13.2	86.3	3030
15 & 30	29.2	1.0	31.6	65.4	1519
30 & 45	8.8	1.0	10.3	87.9	2640
15,30 & 45	26.1	1.0	8.2	88.1	3172
Untreated	51.4	2.1	40.3	58.0	1080
Mean	38.9	1.3	22.2	76.4	2096
SE	2.55	0.08	2.65	2.58	151.1
CV (%)	40.8	34.2	54.8	16.2	42.6
LSD (0.05)	16.1	0.5	12.4	12.6	904

Source: Gashawbeza & Melaku (1995)

Studies on Control Methods

Varietal control

Sorghum germ plasms of national collections and introductions from International Research Centers for various purposes including varieties reported as stalk borer resistant have been evaluated at different times to identify sources of resistance against stalk borers in sorghum. Out of the 90 genotypes evaluated for 4 years (1986-1989), IS-1054, IS-2146, IS-4664, and PS 18822-4 were reported to show better resistance to stalk borers (IAR, 1989). Twenty five varieties obtained from ICRISAT as multi-locational test for stalk borer resistance were evaluated for 3 years (1991-1993) using natural infestation at Ziway and Melkassa. ICSV-708, PB-14376-1, PB-15469-2-1-3 and PB-12747 were reported as good sources of resistance (IAR, 1993).

Chemical control

Effective chemical control of stalk borers was achieved by using cyhalothrin (5% EC) at the rate of 16 g a.i. per hectare (Table 3; IAR. 1989).

Table 3. Effect of different insecticides on damage of sorghum by the spotted stem borer, Chilo partellus, at Melkassa in 1989.

Insecticides	Rate g.a.i/ha	Plants with leaf damage		Damage score		Yield
		4th WAE(%)	*6th WAE(%)	4th WAE	6th WAE	q/ha
Selecron 3G	210	5.08a	10.23a	1.00a	2.00a	48.04a-c
Cymbush 1% G	25	9.33ab	13.85ab	2.00ab	1.33a	46.64a-d
Cymbush 5% G	25	6.72ab	13.04a	1.67ab	1.33a	40.43b-d
Actellic 50% EC	1000	7.12ab	12.45a	1.33ab	1.33a	50.08ab
Cyhalothrin 5% EC	16	7.89ab	9.50a	1.00a	1.33a	56.09a
Sumicombi 30% EC	300	6.58ab	11.43a	1.00a	1.33a	42.85a-d
Sumicombi 1.8% D	360	8.57ab	11.87a	1.00a	1.00a	42.37b-d
Fenom 100 EC	400	8.96ab	12.42a	1.33ab	1.67a	51.38ab
Sumithion 5% EC	1000	7.57ab	14.28ab	1.33ab	1.33ab	33.99d
Sumithion 5% D	1000	6.50ab	11.62a	1.00a	1.00a	35.33c-d
Untreated	-	11.70b	27.19b	2.33b	2.33a	43,41a-d
Mean		7.82	13.44	1.36	1.45	44.61
SE		1.86	4.08	0.35	0.39	3.93
CV (%)		41.10	52.56	44.12	46.77	15.25

Source: IAR 1989

* WAE = Weeks After Emergence

Means with the same letter are not significantly different at 5% (DNMRT)

Cultural control

Sowing date. Late planted sorghums were reported to suffer greater damage than early planted ones; however, level of damage on sorghum planted at different periods vary with locations. For instance, neither early (June 1) nor late (July 15) sowing resulted in least infestation at Melkassa both in 1992 and 1993. Lower level of damage and higher yield were reported from sowings made on June 15 and July 1. On the other hand progressive increases in the level of infestation and a sharp decline in yield, 27.1, 17.3, 4.6 and 0.8 q/ha, was observed at Ziway on June 1, 15, July 1, and 15 sown sorghums, respectively (Gashawbeza and Melaku, 1995b).

Inter-cropping against stalk borers. Experiment to investigate the effect of inter-cropping sorghum with legumes, haricot bean and cowpea, on stalk borer incidence was initiated in the 1994 season. Preliminary data indicated that broadcast inter-cropping regardless of the species inter-cropped could very much help to lower level of damage (Gashawbeza, unpublished).

Horizontal placement of sorghum stalks in the sun against diapausing larvae. Like in the inter-cropping experiment, this experiment was initiated in 1994 to estimate the lengths of time required to kill substantial number of diapausing larvae in sorghum stalks by spreading stalks thinly in the open field after the grains are harvested. Although specific trend in percent mortality of the diapause larvae with the duration of horizontal placement was not observed, 80% of the larvae were found dead in stalks spread for 4 weeks compared to only 3% in stalks stacked immediately after harvest (farmers practice) suggesting the usefulness of horizontal placement in the integrated management of the insects (Gashawbeza, unpublished).

Survey on the cause of sterility of Sorghum

Preliminary survey was made by a group representing various disciplines of IAR to identify the cause of sterility of sorghum seeds at settler's farms of Gambella (West Ethiopia) in 1989. It was reported that sorghum midge and head blight, *Fusarium moniliform* (Sheld.) were the cause of the problem (Ferede and Girma, 1989). Up to 100% infestation had been observed in the sorghum variety, Bakomash 80 (Table 4). Severe problem of midge damage in Merhabete and Humera areas in the lowlands (IAR, 1986) and in late maturing sorghum fields in Wolenchiti area on the Nazareth Awash high way (Sharma, 1990) was also reported.

Table 4. Sterility of sorghum seeds (var. Bakomash) at Gambella in 1989

	Area planted (ha)		
Location	Total	Infested	% infestation
Shabbo	619.41	379.90	61.33
Ukuna kijang	92.00	92.00	100.00
Perbongo	343.00	311.35	91.77
Ubala	792.03	287.97	36.36
Total	1846.44	1071.22	58.06

Source: Ferede and Girma (1989)

Priorities for Future Research

As sorghum is cultivated under a wide range of environment in the country, different insect species including stalk borers hold key positions as pests of economic importance. However, research on sorghum entomology has so far focused on limited insect pests. Most of past attempts to control sorghum insect pests like insect pests of many other crops concentrated on identification of effective insecticides whose acceptance by the major producers, subsistence farmers, is at low level due to, among others, economic problems. Hence the following area of research are suggested for the coming years.

Assessment of the distribution and importance of sorghum midge and head bugs as part of survey and monitoring of insect pests of sorghum.

Studies on the phenology of important ones as they are basis to devise effective control methods.

Identification and utilization of host plant resistance as control method. Establishing laboratory rearing facilities especially for major insect pests like stalk borers is useful for fast and reliable detection of resistance as natural infestation vary from season to season.

Emphasis should be given for the development of cultural control methods, sowing date, inter-cropping, crop residue management, etc. against major pests in different production zones.

Experiment on the use of botanicals for the control of stored pests of beans and maize indicated their potential as pest protectant. Attempts should therefore be made to explore the potential of these locally available materials for the management of both field and storage pests of sorghum.

Studies on natural enemies of major pests with the aim to initiate biological control.

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PEST MANAGEMENT IN LOWLAND PULSES: PROGRESS AND PROSPECTS

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Abstract

This paper reviews the status of entomological research on grain legumes grown in the warmer mid-altitude areas (1500-2000 m) of Ethiopia. Concerted research efforts on the management of lowland pulses started in the early 1980s. Emphasis has been given to developing IPM programmes for major pests of haricot bean. Extensive studies have been carried out on the use of cultural practices, host plant resistance, natural biological control, and the use of botanicals. Future IPM research focus for smallholder bean production should be on low-input approaches that encompass farmers' current practices, including cultural practices, natural biological control, host plant resistance, and use of locally available resources.

Introduction

At least 12 species of the so called lowland pulses (grain legumes that are produced at altitudes between 1400 and 2000 m above see level) are known to grow in Ethiopia at one time or another (Imru, 1980; Ohlander, 1980). Included among these are haricot bean, cowpea, soybean, mung bean and pigeon pea. Of these, only haricot bean has been accorded a high priority in recent years because of its significance in domestic consumption and as an export crop; cowpea and soybean are considered intermediate priority crops.

Organized research on the management of pests of lowland pulses started with the establishment of the lowland pulse research section of IAR with its coordinating center at Melkassa in the early 1970s. Focussed research on bean entomology started in the early 1980s and emphasized pest surveys, documentation, and establishing the economic importance during the initial phase, and devising appropriate management measures for major pests on major lowland pulses in Ethiopia once the pests have been identified. This paper gives highlights of research progress on pests of lowland pulses over the last several years. Suggestions are also made on the future direction of research focus.

The Pests and Their Economic Importance

Results of work on arthropod pests attacking grain legumes, their composition, economic importance, and geographical distribution can be found in several publications (Abate 1984, 1987, Abate et al. 1982, 1990). Some examples of arthropod pest complex on selected crops are shown in Table 1. Although a large number of arthropod pests have been recorded on major crops, only a few of them are of economic importance - i.e. need human intervention to avert crop losses. Table 2 summarizes available data on yield loss estimates due to insect pests attacking haricot bean and cowpea in Ethiopia.

Table 1. Important arthropod pests and total number of pest species recorded on selected lowland pulses in Ethiopia[1].

Crop	Important pest(s)	Record
Haricot bean	Bean stem maggots Bruchids African bollworm Red spider mite Pod bugs Aphids	36
Cowpea	Bruchids Aphids Cotton leafworm Flower thrips Pod bugs Pod borers	35
Soybean	Green stink bugs Banded stink bugs Pod bugs Bruchids Aphids	54
Mungbean	Black pod weevil Green stink bug Pod bugs Bruchids	13
Pigeon pea	Pigeon pea pod borer African bollworm Pod bugs Cottony cushion scale	16

[1]Source: adapted from (Abate et al. 1982).

The bean stem maggots (*Ophiomyia* spp) and bean bruchids (*Acanthoscelides obtectus*, *Zabrotes subfasciatus*, *Callosobruchus* spp) are the most important pests of beans in the field and in storage, respectively (Abate, 1985, 1990b, 1991; Ferede & Abate, 1986). The African bollworm (*Helicoverpa armigera*) is also an important pest of beans in the rift valley and other drier parts of Ethiopia (Abate & Adhanom, 1981; Abate et al., 1985). Highlights of progress made on important pests are given below.

Table 2: Pre-harvest yield loss estimates due to insect pests in haricot bean and cowpea in Ethiopia.

Crop	Pest	Loss (%)	Reference
Haricot bean	Bean stem maggots	11-100	Abate 1990a, 1991, Ferede & Abate 1985
	African bollworm	12-16	Abate & Adhanom 1981
Cowpea	Cotton leafworm	27-39	Abate et al. 1985 IAR 1989
	General	9-18	

Bean Stem Maggots

Ecological studies

Ecological studies carried out so far show that three species of bean stem maggots (BSM) occur in Ethiopia. These are: *Ophiomyia phaseoli* (Tryon), *O. spencerella* (Greathead) and *O. centrosematis* de Meijere occur on haricot bean (*Phaseolus vulgaris*). *Ophiomyia phaseoli* and *O. spencerella* are the most widely distributed and abundant of the three species. *Ophiomyia centrosematis* occurs rarely and represents less than 2 percent of the total BSM population in most instances. It has been recorded from Jimma, Arsi-Negele, Awassa and Melkassa; it occurs in appreciable numbers at Melkassa only in beans sown after September and in the Jimma area.

The incidence of BSM species is influenced by one or a combination of environmental factors and cultural practices, including altitude, sowing date, and growth stage and type of the host plant. *Ophiomyia phaseoli* and *O. centrosematis* are more prevalent at altitudes below 1800 m and warmer climatic conditions whereas *O. spencerella* is dominant at higher altitudes and cooler, wetter environments. *Ophiomyia phaseoli* is more abundant in early sown bean whereas *O. spencerella* becomes more common later in the season. *Ophiomyia phaseoli* is more frequent on thin-stemmed, narrow-leaf, small-seeded, pea bean types whereas *O. spencerella* and *O. centrosematis* show preference for more succulent, broad-leaf, large-seeded, navy bean types.

BSM intensity (as measured by BSM per 10 plants) and species composition vary with location and sampling date (or sowing date). Samples of bean plants collected at Welenchiti, Bulbula, Ambo (Shewa); Hirna, Chelenko, Kobo, Kunie, Kulubi (Hararghe); and Abelti and Seka (Kaffa) did not yield BSM although they showed characteristic symptoms (stunting, yellowing and dying) of damage caused by this insect. BSM intensity at some localities, such as Kersa, Wakmolie, Yabete Anbessa (Hararghe); Melkassa, Shashemene (Shewa); Metu (Ilubabor); and Bonga, and Jimma (Kaffa) is relatively low, suggesting that these insects may not be a limiting factor in haricot bean production in these areas.

By contrast, high intensities are observed in southern and south-central Ethiopia. These include Areka (Sidamo) and its vicinities; the Awassa (Sidamo) area; the Wolaita Sodo (Sidamo) area and the Shashemene area, all of which represent the major concentration of haricot bean production in Ethiopia. Overall, in Ethiopia, BSM is particularly important in areas lying between 1700-1900 m above sea level.

Another factor that determines the abundance and composition of BSM species is the time of planting. For instance, nearly 100% of BSM sampled in June at Awassa is *O. phaseoli* whereas this species accounts for just over 25% when sampled in late August at the same location. Similarly, at Areka, *O. phaseoli* consists of 14-20% and 1-3% in plants sampled in April and July/August, respectively.

Studies on population dynamics

Experiments to determine seasonal changes in BSM numbers were conducted at Awassa in 1991 and 1992, and at Areka in 1992 and 1993. Seeds of the moderately susceptible local variety >Red Wolaita= were sown at 2-week intervals between 9 May and 23 August in 1991 and between 1 May and 9 August in 1992 at Awassa. In a similar fashion, the same variety was sown at Areka between 22 April and 5 September 1992 and 26 February and 2 July 1993. Plots for each planting were 6 m long and 4 m wide, 40 cm between rows and 10 cm between plants, replicated twice.

At Awassa, *O. phaseoli* was the dominant species occurring throughout the experimental period; it accounted for 93 to 100% of the two species in bean plots sown between early May and mid June. In contrast, *O. spencerella* constituted 60 to 100% in plots sown during the cooler and wetter months of July and August. At Areka, *O. spencerella* ranged between 73 and 100% in 1992, and between 57 and 100% in 1993. Here, *O. phaseoli* was found in appreciable numbers only in plots sown during the warmer and relatively drier months of February to May (Abate et al., 1995).

Host range studies

Studies conducted so far indicate that BSM are restricted to the plant family Leguminosae. These include, in descending order, haricot bean, cowpea (*Vigna unguiculata*), the wild host *Crotalaria laburnifolia*, and soybean (*Glycine max*).

Studies on cultural practices

Cultural control studies on management consisted of determining the effects of sowing date and plant density, and of habitat management on BSM numbers. Seeding date and plant density have significant effects on BSM intensity, crop damage and yield (Abate, 1990a). The effects of sowing date are location specific. At Awassa, seedling mortality and the resulting yields did not follow any specific trend among sowing dates whereas at Melkassa seedling mortality increased and seed yield increased with delays in sowing date (Tables 3 & 4).

Table 3: Sowing date and plant density effects on seedling mortality (percentages) in haricot bean caused by *Ophiomyia phaseoli* at two locations during the 1987 and 1988 crop seasons
Table 3: Sowing date and plant density effects on seedling mortality (percentages) in haricot bean caused by *Ophiomyia phaseoli* at two locations during the 1987 and 1988 crop seasons

Factor	Awassa		Melkassa		Mean
	1987	1988	1987	1988	
Sowing date[a]					
1st	22.0 a[*]	6.5 b	7.2 ab	7.5 a	10.8 a
2nd	7.3 c	19.8 a	3.3 b	3.9 a	8.6 a
3rd	19.4 ab	2.7 b	18.4 a	3.7 a	11.1 a
4th	11.4 bc	6.5 b	16.5 ab	2.2 a	9.1 a
Plant density					
100,000 ha^{-1}	28.4 a	18.1 a	21.8 a	7.5 a	19.0 a
200,000 ha^{-1}	19.5 b	11.2 b	14.7 b	4.8 ab	12.5 b
300,000 ha^{-1}	9.9 c	6.1 c	7.7 c	4.3 b	7.0 c
400,000 ha^{-1}	10.4 c	4.9 c	6.9 c	3.0 b	6.3 cd
500,000 ha^{-1}	7.0 c	4.1 c	5.7 c	2.0 b	4.7 d
Mean	15.0	8.9	11.4	4.3	9.9
CV (%)	32.7	39.4	30.4	63.4	37.7

[a]Sowing was done at 10-day intervals (first sowing at Awassa in 1987 started on June 12 and on June 7 in 1988; the corresponding dates at Melkassa were July 6 and July 4, respectively).

[*]Means for each factor, within a column, followed by the same letters are not significantly different at 1%.

Source: adapted from Abate (1990a).

At both locations, percentage seedling mortality decreased and seed yield increased with the increase in plant density (Tables 3 & 4). It should also be mentioned here that there were highly significant negative correlations between seedling mortality and seed yield.

Previous experiments have also demonstrated that between row distance has no effect whereas percent BSM infestation increased with the increase within row space (Abate et al., 1985). Strip-cropping beans with maize did not affect seed yields of beans although yields were reduced significantly in weedy fields. BSM numbers were 2 to 3-fold more abundant in weed-free bean monoculture than in weedy bean plots, with or without strip-crop (Abate, 1990a).

Table 4: Sowing date and plant density effects on seed yield of haricot bean at two locations during the 1987 and 1988 crop seasons

Factor	Awassa		Melkassa		Mean
	1987	1988	1987	1988	
Sowing date[a]					
1st	2438 b	3657 a	867 a	2592 a	2388 a
2nd	2738 ab	3028 b	574 ab	2364 a	2176 b
3rd	2885 a	3165 b	482 bc	2294 a	2195 b
4th	2322 c	2746 c	323 c	1386 b	1694 c
Plant density					
100,000 ha^{-1}	1943 b	2526 c	428 a	1476 c	1602 c
200,000 ha^{-1}	2562 a	3107 b	486 a	1842 bc	1999 b
300,000 ha^{-1}	2860 a	3401 a	617 a	2213 ab	2273 a
400,000 ha^{-1}	2838 a	3449 a	635 a	2593 a	2379 a
500,000 ha^{-1}	2776 a	3224 ab	641 a	2616 a	2314 a
Mean	2596	3149	561	2148	2113
CV (%)	11.6	10.0	36.1	18.4	14.7

[a]Sowing was done at 10-day intervals (first sowing at Awassa in 1987 started on June 12 and on June 7 in 1988; the corresponding dates at Melkassa were July 6 and July 4, respectively).

[*]Means for each factor, within a column, followed by the same letters are not significantly different at 1%.

Source: adapted from Abate (1990a).

Host plant resistance

Several genotypes with resistance to BSM and high seed yields have been identified from studies conducted between 1986 and 1988 (Abate, 1990a). Examples of these are shown in Table 5.

Crosses of some of these materials have been made with commercial varieties in the bean improvement programme and their progenies are evaluated for BSM and disease resistance, grain yield, and food and cooking quality. Further screening of haricot bean genotypes for resistance to BSM and major diseases is also in progress.

Table 5: Percent seedling mortality, dry seed yield (kg ha-[1]), and percent yield loss due to Ophiomyia phaseoli in selected haricot bean genotypes at Awassa, 1988*

Genotype	Mortality	Yield	Loss
G 5773	12.9	3891	6.6
G 5253	7.6	3419	7.6
G 2005	12.4	3955	12.8
G 2472	17.2	3910	16.1
EMP 81	24.1	3007	16.7
Mexican 142	63.4	757	71.3

*All data are pooled mean values of two sowing dates (June 4 & June 18); yield loss is mean of difference between treated and untreated plots.
Source: adapted from Abate (1990a).

Biological control

Studies on biological control of BSM were directed at delineating natural enemies that occur in Ethiopia. Seventeen species of parasitoids have been identified from surveys carried out so far (Abate, 1990a, 1991a,d). Of these, the braconid *Opius phaseoli* is the major parasitoid on *Ophiomyia phaseoli* on haricot bean. Average parasitism at Awassa is roughly 78% and at Melkassa it is about 38% (Abate, 1990a). Seeding rate did not influence *Opius* numbers whereas sowing date had significant effects (parasitoid numbers increased with the increase in BSM numbers).

The pteromalids *Sphegigaster stepicola* and *S. brunneicornis* were also common but they accounted for about 5% of total parasitism in haricot bean. In contrast, they were the major parasitoids of BSM on the wild host *Crotalaria laburnifolia* where the average parasitism reached about 26%. As is the case in other parts of eastern Africa, it is possible that the same parasitoids attack *O. spencerella* (Greathead, 1969) but nothing is known about this in Ethiopia.

Studies on insecticidal control of BSM

Insecticidal control studies have been conducted at Kobo, Mekele, Melkassa, and Awassa primarily to replace aldrin (Ferede & Abate, 1986; Abate, 1990a, 1991b). Although seed dressing with carbofuran (35% liquid formulation) significantly reduced BSM infestation at Kobo and Mekele it had phytotoxic effects, especially where there was a shortage of rainfall (Abate et al., 1985). Experiments at Melkassa and Awassa demonstrated that an effective control of BSM can be obtained with endosulfan seed dressing at the rate of 5 g a.i./kg of seed (Abate, 1990a, 1991b). It should be noted however, insecticidal control does not have applicability in haricot bean grown by smallholder farmers.

African Bollworm

Work on African bollworm (ABW), *Helicoverpa armigera* (previously known as *Heliothis armigera*), focussed on cultural practices and identification of natural enemies. These included studies on trap-cropping, strip-cropping and habitat management in general. It has been shown that pod damage by ABW was lowest and seed yield was the highest in haricot bean strip-cropped with maize (Abate, 1988). In another experiment, where the effects of strip-cropping beans with maize under weedy and weed-free conditions were tested, natural enemy (including the tachinids *Voria ruralis*, *V. capensis*, and *Periscepsia carbonaria*; and the wasp *Tiphia sjostedti*) numbers were significantly greater in the diverse weedy and inter-cropped plots than in bean mono-culture (Abate, 1991c). Further notes on the natural enemy complex of ABW can be found in Abate (1991a, 1992).

Bean Bruchids

Bruchids are the most important pests of stored beans in Ethiopia and elsewhere. Research on bruchids concentrated on determining their complex, host plant resistance, use of botanicals, and insecticidal control.

Identity of bruchid species

Bruchids of economic importance in Ethiopia are: the bean bruchid (*Acanthoscelides obtectus*); the Mexican bean weevil or spotted bean weevil (*Zabrotes subfasciatus*), and the cowpea bruchids (*Callosobruchus chinensis* and *C. maculatus*). *Acanthoscelides* and *Zabrotes* are important on beans (and may occur together) whereas *C. maculatus* is the major pest of cowpea. *C. chinensis* is important on both crops (beans and cowpea). In general, beans and cowpea are preferred grains. A wide range of pulses including pigeon pea, soybean, mung bean, chickpea and faba bean are also attacked by one or more of these insects in storage. Maize is also reported to be an alternative host but bruchids are not important on this crop.

The Mexican bean weevil is of recent introduction to Ethiopia. It had not been recorded in Ethiopia until Ferede (1994) reported it as being the major pest in stored beans in the Rift valley areas.

Ecological studies in Latin America showed that the prevalence of the two species is influenced by the ambient temperature regimes (van Rheenen et al., 1983). For example, *A. obtectus* is reported to prefer cooler climates at higher altitudes where it is the dominant species, whereas *Z. subfasciatus* prefers warmer climates in the lower altitudes and therefore is more important in the tropical and subtropical regions. Recent studies in southern Africa (Giga et al., 1992) and in Ethiopia (Ferede, 1994) show that this is not always the case. It is possible that: a) the African strain of *Z. subfasciatus* may be different from that in Latin America; and b) there may be factors other than altitude and hence temperature differences alone (such as time of year) that influence abundance of the two species.

Host plant resistance

Research on host plant resistance has identified promising cultivars against *Zabrotes*. Out of 100 CIAT accessions tested in the laboratory, the genotypes `RAZ 1', `RAZ 7', `RAZ 8', `RAZ 11' have shown high levels of resistance to this insect (Table 5). No sources of resistance have been found so far against the other bruchids.

Several accessions of cowpea were also tested for resistance to *Callosobruchus maculatus*. The IITA accession `IT-81D-985' showed high levels of resistance to the bruchid; in comparison, the recommended variety `White Wonder Trailing' was highly susceptible.

Table 5: Reaction of haricot bean accessions to the Mexican bean weevil (*Z. subfasciatus*)*

Genotype	Eggs/10 seed	Adult emergence (%)	Damaged seed (percent)
RAZ 1	299	0.0	0.0
RAZ 7	91	0.0	0.0
RAZ 8	4	0.0	0.0
RAZ 11	78	0.0	0.0
Diacol Calima	155	91.0	80.0
Awash 1	191	84.3	92.0

*Source: adapted from Ferede (1994).

Use of botanicals

Research with botanicals (plant products) has yielded promising results. For example, of preparations of several species of trees seed preparations of neem (*Azadirachta indica*), pepper tree (*Schinus molle*), Persian lilac (*Melia azadirach*) (pounded and admixed with bean seed at the rate of 10 g per kg) gave effective control of bruchids for up to 90 days (Ferede, 1994). Similar results have also been reported by Abate et al. (1992). Experiments by Teshome (1993) show that vegetable oils also can give effective control of bruchids in stored beans.

It should be noted here however that these are only experimental results and they have to be tested on-farm and their optimum dosage determined before they can be applied under farmers' conditions. Furthermore, use of vegetable oils is of little use under subsistence farmers' conditions.

Insecticidal control studies

Several tests have been carried out using insecticides against bruchids on beans. Pirimiphos-methyl at the rate of 4-5 ppm a.i. gives effective control of bruchids (Abate, 1985) and is widely used at present, at least in commercial stores.

Currently available cultural control measures for bruchid control under smallholder conditions depend on storage conditions. Stores must be free from bruchids and only adequately dried, clean seeds should be stored. The crop should be grown away from the store to discourage field infestation. All unwanted seeds within and around the store must be collected and destroyed. Well ventilated, cool storage conditions discourage pest establishment.

Other Pests of Lowland Pulses

The red spider mite (*Tetranychus cinnabarinus*), the flower and pollen beetles (*Mylabris* & *Coryna* spp), and the cotton leaf worm (*Spodoptera littoralis*) can cause serious damage to haricot bean and cowpea grown under irrigation during the dry season. Yield losses in cowpea due to cotton leaf worm (CLW) are estimated at 27-39% (Abate et al., 1985). This insect has not been seen as an economic pest since the late 1970s (Abate et al., 1985); the underlying factors for this decline and the economic importance of CLW are not fully understood.

Several species of pod-sucking bugs, including the spiny brown bugs (*Clavigralla tomentosicollis*, *C. schadabi* (previously known as [*C. horrida*], *C. hystricoides*), the giant coreid bug (*Anoplocnemis curvipes*), the green stink bugs (*Nezara viridula* & *Acrosternum pallidoconspersum*), the banded stink bugs (*Piezodorus inexpertus* & *P. rubrofasciatus*) usually occur in large numbers on one or more of the important pulse crops but they are not considered major pests and the extent of crop loss due to their damage has not been determined. Unlike the situation reported from Uganda (Materu, 1970, 1971, 1972), spiny brown bug populations in haricot bean build up late in the season and do not seem to cause economic damage; on pigeon pea they seem to be checked by the egg parasitoid *Gryon gnidus* (Abate, 1991a).

Sporadic outbreaks of the striped foliage beetle (*Medythia quaterna*) on haricot bean in the Melkassa area and of the leaf folder (*Hedylepta indicata*) on soybean in the Awassa area occur (IAR, 1985), but nothing is known about their economic importance. *Acrosternum* and *Piezodorus* are more common on soybean than other pulses.

The pod borer (*Etiella zinckenella*) causes heavy damage, particularly to pigeon pea, in many parts of Ethiopia where this crop is grown; data on yield losses caused by this insect are not available. Although the legume pod borer (*Maruca testulalis*) is reported to be a major pest of beans and cowpea in many parts of Africa (Abate & Ampofo, 1996), it does not seem to cause significant yield loss in Ethiopia.

Several species of thrips (including those in the genera *Frankliniella*, *Megalurothrips*, *Scolothrips*, and *Sericothrips*) attack mainly cowpea and haricot bean but the extent of yield loss due to these insects has not been estimated.

At least three species of aphids (*Aphis craccivora*, *A. fabae*, *A. gossypii*) attack cowpea, haricot bean and soybean across a wide range of agro-ecologies in Ethiopia. Their indirect effect on the crop as vectors of such viruses as the bean common mosaic virus (BCMV) may be more important than the damage caused by direct feeding..

Outbreaks of the cottony cushion scale (*Icerya purchasi*) occur on perennial pigeon pea following the dry season but its populations usually drops to uneconomic levels with the advent of the rainy season. Several species of parasitoids and predators are considered to contribute to natural biological control of this and other pests in Ethiopia (Abate, 1991a). These include several species of *Metaphycus* (Hymenoptera: Encyrtidae) and *Rodolia* (Coleoptera: Coccinellidae).

The black bean pod weevil, *Piezotrachelus ?varium* (previously known as *Apion varium*), is a serious pest of mung bean in the Shewa Robi area of northern Shewa but research on this insect was not pursued after the 1980/81 crop season because the crop was not given a high priority.

Future Focus

Research on the management of bean pests in Ethiopia has concentrated on an IPM approach and relied heavily on cultural practices, host plant resistance, natural biological control, and on the use of locally available and affordable resources. And indeed the Ethiopian government should adopt IPM as an essential component of all agricultural development policies in the future.

It is obvious from currently available data on yield loss estimates that our knowledge of the economic importance of pests, at least under small farmers' field conditions, is inadequate. Thus there is a need for generating meaningful yield loss data that relate to the existing farming practices so that our research is focussed on high priority pests.

Exploration of indigenous farmers' practices and their pest management knowledge should be pursued with vigour. Special emphasis should be given to the influence of habitat management on pest and natural enemy numbers; several studies in the eastern African region (Abate, 1991c; Berg, 1993; Kyamanywa, 1988; Kyamanywa & Ampofo, 1988; Kyamanywa & Tukahirwa, 1993; Kyamanywa et al. ,1993; Ogenga-Latigo et al., 1992a,b) have shown the beneficial influence of these and other cultural practices against important pests. This should serve as a basis for developing an IPM programme that can easily be adopted by farmers.

A knowledge base of the interactions between cropping systems and pests, natural enemies and host plants is essential. For instance, the weed (*Guizotia scabra*, Compositae) serves as a host to *H. armigera*; at the same time it has been observed that several species of predators, including the assassin bug *Rhinocoris albopilosus* (Hemiptera: Reduviidae) and the ladybird beetles *Cheilomenes* spp (Coleoptera: Coccinellidae), are more abundant and their mating and breeding occurs more readily under such fields. Understanding the mechanisms involved will help in establishing a biological control strategy.

Considering the fact that almost all of the known major insect pests in Ethiopia are well established organisms with a good number of associated natural enemies, classical biological control (introduction of natural enemies from abroad) may not be a high priority at present. Efforts must be directed at encouraging the existing natural enemies through proper habitat management. One potential area of biological control that has not received attention in Ethiopia is use of native insect pathogens. Recent studies elsewhere indicate that it is possible to isolate and locally produce preparations of insect pathogens. This should be given a serious thought.

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SESSION IV
Agricultural Implements

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IMPROVEMENTS ON PRE-HARVEST IMPLEMENTS

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Abstract

Research conducted on pre-harvest implements by the Agricultural Implements Research and Improvement Center (AIRIC) have been reviewed with major emphasis on the achievements. The national survey conducted in order to identify and prioritize research areas and the basic studies on draft animal power relevant to pre-harvest implements were used in developing suitable prototypes for the small scale farmers. The moldboard plow that was introduced earlier by other organizations was modified a number of times in order to come up with a low draft, light weight, simple and low cost moldboard plow. Finally, the 'Erf' and 'Mofer' attached moldboard plow was developed which is the combination of the traditional plow of Ethiopia known as 'Maresha' and the moldboard plow. A simple animal drawn row planter which worked effectively in rough and cloddy fields was also developed by avoiding ground wheels which were conventionally used for driving metering mechanisms. The major problem to the adoption of tie ridging (soil and moisture conservation practice) was the high labor requirement. Originally a tying unit was incorporated to an imported ridger which was found to be inconvenient because of its high draft power requirement, heavy weight, and high cost. Finally, to make the implement more suited to local conditions the ridging unit was replaced by 'Maresha' and a 'Maresha' attached ridge-tier was developed. Efforts made at AIRIC to introduce animal drawn mechanical weeders were not successful because of high crop damage by the animals. A manually operated wheel hoe weeder was, therefore, developed and found to be 4 times faster than hand pulling.

Introduction

It is estimated that the cultivable area in Ethiopia exceeds 60 million hectares (1). Only 10% of this area is presently cultivated in any one year. Over 90% of the total agricultural produce comes from 5.5 million farmers employing 5 million oxen and cultivating 95% of the land under plough. However, the farmers use age old implements and production techniques that need to be improved.

Research on animal-drawn tillage implements has been carried out in Ethiopia since the 1950's (2). From 1995 to 1965, there was a substantial amount of research carried out both at Alemaya Agricultural University and Jimma Agricultural Technical School (2). In 1968, the Implement Research Section of Chilalo Agricultural Development Unit began conducting studies on animal traction within Chilalo Awraja. Tests with VITA prototype indicated that design changes in the moldboard assembly and angle of the handle were necessary. These and other modifications were subsequently incorporated into what later became known as the ARDU plough. However, this plough was rejected by both farmers and extensionists because it was too heavy and it had a higher draft requirement (10 to 40%) more than Maresha, thereby causing the oxen to become more easily fatigued.

Simple wooden-framed spike-tooth harrows were first produced by CADU in 1969. Trials have shown that the harrow can provide more uniform seed covering than the traditional ard, and the draft requirement was less than that of Maresha. The major problem of this harrow was the difficulty of transporting it to the field. In addition, much of the highland is too rocky for the implement to be used effectively. Some farmers have also reported that because of shallow seed covering by the harrow, wheat crop suffered from lodging and moisture stress at later growth stages.

Generally, as many as 81 different types of agricultural implements and machinery are reported to have been developed or imported for promotion in Ethiopia in the past (1). The extent of acceptance of these implements by the farmer and the resulting impact on crop production techniques are stated to have been disappointing (3). The development efforts and choice of implements for promotion in Ethiopia seem to have been based on the perception of individuals. Factors like regional variations in soils, topography, climate, crop, size of agricultural holdings, characteristics of draft animal power, economic status of peasant farmer, his work habits and felt needs did not apparently receive adequate consideration. This deficiency might have been an important cause of the reportedly poor acceptance of improved agricultural implements.

Agricultural Productivity can be achieved by increasing either land or labour productivity or both. Improved agricultural implements and equipment will undoubtedly increase labour productivity. The Agricultural Implements Research and Improvement Center (AIRIC) was established in 1985 with the objective of designing, developing and introducing agricultural implements and equipment for pre-harvest, harvest and post-harvest operations. The objective of this paper is to present review of research and development activities AIRIC has been undertaking in the area of pre-harvest (tillage, planting, ridge tying and weeding) with emphasis on achievements since its establishment.

Survey of Agricultural Implements and Crop Production Techniques

In order to document the state of mechanization on peasant associations and to identify mechanization related constraints to production so that a need based program of research and improvement of agricultural implements could be developed, a survey was conducted in 6 different regions of Ethiopia from June 1985 to June 1986 (1).

For the purpose of this survey, the country was divided into three major crop zones to ensure that information was collected for all important cropping systems. Representative nature of a region in relation to the crop zone was the main criteria for its selection. The survey sample comprised twenty four peasant associations and two hundred thirty nine peasant farmers spread over eight Awrajas in six regions of Ethiopia.

Office bearers of each peasant association were contacted to collect data on climate, soils, topography, agricultural land use, crops and yields, crop production techniques, cropping schedules, draft animals and agricultural inputs pertaining to the association. Their views on bottlenecks in agricultural production, and what they considered to be the immediate improved implements needed by the members of the association were recorded. The head of each family included in the survey was interviewed to obtain information on his production resources (land, labour, draft animals, equipment), crops and yields, crop production techniques, cropping schedules, harnesses, daily working hours and total hours of use of labour and draft animals for different crops and operations and cash inputs. His views on hardship drudgery, bottlenecks and need for improvement of implements, and his response to the enquiry whether he was willing to try new implements were recorded. Specification of his tools and implements were also recorded after verification by the survey team.

Most of the farmers complained about the low output and inadequate weed control of the traditional ard, Maresha. Nineteen peasant associations out of 24 reported timeliness problem because more than one operation had to be carried out at the same time or the same operation had to be carried out simultaneously for more than one crop. Seedbed preparation in Ethiopia starts during February to April period depending on the time of first substantial rain in ' belg' or short rain season. Plowing is repeated 2 to 8 times, usually after each rain. The soil is easier to work when moist and after the first plowing. But *Maresha* which is the only tillage implement in use, because of its low output limits the secondary tillage capacity of the farmer who may be forced either to limit the cultivated area or to accept inadequate pre-planting weed control.

As draft animals are important components of seedbed preparation in Ethiopia it was felt that a basic study on the draft performance of the indigenous oxen be carried out (8). Studies on the effect of draft force on speed and work output under high and intermediate altitude conditions were carried out at two research centers; Holetta and Nazareth (2400 and 1550 m above see level, respectively). Similar studies on single animal harness were also carried out at Nazareth. Oval and circular test tracks of firm surfaces with zero slopes were used for a pair of oxen and single ox studies, respectively. Hydraulic loading carts were used to apply different levels of pull. A 0-5000N force transducer and an amplifier indicator was used to measure the pull. The distance traveled was measured using an odometer. The signals from the force transducer and the odometer were supplied to an integrated display (ID) unit for processing and simultaneous display of distance and work. Stop watches were used to measure working time.

The average working speed of Ethiopian oxen was found to be only 0.4 to 0.5 m/s (Table 1) while 1.1 m/s is a commonly reported speed for draft oxen. This low speed enabled the Ethiopian oxen to generate more pull (up to 100 kg for a pair of local oxen) and under the conditions of the study they performed best at a pull level of 15% of their body weight contrary to reports of 10% elsewhere (8). The oxen performed better at higher altitude. Also the v-yoke was found to be better than the neck-yoke for single animal harness.

Based on these results it was recommended that wider implements than *Maresha* be introduced for secondary tillage in order to alleviate timeliness problem through full utilization of the pulling capacity of a pair of indigenous oxen. It was also found that for the large number of farmers owning only one ox the introduction of a low draft tillage implement would be beneficial together with the single animal harness.

Collection, Evaluation and Modification of Implements

Tillage

During and prior to the survey, various types of plows were collected. The most important plows of the initial collection were ARDU plow, NARDI plow, SUBHASH plow, DANISH plow and *Maresha*. In 1984/85 comparative field tests were carried out but there was no significant differences among yields which was attributed to severe moisture stress in the season (4). It was recommended that more accurate equipment and techniques be employed to evaluate the plows. This led to the development of facilities for laboratory tests, (profilographic techniques) (5) and field tests (6). Extensive field and laboratory tests were carried out from 1985 to 1986. Modifications were made on the most promising prototypes and finally a plow named after Nazareth was developed (Fig. 1a). Field tests of this plow showed promising results (Table 1). The plow was also given to Agronomy/Physiology division for further trial (Table 1) who reported a 12% increase in maize grain yield comparing the moldboard plow with *Maresha* (7).

Field demonstrations to farmers living close to the research center were also made and feed backs were collected.

Table 1. Effect of plough type on growth and yield of maize

Type of plough	Stand count at harvest (000 Pl/ha)	Seed yield (Q/ha
Maresha	5.30	22.84
Nazareth Plough	5.60	25.52
$LSD_{0.05}$	0.260	1.54

The following were the most frequent complaints of the farmers about Nazareth Plow.

1. The plow was too heavy
2. The handle was not comfortable
3. The depth adjustment and attachment system were too sophisticated.

Based on the feed backs collected a series of modifications were made on the plow and finally the 'Erf' and 'Mofer' attached Mouldboard Plow was developed (Fig. 1). As the name implies the plow incorporates the moldboard plow bottom that was found to be superior to *Maresha* in terms of field performance with the simple, light weight and low cost components of *Maresha* viz; the 'Erf' (handle), the 'Mofer' (beam), and 'Merget' (a rope used for attachment). A portion of 'Deger' (the wooden wing of *Maresha*) was also used to stabilize the plow.

Field test showed that the plow operated deeper and wider than *Maresha* (Table 2). The draft power requirements did not show appreciable differences. However, it has been observed during field tests that the draft power requirement of the moldboard plow can greatly vary with the width of cut. Farmers can, therefore, adjust the width of cut depending on the power out put of their oxen. The field capacities were also the same because *Maresha* left unplowed strips which enabled it to cover the field quickly.

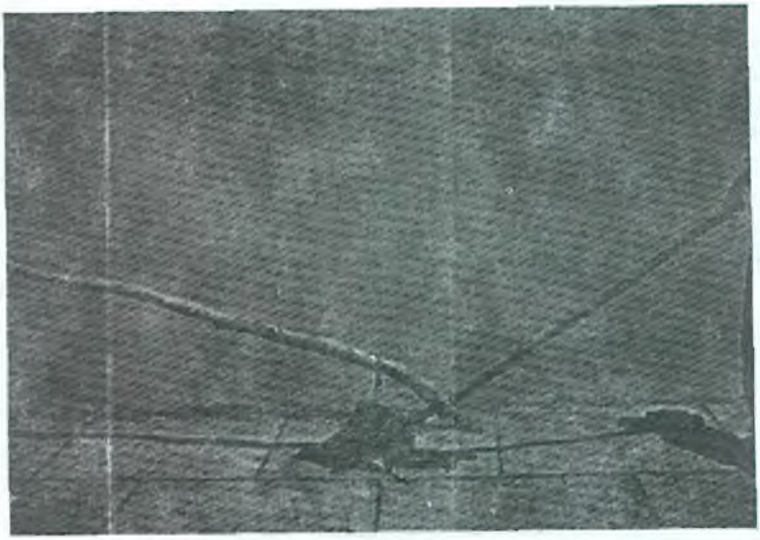

Fig. 1 The "Erf" and "Mofer" Attached Moldboard Plow

Table 2. Field Performance of *Maresha* and the *Erf* and *Mofer* Attached Moldboard Plow.

Parameter	Maresha	Erf & Mofer Attached Mouldboard Plow
Draft power (kg)	103.6	104
Cross-sectional area of furrow (cm^2)	209.2	315.6
Unit draft (kg/cm^2)	0.52	0.34
Working depth (cm)	9.28	12.8
Effective width of cut (cm)	16.67	23.33
Field capacity (ha/hr)	0.047	0.05

The plow was also verified by the Agricultural Economics Division of NRC. They reported that the plow was able to kill some thick-steamed weeds that are missed by *Maresha*. Some farmers also commented that the plow would do the same soil disturbance in a single pass that would need two passes with maresha. They found the depth adjustment and attachment system to be simple. Farmers also failed to appreciate the weight differences between the new plow and *Maresha*. The new plow weighed 16.8 kg while *Maresha* weighed 14.8 kg with the same *Erf* and *Mofer*.

According to studies conducted at AIRIC the cost of production of the new plow was about Birr 148 while that of Nazareth plow was Birr 289 which is nearly double . The cost of production was reduced so much because the metallic handle plow involved 11 kg of metal while the new plow had only 5 kg of metallic part.

Row planter

Row planting improves crop productivity by controlling plant population and facilitating improved cultural practices such as inter-row weeding and tie-ridging. AIRIC has made several attempts to introduce animal drawn and manually operated row planters. Among these are a two row animal drawn row planter, a *Maresha* attached seed drill, Rotary Jab Planter, and Earthway hand pulled precision planter. All of these planters were developed based on the most common metering mechanism that involves ground wheels to rotate seed plates. Such a mechanism has been successful in the tractor drawn row planters which are sufficiently heavy and operated in a well prepared seed bed. However, in rough and cloddy fields of the small scale farmers the rather light weight and small ground wheels failed to rotate effectively. The Indian hand metered planter, on the other hand, was found unsuited because Ethiopian farmers employ whips to guide the animals which prohibits a second operator walking nearby. Moreover, dropping seeds into the funnel required intensive training because there was no mechanism to assist the operator in regulating the seed rate and distribution. Therefore, a new type of animal drawn row planter was developed that is operated by the plowman with a mechanism to control the seed release. The operation is such that a pipe is rotated over 90 degrees in reverse directions corresponding to the foot steps of the operator. Seeds are released in every stoke by a moving plate that is provided with holes made depending on the size and rates of seeds to be applied (Fig. 2).

The planter was tested in comparison with dibbling seeds behind the plow and broadcasting. The results are shown in Tables 4 and 5. The field capacity of the row planter was about 4.5 times higher than broadcasting. This was because more time was spent in covering broadcast seeds with *Maresha* whereas the row planter operated at a width of 120 cm. Dibbling behind the plow required even more labour and time because a second person was necessary to dibble seeds behind the plow man and that two passes were required to complete a single row.

A second test was conducted to evaluate seedling emergence (Table 5). The row planter resulted in higher seedling emergence percentages because of proper placement of seeds in the moist zone.

Table 4. Field efficiency of different planting methods

	Broadcasting and covering with Maresha	Dibbling behind the plow	Row planter
Field capacity (ha/hr)	0.029	0.023	0.134
Labour requirement	1	2	1
Man - hr per hectare	35	86.67	7.4

Table 5. Percentage seedling emergence of different planting methods

	Row planter	Broadcasting
Rep. 1	62.9	45.1
Rep. 2	66.1	41.8
Rep. 3	70.1	47.7
Mean	66.37	44.87

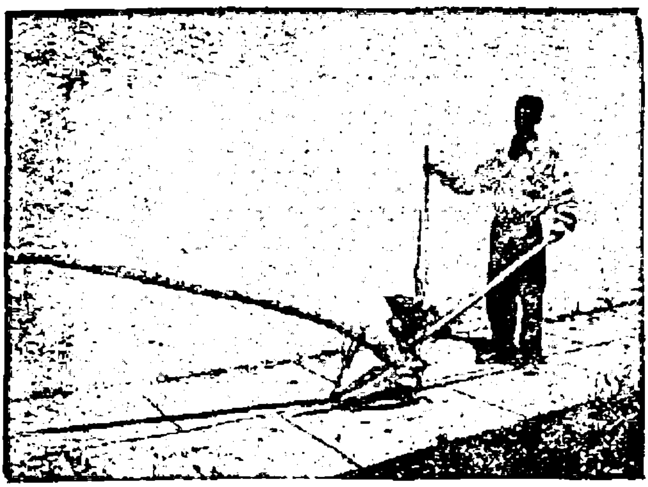

Fig. 2. The Hand Operated Animal Drawn Row Planter

Ridge-Tier

Tied ridges are made by closing furrows at intervals in order to catch and hold rain water and minimize surface runoff and improve down ward infiltration of water. Tied ridges increased grain yield of sorghum (Prentice, 1946, Kidane, 1982 and Adjei-Twum, 1987), maize (Prentice, 1946, Dagg and Macartney, 1968 and Senayit, 1984), cotton (Lawes, 1961), millet (Hanisch, 1974) and groundnut (Lawes, 1966).

Experiments conducted at Kobo, Mekele and Melkassa (Nazareth) showed that grain yield of sorghum, maize and mung bean were significantly increased by using tied ridges compared to flat seed bed particularly in drier years. At kobo & Mekele over 50% increase in yield was recorded for sorghum.

Considerable amount of labor is required when making tied-ridges by hand with hand hoe and it remained to be the major limitation for the adoption of tied-ridging practice by Ethiopian farmers. Availability and popularization of appropriate implements was underlined by researchers for adoption of this practice. (Hailu and Kidane, 1988). The Agricultural Implements Research and Improvement Center (AIRIC) of the Institute of Agricultural Research(IAR) explored ways of mechanizing construction of tied-ridges. The work started with ridge-tier attached to an imported ridger. The imported ridger was heavy, with chain attachment instead of a beam and two handles for control and finally AIRIC has developed a simple and appropriate animal drawn *maresha* attached ridge-tier (MART) as shown in the Figure.

Operation of ridge-tier

As the *Maresha* moves forward forming furrows, the spade attachment (tying unit) which is attached behind the *Maresha* is made to collect soil and widen the furrow formed by *Maresha* by lightly holding it down with the handle. The tying unit is lifted about 17 cm above the ground level after a recommended tie interval, and then dropped back in order to tie the furrow with the collected soil. As the process is repeated along the plot series of basins are made, separated by ties.

This implement was tested in comparison with manual tying (*Maresha* made ridges tied using hand hoe) as a control at Melkassa Research center on light soil with moisture content of 19% (db) and the results are summarized in Table 1. The results indicated that the *Maresha* attached ridge tier was 4 times more efficient in terms of time than manual ridge tying and the furrow cross-sectional area obtained was 1.14 times greater which allows more water to accumulate during a rain thus creating a larger moisture reserve. The draft requirement of the implement was found to be within the capacity of a pair of Ethiopian oxen.

At an average tie spacing of 2.5 m and ridge spacing of 75 cm the implement worked 0.17 ha/hr. It also removed the drudgery of manual tying. Extensive use of this implement could increase the number of hectares that can be tied ridged in moisture stressed fields and there by increasing crop production.

Since this *Maresha* attached ridge tier is proved to be technically viable, trouble free, efficient in the field and since it is easy to assemble, adjust, manufacture and maintain under local conditions, it could be easily accepted and adopted by the end users if introduced in large number.

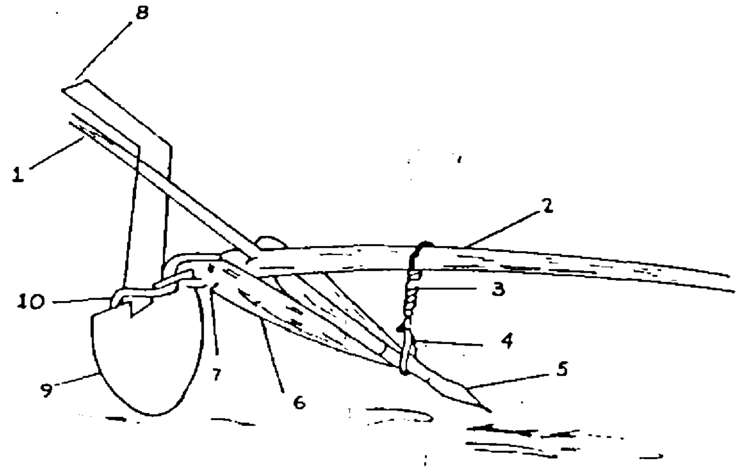

Fig. 3. "Maresha" attached ridge tier

1.	Handle	2.	Beam	3.	Rope	4.	Hook
5.	Spear point share	6.	Board	7.	Pin	8.	Handle (tying unit)
9.	Tying blade (disc)	10.	Attachement to "Maresha"				

Table 1. Test Results of Manual Ridge Tying and MART

Observation	Manual Ridge Tying	MART
Soil Moisture (% db)	18.5	19.0
Plot size completed (m^2)	300	300
Ridge width (cm)	49	52
Max. ridge height (cm)	17.7	16.9
Tie-height (cm)	17.2	14.0
Cross-sectional area of furrow on each pass (cm^2)	429	487
Tie-ridge spacing with in the row (cm)	253	248
Draft (N) -	875	
Time taken to complete operation (hr)	0.583	0.140
Number of ties made in the plot	109	123
Number of ties per hour	187	897
*Labour requirement (man-hr/ha)	28.5	6.1

* Labour requirement was calculated using an average tie-spacing of 2.5 m and ridge spacing of 75 cm. MART:- "Maresha" Attached Ridge Tier.

Weeder

The use of draft animals is limited to very few agricultural operations like primary tillage, clod breaking, seed covering & threshing by trampling. Farmers do not use animal drawn weeders other than *Maresha* used at time of Shilshalo. Hand pulling of individual weeds and use of inefficient weeding tools is the common practice of weeding in Ethiopia. The farmer is usually short of time to carry out this operation.

Effort was made at AIRIC to use animal drawn mechanical weeders for inter-cultivation. Three different prototypes of inter-row cultivators, five tine adjustable cultivator, five blade adjustable hoe, and adjustable duck foot cultivator were tested using single ox. The spacing between rows was 75 cm and the width of operation was adjusted to 60 cm. The major problem observed was crop damage. The weeding efficiency could be increased at the expense of high crop damage.

An expandable Bulgarian animal drawn weeder was tested at AIRIC using single ox. A mechanical damage was observed though the ox was trained before the test. The problem was keeping the animal with in the row despite the three people involved. The damage was about 7% & it was substantial. Therefore the use of the weeder was not successful.

A wheel hoe attached weeding tools were developed at AIRIC and performances were investigated with the assumption that this kind of equipment could reduce drudgery of weeding compared to digging hoes. Comparative test was conducted among "A" blade wheel hoe, straight blade wheel hoe and hand pulling. Wheel hoe weeders were found to work 4 times faster than hand pulling. In hand pulling, the weeds were not totally uprooted and therefore, were able to recover easily which implies lower weeding efficiency. The difference in plant damage was found to be non-significant at 5%. However, wheel hoe weeders can only be used with row planted crops and are best suited to friable soils.

Table 6. Performance of wheel hoe attached single "A" blade and straight blade weeding tools.

	Time needed man-hr/ha	Weeding efficiency	Plant damage %
Hand weeding	169.9	32.5	2.1
"A" blade Wheel hoe	41.7	75.0	1.5
Straight blade wheel hoe	41.8	71.7	1.6
LSD 5%	34.9	22.7	NS
SE	79.1	5.8	0.4
CV%	18.2	16.8	42.5

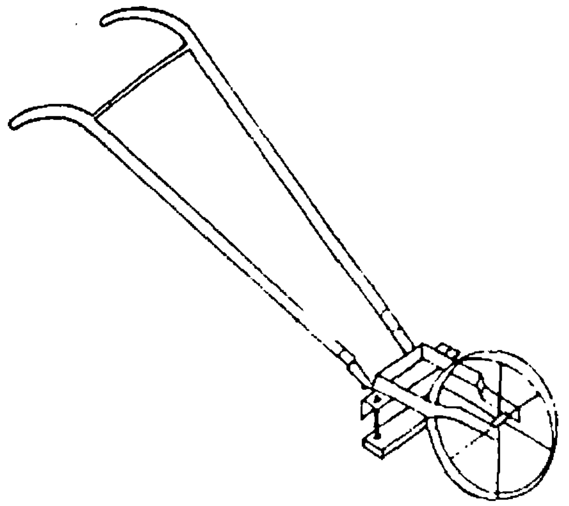

Fig. 4. Wheel hoe weeders

Future Trends

Research on the development of suitable tillage implements is being conducted to improve the moldboard plow and to introduce a tine plow for low draft power and higher depth of operation during primary tillage and a wider operation with minimum soil inversion during secondary tillage.

For farmers owing only one or no ox, the traditional beam (Mofer) is being modified for single ox operation. Field testing of land preparation implements have so far been focused on maize crop. Future tests should also include other crops such as sorghum, haricot bean and tef.

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REVIEW OF IMPROVEMENT EFFORTS ON HARVESTING IMPLEMENTS

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Abstract

The paper reviews crop harvesting practices and associated problems, and efforts made at Agricultural Implements Research and Improvement Center (AIRIC) to solve these problems. The use of improved technology for harvesting, threshing and shelling of crops by farmers is very limited. Most of the traditional tools used suffer from poor design and fabrication which results in inefficient use of power, poor quality of work, low output and quick wear of working parts. In some of the operations human and animal efforts is not assisted by any tool or implement. Therefore, these brings delay in harvesting which results in a loss of up to 20% caused by rain, heat, rodents and insects. In efforts made at AIRIC, different prototype implements for harvesting, threshing and shelling were collected and evaluated. Promising prototypes were selected and further developed. A threshing-shelling machine for wheat, barley, tef and maize, driven by 5 - 8 Hp. engine is on extension stage. A low power, hand or small engine driven, maize sheller is developed for farmers who have no access to bigger shellers. Regarding harvesting implements evaluation of single axle reaper, scythe and root crop (potato and ground nut) harvester were done. Scythe was found to be suitable for harvesting pasture and at relatively high moisture content for wheat and barley. Single axle reaper was found to perform better than the traditional method. 'Selam' root crop lifter was also found to be promising than conventional method.

Introduction

Harvesting operation includes cutting and collecting of matured crops, threshing or shelling and separation of the chaff from grain. It is known to be the most important, but most tire some and labour consuming operation. It is given second priority in survey made to identify crop production constraints in 1985/86 by AIRIC. Most of the traditional tools used is of low efficiency. The use of improved technology by farmers is very limited. Mechanical-powered crop harvesting machinery is little known except in the state farms and to some extent in the agricultural co-operatives.

Efforts were made at AIRIC to improve this situation. Different prototypes for harvesting, threshing and shelling implements were collected, and evaluated, and some of the prototype were further developed. For harvesting cereals and pasture sickle, scythe, single axle tractor reaper were evaluated. A threshing-shelling machine for wheat, barley, tef and maize driven by 5-8 hp engine is developed by successive improvement of ARDU thresher. A low power hand or small engine driven, maize sheller is developed for farmers who have no access to bigger shellers.

Crop Harvesting and Threshing Practices of the Farmers

At the end of the rainy season, many crops mature and are ready for harvest at the same time, creating peak in labour requirement. According to the information collected in Shoa region. it takes 100 hrs, 125 hrs, 200 hrs and 210 hrs to harvest a hectare of maize, sorghum, tef and wheat, respectively using the locally made sickle (3).

In the absence of proper equipment and because of the advantage of dry weather after harvest, threshing of most crops in Ethiopia progress slowly. Crops like teff and wheat are frequently stacked after harvest and threshed in small amounts at a time. Storage of harvested crop in the open for long periods is likely to result in grain losses of up to 20%. This may be caused by rain, heat, rodents and insects (2).

The threshing season usually lasts for 2-3 months. The threshing floor is prepared by smearing the ground with cow dung and left to dry for sometime. It has a diameter which range from 10-15 meters. During threshing the lose crop is laid on the floor and several oxen tread on it. The oxen go around on the threshing floor over the crop for sometime and are taken out to turn the unthreshed crop from the bottom up and spread it laying the heads up for efficient treading. Depending on the variety and condition of the crop there can be 7-11 treading for ½ - 2 hrs.

Threshing with animals need skill and energy to keep the animals moving around the threshing floor. Usually, the best trained animal is used as the pivot in the center of the ring while other animals circle around. During the operation care is taken not to under thresh. High mortality of cattle occurs because of strain during the long threshing period (1).

Manual threshing is usually done in some parts of the country, using *dula*. Usually a team of four or more person beat the pile of harvested crop with the stick to loosen the grain from the head.

In the process of threshing a two prong wooden fork called *Mensh* is used for raking the crop on the threshing floor to loosen the crop heap and bring the unthreshed material to surface. The three pronged pick fork called *Mensh* is used for separation of straw from threshed grain and for straw handling. *Laida* is also a typical Ethiopian tool used to assist winnowing operation. Threshed grain is picked up in the shovel and dropped from a height to allow separation of chaff in a moderate breeze. *Aferssa* or *Maragebia* is used to separate fine chaff from the grain heap and is commonly used for tef. *Wonfit* or *Gengilcha* is used for cleaning small grains (3).

Most of the tools used suffer from poor design and fabrication and the material of construction of the working parts is generally mild steel. This results in efficient use of power, poor quality of work, low output and quick wear of working parts. In some of the operation human and animal effort is not assisted by any tool or implement (3). The traditional threshing practice involves much processes such as trampling turning, winnowing, sweeping and gathering which is time consuming, tedious with unfavorable working condition and incurs grain damage, loss and quality deterioration. According to the 1985/86 survey results made by AIRIC, threshing operation stands second priority problem to be tackled.

To overcome these problem of harvesting and threshing, efforts were made at AIRIC. Different implements for harvesting, threshing and shelling were adapted, evaluated and developed. Details of some of these efforts are reviewed here.

Improvement Efforts

Harvesting

Harvesting of corps in our county is widely done using sickle for cereals and pasture and hoe for root crops. The available hand tools are simple in design and cheap enough to be afforded by most farmers. However, they are laborious, tiresome, time consuming and have little mechanical advantage, which could be costly affair during peak harvesting period where labor shortage is a problem. Farmers suffer from back pain and physiological stresses after a serious of harvesting days performed with these hand tools.

The efficiency of these hand tools is very low and thus is not possible to complete the harvesting operation in time. These delay in harvesting results in yield loss. On the other hand, timeliness is critical in harvesting operation. Therefore, developing efficient implement within the techno-socio-economic conditions of the farmers is crucial.

With this objective AIRIC have been trying to evaluate the performance of different harvesting equipments such as sickle, single axle reaper, scythe and animal drawn groundnut lifter.

Evaluation of single axle tractor reaper for harvesting wheat

Diversified and average-sized mechanically powered harvesters (10-12 hp) have already been designed and are in commercial production in most developing countries. These machines are less sophisticated than combine harvesters and the straw recovery is complete, which is desirable for Ethiopian farmers. The power required for such harvesters is low, they are very simple for farmers to operate and maintain, and they are versatile under adverse topographical situations. Therefore, it was found to be essential to investigate and identify appropriate size crop harvesting machinery which is suitable for small fields capable of working under variable topographical conditions. To meet this objective comparative test of single axle tractor reaper were carried out with traditional harvesting method.

The result shows that (Table 1) there is great difference between treatments in field capacity and straw recovery efficiency at both locations while their is no significant difference for field losses at both locations. The reaper is recommended for socio-economic studies (AIRIC Progress Report 1991).

Table: 1. Performance of single axle tractor reaper and sickle on wheat at Holleta and Kulumsa.

Wheat Variety	Mode of Harvest	Capacity ha/hr.	Losses %	Straw recovery %	Location
IAR-609	Reaper	0.192	5.21	82.27	Kulumsa
	Sickle	0.016	2.55	54.90	
Dashin	Reaper	0.214	2.15	79.35	Holleta
	Sickle	0.024	2.15	49.49	

Scythe for harvesting of wheat, barley and pasture

The implement farmers broadly uses for harvesting is of low capacity. It does not allow timely harvesting. Mechanically powered harvesting equipment is beyond the means and economic reach of most small scale farmers. Scythe had been used for long time and is still in use for harvesting in most part of the world. With the objective of filling this gaps study was made on scythe for harvesting pasture, barley and wheat. Comparative test of performance were conducted on scythe and sickle at Holleta for harvesting pasture, wheat and barley.

On Pasture. Two types of scythe (curved and straight handle) and a sickle were tested at Holleta on field of natural pasture.

From the result (Table 2), scythe is found out to be efficient when compared to sickle. Working ratio of straight handle scythe to sickle is found to be 7.8:1 and of that of curved handle scythe to sickle is 6.3:1. Among the two types of scythe straight handle is found to perform well in both cutting efficiency and cutting quality. For cutting quality sickle is the best among the three and among the two scythe, straight handle is good (AIRIC Progress Report 1993).

Table - 2. Performance of scythes compared to sickle on pasture

	Capacity (hr/ha)	Height of cut (cm)
Straight handle scythe	30.15	11.57
Curved handle scythe	37.80	17.97
Sickle	234.00	6.84

On Wheat and Barely. From observation trials for curved handle scythe, loss due to shattering and conveying was found to be high. Because of this, curved handle scythe is left out from treatment and testing were done only on straight handle scythe and sickle on wheat and barely field at Holleta.

The result shows (Table 3) that for both wheat and barley, scythe is efficient in working capacity, ratio of scythe to sickle 3:1 and losses were found to be higher for scythe on wheat. There is no difference in harvesting losses on barley for both sickle and scythe. In both cases, losses were found to be high (37%). The reason for these might be due to the low moisture content and shattering nature of the crop. Generally, using scythe for harvesting of cereal (wheat and barley) the moisture content should be relatively high and special modification should be made to scythe by adding structure which reduce conveying losses (AIRIC Progress Report 1993, 1994).

Table 3. Performance results of scythe and sickle for harvesting wheat and barley

			Harvesting loss (% by yield)			
Crop	Implement	Capacity hr/ha	Conveying	Fallen	Uncut	Total
Wheat	Scythe	20	3.49	11.05	1.25	15.79
	Sickle	74.27	1.91	3.15	0.78	5.84
Barley	Scythe	25	18.81	13.76	2.6	35.17
	Sickle	68	10.7	24.22	2.11	37.03

Evaluation of groundnut lifter

In Ethiopia groundnut is harvested manually and produced in areas where there is labour shortage during harvesting period. Due to labour and money constraints farmers can not afford to hire casual labour during this period and this remains to be a constraint to increase groundnut production. Most of the farmers have a pair of oxen and there is a need to introduce an animal drawn groundnut lifter that increases labour productivity and reduce drudgery.

To select suitable ground nut lifter four animal drawn groundnut lifting implements, namely; potato digger, local plow, *Marsha*, moldboard plow and V-type groundnut lifters were tested on Roba ground nut variety and compared to conventional lifting method.

Table 4. Groundnut lifting performance of different implements at Melkassa Research Center.

Parameters	Potato digger	Moldboard plow	Maresha	Groundnut Lifter	Manual lifting using hoe
1. Soil moisture(%)	3.46	3.28	4.05	3.90	4.16
2. Bulk density(gm/cc)	1.12	1.07	1.08	1.16	1.13
3. Actual field Capacity (hr/ha)	13.82	13.82	13.24	13.24	234.11
4. speed of the oxen (km/hr)	2.933	2.61	2.727	2.987	0.073
5. Exposed pods (%)	67.47	55.21	63.67	40.71	100.0
6. Unexposed pods(%)	32.53	44.79	29.90	21.40	0.0
7. Undug pods (%)	0.00	0.00	6.43	24.91	0.0
8. Separated pods (%)	0.00	0.00	0.00	12.98	0.0

$$\text{Percentage of exposed pods} = \frac{G}{A} \times 100$$

Where

G = Quantity of lifted pods lying exposed on the surface by mass, and

A = Total quantity of pods collected from the plants in the sample area by mass

$$\text{Percentage of unexposed pods} = \frac{H}{A} \times 100$$

Where

H = quantity of lifted pods but remained inside the soil in the sample area by mass, and

A = total quantity of pods collected from the plants in the sample area by mass

$$\text{Percentage of undug pods} = \frac{K}{A} \times 100$$

Where

K = quantity of pods remained in the undug plants in the sample area by mass, and

A = total quantity of pods collected from the plants in the sample area by mass

$$\text{Percentage of separated pods} = \frac{C}{A} \times 100$$

Where

C = quantity of pods separated from the main plant and dispersed in the sample area by mass, and

A = total quantity of pods collected from the plants in the sample area by mass

From the result (Table 4) it was observed that the potato digger, local plow, *Marsha*, moldboard plow and V-type groundnut lifter had an exposing efficiency of 67.5%, 63.7%, 55.2% and 40.7% and time taken was 13.8 man-hour/ha, 13.5 man-hour/ha, 13.8 man-hour/ha and 13.2 man-hour/ha, respectively. The conventional method of pulling the plant from the ground with the help of hand hoe took a very long time (234.1 man-hour/ha). Leaving the pod in the ground after it matures will result in infection by fungus, which is a serious problem in groundnut producing areas. Hence, the potato digger is preferred out of the rest due to high exposing efficiency and saving labour and time as compared to manual lifting (AIRIC, 1994).

Threshing

Development and evaluation of threshers

To overcome farmers threshing problem, the Chillalo Agricultural Development Unit (CADU), later on Arsi Rural Development Unit (ARDU) took a number of initiations to develop threshers. ARDU developed an eight Hp diesel engine driven non-cleaning type wheat and barley thresher. AIRIC started development of thresher by collection and evaluation of different prototypes out of which ARDU thresher was selected for further improvement. In addition to this, other threshers were tested upon request and for design purpose.

Keeping the basic mode of operation of the original ARDU=s non-cleaning barley and wheat thresher, with all necessary changes, IAR redesigned and developed a new non-cleaning thresher. With the objective of making IAR non-cleaning thresher a multi-crop cleaning type thresher, two types of concave of 12 mm for maize and 6 mm openings for wheat, barley and tef were designed and fabricated. Both of these concave are replaceable types depending on the type of crop to be threshed. A guard was also added on the feed inlet to stop grains from hitting back the operator. Part of the shoot was replaced with canvas to reduce weight of the thresher. Three different sizes of pulleys with diameters of 360 mm for maize, 115 mm for tef, 180 mm for wheat and barley were fabricated.

The shelling-threshing machine was tested on tef (mixed variety) and wheat (dashen mixed with other varieties). Threshing capacity of 122 kg hr^{-1} on tef and 450 kg hr^{-1} on wheat were obtained and the grain breakage (loss) was not more than 5% (Tables 5 and 6). Highest specific energy, 20.3 Kwh/ton, was recorded on tef and lower specific energy, 3.16 Kwh/ton, was recorded on wheat. The threshing and shelling capacities of the machine are 2.2 man-machine hr qt^{-1} for tef and 1.6 man-machine hr qt^{-1} for wheat which is much better than traditional practice of oxen treading which is recorded in literature as 10.1 man hours and 12.2 oxen hr qt^{-1} (1). Development of cleaning type of thresher is on progress.

Optimum operational speed, concave-drum clearance is indicated in Table 7 and should be considered to use the machine to its full potential.

Table 5. Test conditions and performance of threshing shelling machine in tef threshing trial (Wolenchiti, April 1989).

Description	Test condition and performance
Moisture content (%)	
Grain	15.43
Straw	10.09
Chaff	11.37
Grain/straw ratio	1:1.52
Losses (%)	2.23
Capacity kg/hr^{-1}	105.00
Energy requirement $Kwht^{-1}$	16.72
Labor requirement man-hr t^{-1}	19.36
Speed (RPM)	1200.00
Clearance (mm)	8

Table 6. Test conditions and performance of threshing-shelling machine in wheat threshing trail (Holleta Genet, December 1986)(4).

Description	Test condition and performance
Moisture content (%)	
Grain	13.75
Straw	10.6
Grain/straw ratio (wb)	1:1.26
Losses (%)	4.05
Capacity kg/hr^{-1} (wb)	450
Energy requirement $Kwht^{-1}$	3.26
Labor requirement man-hr t^{-1}	7.65
Speed (RPM)	1134
Clearance (mm)	10

All measurement is on wet bases

Table 7. Recommended typical rasp bar cylinder peripheral speed for various crops and corresponding R.P.M. as calculated based on the IAR threshing shelling machine.

Crop	Speed(m. min^{-1})*	R.P.M**	Clearance
Wheat	1371 - 1676	991 - 1211	0.64 - 1.27
Maize	762 - 1200	551 - 868	2.50 - 3.20
Sorghum	1219 - 1524	881 - 1102	0.64 - 1.58
Tef	1219 - 1829	851 - 1322	0.15 - 0.79

Source:- * = (*FAO. 1977*)
** = Calculated based on diameter of IAR threshing-shelling drum.

Shelling

Development and evaluation of shellers

In efforts made to solve shelling problems, different implements were tested, evaluated and successful prototype of shellers which is driven by engine (8 Hp) was developed. The prototype (IAR thresher) which was originally used to thresh wheat and barley was modified to include maize. The modification was making replaceable concave with 12 mm opening and fitting 360 mm diameter pulley. The threshing-shelling machine can work both husking-shelling operation and shelling (Table 8).

Table 8. Performance of threshing-shelling machine in maize husking-shelling and shelling trials.

	Husking-shelling	Shelling
Moisture content (%)	10.63	13.85
Grain to cob ratio	1:0.24	1:0.28
Losses (unshelled) (%)	2.65	9.01
Shelling efficiency (%)	97.35	90.99
Damaged grain (%)	0.66	4.47
Capacity (kg/hr)	1492.23	3060.00
Energy requirement ($kwht^{-1}$)	1.59	0.90
Labor requirement (man-hrt^{-1})	0.65	-

With the new modifications the additional maize shelling operation was successfully conducted with machine which was previously limited only to wheat-barley threshing.

A maize husking-shelling capacity of 1536 kg hr^{-1} and sole maize shelling of 3060 kg hr^{-1} were recorded. The shelling capacity of the machine are much better 0.06 man machine hr q^{-1} of maize, than the traditional practice of oxen treading which is recorded in literature as 10.1 man hours and 12.2 oxen hr q^{-1} (1).

For farmers who have no access to engine or tractor, hand (manual) operated sheller was developed. This machine can also be powered with small engine (1.5 hp). The machine was developed by modifying the Indian made cossul sheller. The performance of the modified prototype compared to the original cossul sheller and conventional shelling is shown in Table 9.

Table 9. Performance result of AIRIC sheller compared to cossul and conventional shelling tested at AIRIC

	AIRIC			
	Hand	Engine (1. 5 Hp)	Cossul (1. 5 Hp)	Engine Conventional*
Capacity (kg/hr)	306.04[a]	171.93[b]	123.66[b]	6.36[c]
Shelling efficiency(%)	97.62[a]	89.83[b]	84.00[b]	100.00[a]
Blown grain (%)	3.41[b]	1.09[c]	11.64[a]	0[c]
Breakage (%)	0.85[a]	0.53[b]	0.98[a]	0[c]
Energy requirement (kwh/tone)	3.03[b]	0.58[c]	5.40[a]	-

*Conventional - using bare hand or rubbing one to another; @ - LSD test at 5% level

Result of the test shows the AIRIC sheller is superior to both cossul sheller and conventional shelling. Its output is three fold compared to that of cossul sheller when both are driven with the same power unit (1.5 Hp). In manual operation AIRIC sheller has a 40% capacity advantage over cossul driven by engine (1.5 Hp). The energy expended for cossul as recorded is 100% greater to AIRIC sheller with engine driven and 1000% greater by manual shelling, the energy saving is an advantage. Breakage and loss is minimum, cleanness is to the required level. The result also shows that it takes more than 25 hours to shell about 170kg of maize by conventional method which is shelled within an hour using AIRIC sheller.

The modified machine is manufactured from easily available material and could be manufactured at simple local workshop. To facilitate transport wheel is provided. Operation and adjustment is easy, moreover it needs minimal maintenance. The sheller is suitable for farmers who are away from the main infrastructure, where bigger sheller may not be available even on rental bases (5).

Conclusion and Recommendation

In efforts made to solve harvesting problems successful results were obtained in development of multipurpose (barley, wheat, tef and maize) threshing-shelling machine. The machine is successful in maize shelling which can work both husking-shelling and shelling operation. In threshing of wheat, barley and tef, low capacity of the machine is the area that need improvement. Development of cleaning type of thresher which started recently should be given much attention. Provision of flexible wheel, if possible, old pneumatic tire, so that it can easily be taken to field either by oxen or pulled by station wagon with out need of labour is a necessity.

Even though efforts were made towards solving the problem of harvesting so much remain unsolved and much consideration is needed.

Basic information on harvesting losses due to use of traditional practice and delay in harvesting and threshing and other different factors are not studied well which may be helpful to concentrate efforts in areas with higher losses.

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REVIEW OF RESEARCH AND DEVELOPMENT ON POST-HARVEST EQUIPMENT AND FARM POWER

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Abstract

The introduction of resource-saving techniques, the need for greater efficiency, the protection of the environment, the improvement of food quality and animal welfare called for the establishment of agricultural mechanization research in Ethiopia in 1952, which was later transformed to AIRIC (Agricultural Implements Research and Improvement Center) in 1976. AIRIC has been undertaking research on pre-harvest, harvest and post-harvest areas to design and develop agricultural implements and equipment suited to the socio-economic conditions and different agro-ecological zones of Ethiopia. Among these, development of post-harvest technology has brought about an enormous increase in productivity and reduction in crop losses. Post-harvest equipment research work embraces activities from basic studies to prototypes development and testing. Since then attempts have been made on eighteen research projects in this area. Promising prototype equipment developed recently include: enset processing devices, donkey cart, sorghum dehuller and grinder, harness; and basic data generated include: effect of draft on the performance of draft animals, draft capacity of cross-bred oxen in low altitude areas, and anthropometry. Details of these and briefs of the rest of research projects on post-harvest area are reviewed here. From the research work and the outcomes so far, undertaking research in this area is found relevant and pertinent to the development of Ethiopian agriculture, though this area still lacks trained manpower and the necessary facilities. Therefore, to improve research methodologies and approaches on post-harvest technology this area has to be strengthened and equipped with trained manpower and the necessary facilities.

Introduction

The agricultural soils of Ethiopia are relatively fertile and very high yields of various crops are attained on research stations. Similarly, the climatic conditions, on the whole, are favorable for intensive crop cultivation. However, the average yields of major crops at farmers' field are very low and not more than half of the available land under agriculture is put into production in any one year. Thus, the Ethiopian peasant farmer is severally handicapped and is not able to take the full benefits of the country's agricultural potential. The reason could be attributed, mainly, to the none availability of appropriate agricultural equipment, implements and tools in the country.

The importance of agricultural mechanization (improved equipment, implements and tools) has been recognized in Ethiopia for many years. Immediately after the second world war, hand tools and animal drawn implements were imported and distributed to farmers by relief and religious organizations. Some work on design and development of improved implements and tools has been carried out at ARDU (Arsi Rural Development Unit), at Bako under the Ministry of Agriculture and in the Agricultural Engineering Department of IAR (Institute of Agricultural Research). However, none of these locations had the "critical mass" in terms of physical facilities and expertise to successfully undertaken research and development work on agricultural mechanization on a continuing basis.

Therefore, in order to contribute effectively to the national endeavor to increase agricultural production, the Ethiopian farmer need improved implements and tools to enable him to raise the standard of cultivation, crop care, cultivate more land and to raise the intensity of cropping with the available draft animal power. Institutionalized research and development in puts are needed to bring about an improvement in the essential agricultural equipment within a short period and on continuing basis. This important need has been recognized by the government and as a first step towards better coordination, the responsibility for design and development of agricultural mechanization has been transferred from different organizations to IAR and in 1976 AIRIC (Agricultural Implements Research and Improvement Center) was formally established for this purpose.

Since its inception AIRIC has been undertaking research development and testing on pre-harvest, harvest and post harvest agricultural equipment and implements suited to the socio-economic conditions and different agro-ecological zones of the country. Therefore, the objective of this paper would be to review, analysis and assess the achievements (along with weakness and strength) of AIRIC research and development program on post-harvest and farm power activities executed during the 1976-1995 period.

REVIEW OF COMPLETED OR NEARLY COMPLETED POST HARVEST IMPLEMENT/FARM POWER STUDIES

Enset Processing Device

Enset, *Enset ventricobum*, is growing in the South and South West of Ethiopia. An estimated five to six million people in the country live wholly or partially on enset as a food. Enset food is prepared by fermenting the decorticated parenchyma tissues and pulverized enset corm together. There are two traditional methods of enset processing, namely the Gurage and Sidama method and the Kambata and Hadia method. These traditional enset processing methods are very crude and of no mechanical advantages. Hence, the objectives of this study were to develop efficient village level technology of food and fiber extraction and to
to ease the drudgery of enset decortication, kneading, squeezing and shredding.

Development work and results

In order to achieve the above objectives, a simple approach to the development work was established and four different devices were designed, developed and manufactured in AIRIC workshop. These devices were tested at various places in Sidama and Wolaita region. The results are shown below in Table 1.

Table 1. Technical performances of various enset processing devices

Stages of processing	Device	Capacity (kg/hr)	Work quality	Comparative advantage (ratio)
Psuedostem decortication	Flat plant	no data		
Corm pulverizing	Rotary blade	28.5	fine	2.24:1
	Traditional	12.7	coarse	
"Bulla" squeezing	Piston press	0.23	good	2.86:1
	Traditional	0.08	fair	
Dough kneading	Centrifugal	0.91	good	1:1.49
	Traditional	1.30	v. good	

Conclusion/Recommendation

Although there is no qualitative field testing data for psuedostem decortication for both improved and traditional devices, it was found out that the improved flat plant decorticator is more better than the traditional device in argonomic aspects. As a result, the users has accepted the device and the rural technology department of the MOA has produced and distributed large quantity of the device to users in Sidama and Wolaita regions. The rotary blade corm pulveriser could be recommended for socio-economic studies after minor technical improvements. The wooden piston press type "Bulla" squeezer is recommended for socio-economic studies.

Future Work

Some improvement work shall be continued on the centrifugal dough kneader.

Improvement of Transport Capacity of Donkey Carts

Even though donkey carts are extensively used in Southern Shoa, observation on their performances indicated that their rolling resistance is high, their durability is less, they are unstable and hence their transport capacity is very limited. In order to improve the transport capacity of such carts details studies were undertaken in AIRIC. The main objective of the study was to improve the transport capacity and durability of the existing Ziwai cart.

Development work and result

A study was conducted on the performance and a new cart was developed and compared with the existing cart and as a result the following data are collected as shown in Table 2.

Table 2. Field performance of Ziwai and AIRIC donkey carts

Live load (kg)	Ziwai Cart			AIRIC Cart		
	Horizontal pull (kg)	Speed (m/s)	Capacity (ton-km/hr	Horizontal pull (kg)	Speed (m/s)	Capacity (ton-km/hr)
100	14.8	0.88	0.13	6.8	0.95	0.34
200	22.9	0.84	0.19	11.6	0.90	0.68
300	30.0	0.80	0.24	17.5	0.86	0.93
400	-	-	-	22.8	0.82	1.18
500	-	-	-	27.2	0.75	1.35
600	-	-	-	32.7	0.71	1.53

Conclusion and Recommendation

Field test results and feedback from farmers indicated that AIRIC donkey cart has shown about 200% improvement in loading capacity over Ziwai cart. Extension programs for the improved cart (AIRIC) should be undertaken extensively in similar topographic area in the country other than Ziway.

Future work

Field trials using one ox and improved single harness with the improved cart shown that an ox could pull up to 600 kg pay load for five hours in a day without showing abnormal sign of fatigue. Therefore, future work should consider the use of single ox as a power source for the cart.

Efficiency Assessment of PRL/RIIC Dehuller on Sorghum in Ethiopia

The Ethiopian Sorghum Improvement Project (ESIP) requested PRL/RIIC sorghum dehuller from International Development Research Center (IDRC) Candada to evaluate the milling qualities of improved sorghum varieties and advance lines. The responsibility of handling and operating the machine was given to the farm implements research section of IAR which emphasized on testing the performance and assess the economic feasibility for use by farming community and the suitability of the machine for local manufacturing and repair. The main objective of the work was to test the performance of PRL/PIIC sorghum dehuller of 13 stones, 250 mm diameter and 21 mm thickness under batch-system and continuous operation.

Results and Recommendation

In the batch-system operation it was observed that the highest percentage (81%) of dehulled grain and the best grade of 87.8% was recorded when the position of the air-vent opening was 25 cm^2, retention time one minute at 2000 rpm barrel shaft and with fan shaft speed 1700 rpm.
Results on the triple on continuous operation revealed that at three minutes retention-time setting the feed gate and dehulled grain out let to 3.89 cm^2 and 52.50 cm^2, respectively. The air-venting opening was set 75 cm^2 with fan shaft speed of 1800 rpm. These setting resulted an average extra rate of 84.7% with through-put rate of 292 kg/hr and power consumption of 2.29 kwh/100 kg of grain.

Future Work

Further trials need to be continued on different varieties of crops in order to evaluate its economic suitability to the peasant sector.

Draft Animal Power (DAP) Studies

Information on the draft performance of both indigenous and cross-bred oxen available in Ethiopia has been scarce. Farmers appear to hold reservation about the suitability of cross-bred male oxen for draft purposes. Therefore, a study on draft animal power was planned and executed during 1986-1988 period both at Holleta and Melkassa Research Centers with following objectives.

- to study the effect of draft force on the speed and work output of indigenous and cross-bred male ox under conditions of good feed and moderate climate.

- to study the effect of draft force on the speed and work output of indigenous oxen under poor feed supply and relatively high day temperature.

Results

The breed and weight status of oxen used in the experiment are tabulated in Table 3 and the experimental results are tabulated in Tables 4 and 5.

Table 3. Status of oxen used in the experiment

Place	Breed	Weight (Kg)
Holleta	Local (pair)	675
Holleta	Jersey X local (pair)	916
Holleta	Simmental X local (pair)	1115
Holleta	Friesian X local (pair)	1172
Melkassa	Local (pair)	758

Table 4. Average speed of cross-bred and indigenous oxen on three consecutive days

Breed-type	Harness method	Place	Pull (%body weight)	Speed (m/s)		
				Day-1	Day-2	Day-3
Holleta local	Pair	Holleta	10	0.70	0.68	0.68
			15	0.56	0.55	0.56
			20	0.35	0.35	0.35
Jersey x local	Pair	Holleta	10	0.81	0.81	0.78
			15	0.63	0.65	0.73
			20	0.50	0.47	0.45
Simmental x local	Pair	Holleta	10	0.80	0.80	0.79
			15	0.67	0.69	0.70
			20	0.50	0.49	0.50
Friesian x local	Pair	Holleta	10	0.74	0.74	0.77
			15	0.69	0.69	0.57
			20	0.49	0.53	0.57
Melkassa local	Pair	Melkassa	10	0.57	0.60	0.49
			15	0.44	0.44	0.38
			20	0.29	0.24	0.29

Table 5. Work output on different breeds of oxen at three level of pull

Breed-type	Harness method	Place	Pull (% body weight)	Work output (MJ)	
				Average	For 100 kg
Holleta-Local	Pair	Holleta	10	7.99	1.18
			15	9.38	1.39
			20	7.98	1.18
			Av.	8.45	1.25
Jersey X Local	Pair	Holleta	10	12.20	1.33
			15	15.21	1.11
			20	14.69	1.60
			Av.	15.33	1.53
Simmental X Local	Pair	Holleta	10	15.33	1.35
			15	19.44	1.74
			20	18.02	1.62
			Av.	17.60	1.58
Friesian X Local	Pair	Holleta	10	15.83	1.35
			15	20.16	1.72
			20	20.30	1.73
			Av.	18.76	1.60
Melkassa-Local	Pair	Melkassa	10	7.53	0.98
			15	7.71	1.01
			20	6.86	0.81
			Av.	6.54	0.96

Conclusion and Recommendation

The average work speed of indigenous oxen is only 0.4 to 0.5 meter/second against the work speed of 0.7 to 1.1 meter/second commonly known for draft oxen.

Average work speed of all cross-bred animals was observed to be 0.6 meter/second which is significantly higher than the local oxen.

The indigenous oxen, Jersey x local and Simmental x local performed best at 15% body weight pull whereas Friesian X Local performed best at 20% body weight.

For best performance of the draft oxen implements and tasks should be designed to require a force of 15-20% of the animal's body weight.

A pair of cross-bred oxen could produce a draft force of 200 kg or more which may be sufficient to perform tasks like harvesting which are generally considered too heavy for a pair of oxen.

The cross-bred oxen, under good management, out put per 100 kg body weight as compared to the indigenous oxen.

An indigenous ox weighing 250-300 kg can produce a draft force of 50 kg. This is adequate to perform secondary tillage operations and to pull a moderately loaded cart.

The cross-bred ox can produce a draft force of 80-100 kg which is adequate to meet the draft requirement of primary tillage operations.

Agricultural Implements and Crop Production Techniques Survey

The agricultural implements and crop production techniques survey was the fundamental activity in the first phase of the implementation of AIRIC project. The survey was carried out in six different regions of Ethiopia from June 1985 to June 1986. The survey sample comprised 24 peasant associations and 239 farmers spread over eight Awrajas with the objective of documenting the status of peasant agriculture and identifying implements related constraints to agricultural production.

Results

Holding size. Peasants holding size group of 1.01 to 2.0 ha was 62%; 0.10 to 1.0 ha was 24% and > than 2.0 ha was 14%. Regional differences in holding size distribution were noticeable. In Harrargie over 50% of holding were in size-group of 1.0 ha or less.

Number of land parcels per holdings. In 21 out of 24 peasant associations the number of land parcel per holding varied from 1 to 6. In two peasant associations in Shoa and one in Gondar the number of parcels per holding exceeded 6. The average size of a land parcel in all peasant associations was 0.3 ha or more.

Area under pasture. There was a wide variation in areas under pasture. In Shoa, Welega and Keffa the area under pasture accounted for 50% or more of the net cultivated area while 11 of 24 associations had relatively small area not exceeding 10% of the net cultivated land.

Tools and implements. The survey team have identified 31 tools and implements in use and all of them are locally made.

Farm power. Oxen are the main source of draft power while mules and donkey are used for pack works. Ten percent of the peasant farmers had no ox, 28% had one ox each, 45% had two oxen each and the remaining 17% has more than two oxen each. The peasant farmers assisted by their family carry out a large number of agricultural operations manually which has a substantial contribution to the farm power.

Working hours. The daily working hours for oxen are relatively short, varying from 4-5 hours.

Crop-production techniques. Information on cultural practices currently in use and type of implement in use are shown in Tables 6 and 7.

Peasant priorities. Peasant priorities for each association has been identified and summarized in Table 8.

Conclusion/Recommendations

Short term research program

- Animal drawn implement with high field capacity and effective weed control.
- Secondary tillage implement matching the single ox's draft capacity.
- Line sowing equipment both manually operated and animal drawn for seeding maize, sorghum and pulse crops.
- Improved sickle with prolonged sharpness of cutting edge, reduced weight with economically designed handle for wheat, barley and teff crops.
- Light weight, portable and multi-crop thresher for barley, sorghum, maize and teff.
- Single animal harness for the Ethiopian ox to perform low draft tasks.

Medium term research program

- A soil inverting plow with lower draft requirement than that of "Maresha" for the central highlands.
- A chisel plow requiring 100 kg draft for post harvest tillage.
- Animal drawn tie-ridger for moisture stressed farming area.
- An animal drawn precision planter with fertilizer attachment for seeding maize, sorghum, and legumes.
- Animal drawn implement for weeding row planted crops.
- Animal drawn harvesting implement with matching draft requirement for a pair of local oxen.

Table 6. Use of implements

PA. No.	Tillage	Ferti. Application	Sowing	Seed covering	Thinning	Weeding	Harves-ting	Thresh-ing	Winnow-ing
1	C	NT	NT	C	CNT	C	C	C	C
2	C	NT	NT	C	CNT	C	C	C	C
3	C	NT	NT	C	CNT	C	C	C	C
4	C	NT	NT	C	NC	CNT	C	NT	C
5	C	NT	NT	C	NC	CNT	C	NT	C
6	C	NT	NT	C	NC	CNT	C	NT	C
7	C	NT	NT	C	NT	CNT	C	NT	C
8	C	NT	NT	C	NT	NT	C	NT	C
9	C	NT	NT	C	NT	NT	C	NT	C
10	C	NT	NT	C	NC	NT	C	NT	C
11	C	NT	NT	C	NC	NT	C	NT	C
12	C	NT	NT	C	NC	NT	C	NT	C
13	C	NT	NT	C	C	CNT	C	CNT	C
14	C	NT	NT	C	C	CNT	C	CNT	C
15	C	NT	NT	C	C	CNT	C	CNT	C
16	C	NT	NT	C	NC	NT	C	NT	C
17	C	NT	NT	C	NC	NT	C	NT	C
18	C	NT	NT	C	NC	NT	C	NT	C
19	C	NT	NT	C	C	CNT	C	CNT	C
20	C	NT	NT	C	C	CNT	C	CNT	C
21	C	NT	NT	C	C	CNT	C	CNT	C
22	C	NT	NT	C	NT	CNT	C	CNT	C
23	C	NT	NT	C	NT	CNT	C	CNT	C
24	C	NT	NT	C	NT	CNT	C	CNT	C

C - conventional tool/implement; I - Improved tool/implement ; NT - No tool/implement; NC - operation not carried out

Table 7. Power source for different agricultural operations

PA. As.	Land clear- Ing	Tillage	Clod break- Ing	Seeding fertilizer Application	Seed cover- ing	Thinn- ing	Weed- ing	Earth- ing	Plant protec- tion	Harvest- ing	Thresh- ing	Winnow- ing	Transport
1	NC	DA	NC	H	DA	H	H	H	NC	H	H	H	PH
2	H	DAH	NC	H	DAH	H	H	H	NC	H	H	H	PH
3	NC	DA	H	H	DA	H	H	H	NC	H	H	H	PH
4	NC	DA	NC	H	DA	DA	H	NC	H	H	DA	H	PH
5	NC	DA	NC	H	DA	NC	H	NC	H	H	H	H	H
6	H	DA	NC	H	DA	DA	H	CN	NC	H	DA	H	DAH
7	NC	DA	NC	H	DA	NC	H	NC	H	H	DA	H	PH
8	NC	DA	NC	H	DA	NC	H	NC	NC	H	DA	H	H
9	NC	DA	NC	H	DA	NC	H	NC	NC	H	DA	H	PH
10	NC	DA	NC	H	DA	NC	H	NC	NC	H	DA	H	PH
11	NC	DA	NC	H	DA	NC	H	NC	NC	H	DA	H	PH
12	NC	DA	NC	H	DA	NC	H	NC	NC	H	DA	H	PH
13	NC	DA	NC	H	DA	NC	H	NC	NC	H	DA	H	H
14	H	DA	NC	H	DA	NC	H	NC	NC	H	DAH	H	H
15	NC	DA	NC	H	DA	NC	H	NC	NC	H	DAH	H	PH
16	H	DA	NC	H	DA	NC	H	NC	NC	H	DA	H	H
17	H	DA	NC	H	DA	NC	H	NC	NC	H	DA	H	H
18	H	DA	NC	H	DA	NC	H	NC	NC	H	DA	H	H
19	H	DA	NC	H	DA	NC	H	NC	NC	H	DAH	H	H
20	H	DA	NC	H	DA	NC	H	NC	NC	H	DA	H	H
21	H	DA	NC	H	DA	NC	H	NC	NC	H	DAH	H	H
22	NC	DA	NC	H	DA	NC	H	NC	NC	H	H	H	H
23	NC	DA	NC	H	DA	NC	H	H	NC	H	DAH	H	H
24	H	DA	H	H	DA	DA	H	NC	NC	H	H	H	H

H - Hand labour DA - Draught animal NC - Operation not carried out P - Pack animal

Table 8. Peasants' priorities

PA. No.	Tillage	Planting	Weeding	Plant production	Harvesting	Threshing	Transport
1	X		X			X	
2	X		X		X	X	
3	X		X		X	X	
4	X	X	X	X	X	X	X
5	X		X	X			
6	X			X	X	X	
7	X				X	X	
8	X				X	X	
9	X				X		
10	X	X	X		X	X	
11	X						
12	X					X	
13	X	X	X		X	X	
14	X	X	X		X	X	
15	-	-	-	-	-	-	-
16				X	X		
17					X		
18					X		
19	X				X	X	
20	X	X			X		
21	X				X	X	
22	X						
23	X				X	X	
24	X	X	X			X	
	20	3	9	4	17	15	1

Note:- X affirms priority; - priorities not ascertained

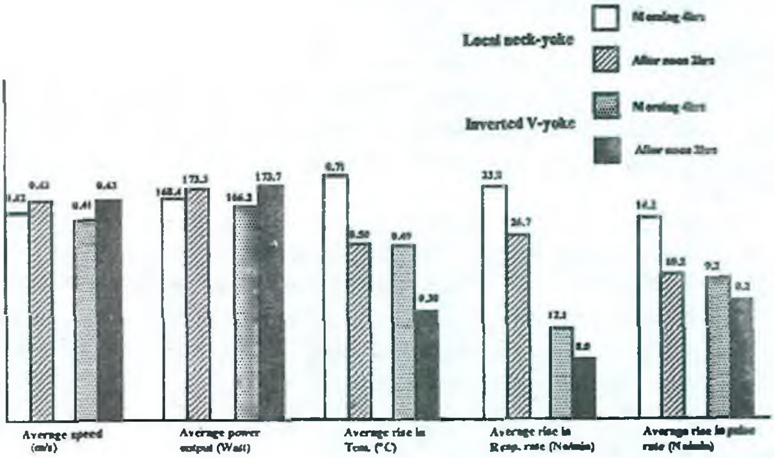

Fig. 1 Comparison of inverted V-yoke and neck-yoke

Performance and Evaluation of Single Animal Harnesses

Ethiopia has a vast resources of draft animals that are used to supply tractate power for various tillage operations. The use of oxen in pairs is the most common. However, 32% of the peasant farmers own only one ox. In addition the possibility of using single ox for low draft tasks. The selection of single animal yoke and better harnessing method for the exploitation the animal's power is required. Therefore, an improved version of inverted V-yoke and rigid neck yoke modified for single animal were studied and evaluated. The main objective was to evaluate the performance of various single harnesses for use with local oxen.

Results

The relationship between pull and speed; respiration rate and body temperature of a single ox while working; work out put and relationship between pulse and working hours are evaluated.

Conclusion/Recommendation

The modified inverted V-yoke offered larger contact area for efficient utilization of the anima's power and was found to be comfortable for the animal, thus, extending the work period. The neck-yoke can be easily made by the local farmers.

roper matching of machine requirements with human capabilities is basically necessary for optimum performance of any man-machine system. As such anthropometric data has great importance in ergonomic studies as its role in solving ergonomic problems has been accepted. Internationally anthropometric study deals with the measurements of human body dimensions and mechanical aspects of human motion. Anthropometric studies were conducted in different countries for successful farm equipment design. Most of these studies indicated that there was considerable variation in results reported and as such the data of one country could not be used in farm equipment design in other countries. Therefore, realizing the need of such studies in performance improvement of many farm equipment, AIRIC conducted anthropometric study on Ethiopian agricultural workers to study useful body dimensions and work pastures of Ethiopian agricultural workers for optimum design, development and selection of agricultural equipment.

There were two sets of experiments.

Anthropometric data

Body dimension data useful for farm equipment design are collected and analyzed for 60 agricultural workers at 5 different locations of Arsi and Shoa. A portable anthropometric equipment was used for the measurement.

Table 9. Anthropometric data for agricultural workers (Arsi & Shoa regions)

Dimensional element	5th percl.	50th percl.	95th percl.	Diff. b/n 5th & 95th	S.D.	C.V (%)	Max.	Min.
Body weight, kg	52.5	60.0	73.0	23.0	6.105	10.05	74.0	50.0
Standing height, cm	160.5	171.0	181.0	20.5	6.434	3.77	185.0	157.6
Elbow height, cm	93.0	101.0	110.0	17.8	5.694	5.63	113.3	92.0
Metacarpal III height, cm	67.0	73.0	79.5	12.5	3.866	5.32	82.5	62.0
Arm reach, cm	77.8	86.1	93.2	15.4	5.754	6.77	99.7	59.8
Vertical grip reach sitting, cm	104.0	122.0	134.4	30.4	8.318	6.85	137.0	101.8
Sitting height, cm	79.0	83.0	90.6	11.6	3.667	4.38	93.7	74.4
Seat height, cm	37.0	40.0	43.2	6.2	1.761	4.43	45.9	35.9
Shoulder seat, cm	52.5	56.2	61.8	9.3	3.214	5.75	68.3	48.2
Knee height, cm	44.1	50.0	55.0	5.9	3.386	6.79	55.0	41.0
Hip breadth, cm	26.6	29.5	32.8	6.2	1.781	6.05	34.0	24.2
Shoulder-breadth, cm	38.0	41.2	47.0	9.0	2.532	6.09	48.7	36.0
Seat length, cm	43.0	47.3	51.5	8.5	4.815	10.10	58.0	38.0
Forearm length, cm	45.0	48.0	52.0	7.0	2.237	4.67	53.0	41.0

Percl. - Percentile

Results & discussion

Table 9 shows percentile values for each dimensional element. Adjustable facility such as seat height or height of handle of equipment should be designed to accommodate a reasonable range of individuals usually from 5th to 95th percentiles representing 90% of the population. The standard deviation and coefficient of variation are also calculated to show the distribution of values of each dimensional element.

There is a considerable variation in the body dimension from one country to another. Therefore, data of one country can not be used for farm equipment design in another country. Based on studies and experience, surface heights must be 5 to 10 cm below elbow height for light manipulations, and lower levels are recommended for arm movements requiring considerable exertions. Therefore, the range of variation for work surface height should at least be 88 to 105 cm to accommodate 90% of the population to work at the standing pasture.

Shoulder breadth, shoulder-seat, seat height and seat length are the critical dimensions for the design of a seat and values ranging from 38 cm to 47 cm; 52.5 cm to 61.8 cm; 37 cm to 43.2 and 43 cm to 51.5 cm, respectively can be used to design a seat that can accommodate 90% of the population.

Work pasture effect on performance of cultivation tool and on the operator

Three pastures, squatting, standing (back bent) and standing (back vertical) were considered. A cultivation tool with the same working unit was used for the experiment. The results are shown in Table 10. Area cultivated per hour, capacity was found to be higher where the person works at standing back bent pasture. However, the difference is non-significant at 5% level. He could work at a greater depth at standing back vertical posture. Therefore, this posture is preferable for first plowing using hand tools. The sites of pain at standing, back bent posture are the hip joint and shoulder-upper arm joints and the wrist of hand at standing back vertical posture. The operator suggested that the squatting posture is less tiresome. However, capacity and working depth are relatively lower.

Fatigue is dependent not only on the work posture but also on the ambient temperature condition.

Table 10. Effect of work posture on cultivation tool

Treatment work posture	Performance capacity (m^2/hr)	Av. depth of cultivation (cm)	Cross-sectional area (cm^2)	No. of strokes/minute
Squatting	42.99 A	3.56 A	250.4 A	48.0 A
Standing, back bent	53.90 A	4.33 A	229.3 A	43.0 A
Standing, back vertical	46.56 A	5.073 A	248.9 A	48.67 A

Means followed by the same letter in a row are not significantly different according to multiple range test at P - 0.05.

Study and Development of Suitable Harvesting and Transporting Boxes for Tomato

Post-harvest losses of horticultural crops are estimated to be in the range 25-35% in the state farms and are expected to be much more in the peasant sector (1). Among the common vegetable crops the largest loss as high design of harvesting and transporting boxes is indicated as one of the important reason of post-harvest losses (1).

Some of the commonly used equipment are tags and field boxes. Tags, because of their configuration allow air circulation, but damage at the lower part have been recorded. Tags and field boxes are suitable for staking and transport, but damage to the lower part due to over filling is recorded with the objective of developing a sturdy non-respiratory inhibiting harvesting and transporting boxes for tomatoes.

Development work and result

A compression test apparatus which enable uniforms loading of the tomatoes was developed. A detailed data was collected on the compression test and soling test. Based on these, experiment was conducted on various box dimension and temperature effect. Tests were conducted on Marglobe variety. The parameters considered were temperature variation, extent of damage, dimension of boxes used, and rolling angle on the different types of surfaces as construction materials. The results are shown on Tables 11 and 12.

Table 11. Rolling angles as tested on four different surfaces.

Surface of construction materials	Mean rolling angle (□)	Standing deviation
Wooden edge planned	20.3	4.7
Wooden round field	20.1	5.1
Reed surface	25.0	6.9
Reed outer surface	30.0	6.3

Table 12. Percent damage as related to box dimension

Box dimension	Out of 14 kg tomatoes % damaged
19 x 30 x 50 cm	46.0
25 x 30 x 60 cm	28.0
20 x 30 x 50 cm	30.0
18 x 30 x 50 cm	32.0
19.4 x 38 x 54 cm	47.0

Conclusion and Recommendations

The least rolling angle was recorded in the case of the smooth planned edge wood (Table 12). This indicated that for less mechanical damage this kind of material is superior to the others, though reed is less expensive because of a higher rolling angle, more brushing could be sustained on the tomato. An economic analysis is needed to select one of the others.

As far as the temperature variation is concerned, the damage or the rate of spoilage was recorded. From the data there is an indication that the spoilage recorded in the bigger boxes is minimal compared to the smaller ones.

The study has indicated the technically optimum size and preferred material type for handling tomatoes, but to give a good recommendation it should be supplemented with an economic analysis.

REVIEW OF ON-GOING POST HARVEST PROPOSALS

(Processing devices and Storage Structures)

Testing and Improvement of Suitable Storage Structure for maize and Haricot Bean

The objective of the experiment was to test and select a structure which will minimize storage losses of maize and haricot-bean. Three types of storage structures were constructed mainly "gottera", which is raised from the ground and with rat dapples, "gottera" as commonly used by farmers and "debignite". Construction of another two storage structures which should be include in the experiment such as chines silo and pole-house will be done. After the construction the test will continue for the maize and haricot bean in the coming season.

Evaluation and Improvement of Storage Structure for Onions for use in Hot Climate of Ethiopia

The objective of the experiment was to evaluate and improve a storage structure so as to lengthen the shelf-life of onions. Literature review and preliminary survey was made, and based on this, four structures namely, ventilated bamboo structure thatched with dry grass; ventilated bamboo structure roofed with mud and "filla"; structure with mud wall and roofed with windows; and controlled ventilation (through windows) roofing thatched with grass are designed. The future plan will include the collection of construction materials such as dried grass, wooden poles, bamboo and mud bricks. Ones the structures are completed necessary data will be collected.

Development of a Low Cost Oil Processing Equipment for Rural Areas

The objective of the proposal was to develop a low cost hand operated oil extracting equipment. A laboratory experiment was conducted on noug seeds of different moisture contents and practice size in order to determine the technical feature of the equipment being developed. Based on the test result the first prototype was fabricated, but it needs some modifications so as to per optimum torque. Another design of the prototype was given to the workshop and the fabrication is in progress. Testing will be carried out after the modification of the first prototype and the fabrication of the second prototype. Based on the test results the one that has the best performance will be selected and the necessary steps will be taken accordingly.

Testing and Improvement of Groundnut Decorticator

The objective of the proposal was to test and improve the here before available groundnut decorticator in AIRIC. The fabrication of the rubber tire drum groundnut decorticator is completed. The prototype consists namely a main frame, rubber tire drum, a concave and a hopper. Preliminary testing was made using Roba and NC-343 groundnut varieties in order to determine the optimum clearance for shelling. The clearance used between the drum and the concave wire mesh were 9, 10, 11 and 13 mm. Further improvement will be done to have a better performance and finally a comparative test will be carried out.

Testing and Improvement of Coffee Huller

The objectives of the project were to make survey of indigenous and exogenous coffee processing devices and to test and improve devices suitable for Ethiopian coffee decortication. Survey was conducted around Sidamo, Wellega, Bedessa and Jimma regions in order to assess decortication frequency; manpower requirements for the processing task; economic status of the coffee growers; traditional processing methods in use and their performance capacities. Laboratory experiment was done to determine the physical properties and the geometry of the coffee beans grown in the country. The determination of the physical characteristics of the coffee varieties was so much involved because of their irregular shape and variability in the sizes. Finally based on the results of survey and laboratory experiments hand operated mechanical coffee huller will be designed and developed.

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SESSION V
Agricultural Economics and Food Science

Chair: Ato Tesfaye Zegeye
Rapporteur: Ato Mohammed Dawd

ON - FARM EXPERIMENTS IN THE RIFT VALLEY AREAS OF ETHIOPIA

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Abstract

Failure in the traditional research emphasized the need for taking farmers knowledge and circumstances into consideration for technology development and dissemination process. Over the past 10 years, the Institute of Agricultural Research has set up a farming system research program in order to bridge the gap and strengthen the link in the process of technology development and transfer system. On-farm research was used to assess and confirm the performance, adaptability, profitability and effectiveness of different technologies under a wider range of soil, climate, and farmers' management conditions. On-farm research has different stages. Tthe agricultural economics and farming systems research division deals mainly with the verification of different improved technologies by comparing them with the existing farmers common practices. Different improved technologies on maize, sorghum, haricot bean and tef were evaluated and feedback and information from on-farm trials were used to modify, and/or generate new and appropriate technologies to solve farmers priority problems.

Introduction

The historical record of Farming System Research in the Institute of Agricultural Research (IAR), Ethiopia shows that On-Farm Research (OFR) was started in 1976/77 when the Department of Agricultural Economics initiated a Package Testing Program at Holleta and Bako Research Centers. The objective of the program was to demonstrate available research results (packages of innovation/ recommendations) from the research center to the nearby farmers. The package included all recommended technologies like variety, seed rate, fertilizer rate, weeding time and frequency. The program was extended to Nazareth Research Center in 1979/80. Recommended package of maize, haricot bean and sorghum were tested on farmers' fields in the Nazareth area.

Among the packages demonstrated, farmers adopted only those technologies that they found to meet their priority problems such as early maturing maize variety Katumani. By 1986 over two thirds of the farmers in the Nazareth area were using this variety (Tilahun et al. 1990). However, farmers failed to accept other components of the package such as row planting, planting date and fertilizer rate. In general farmers were reluctant to accept complete packages as a whole.

Testing one or two components at a time was found to be more efficient in the adoption process for the resource poor farmers. Hence, diagnostic survey and on-farm experiment approach was designed to increase the capacity of technology generation and transfer systems to respond more effectively to the needs of specific clients most commonly the resource poor farmers. Results of surveys were used in planning on-farm and on-station experiments tailored to the needs and capabilities of the local farmers.

Since technologies were developed in the station, a verification type of trial was done on farmers' fields. The objective of on-farm verification trial is to assess and confirm the performance, adaptability, profitability, and effectiveness of new technologies under wide range of soil and climate as compared to common farmers management condition.

Verification trials are more simplified and treatment numbers are relatively small with larger plot size. Type of treatments are decided by researchers and are kept uniform across all sites as much as possible. Site selection is done in collaboration with extension. Number of sites are usually greater than five. Most of the management are left to the hosting farmers, the non experimental variables such as land preparation planting method weeding and harvesting were kept at the level of representative farms. Data collection and analysis combine agronomic, statistical, economic and farmers assessment.

This paper provides an over view of the on-farm experiments conducted by the agricultural economics division of the Nazareth Research Center in the past years.

Review of On-Farm Experiments

A survey conducted in the Nazareth area in 1985 identified farmers major production constraints. Based on the problems identified experiments were designed to address them. The principal problems identified during the survey are summarized as follows:

Physical

Moisture stress; Low and erratic rain fall pattern is the major problem faced by farmers. Rain may start early or late which in either case affect crop growth.

Biological/Technical

Weed infestation; due to shortage of labor and overlapping of farm operations during peak season, controlling weeds on time is difficult.
Low soil fertility; soil in the area is poor in the essential plant nutrients
Shortage of feed for livestock in the dry season
Attack by quelea (bird damage on sorghum)
Poor seedling emergence in sorghum

Economic

Cash shortage; to purchase input, credit is not available
Farmers use backward farm implements
Shortage of pulses in diet
For the details on the farming systems and farmers constraints and problems see Tilahun and Teshome 1987.

On-farm and on-station trials designed and conducted to address these farmer problems are presented as follows in a summary form (Table 1). For the detail see, Tilahun et al. 1990, Teshome et al. 1992.

Maize

On - farm evaluation of early maturing maize varieties

Although maize is one of the important cereals produced in the area, farmers grow a long cycle maize variety which requires more than 140 days to mature in an area where the nature of rain fall is erratic. Therefore, evaluating early maturing varieties which can fit into the rainfall condition was suggested as one of the available thrust.

Among the varieties tested namely, Katumani- AW-8047, Alamura, and AW 511, maize variety AW-8047 performed best under farmers management condition for yield, plant vigor, storability, and biomass. However, the variety is found to be susceptible to leaf rust that hindered its official release.

Table 1. **Summary of the main on-farm experiments in Nazareth area. Problems and proposed solutions for different crops.**

Problems(technologies)	Proposed solutions	Crop type
1. Moisture stress	Evaluating early maturing varieties	Maize, Sorghum
	Verification of soil moisture conservation methods (tied ridging)	Maize, Sorghum
2. Weeds	Evaluation of weeding frequency & seed rate	Haricot bean
	Evaluation of different herbicides vs hand weeding	Haricot bean, Tef
	Evaluation of wheel hoe for weeding	Maize, Sorghum
3. Quelea (bird damage)	Screening early maturing variety	Sorghum
4. Poor soil fertility	Evaluating different fertilizer levels	Maize
5. Cash shortage	Variety verification	Tef, Haricot bean, Potato
6. Shortage of pulse in diet	Variety verification	Cowpea
7. Dry season feed	Identifying appropriate time of shilshalo	Maize, sorghum
8. Shortage of animals	Evaluating different fodder trees Testing alley cropping methods	

Source: Tilahun et. al. 1990.

On - farm verification of soil moisture conservation measures (maize and sorghum).

Farmers in the area use a broadcast method to sow their grain crops. Agronomists at Nazareth Research Center (NRC) advise that tied ridges made by hoe effectively conserve moisture and increase yield. Hence the trial was initiated to test the tie ridge system under farmers management condition and obtain farmers evaluation for the method.

According to the result, tie ridges are effective when the rainfall condition is below average. However, there was no significant yield difference between treatments due to various factors like water logging and crop failure because of sever moisture stress. The tied ridge technology was found to be expensive requiring excessive labor. It has been suggested tied ridges may be cost effective in very dry locations considering the following factors: Ridges tied at 5 meter are more cost effective than ridges tied at 1 meter, ridge-making animal drawn implements are required for effective use of the technology, later tying of ridges (August instead of June) and shallower furrows can minimize the risk of water logging and further on-station work is suggested for improvement.

Hand pushed wheel hoe for weeding maize

Weed is one of yield limiting factors in maize production in Nazareth area. Although farmers are aware of the importance of controlling weeds, the timeliness and frequency of weeding for individual farmer depends on the amount of labor available in the household. Mechanism devised to control the problem is to use implements that can save time and labor. Therefore, the objective of the experiment was to verify the performance of wheel hoe under farmers' condition and test acceptability of the tool by the farmers.

Axle extended out too far beyond the wheel on each side, prevent maneuvering it close to a maize plant without injuring. Handle should be lowered to push it easily. Hence it has been suggested to be modified.

Evaluation of low power operated mechanical maize sheller

The efficiency of low power operated mechanical maize sheller was evaluated on farmers field. Farmers liked grain quality threshed by the machine. The seed obtained was clean, not cracked, not broken, and uniform. However, the machine requires time and labor. Farmers require an engine machine that could save more time and labor.

Economic evaluation of fertilizer response

46 N and 46 P_2O_5 fertilizers were found to be the most economical level in the wet zone.

Haricot Bean

On - farm haricot bean variety verification trial

Haricot bean is one of the most important crops in the central Rift Valley areas of Ethiopia primarily produced for cash purposes. Haricot bean on-farm variety verifications were conducted to evaluate the performances of new varieties under farmers management condition.

There was no statistically significance yield difference among the varieties (A-410, A-262, Brown speckled and Mexican 142 (check)) tested. Among the colored beans, farmers showed greater interest in brown speckled because of its large seed size and color.

On-farm haricot bean variety verification trial.

Bean varieties W-108 (0177-2), W-95-08, W-117 (0150-1), 6R-395-08 were compared against Mexican 142 (check). The results show that in terms of yield and stability, none of the new varieties performed better than the check, Mexican 142. Mexican 142 was earlier than the new varieties and has got better marketing quality.

Effect of seeding rate and weeding frequency on growth and yield of haricot bean.

Farmers in the Nazareth area do not weed haricot bean because of labor shortage and overlapping of farm activities during the peak season. Rather farmers use high seed rate and broadcasting method to suppress weeds. It has been tried to see the effect of the seed rates and frequency of weeding on yield. The effect of different seed rates, the effectiveness of different cultivars in suppressing weed and the effect of different weeding frequencies on yield were tested. The farmers practice of using high seed rate to suppress weeds was proved to be true.

Economic evaluation of selected weed control practices in haricot bean.

Neither one time hand weeding nor alachlor herbicide was economical in controlling weeds in haricot bean compared to the farmers usual practice.

Tef

Tef is the most common and widely grown crop as a major source of cash in the rift valley areas of Ethiopia. Since the Rift Valley area is characterized by erratic nature of rainfall, testing available varieties for their adaptability and profitability was found essential.

Tef variety on-farm verification trial

Released varieties namely, DZ-01-x37, DZ-01-196, DZ-01-354 were compared against the farmers variety . Statistically no significant yield difference was observed among the varieties but better grain yield was obtained from DZ-01-x37 and higher straw yield was obtained from varieties DZ-01-354 and DZ-01-196.

On - farm herbicide trial on tef

Majority of the surrounding farmers use herbicide 2, 4-D to control weeds in tef. Since tef is main cash generating crop for small farm holders, farmers give priority for tef crop in the use of inputs.

Then an on farm herbicide trial was initiated in order to study the economics of different weed control methods. 2, 4 - D herbicide was found to be the most economical. Diplosan could be used over two hand weeding in the absence of 2, 4 - D.

Sorghum

Sorghum is the most important staple crop in the Miesso Assebot areas. It is grown by almost all farmers covering about 73% of the total cultivated area. Farmers usually grow brown or red sorghum varieties for bird tolerance. Drought and stalk borer are the most limiting constraints of sorghum production in addition to shoot fly, grass hopper, armyworm and aphids.

Screening early-maturing sorghum varieties for bird tolerance

Sorghum variety, Seredo, was found to fulfill the characteristics (relatively tolerate moisture stress, bird damage and preference by farmers). Farmers liked Seredo for its stand establishment, seed weight and seed size.

Cowpea

Introduction of cowpea was considered for its advantage:- drought resistant, nitrogen fixing ability and protein content (additional pulse in diet and its taste).

On-farm cowpea verification trail

Farmer evaluation indicated that farmers have appreciated cowpea variety Black-eye-bean Ex-DZ for its yield, drought tolerance and taste. However, large scale production was hindered due to storage insect pest problems.

Irish Potato

on-farm irish potato variety verification trial

A new potato variety 'Sisay', an earlier maturing type, was compared with local varieties with regard to yield, disease resistance and other important characteristics required by farmers.
Sisay has two important advantages over the local:

1. Matures 20 to 30 days earlier than the locals and
2. Tolerate late blight much better than the locals and also gives more yield compared to local varieties/types, but have a sprouting problem. Farmers preferred Sisay for its higher yield, early maturity, and bigger tuber size (high market demand). They also reported that Sisay needs less time and fuel for cooking and it is good for making stew. But the boiled form is not as tasty as the local variety (2).

Farm Implements

Evaluation of Improved moldboard plow

It was reported by farmers that the improved moldboard plow is effective in terms of weed control, plowing depth, less clods, and saving time. It requires less human power particularly during primary tillage compared with the local plow 'maresha'. The plow has depth and width adjustment. However, it requires spanners which are expensive for the farmers to afford. Farmers complained about the heaviness of the improved moldboard plow. To address this problem AIRIC has made certain modifications replacing the bolts by rope and changed the metal handle to wooden.

Conclusion

Over the last 10 or more years farming systems research has contributed a great deal in technology development and transfer systems more appropriate to resource poor farmers. It contributed in identifying farmers problem and guiding researchers towards appropriate solutions to these problems, verifying appropriate recommendations to farmers and providing feedback to technical researchers on the performance of the technologies so as to modify them to better fit the needs and circumstances of the farmers.

On-farm experiments done so far in the Nazareth area helped to:

1. Identify and or confirm key factors for further research
2. Refine technology by sharpening the research focus that is pre screening priority technological components.
3. It has been observed that farmers use different parameters to assess technologies. Grain yield is not the only factor that influence farmers' choice of technology. Color, shape, stover yield, taste, cooking time and risk management are among the major criteria used by farmers to evaluate technologies.
4. Farmers in the area have complex objective, risk avoidance; and are also cash oriented giving much emphasis for cash crops like tef and haricot bean. Since farmers deal with unreliable rainfall condition, earliness and drought tolerance are among the major needs of farmers.

Further investigation in problem identification and prioritizing should be gained. Based on the interest of farmers more knowledge on decision making criteria should be identified for the priorities that need immediate attention.

Research results will effectively be utilized when they address the problem of the household as a whole. Hence, future technology generation process should include gender variables in research planning, design and dissemination.

Although considerable research activities have been carried by the division of Agricultural Economics, the important component of farmers enterprise, livestock, is not included due to lack of trained personnel and livestock research at the center. It is an area that needs further research focus.

At the moment information on what variables determine the decision to adopt and intensity of adoption by farmers and what characteristics determine aggregate speed of adoption are lacking.

On-farm experiments are found to demand full time follow up and resource for effective results. It also requires agronomic background for effective follow up. Hence, trained manpower in respective field of specialization is indispensable.

On-farm research is more effective when researchers and extension workers collaborate effectively. Hence, strong link between research and extension in on-farm research is recommended.

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FARMING SYSTEMS RESEARCH: ACHIEVEMENTS AND PROSPECTS IN MOISTURE LIMITING ENVIRONMENTS OF ETHIOPIA

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Abstract

In the past 10 or more years, farming systems research has contributed very much to the understanding of production practices, resource use patterns and priorities, system constraints and other circumstances of smallholder farmers in moisture limiting risky environments of central Ethiopia. Farming systems research demonstrated the utility of a problem (client) oriented, farmer participatory and multi-disciplinary approach to technology development more appropriate to resource poor farmers for increased farm productivity and welfare. The potential production impact of farming systems research has been constrained by poor linkages with extension, input supply services and policy makers. Also most of the technologies tested on-farm for farmer adoption required extra resources such as cash or peak season labor that farmers failed to afford. Farmers participation in farming systems research in the past years remained modest. The problem oriented approach, farming systems research has much wider potential if it can be more fully integrated into component research as well as into extension. Effective linkage has still to be developed. If these developments can be fostered and both formal and informal linkages encouraged and farmers involvement in research up-graded, then the prospects for building on the lessons learned and results achieved through farming systems research is promising.

Introduction

Farming systems research (FSR) has been adopted by many national agricultural research systems (NARSs) in Africa and elsewhere as a complement to station-based research to improve the capacity of NARSs to effectively respond to the production problems and opportunities of smallholder farmers, who are not well placed to make their needs known to researchers and who operate under a diverse set of circumstances (Low and Waddington 1990).

Farming systems teams conduct surveys to identify farmer problems and propose appropriate means to solve the problems. They carry out on-farm trials to test and develop improved technologies that will be adopted by target groups of farmers, and farmers play an important role in the design, implementation and evaluation of new technology (shaner et al. 1982). On-farm testing of packages of new technologies was operational at Nazareth Research Center (NRC) since 1979. However, it was not developed within the farming systems philosophy. On-farm research with a farming systems perspective was launched at NRC in 1984 along with a donor funded IDRC "Farming systems Research project".

In this paper the major activities, impact, constraints (limitations) and prospects of FSR under moisture limiting semi-arid environments of Ethiopia are discussed.

Evolution of FSR in the Institute of Agricultural Research

The history of on-farm research (OFR) in the Institute of Agricultural Research (IAR), Ethiopia dates back to 1977 when the Department of Agricultural Economics initiated a Package Testing Program around Holetta and Bako Research Centers. The objective of the program was to demonstrate available technologies from the research centers to the nearby farming community (Mulugetta et al. 1992).

In 1979, the Department of Agricultural Economics conducted a farm survey in the Nazareth area. In the following year, 1980, the package testing program was started at Nazareth and sorghum, maize and haricot bean production packages were tested on individual and farmers producer cooperatives fields. Farmers provided fertilizers, labor and a hectare of land for each crop. The research center provided improved seeds and technical supervision (NRC, Agricultural Economics Division Progress Reports, 1980-1984).

From the package developed at the research center and tested on farmers' fields some innovations have been adopted by the farmers. These include early maturing maize variety Katumani and white pea bean variety Mexican 142. However, farmers failed to accept recommended fertilizer levels, row planting and recommended weed control methods and sowing dates. Shortage of cash and risk for fertilizer use, lack of awareness about the benefits of row planting and unavailability of row planter, shortage of labor for weeding as recommended and the nature of rainfall which is erratic unreliable were some of the factors that has contributed for farmer rejection of these production practices.

The lessons learned from package testing were first to conduct surveys to better understand the farming systems and farmers problems and to go beyond testing already developed packages to developing technologies on farmers fields with greater participation of farmers.

Farming Systems Research at Nazareth

The research reported in this paper documents the work of FSR team at Nazareth using the farming systems approach for developing technologies and policies for smallholder agricultural development. The principal techniques used include (1) informal and formal surveys to identify farmers' problems and (2) on-farm trials to examine the performance of new technologies in the farmers' environment and to obtain farmers' assessment of them. Farmers are active participants in the research activities described. A major objective of the surveys is to elicit from farmers their view on their problems and possible measures for solving them. In on-farm trials, farmers are actively involved in the design, testing and evaluation of new technologies aimed at improving productivity.

Farming systems research teams at Nazareth have two major roles:

To identify research opportunities for improving the productivity of target groups of smallholder farmers. This goal is achieved through an understanding of production problems, current production practices, and the circumstances influencing farmers' current choice of enterprise and production techniques.

To test and develop improved technologies that will be adopted by target groups of farmers. This goal is accomplished mainly through on-farm trials and demonstrations.

Major activities

Farm surveys

Farming systems research teams at Nazareth began their work by conducting a diagnostic survey in Adama and Bosset Sub-Districts in the Nazareth area in late 1985 and early 1986. These were followed by a number of other surveys in the Nazareth and other areas in the central rift valley of Ethiopia.

In addition to the diagnostic surveys researchers at the agricultural economics division also conducted special surveys to examine in depth particular constraints identified in the informal and formal surveys (diagnostic survey). These surveys can be categorized into two types (Table 1). First are those on topics on which researchers need information for planning their research programs. The second group examines policies and support services that affect the adoption of technologies.

Table 1. Inventory of major farm surveys conducted by agricultural economics and farming systems division since 1985.

Survey	Area conducted	Year conducted
1. Diagnostic survey	Nazareth	1985/86
(both formal and informal)	Meki/Ziway	1989/90
2. Labor use survey	Nazareth	1988/89
3. Sorghum variety survey	Nazareth	
	Meki/Ziway	1988/89
4. Maize variety survey	Nazareth	1988/89
5. Haricot bean production	Meki/Ziway	1987
6. Sorghum production	Miesso/Assebot	1989
7. Local measurement units	Nazareth	
	Meki/Ziway	1990
8. Marketing of tef, maize, beans	Nazareth	
	Meki/Ziway	1990-1992
9. Crop profitability		
(tef, maize, beans, sorghum, potato)	Nazareth	1990-1993
10. Weed and farming systems survey	Habro/Hararge	1986
11. Vegetable production	Nazareth	1993/94
12. Adoption of technologies	Nazareth	1994
	Meki/Ziway	1994
13. Input use	Nazareth	1994

On-farm trials to address farmers problems

The on-farm and on-station trials to address farmers principal problems identified by the surveys are presented in Table 2 and in Tilahun et al.(1990) and Teshome et al.(1992).

Impact of Farming Systems Research

Create awareness among researchers and others concerned with small farm development of small farming systems

Developing research thrust for on-farm and on-station research

Results from surveys and on-farm trials have identified major constraints and problems to be addressed . Among these include moisture stress, weeds, seasonal livestock feed shortages and diseases and pests. For the detail, see, for example, Aleligne et al. 1994, Tilahun and Teshome 1987.

Problem-solving orientation of research

Rather than basing proposals for new studies and experiments on objectives and needs perceived by individual researchers in a disciplinary context, each research program was expected to present proposals that responded to priority problems at the farm level.

Planning on-farm and on-station experiments

More than 20 experiments, either on-farm or on-station, were planned and carried out in response to the principal problems identified by surveys. Complementary approaches to overcoming moisture stress included the on-farm testing of early-maturing maize and sorghum varieties for drought avoidance and tied ridges for moisture conservation. Herbicide trials on tef and bean offered alternative strategies within the farming system: Poor control of weeds in beans might be overcome by releasing labor from hand weeding of tef (for which herbicide selectivity is technically easier) or by the more direct and probably more expensive route of herbicide application to beans. Some issues warranted similar experiments on several crops: on-farm evaluation of potential varieties of haricot bean, tef and potato held out the prospect of raising cash income for the farmers.

Table 2. Experiments to address farmer problems in the central rift valley areas of Ethiopia.

Farmer proble	Experiments*	Target group
Moisture stress in maize and sorghum	Evaluation of early-maturing maize varieties	Farmers(esp. dry-zone group) Researcher (feedback to breeders)
	Tied ridging with maize and sorghum	Farmers(esp. dry zone) Researchers(feedback to agronomists and agricultural engineers)
	Timing of shilshalo cultivation in maize and sorghum	Farmers (esp. dry zone)
Dry-season shortage of animal feed	Fodder tree evaluation (on-station) Alley cropping(on-station)	Farmers (both groups) Policy makers (land-use planning)
Weed	Tef herbicide vs. hand weeding: economic evaluation Haricot bean herbicides and hand weeding economic evaluation	Farmers (both groups) Policy makers on herbicide use and imports Researchers (feedback to weed scientists)
	Haricot bean seed rate x genotype x frequency of hand weeding (partly on-station)	Researchers (esp. breeders) Farmers (both group)
	Wheel-hoe evaluation for weed control in maize and sorghum	Farmers (both groups) Researchers(esp. agricultural engineers and weed scientists)
Bird (quelea) damage in sorghum	Red and brown sorghum variety testing	Farmers(esp. dry zone) Researchers (feedback to breeders)

Table 2. Continued

Poor soil fertility	Economic evaluation of fertilizer use in maize Fertilizer response, sorghum maize (on-station)	Farmers(both groups) Policy makers(on fertilizer and on pricing of crops and fertilizer)
Shortage of pulses in diet	verification of cowpea varieties	Farmers(both groups) Researchers(feedback to breeders) Research managers(on importance to be given to minor crops)
Cash shortage	Verification of haricot bean varieties Verification of tef varieties Verification of potato varieties	Farmers (both groups) Breeders Farmers(esp. wet zone) Researchers(feedback to breeders)
Poor seedling emergence in sorghum	Emergence studies: screening sorghum varieties, including effect of seed size on seedling vigor	Farmers (both groups)

Table 3. Major researcheable constraints of the farming systems in central rift valley of Ethiopia.

Type	Nazareth	Meki/Ziway	Miesso/Assebot
Moisture stress	xxx	xxx	xxx
Weeds	xxx	xxx	x
Poor soil fertility	xx	xx	xx
Dry season feed shortage	xxx	xxx	xx
Insect pests	x	x	xxx
Diseases	xx	xx	xxx
Birds	xx	xx	xxx
Seasonal labor shortages	xxx	xxx	xx
Seasonal cash shortages	xxx	xxx	xx
Draft power shortage	x	x	xx
Seed emergence problem	xx	xx	xx

xxx : very important problem; xx: important problem; x: not much important problem

Providing plant breeders with information on characteristics of needed varieties

Traditionally crop improvement programs in Ethiopia have used criteria as yield and disease resistance in selecting varieties for dissemination to farmers. Surveys and on-farm trials have helped plant breeders to identify other criteria that need to be taken into account in order to ensure that varieties will increase productivity and be acceptable to farmers and consumers.

In Nazareth during the late 1970s and early 1980s, haricot bean researchers emphasized yield and disease resistance in their varietal improvement programs. Surveys showed that neither farmers nor consumers were interested in beans of these colors; hence researcher emphasized white and red varieties, which farmers and consumers preferred. By 1988, all black-seeded varieties had been superseded by high-yielding lines of lighter seed color.

Providing agronomists and other researchers with new information on farmers problems

Information from surveys and on-farm trials has also been important for agronomists and other scientists in planning research to solve farmers' problems. On-farm verification trials of tied ridges confirmed that tied ridges to conserve soil moisture are effective in dry areas for maize and sorghum. But farmers rejected the technology, largely because of the high labor inputs required to construct ties and ridges. The information was fed back to agricultural engineers for testing, and oxen-drawn implement to construct tied ridges has been developed and tested on farm.

Providing feedback to researchers on the performance of new technologies

Other on-farm trials have given researchers important feedback for modifying technologies to make them more effective and acceptable to farmers. In on-farm trials of wheel-hoe in Nazareth, farmers found that the axle extended out too far from the wheel, injuring maize plants, and that the handle was too high, making it difficult to push. Researchers shortened the axle and lowered the handle accordingly.

Formulating recommendations appropriate for smallholder

FSR activities have also helped establish more appropriate farmer recommendations by considering such factors as profitability, risk and cash constraints.

Making recommendations to policy makers.

The results from surveys and on-farm trials have also provided information and guidance for policy makers and managers of organizations serving smallholder. For example, the results from fertilizer trial economics analysis have indicated that Agricultural Marketing Corporation (AMC) prices for crop grains were discouraging farmers from using fertilizers.

Limitations and Constraints

The potential production impact of FSR is constrained by many factors. The major limiting factors for FSR activities are summarized as follows.

Technological

- Limited technologies for on-farm testing
- Technologies requiring extra resources that farmers can not afford

Linkages with other organizations

- Poor linkage with extension
- Poor linkage with policy makers and input suppliers

Limited farmer participation in on-farm trials

Methodological issues

When to take varieties for on-farm testing (before release, after release).
How to fix non-experimental variables (at farmers level, recommended level).
Types of experiments to conduct (only verification, additional others).

Institutionalization of FSR

Agricultural economics research relation with other divisions
Division and responsibility of work among FSR and other research divisions.

Manpower

Most of the division staff were junior researchers
Problems in managing trials due to lack of labor

Proposals for Future Development of Farming Systems Research

FSR has made important contributions to IAR's research but efforts are needed to strengthen the approach and ensure that it results in increases in productivity in Ethiopia's agricultural sector. The following proposals are grouped into two categories: Improving methods and strengthening linkages between IAR and other organizations serving smallholder agriculture.

Improving methods

Incorporating farmer participatory methods

FSR researchers have been exposed to the farmer participatory approach and have incorporated some of the new methods in their research. But much more needs to be done:

Farmers should play a more active role in evaluating new technologies on research stations for example, in evaluating new varieties and inter-cropping technologies.

Farmers are consulted about new technologies individually in on farm trials, but much better feedback could be obtained if they met in groups with researchers. Farmer panels to evaluate new technologies should be formed and groups of farmers should accompany researchers to visit on-farm trials.

Farmer-designed trials have been useful for verifying a technology's potential for adoption and have provided important feedback to researchers. Their use in on-farm research should be expanded.

Improving methods in conducting on-farm trials

Strengthening linkages

The bottom line for assessing IAR's and FSR's contributions is determining the impact of new technologies and policies on smallholder. Here the impact of the approach has been much less, partly because of weak linkages between IAR and other organizations supporting farmers. The following proposal address the problem:

Linkage with on-station research (integrated research planning)

Developing strong links between FSR and component research is essential for effective research, yet in practice such cooperation has proved difficult to establish and maintain. Improving links was the subject of a recent comprehensive review by Merrill-Sands and McAllister(1988) (quoted by Low and Waddington 1990) which included Zambia and Zimbabwe in its analysis. Unfortunately, a major reason why integration has proved difficult is that FSR has been introduced mainly as an activity of teams which are separated from the already-established research organization.

Through its explicit use of a production problem/production circumstance approach and close contact with farmers and extension, FSR is in a unique position to help orient component research agendas towards developing technologies that stand a good chance of being useful to farmers. By providing appropriate information and guidance to component researchers on research needs, farming systems research and extension can ensure a flow of appropriate new technologies for adoption and dissemination. This has long been recognized as one of the main roles for FSR (e.g., Collinson 1986; Merrill-Sands and McAllister 1988; Tripp and Woolley 1989 all quoted by Low and Waddington) but has been neglected.

The information to be shared between FSR and component research needs to cover than just the problem(s) to be addressed and how serious and widespread they are. Information from FSR on the reasons for a problem(i.e., its causes) and suggestions on which solutions (technologies) would be more appropriate given farmers' circumstances, should be provided to commodity researchers. On the other hand, component researchers have a responsibility to show adaptive researchers why they think a new technology is valid candidate for further FSR in terms of its potential benefits to particular groups of farmers. Hence, joint planning of work among FSR teams and on-station researchers is indispensable for successful research.

Linkage with extension

Ministry of agriculture development agents often assist IAR researchers in assembling background information about an area and in selecting farmers for surveys and on-farm trials. However, there is little MoA involvement in planning or implementing diagnostic surveys and experiments (Tilahun, 1986).

A direct working relationship needs to be established between IAR and MoA in conducting surveys and on-farm trials. Such a linkage would be useful for both institutions in the effective understanding of their work. In addition, it would be useful for further integrating research and extension in the effort to successfully develop and disseminate new technology. Specific areas of collaboration and the possible benefits are discussed below.

Diagnostic surveys. In the diagnostic surveys conducted by IAR, MoA extension workers can make important contributions. First , they often have much experience in the survey zone and can contribute to developing an understanding of farmer practices. Second, they have knowledge about the past and present efforts of the extension service , other development organizations working in the area and results from MoA trials and demonstrations (Franzel, 1992).

The subject matter specialists can also benefit from participating in the survey in several ways. First, they can learn from the researchers , who have more knowledge about research results and potential solutions to identified problems. Second, the surveys can be useful to the subject matter specialists in planning their own extension programs. Moreover, since the survey team consists of members of different disciplines, each benefits from the other's different disciplinary perspective (Franzel 1992).

On-farm trials. Several advantages of close IAR-MoA interaction in the implementation of on-farm trial can also be shown:

Both DAs and subject matter specialists need to be involved in the verification of new technologies, so that they can judge for themselves its effectiveness.

Subject matter specialists can make important contributions to the planning of experiments and the fine-tuning of new technology for specific groups of farmers, based on their experiences in the area.

The implementation of on-farm experiments can also be made much more efficient and extensive with MoA participation. Currently IAR spends much fuel and time visiting sites to record data that could otherwise be collected more cheaply by development agents based in the area. The agents could plant and monitor the trials and the subject matter specialists could supervise the work.

Linkage with policy makers and input supply services.

Although input supply problems have been recognized as a constraint to the use of some technologies FSR teams have not been adept at orienting their research results and reports to convincing senior executives in government and private sectors and NGOs of the need to change in input supply policies. It is therefore, clear that FSR teams need to address agricultural policy makers more directly in the future. This is a role that economists as members of FSR teams, should increasingly be able to take a lead. So far linkages between IAR economists and policy makers are weak; in some cases the only link is that a copy of the report on particular policy is sent to the concerned organization. IAR needs a team of economists working on policy issues. This team should involve policy makers in the design and implementation of its work. If policy makers have input into the design of a study, they will be much more likely to take an interest in and accept the recommendations from the study.

Appropriate organization modes for FSR activities

In terms of organizing farming systems research, IAR changed from a system of specialized FSR teams within DAE/FSR to one in which scientists throughout IAR incorporated on-farm research functions into their on going activities. Both systems have their advantages and disadvantages (Merrill-Sands et al. 1991), but there is a strong rationale in starting an FSR project with specialized and then switching to an approach in which FSR is adopted system-wide by the research organization. The major advantages of the specialized team approach are that it (1) facilitates interdisciplinary interaction (within the team at least), (2) promotes the learning of specialized FSR skills, (3) facilitates stronger links with farmers and extension agents and (4) is conducive to adaptive testing of 'off-the-shelf' technologies. FSR teams in Ethiopia exploited these advantages to build effective team for diagnosing farmers' testing station- developed technologies and providing feedback to station scientists. The teams demonstrated the usefulness of the approach to IAR managers and were active in publishing their results thus gaining needed scientific credibility.

Mechanisms for promoting interdisciplinary collaboration

Interdisciplinary research, a key to FSR success, cannot be expected to occur by itself, even when individual researchers desire interdisciplinary research. Interdisciplinary collaboration was reasonably effective within the specialize FSR teams; it was much less effective between the team and other IAR researchers. Sustaining interdisciplinary research became even more of a challenge after IAR eliminated the specialized teams and sought to incorporate the FSR approach into the institution as a whole (Franzel, 1992). Hence, for a better use of the FSR approach rather new mechanisms are required to promote and facilitate its operation.

Conclusion

Researchers using the farming systems approach have demonstrated the utility of client oriented, farmer participatory and multi-disciplinary research to technology development and transfer more appropriate for small holders. But much remains to be done to assure that the efforts results in increase in agricultural productivity and welfare of small holders. Farmers input into the design, implementation and evaluation of new technology needs to be strengthened. Researchers linkage with policy makers and organizations supporting the smallholder sector need to be improved. Researchers should expand their activities in the area of crop/livestock interactions, agro-forestry and conservation of resources. If these developments are encouraged then the prospects for building on the lessons learned and results achieved through farming systems research is promising.

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QUALITY EVALUATION OF LOWLAND CROPS: PROGRESS AND FUTURE DIRECTION

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Abstract

As part of the crop improvement effort, breeder materials were tested for quality in terms of physical, chemical and organoleptic parameters. Studies have been made to compare quality attributes of new cultivars, assess the likely success of consumer acceptability in order to select the best for further multiplication and dissemination. The crops under consideration were field crops (sorghum, haricot bean, maize, tef) and horticultural crops (citrus, banana, papaya, tomatoes, sweet potato). In the initial phase of the program, the emphasis was on preservation of fruits and vegetables by dehydration method, specifically sun drying, shade drying and osmosis dehydration. The study was made with variety of horticultural crops to study preservation methods and observe end-product quality differences among varieties. In the early 80's the emphasis was on processing of horticultural crops. A pilot plant was installed to process jams, juices, fruit preserves, tomato paste and ketchup. In the mid-80's haricot bean and sorghum were included in the program. The emphasis shifted towards utilization aspect of the crop in terms of standardization of traditional foods, shelf-life studies and cooking time evaluations. In mid-90's few basic research programs were proposed in the area of fermentation, chemical composition and new product development. The future direction of the program is to include processing of animal products, encompass all major crops for varietal evaluation, new product development, and conduct some basic research.

Introduction

The major role of Food Science activities in agricultural research is to complement the crop improvement effort in terms of preferred grain quality as one of the selection criterion. In the process of varietal selection and development, new varieties are produced. Differences in physical characteristics and chemical composition may exist among the varieties. This in turn contributes to differences in food making qualities. Therefore, cultivars in advanced stage of breeding need to be evaluated for food making qualities. Consumer acceptability tests of the food products is also assessed.

Fruits and vegetables are evaluated to identify their quality differences in terms of their chemical components and consumer acceptability tests. Sun drying of fruits and vegetables was also conducted to establish methods of sun drying and extend shelf life. Processing methods for some horticultural crops were developed. Crop utilization surveys were conducted to identify processing constraints which would serve as basis for future research agenda. This paper highlights the results of these past work on quality evaluation of lowland crops. The future research direction of the division is also indicated.

Preservation of Fruits and Vegetables

Fruits and vegetables are perishable in nature and needs to be preserved. Different preservation methods are available to prolong their shelf life. Dehydration is one of the preservation methods which applies the principle of moisture loss to discourage the growth of spoilage microorganisms. Dehydration could be effected in dehydration plant using hot air to remove moisture. Use of solar energy is an alternative. Sun drying is a cheap method of dehydration because it uses the natural resource, sunlight. Variety of fruits (mango, banana, papaya, grapes, water melon, mask melon and straw berries) and vegetables (onion, garlic, tomato, pumpkin, cabbage, sweet pepper, green beans, potato, sweet potato, cassava, leeks and carrots) were tried to develop methods and evaluate end-product quality. In the experiment different drying methods were used.

a. Direct sun drying for non- green vegetables
b. Shade drying for green vegetables to avoid color fading
c. Osmotic dehydration specifically for fruits, to initially remove some moisture in a strong sugar solution by a process of osmosis

Details of preparation procedures, trimming, selection, drying, handling, packaging and storage was published earlier (Senayit and Askale, 1987).

Processing of Horticultural Crops

Some horticultural crops were processed in a pilot plant. The objective was to develop recipes to process fruits and vegetables which could be used by cottage industries. The end-products were given to hotels along with some questionnaires to collect consumer responses. They were also test marketed in some groceries where samples were sold fast. These were tomato products, fruit juices, jams and jellies.

1. Tomato products (Bauchau et al. 1981a)
   ketchup, chili sauce and tomato in brine
2. Fruit juices and squashes (Bauchau et al. 1981b)
   lemon and lime squash; orange, grape fruit, passion fruit and guava juices
3. Jams, jellies and marmalades (Bauchau et al. 1981c)
   mango, plum, papaya and tomato jams, orange marmalade, pineapple jelly

Recipes were developed for the above products, consumer responses were collected, market tests were conducted. List of recommended equipments and chemicals required with their cost estimates were given.

Quality Evaluation of Horticultural Crops

Quality attributes of horticultural crops were studied in order to select the best for further multiplication and dissemination. The quality attributes under consideration for fruits were color, size, volume of juice, acidity, total soluble solids and sensory evaluation (taste, flavor and texture). For sweet potatoes cooking time and few of the above parameters were included.

The crops under these tests were banana, papaya, grapes and sweet potatoes. Ranges of data were obtained for varieties of each test crop. Among the parameters measured taste panel responses brought out quality differences clearly. Although results of all measured parameters are available (Senayit et.al. 1994), this paper discusses only sensory evaluation results.

Banana

Ten banana varieties were evaluated for 3 parameters (texture, taste and flavor). The texture value ranged between soft and firm. The taste evaluation identified Ducasse, Giant cavendish, Poyo and Dwarf cavendish as sweet. Varieties with distinct and strong banana flavor were Giant cavendish, poyo and Dwarf cavendish. Varieties with flat and mild banana flavor were Ducasse and Matoke, respectively.

Papaya

Nine papaya varieties were evaluated for 3 parameters (taste, flavor and texture). The varieties Higging and Sunrise were rated as sweet. A variety called Red Maradol was not acceptable due to unpleasant and repulsive taste and flavor.

Grapes

Twenty grape varieties were evaluated by taste panels and the result indicated that Thompson seedless was a sweet variety popular. as a table grape. Black hamburg, Royalty, Muscat of hamburg, and Tikur woyn were also preferred. A variety called barbra was sour and not accepted as table grape. It could be used for making wine.

Oranges

Five orange cultivars on five different root-stock combinations were evaluated for fruit and juice qualities. The result for oranges showed that the average fruit weight ranged from 153.9g(Hamlin on Carrizo Citrange) to 393.9g (Washington Navel on Volkamariana). Highest percentage juice was obtained from Jaffa on Rungpur Lime(55%), while the lowest was recorded for Washington Navel on Troyer citrange (43%). Based on panelist response Washington Navel, Jaffa and Hamlin on most root-stocks were highly accepted. Olinda on most of its root-stocks was the least accepted variety.

Manderin

Three manderin cultivars on five different root-stock combinations were evaluated for fruit and juice qualities. The weight for mandarin varieties ranged from 93.04g (Clementine on Troyer Citrange) to 120.3g (Dancy on Cleopatra mandarin). The highest percent juice was obtained from Fair Child on Carrizo Citrange(56%), while Dancy on Rungpur Lime showed the least (39.6%). Among the varieties Fair Child on most of the root stock combinations gave the highest percent total soluble solids. Generally the variety Fair Child was highly accepted for both fruit and juice quality. The next preferred variety was clementine

Sweet potato
Sixteen sweet potato varieties were evaluated by taste panel. The result indicated that TIB 9 (62), Alemaya II, Wolaita, Erergota, Koka 6 and CN 941-32 were varieties with sweet taste. Among these TIB 9 (62) and Alemaya II were the most preferred. Koka 12 had a carrot red color, soft and mushy texture which was not favored by the taste panels.

Tomato
Ten processing tomato varieties were tested for processed tomato products (paste, juice and ketchup) (IAR 1995). Some physical (color, size, number of locules, etc.) and chemical (acidity, total soluble solids, amount of juice) were measured before and after processing the final products (IAR 1995c). Based on sensory evaluation, Serio and Interpeel were preferred for tomato paste; Serio and Nova-70 for juice. Meremma, Red ball, M-22 and Red pear were good for ketchup making. These varieties showed better processing quality than the check Roma-VF.

Haricot bean
Haricot bean is a lowland pulse widely grown in the rift valley. Farmers in this region grow predominantly the white variety for export. Some colored varieties are grown for home consumption and local market.

Utilization of Haricot Bean. Varieties of haricot beans are evaluated for food making qualities. The traditional foods from legumes are *nifro*, *kik* and *shiro wot*. Seven varieties were evaluated for *kik* and *shiro wot* preparation. Most varieties had a beany flavor which was not acceptable by panelist. Among the lot a cowpea variety named black eye bean made the best *kik* and *shiro wot* (unpublished paper). The taste and acceptability of this variety was better than field pea which is the preferred endogenous crop for making these products. The storage life of cowpea grain is the major draw back and needs further investigation by entomologists.

Cooking Time of Haricot Bean. Beans are consumed cooked. A fast cooking variety is preferred to reduce time to cook and fuel consumption. Therefore, varieties at different stages of development are being evaluated for cooking time in conjunction with efforts of other disciplines. A set of common beans, of three classes (white pea beans, different colored beans and large seed beans) which were at three stages of varietal development (Nursery II, PNVT and NVT) were tested for seed weight, cooking time and interactions between seed weight and cooking time. A total of 147 bean genotypes were included in the experiment. The experiment was replicated thrice in time (unpublished report).

Length of cooking time in the overall experiment ranges between 12 and 35 minutes. The variation is highest in the different colored beans (DCB) in almost all cases. The high variance obtained in the colored beans also suggest the range of possibilities that exist in variation in cooking time. In white pea beans (WPB) and large seed beans (LSB) the range of variation in cooking time is low with lowest variances among the three types of beans. Variation in cooking time among the three stages of varietal development within each classes of beans is not significantly different. However, among the three class of beans, the WPB on the average took shorter time to cook. With few exceptions it can be concluded that:

1. Hard-to-cook genotypes are found most commonly in different colored beans and large seed beans.
2. Easy-to-cook genotypes are most common in white pea beans.
2. The degree of relation between seed weight and cooking time depends on bean types; the relation being strong in different colored beans.

Sorghum Utilization Studies

The theme of this research area is to study the food making quality of varieties in advanced lines. Crop varieties differ in their food making qualities. To realize these variations a standard methods were developed. Then the test materials were being evaluated under standard and identical conditions.

Standardization of sorghum "injera" preparation
Preparation of sorghum "injera" was standardized to use it for varietal evaluation of advanced lines. Each step in the preparation procedures were experimented under different levels. The outcome of the experiment for the standard procedure was dehulling the grain, fine milling, addition of 10% "ersho" (starter culture) on a flour weight basis, 48 hrs of fermentation, addition of "absit" (gruel) at a temperature of 40 ^{0}c were found optimum for sorghum "injera" preparation (IAR, 1985).

Brown sorghum utilization
Seredo, is a brown sorghum variety released for the moisture stress areas where bird damage results in a substantial loss of yield. Previous work done on this variety revealed that injera made from undehulled seredo and dehulled with traditional method (mortar and pestle) resulted in poor quality "injera" due to presence of tannin in the seed coat. Dehulling seredo with mechanical dehulling device up to 4 minutes of retention time didn't change the quality of *injera*. However, when seredo was mechanically dehulled with a TADD (Tangential Abressive Dehulling Device) mill for 5 minutes, the quality improved, but about 56% of the endosperm was lost along with the seed coat.

As dehulling seredo for 5 minutes resulted to a high loss of the endosperm, *injera* was prepared from composite flour (tef and undehulled seredo mix). The product obtained from different mixing proportions were evaluated by panelists for color, taste, texture, appearance and general acceptance. The result obtained suggest that 1:1 seredo and tef mixture gave good quality *injera*. When the proportion of tef increased the quality of *injera* also improved. It is, thus, recommended that for *injera* preparation from a composite flour of sorghum and tef, mixing them in at least a 1:1 proportion gives good result.

Shelf life studies of sorghum *injera*

Injera prepared from 100% sorghum becomes brittle and dry after brief period of storage. This was a major problem mentioned during the survey. This experiment was initiated to identify best storage material which extends its shelf life.

Five different proportion of sorghum (Gambella 1107) and Tef (local) mixtures (0,25%, 50%,75% and 100%) were used to prepare *injera*. From each preparations, five *injera* were stored in five different storage materials (*mesob*, *sefed* and both with and without polyethylene linings and *mesob* with eucalyptus linings) (unpublished report). The *injera* kept in these materials were tested in three different seasons (hottest, moderate and coldest) of the year. After the *injera* is stored, texture and mold development were evaluated at 6 hrs intervals. Daily temperature and relative humidity were recorded during the storage periods.

The result obtained suggested that *injera* prepared from 100% sorghum remained soft for 48 hours when kept in *messob* and *sefed* with polyethylene linings. At higher temperatures the use of *sefed* with polyethylene linings retained the softness for up to 72 hours. In 75% sorghum *injera* preparations, same materials retain softness till 72 hours after storage. If polyethylene are limiting, *injera* kept in *sefed* and covered again with *sefed* or kept in *mesob* either with eucalyptus linings or without any lining could serve as a better alternative in 100% and 75% sorghum proportions. In 50% and less sorghum proportions of sorghum-tef mixtures, no differences were found among the different storage methods.

Extended storage under all conditions resulted in high mold development. During the hottest period and when tef is used in the mixture, storing tef *injera* in *sefed* and covered with *sefed* resulted in low mold. At moderate temperatures keeping *injera* in *mesob* without any lining or in *sefed* and covered with *sefed* produced better results.

Experiments conducted previously and herewith provided concrete evidence that sorghum/tef mixture produced good quality *injera*. When the proportion of tef increases in the mixture, the study indicate an increase in mold spoilage. In the future, an experiment will be initiated to study factors that may contribute to moldiness in *injera* prepared from high proportion of tef in sorghum/tef mixtures.

Sorghum varietal evaluation for food making qualities

Thirteen sorghum vareities with three color groups (white, red and brown) were evaluated for seven food types("injera", "kitta", "nifro", "genfo","tella", "kollo" and "bekel"). The objective of this experiment was to evaluate sorghum varieties for food making quality. Different parameters relevant to each food product were measured. Based on taste panel evaluation, three varieties Gambella 1107, AL-70 and IS-2284 were good "injera" makers, while, 0Zx26/Fs/5/E3 and Seredo gave poor quality. These two varieties were brown sorghum varieties with high tannin content which renderd bitter taste and poor appearance. For "nifro" AL-70, M-90411 and 85MW-5667 were selected. 0Zx26/Fs/5/E3 was rated as poor. For "kitta" AL-70, 85MW-5667 and IS2284 were best. 148 x Framida made poor "kitta". For "genfo" AL-70, PGRC/E # 69391 and Birmash were rated as best, while IS2284 gave poor result. In "tella" preparation, Birmash, 12x34/1/F4/3/E and M-90411 were best. Seredo gave poor quality "tella". The same set of varieties were tested for malting quality, the diastatic power is yet to be tested in the malt industry. The other product tested was "kollo", none of them were popping varieties, hence, gave poor result. This experiment indicates that a given variety is good to specific food product.

Surveys on Crop Utilization

Surveys on utilization of different crops were conducted. The objectives of these surveys were to identify processing constraints, document traditional food preparation procedures, assess varietal preferences. Some constraints indicated during the survey could be a research agenda to come up with some solutions. Among the lowland crops, surveys were conducted for haricot bean, sorghum, tef and maize.

Haricot bean

A survey was conducted in 6 surplus haricot bean growing districts, Sidama, Wolaitta, Alaba, Adami Tulu, Adama, Boset and two boarding institutions (Kuyera and Akaki). From each awraja sixty households were selected randomly. A total of 360 households were interviewed. The survey result indicated that six dishes (*nifro*, *shiro*, *kik*, soup, *kollo* and *blandwa*) were locally prepared from haricot bean (IAR, 1995b). The last two dishes are prepared in Wolaitta area only. The most common and popular dish in the rift valley area is *nifro*. Large seeded beans and different colored beans are preferred for *nifro* preparation. Red Wolaitta is the most preferred variety in Wolaitta area due to its taste and color. The straw and other threshing residues were used for animal feed, fuel and soil improvement.

Sorghum

A survey was carried out in surplus sorghum producing areas covering nine Woredas in three awrajas of the central zone of the country. Six traditional foods from sorghum were recognized i.e. *injera*, *tella*, *nifro*, *kollo*, *genfo* and *kitta*. Methods of preparation and varietal preferences in each surveyed area were identified (IAR, 1987). One of the processing constraints mentioned was drying of sorghum *injera*.

Tef

Tef utilization survey was conducted in 9 districts of major tef growing areas. Within these districts 36 sub-districts were surveyed. A total of 540 households were interviewed (IAR 1995a). The result indicated that there were four food types prepared from tef. These were *injera*, *kitta*, *genfo* and *atmit*. Tef is utilized for *tella* local beer brewing. *Kitta* from tef is added in the fermentation process of *tella* preparation".

Major constraints in tef processing were aspiration of the grain and baking of *injera*. *Injera* was stored in different containers depending on the availability of material. These containers were locally known as *mesob*, *sattera*, *enkib* and *wotabo*. The shelf-life of *injera* was 3-4 days depending on the storage temperature.

Although white tef makes good *injera*, farmers prefer to sell it at higher price and buy red varieties at a cheaper price for home consumption. White tef was consumed occasionally in holidays (new year, christmas, easter, etc.). The use of straws as a result of threshing were for feed, construction (as a mix in a mud) and sale.

Maize

A household survey was conducted in 3 awrajas (Yerer and Kereyu; Haikotch and Butajira; and Yefat and Timuga) to study maize utilization (Senayit, 1993). A total of 79 households were interviewed. The result suggested that at least six types of food are prepared from maize. These includes *tella*, *kollo*, *nifro*, *injera*, *genfo* and *kitta*. Varietal preferences of maize for different food making was identified. Maize food preparation is found to be cumbersome and time consuming due to manual dehulling with a morter and pistel and wet milling with grinding stone. This suggests the need to develop a mechanical dehulling device.

Future Directions

The IAR management is building a central food laboratory at the head quarter. It is intended to centrally strengthen the available manpower and facilities to render better services to all commodities and open up specialized section to handle different facets of the discipline. When this become a reality, the future direction will be to:

1. Continue varietal evaluation of all crops
2. Initiate Quality evaluation and processing of animal products
3. Undertaken new product development and to introduce industrial uses of crops
4. Conduct basic research to solve problems in food industry

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SESSION VI
Technology Transfer

Chair: Ato Elias Urage
Rapporteur: Ato Haile Kefene

REVIEW OF AVAILABLE TECHNOLOGY PACKAGES AND POPULARIZATION PROGRAMS FOR DRY-LAND FARMING: THE MELKASSA EXPERIENCE.

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Abstract

In the attempt to solve the prevailing problems particularly in the low, erratic and often unreliable rainfall areas of the central rift valley, Melkassa Research Center has devoted much of its resources for the development of appropriate agricultural technologies for the last 25 years. As a result, several improved crop varieties of sorghum, maize, teff, haricot bean and horticultural crops, crop management practices and small farm implements have been developed. Along this technological package, development efforts have been made also in area of extension. The extension intervention has been effected through package demonstration and popularization supported with extension hand books, leaf lets, field days and frequent in-service training for farmers, Development Agents, Subject Matter Specialists and for staff of the NGOs operating in Central Rift Valley areas of Ethiopia. For not less than a decade a total of 16 varieties of sorghum, haricot bean, teff and maize were popularized at 251 sites in Eastern and Northern Shoa and Western Harrarge. In areas where demand for improved crop varieties were created as a result of extension intervention, about 4270 Qt of improved seeds, 7952 planting materials of various horticultural crops and 43 small farm implements have been dispatched to individual growers and NGOs mainly on sale. The efforts made in area of extension were not without challenge. There has been a number of limitations and gaps that are seriously affecting the intervention. This paper thus reviews available technological packages for dry-land farming and presents major achievements, limitations and gaps in technology transfer in the rift valley areas of Ethiopia.

Introduction

The Institute of Agricultural Research (IAR) established as a semi autonomous public institution in 1966, is the organization given the mandate to coordinate and execute agricultural research in Ethiopia. Over the years IAR, through its centers, carried out numerous experiments to identify technologies that may contribute to increased productivity of crops and livestock under various agro-ecological conditions.

The conventional wisdom of generating and transfer of technology in the IAR has a well defined schematic procedures which start with the identification of priority problems through diagnostic surveys and on-farm experiments and eventually transferring the generated technologies to end-users by way of on-farm, pre-extension demonstration and training. Even though there were a number of research recommendations that had been documented across the research centers, the contribution of the IAR to the agricultural development of this country remained unrecognized merely for weak extension of its research findings to the users. This point of concern led to the institutionalization of Research Extension Division (RED) in April 1985. The division was mainly institutionalized for the following objectives.

[1] Creating strong linkage between research, extension and farmers.
[2] Facilitate and ensure the efficient transfer and utilization of the research recommendations.
[3] Monitor adoption and impact of technologies on the livelihood of the farming communities.

[4] Direct research agenda by devising a system for assessing relevant feedback from users to researchers.

[5] Update the technological package data base at each research center of the IAR from which the formulation of extension recommendation can be made in a way compatible with identified needs of the farming community.

[6] Ensure and follow up the functioning of IAR/ADD adaptive trials and also establish joint adaptive and verification trials as deemed necessary.

In the attempt to achieve the stated objectives different strategies have been used by the division.

Technology Transfer Strategies

[1] Demonstration and popularization of research results on farmers' field in collaboration with agricultural development departments and NGOs operating in the zones, if any.

[2] Organize training for front-line extension staff, Subject Matter Specialists, farmers and blacksmith in collaboration with zonal agricultural departments and NGOs.

[3] Organize field visits/days on farmers' fields and in the research centers, symposia and workshops for farming communities, front-line agricultural experts, policy makers, politicians and NGOs.

[4] Conduct surveys and case studies related to feedback assessments, adoption and impacts, dissemination method studies and institutional gap analysis and other technology transfer related problems.

[5] Prepare production guidelines or extension bulletins for SMSs and extension agents.

Released Technologies

For more than two decades improved crop varieties that are adaptive to moisture stress, low, medium and high altitude areas have been developed at Nazareth Research Center. Until 1992, about 32 varieties of different cereal crops, haricot beans, vegetables, banana and citrus have been released (Table 1). Along with the varietal development effort, a number of crop management practices and farm implements had also been generated.

Pre-Extension Demonstration of Recommended Package on Farmers' Field (1986-1995)

Demonstration of recommended packages on farmers' fields is one of the technology transfer strategies used in the IAR. At Melkassa the pre-extension research center-based demonstration includes mainly technologies that are adaptive to moisture stress and low altitude areas of the rift valley of Ethiopia. The pre-extension demonstration under Melkassa was fledged to Meisso-Asebot Plain in the East, Shashamane and Siraro sub-districts to the South and Merabitte and Shoa-Robit to the North.

From 1986 to 1995 about 32 improved varieties of different crops have been demonstrated at 721 sites in the rift valley excluding the demonstration sites used for banana and citrus. This means that at least 721 farmers have been reached apart from neighboring and copy farmers through popularization programs used for major food crops. Yield increment as a result of change in management practices ranges from 33%-183% (Table 1).

Table 1. Mean grain yield obtained from pre-extension demonstration conducted in the rift valley areas from 1986-1995, Melkassa.

Crop	No. of variety	No. of demonstration	Mean grain yield Q/ha* IP	FP	% yield increment
Maize	1	91	19.68	10.63	85
Sorghum	6	85	15.49	8.89	74
Haricot bean	5	93	12.53	8.72	44
Teff	2	41	11.00	8.00	37
Tomato	2	6	446.33	335.60	33
Onion	3	5	257.13	90.97	183
Banana	3				
Citrus	10				
Total	32	721			

* IP - Improved practice; FP - Farmer Practice

Popularization of Improved Crop Varieties

In areas where demand for improved varieties once created as a result of extensive research center based pre-extension demonstration, it is imperative to transfer technology to large users in more wider areas. This was effected through popularization program where by interested farmers were given a sample of improved seeds for not more than a half hectare. This approach was found to be useful not only for reaching more farmers and front-line agricultural experts in areas under our mandate but also helped farmers to harvest and save seed for following season. From 1993 to 1995 about 718 farmers had participated in popularization program in the rift valley areas of Ethiopia (Table 2).

Table 2. Popularization of improved cereal crops, low land pulses and fruit crops in the rift valley areas of Ethiopia, 1993-1995, Melkassa.

Crop	Type of variety	No. of participating farmers	Mean grain yield [q/ha]
Maize	Katumani	180	15
Sorghum	76t₁#23 Gambella-1107 Birmash	220	13
Haricot bean	Mex-142 Awash-1	292	10
Banana	Giant Cavandish Poyo Ducasse hybrid	8	NA
Citrus (Orange, mandrin, lemon and lime) (seed on table)	Ten varieties	18	NA

Provision of Improved Seeds to Users

To strengthen the pre-extension demonstration and popularization programs, the Nazareth Research Center has been providing improved seeds of major crops on sale to users through research extension division. A total of 6729 Quintals of improved seeds of major crops grown in the moisture stress areas has been provided to the users on sale. Of these total, 2793, 1988 and 1948 quintals were improved seeds of maize, sorghum and haricot bean, respectively (Table 3). The intention is not to serve as seed supply agency but only to complement the pre-extension demonstration and popularization programs of the research center.

Table 3. Quantity of seeds dispatched to 'intermediate' (ESE and NGOs) and end users (farmers). 1986 - 1994.

Crop	Quantity dispatched [Quintal]		
	1*	2	Total
Maize	2554.62	238.13	2792.75
Sorghum	142.38	1845.68	1988.06
Haricot bean	386.98	1561.39	1948.37
Total	3083.98	3645.20	6729.18

* 1 Individual growers and NGOs
2 Ethiopian Seed Enterprise

On-the-Job Training for Front-Line Agricultural Experts

Training is used as one of the mechanisms to bring together different actors including farmers and NGOs both on farmers' fields and in research center. It is also used as media for assessing feedback. Moreover, an urgent need also exists to upgrade the technical competence of SMSs, DAs and farmers for which training is required. This is particularly true for the fact that high agricultural production level does not necessarily require high inputs rather it calls for well trained front-line actors mainly farmers who are capable to take care or manage the recommended practices throughout the growing period of a crop. This training form an important element in the process of technology transfer.

In collaboration with zonal agricultural development departments and NGOs (World vison, CARE-International), training for SMSs, DAs, farmers and blacksmith was organized at Nazareth Research Center, Melkassa since 1986. A total of 1080 SMSs and DAs and about 127 farmers were trained at Melkassa for the last nine years (Table 4). In collaboration with Agricultural Implements Research and Improvement Center (AIRIC), about 25 blacksmiths from Negele Borena, Nazareth, Melkassa and Wolenchiti were trained on fabrication techniques of moldboard plow, wheel hoe weeder, and ridge-tiers. The trainees from Nazareth have produced 30 tie-ridgers and 30 moldboard plows within one month time.

Table 4. IAR/ZONAL/MOA/NGOs joint training for SMSs, DAs and farmers, 1986-1995, Melkassa.

Year	No of trainee		Organization responsible	Course Covered
	SMSs/Das	Farmers		
1986	95	13	Nazareth RC, Zonal MOA, CARE Shoa, World vision, SOS Sahel, SG 2000, Hunger Campaign.	Horticultural crops production, Research and Extension methodologies, Agronomic practices, Pre and post harvest insect and disease management, Transportation and storage facilities, Fabrication techniques of farm implements
1987	187	12		
1988	164	16		
1989	139	11		
1990	51	9		
1991	28	17		
1992	45			
1993	70	15		
1994	254	25*		
1995	47	34		
Total	1080	152		

* Blacksmiths

The number of trainees were high between 1987-1989 when T and V system was actively operating in the area. These numbers were raised in 1994 because of the active involvement of NGOs.

Extension Handbook

Technology popularization and transfer should not be restricted to the art of managing beautiful demonstration plots and field days but also by providing written manuscripts which could be used as reference materials for SMSs and DAs on which they have to base their technical advice. Hence, two extension hand books on haricot bean and sorghum have been published and distributed to front-line experts working in major production areas of the two crops in the country. Moreover, at various training sessions handouts on horticultural crop, dryland agronomy, farm implements, major diseases and pests of lowland crops have been provided to the trainees.

Major Achievements

The achievements of the research extension programs primarily lie in the conveying of research findings and creation of awareness to the farming community. Moreover, since its establishment in 1966, it is only recently that the IAR came to be known as an important parastatal institution for changing the agricultural sector of this country. This is due to the research extension programs that has brought the importance of IAR to the knowledge of policy makers, politicians and users than any of the extension program ever exercised before. It is not only by demonstration and popularization that research findings and IAR efforts exposed to users and policy makers but also through mass media, organized field trips/days, workshops and technology exhibition, etc. used as part of the extension approaches.

Farmers surrounding the research center used to acknowledge zonal agricultural development department and NGOs for providing them with improved seeds and information. But, as of now they came to realize and trace that the IAR research centers are the source of agricultural technologies. As a result of this awareness a number of farmers directly come to the research center for seed request. In areas where this extension program is effectively implemented, large quantities of improved seeds (cereals, pulses, horticultural crops] have been provided both on sale and free of charge for those who showed their interest.

Major achievement was also realized in area of linking the IAR with MOA, NGOs and international organizations. This linkage was effected not only around the table or in offices but also on practical settings. Joint extension intervention that exist between IAR/MOA/NGOs (World-Vision and Care-Shoa) and International Organizations [CIAT and FAO] at Melkassa can be cited as good examples. The good working relationship established between IAR/MOA and SG 2000 at Bako is also another example to be mentioned here. In fact the joint extension intervention between IAR and SG 2000 will be functional also at other research centers in the shortest time possible.

Research-extension also played an important role in upgrading the technical competence of the front-line actors. This was materialized through organizing frequent hands-on training for SMSs, DAs and farmers.

Limitation and Gaps

Limitations

[1] Lack of late and/or medium maturing improved sorghum varieties. Farmers in rift valley areas plant only late maturing local sorghum cultivars not only for yield but also to use the stalk for fire wood, house construction and fences. They do not plant early maturing varieties in June/July not only because of their poor stalk quality but also they are heavily attacked by birds since they mature when there is no other crops on the field that reach maturity. Instead farmers give priority to haricot bean and teff in allocation of limited land for socio-economic advantage they have over sorghum. As a result, it has been found difficult to encourage farmers to grow short and early maturing sorghum varieties where they have other options.

Birds scarring is another problem for sorghum production particularly in areas where bird scaring is not practiced. Seredo, a relatively bird tolerant variety, is not accepted by farmers because of its poor food quality caused by its high tannin content. This would be another area of concern for sorghum research.

[2] Inadequately organized and decentralized input delivery system. Even though technology popularization program have been carried out in rift valley areas, no consecutive intervention have been taken particularly in provision of seeds, planting materials and farm implements by concerned organizations.

[3] Lack of responsible organizations to multiply horticultural crops and farm implements.

[4] Some of the technologies on the extension programs are obsolete ones. For instance, Katumani is the only maize variety used for almost two decades. This variety is no more a new variety in the central rift valley areas of Ethiopia. Farmers remain with this variety not because of its yielding potential but rather for its adaptive quality under moisture stress condition. Otherwise the variety is yielding low, low seed weight and susceptible to weevil as compared to local cultivar. Early to medium maturing maize varieties are urgently needed for moisture stress areas of Ethiopia.

[5] Low emphasis has been given to teff research at Melkassa. Despite the importance of teff as a source of staple food and its wide range of ecological adaptability, very low emphasis has been given to teff research in terms of budget and manpower.

Gaps

[1] Level of adoption and impacts are not yet assessed. Even though technology transfer efforts have been made to popularize and transfer technologies, no concrete evidence has been documented on the level of technology adoption and impact realized by farmers. Hence, adoption and impact monitoring studies need to be undertaken.

[2] Extension problems related to infrastructure, credit, incentives, communication and interaction between front-line actors and other related problems are not studied. Extension intervention so far operated by assuming the above points as if they are on smooth terms. Much of the lack of success in extension might be attributed to the above issues. This also need further investigation.

[3] The premise behind popularization and dissemination program underpin linear Transfer of Technology (TOT) Model. A more rational step to turn upside down this model is needed to make technology generation and transfer people-centered. This can be feasible through exercising Participatory Rural Appraisal (PRA) and Farmer Participatory Research (FPR) or Participatory Technology Development (PTD).

THE EMERGING LEARNING PARADIGM IN EXTENSION INTERVE. TOWARDS PARTICIPATORY INQUIRY.

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Abstract

When Research-Extension Division was first institutionalized in the mid 1980's in the IAR it was mandated to transfer research findings from research centers to end-users. At this historical event the conventional thinkin in which extension swamped was that of Transfer of Technology [TOT] model, a model that advocates a large backlog of scientific information and powerful technology ('Miracle seeds' and sowing dates, etc) were stockpiled in the research centers ready for "transfer" to farmers through technical oriented downstream actors. In this conceptual framework extension was perceived as 'cargo' image of intervention, extension worker as battery powered megaphone, researcher as technology provider and farmer as passive recipient. However, experience in extension intervention in rift valley areas of Ethiopia revealed that this TOT model is in crisis. In the first place, the conditions required (agro-climatic situations, credit, market and socio-economic factors, etc) for the utilization of shelved technology are not readily exist in this risk prone environment. Secondly, the assumption that technology coming from research center is a "power" for agricultural development contributes much to the neglect of useful ideas and insights emerging from rural people context. Consequently, local land race varieties, farmers' indigenous knowledge and lateral technology transfer were trivially considered in extension intervention. Thirdly, even though extension was trapped by downward drifts, adoption of those trickled technologies is entirely a voluntary behavioral act on the part of a farmer. Hence, farmers either adopted, rejected, or unpacked some of the packages. The key challenge to extension intervention is thus to create a new mode of functional network to legitimize the complementary role of researchers, extension specialists and farmers, and to adopt various methods of participatory inquiry that reverse part of TOT model. This paper presents some reflections learnt from our past actions and experiences and also sketches the state-of-an-art overview of the current thinking and methodological implications for future extension intervention.

Introduction

When the Institute of Agricultural Research (IAR) came into being as an important organ of the government in 1966, extension was seldom considered. At that historical event the institute was entirely mandated to formulate national research policy, under take and also coordinate agricultural research programs carried out by various organizations in the country. The reason why extension pushed to the periphery in the research institutional setting seems that technology development either considered as an end by itself for IAR or extension was considered exclusively as business of other organizations like Ministry of Agriculture (MOA). From 1966 to 1973/74 IAR was operating without extension wing and with very limited out-reach programs that were mainly used for package testing.

But, later in 1973/74 the IAR/EPID (Extension Project Implementation Department) joint program was started mainly for formulating research recommendations for specific target areas. This was discontinued in 1976/77. In early 1980's IAR/ADD (Agricultural Development Department) joint program was re-initiated more or less with similar mission with that of IAR/EPID program. In both out-reach programs the role of the IAR was limited to provision of improved seeds, improved crop management practices and technical support while the MOA (EPID and ADD) was responsible for financial and other administrative supports.

Even though the two joint programs played important role particularly for adjusting research center recommendations to the specific areas, the out comes had not gone outside the out-reach fences as expected. Such low progress in transfer of research findings has been the debating point in many occasions among policy makers, managers, researchers and even other funding organizations like World Bank. This state of affairs raised the obvious need for re-assessing the strategies of the national research system. It is for this concern that the IAR recast its organizational structure and resource distributions which eventually led to the institutionalization of Research-Extension Division (RED) as of April 1985.

The Conventional Conceptual Framework in Research and Extension Tradition

The conventional thinking on the agricultural research and extension setting isolates the agricultural management system into building blocks or sub-systems [research, extension and utilizer sub-systems) separated in space and time. They are separated in space because research and extension organizations are institutionalized under different ministries in some cases, they are separated in time because research and extension intervention is very much sequential. In this conventional thinking the under- lying conceptual framework in which extension intervention swamped was that of popular 'Linear Model' or Transfer of Technology (TOT) model (Chambers, R. et.al. 1989). The model is linear and sequential, in that research first generate technology, which is then transferred by extension and finally used by farmers (center-periphery process). This implies that once a scientist is done with it, no need for his/her further involvement in the technology. That is the responsibility of "down-stream actors" (Roling, 1990).

This conceptual model reflects the rationale behind extension intervention. These are:

[1] A large backlog of scientific information and technologies were stock piled ready for "transfer" from research center to farmers. Where as farmers' local knowledge and technical practices generated through generations considered inferior and unproductive.
[2] A research center is considered a "solution building institution" or a source of powerful technology [`Miracle seeds', sowing dates and planting methods, etc] that has to be conveyed to the end users. In contrary, the constructive ideas and insights emerging from rural people-context and the lateral information/technology transfer is neglected. Thus, the hallmark of extension within the TOT model lies on 'cargo image' of intervention, where the extension pick-up car serve as a 'cargo' to carry the package to the farming community and the extension agents serve as battery powered megaphones. That is, researchers generate and package technology and then inflate into the mind of extension agent about importance and powerfulness of the technology and ways of using them which the extension agent in turn preach the farmers to accept these technologies generated by researchers. The network of this functional relationships is more or less that of "doctor-patient" relationship. May be physicians are smart in one aspect than agricultural researchers or extension specialists; they can anesthetize the patient and change into an object to give any type of treatments [eg. surgery]. But in case of extension intervention neither the extension specialist anesthetize the farmer nor forced them to act against their perceived domain of interest. Thus, taking research recommendations is entirely a voluntary act on the part of a farmer. This can be explained from empirical evidences envisaged in our past actions in extension intervention.

Some Reflections

From our past actions and experiences in extension intervention at Melkassa some reflections or learning points have been envisaged. These learning points comprise:-

Extension is governed by voluntary act or human intentionality.
Had it not been for this reason we could have been successful in increasing the rate of adoption of improved early sorghum varieties in central rift valley of Ethiopia. The same is true for shilshalo (farmers' weeding practice) which could have been substituted by frequent hand weeding and hoeing (research recommendations). This voluntary behavioral act is, however, governed by environmental factors and farmers' socio-economic circumstances.

This learning points would lead us to ask our self that 'why don't farmers do what we want them to do?'. Is it because they are ignorant and conservative? Not at all. Farmers are perfect professionals in farming. Hence, they have their own reasons for 'not to do what we want them to do' or for 'why they do the way they do'. Instead we need to ask our self that how do we (researchers) help farmers achieve what they themselves want to achieve?. This query has methodological implication. Could extension remain as provider to induce voluntary behavioral change? could it remain on the art of giving technical advice? This issue will be discussed later in detail.

Farmers unpacked the package.
A method used for conveying technologies from research centers to farmers was that of full package demonstration contrasted against farmers practices as if farmers' adoption pattern commonly characterize by sudden switch to the whole package. But, a cursory glance showed that farmers adoption pattern consists of step wise testing of the component rather than adoption of a complete set of a recommended package. Farmers showed this adoption pattern for various reasons such as lack of cash, risk aversion, poor service, labour availability and societal preference. As a result, farmers either adapted, rejected or unpacked some of the packages. But, in contrary, extension was continuously insisting to transfer technological package but not basket of choices.

Technology is assumed as a "power" because it is a product of 'science'.
Because of this hegemony in scientific knowledge extension staff were continuously under pressure to carry the technology (seeds, planting dates, planting method, fertilizer type and rate, etc) from which farmers should extract maximum returns. However, in the first place, the condition required for the utilization of that technology are not readily available. Secondly, the assumption that technology is a 'power' for agricultural development contributes much to the neglect of farmers' technical knowledge and local land race varieties. Despite the type of agriculture we have today that is largely sustained by these local knowledge and practices, extension intervention waste much of its time as technology 'provider' to replace farmers' local knowledge and indigenous land race varieties.

The development and utilization of technology constitute center-periphery process.
This continuum neglects the multiple sources of new ideas and emerging from rural people

context. The process assumes research center and/or universities are the only source of knowledge and technology and the rural people are seen either as adopter or rejecter but not as originator of either technical knowledge or improved practices. The knowledge and technical practices embodied in rural people's context are considered as primitive, unscientific and wrong. From this premise there is no need for extension to give due consideration for this 'unscientific rural people's knowledge and/or technical practice'; only downward drifts is sufficient to modernize agriculture.

There is system boundaries

There is no sense of interdependency among actors and the synergetic or holistic nature of the system is not perceived in conventional wisdom of extension intervention. For one thing, the agricultural research and extension are demarcated into building blocks/boundaries with no cross-over as they are defending themselves by their given mandate, specialization and organizational boundaries. Secondly, actors do not perceive that they are part of the same system simply because they are working for different institutions with varying specialization. This type of institutional settings require unique linkage arrangements to bridge sufficient interface.

Heterophily gap in information communication

By virtue of international reputation for the institute and researchers, research findings has to be published in a scientific standard and in English. But, what is really surprising is that those publications as they are abstracted in technical language and statistical expressions have no practical value at least in the eyes of SMSs and extension workers, let alone the illiterate farming majorities. It can not be denied that researches are more worried about where and when to publish than what, how and for whom to publish. This professional status quo resulted in heterophily gap and more precisely create communication barrier between researchers and those majority farmers who are illiterate. In response to these short comings in extension intervention there are emerging learning paradigm to make extension intervention more participatory.

Emerging Learning Paradigm: Towards Participatory Inquiry

In seeking to serve farmers in achieving production breakthroughs, the TOT paradigm is in crisis. Historically non-adoption of recommendations has been attributed first to farmers' ignorance, to be over come through more and better extension, and then to farm-level constraints (Table 1); gaps in yield between research station and farm were analyzed with solution in easing the constraints to make the farm more like the research station (Chambers, 1993). As of now the explanations have been reserved. Farmers are far more knowledgeable and better informed than agricultural professionals used to suppose; and farming conditions are, and will remain, different from those of the research station.

So the crisis has led to questioning the very processes which generate agricultural technology, and to the exploration of new approaches in research and extension. The first step is to reverse 'normal professionalism' the thinking, values, methods and behavior dominant in a profession of discipline reproduced by teaching and defended by specialization (Chambers, 1993). It is to question the extension intervention trapped by downward drifts and to disregard the thinking that technology is a power for agricultural development.

Table 1. Research and extension: beliefs and socio-economic research frontiers 1950-2000.

	Explanation of farmers non adoption	Prescription	Key extension Activity	Socio-economic research frontiers	Dominant research methods
1950s 1960s	Ignorance	Extension	Teaching	Understanding the diffusion and adoption of technology	Questionnaire surveys
1970s 1980s	Farm-level constraints	Remove Constraints	Supplying impact	Understanding farming systems	Constraints analysis, FSR
1990s	Technology does not fit	Change the process	Facilitating farmer participation	Enhancing farmers' competence, changing professional behavior	Participatory research by and with farmers

Source: Chambers [1993]

The essence of participatory inquiry is reversals of parts of TOT that have tended to go unquestioned and also reversal to normal professionalism. A reversal of explanations looks for reasons why farmers do not adopt new technology not in the ignorance of the farmer but in deficiencies in the technology and the process that generated it. Locations and roles are reversed, with farms and farmers central instead of research center, laboratories and scientists. The assumption behind this reversal is to perceive technology development and utilization as social phenomena. More specifically, it is the mutual enrollment of many social actors, not just scientists in technology generation, transfer and utilization continuum. All actors have scientific and/or local knowledge to complement. Thus, it is not only research center from which technology is fetched and transferred by down-stream actors but from rural people's context as well.

Farmers need choice for improving their risk prone agriculture. The role of researcher or extensionist is then to look for and supply a range of genetic materials and a range of information about practices and potentials. The demand here is not for the package of practices of normal research and extension, but for a basket of choices. The key challenge to extension intervention is thus to create a new mode of interaction between farmers, researchers and extensionist than to remain mere provider/conveyer.

Methodological Implications for Future Extension Intervention

No exclusive biological solution readily exist from research center to be on extension 'cargo' for immediate transfer. Similarly no body of knowledge (scientific or local) has exclusive claims in controlling all aspects of rural life. Instead there is complementarity in that; farmers know something that agricultural scientists do not know and can not completely know and vice-versa. Thus, each has his/her domain of expertise to inform other. In this regard extension intervention has to move from teaching or preaching to a joint learning style to accommodate and legitimize the complementary role of the two bodies of knowledge.

The above fundamental notions underscore the need for shift in extension methodologies. In this shift in extension methodologies the new role of farmers, the new participatory approaches and methods and the new learning environments, all imply new roles for agricultural scientists and extensionists. Scientists must continue their normal science, in laboratories and on research stations. In addition, they will have to learn from and with farmers, and so serve diverse and complex conditions and farming systems. The new roles for extensionists include: catalyst and consultant to stimulate, support and advise; facilitator of farmers' own analysis; searcher and supplier of a range of genetic resources and practices for farmers to try; and enable farmers to learn from one another (Table 2).

In this vision for the future there are three areas to tackle as identified by Pretty (1994). These are new methodologies for participatory analysis and sharing; new learning environments for professionals and rural people to develop capacities; and new institutional environments, including improved linkages within and between institutions. The following assumptions underlie this conceptual framework:

- Participatory approaches and methods support local innovation and adaptation, accommodate and augment diversity and complexity, enhance local capabilities, and so are more likely to generate sustainable processes and practices;

- An interactive learning environment encourages participatory attitudes, excites and commitment, and so contributes to jointly negotiated courses of action;

- Institutional support encourages the spread between and within institutions of participatory methods, and so gives innovators the freedom to act and share. This include where a whole organization shifts towards participatory methods and management, and where there are informal and formal linkages between different organizations.

In recapitulation the ultimate goal of extension intervention is not transfer of technology but to empower farmers, to develop common language, to build trust for joint construction and analysis of technology and above all to assist farmers achieve what they themselves want to achieve. And hence, all rural women and men with whom development work such as agricultural research and extension are undertaken should constitute the center of our learning. They are where the action is, what is available and happening with them is what ultimately decides the effectiveness of our work.

Table 2. Methodological implications for research and extension intervention Under contrasting theoretical paradigms

Variable	Theoretical Paradigm	
	TOT Model	**New Professionalism**
Assumption about source of technology	Research center, by specialized scientists	Farming community, social construct
Method of transfer	Package demonstration messages	Piece-meal [basket of choices], principles, methods
Extension scheme	Vertical	Lateral, up and down wards
Role of extension	Provider	Facilitator
Role of farmer	Adopter or rejecter	Originator, source of insights, adapters
Style of interaction	Teaching/preaching	Social learning, dialogue and negotiation
Nature of relation ship	Doctor-patient	Equal partnership
Methods of inquiry	Diagnostic survey, RRA, quantitative data measurement	PRA, ethnography, social and mobility maps, network and systems diagrams, etc.
Impact assessment	Yield average, area allocation	Degree of exposure, diffusion pattern, socio-economic advantage
Stage of extension involvement	At the end of the research process; to convey the end results	From initiation, execution, generation, and up to final utilization: to enquire the social side of technology development, change in attitudes, impacts and facilitate the process.
Research tradition	Controlled experiments by specialized professionals, control and monitor clients from a distance	FPR. PTO, professionals enable and empower inclose dialogue, they attempt to build trust through joint analysis and negotiation resulting in joint generation of technology
Main objective	Transfer technology	Empower farmers

Source: adapted from Beyene (1994) and Pretty (1994)

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SESSION VII
General Issues

Chair: Dr. Asnakew Wolde-Ab
Rapporteur: Dr. Alemu Gebre-Wold

GEOGRAPHIC INFORMATION SYSTEMS: CONCEPT AND APPLICATIONS

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Abstract

Many organisations nowadays spend large amounts of money on Geographic Information System (GIS) and on geographic data bases. Predictions suggest that billions of dollars will be spent on these items over the next decade. Rapidly declining computer hardware costs have made GIS affordable to an increasingly wider audience. More importantly, we have come to realise that geographic information (and the data describing it) is part of our everyday world; almost every decision we make is constrained, influenced or dictated by some fact of geography. The fire brigade sends fire trucks to fire trucks to fires by the fastest available routes. We study disease by identifying areas of prevalence and rate of spread. We research on crops by identifying the importance and social acceptance. This demand for geographic information parallels the need for GIS, explaining its rapidly growing popularity. Such generalisations do not, however, explain why and how GIS can help us. First, we must know what a GIS is and what it can be used for. The concepts and applications of GIS are explained in this paper. The paper being done is in the frame work of the specialists and experts involved in IAR's own activities and hence, is in the fulfilment of the personal objectives introducing:

. GIS concepts and theory;

. the capabilities on GIS software; and

. basic knowledge on GIS-related science and technology. The concepts and applications of Geographic Information System (GIS) are explained in this paper. The paper being done is in the frame work of the specialists and experts involved in IAR's own activities and hence, is in the fulfilment of the personal objectives introducing:

1. GIS concepts and theory
2. The capabilities on GIS software
3. Basic knowledge on GIS related science and technology

Prologue

Many organizations nowadays spend large amounts of money on GIS and on geographic data bases. Predictions suggest billions of dollars will be spent on these items over the next decade. Rapidly declining computer hardware costs have made GIS affordable to an increasingly wider audience. More importantly, we have come to realize that geographic (and the data describing it) is part of our everyday world; almost every decision we make is constrained, influenced or dictated by some fact of geography.

The fire brigade sends fire trucks to fires by the fastest available routes. We study disease by identifying areas of prevalence and rate of spread. We research on crops by identifying the importance and social acceptance. This demand for geographic information parallels the need for GIS, explaining its rapidly growing popularity. Such generalizations do not, however, explain why and how GIS can help us. First, we must know what GIS is and what it can be used for. This paper addresses topics to help us understand GIS; specifically:

- What is a GIS?
- The components of a GIS
- Spatial Modelling Concepts

- Questions a GIS can answer
- Some applications of a GIS

What is á GIS ?

The use of GISs grew dramatically in the 1980's. It is now common place for business, government, and academia to use GIS for many diverse applications. Consequently, many definitions of GIS have developed. GISs are a set of tools for coding, storing and retrieving data that is spatially (geographically) referenced. Many definitions of GIS exist and in this report only some of them will be given. GISs are defined as a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes (Burrough, 1993). Environmental Sciences Research Institute (ESRI) defines GIS as an organized collection of computer hardware, software, geographic data and personnel designed to efficiently capture, store, update, manipulate, analyse and display all forms of geographically referenced information (ESRI, 1993). Aronoff (1993) describes GIS in its broadest sense as any manual or computer based set of procedures used to store and manipulate geographically referenced data (Aronoff, 1993). This broad definition of GIS is elaborated by Manfred ( ) as a computer based information system capable of acquiring spatially referenced data (locational or topological, temporal and attribute information) from a variety of sources, changing the data into a variety of useful formats, storing the data, retrieving and manipulating the data for analysis and then generating the outputs required by a given user. GIS operate within an organizational context by employing different tools to model specific characteristics of the real world. Quite often GIS is used as a decision support tool by simulating a range of possible scenarios and the consequences of a course of actions prior to making a final choice, such as, data input and verification, data storage and database management, data output and presentation, data transformation, Interaction with user.

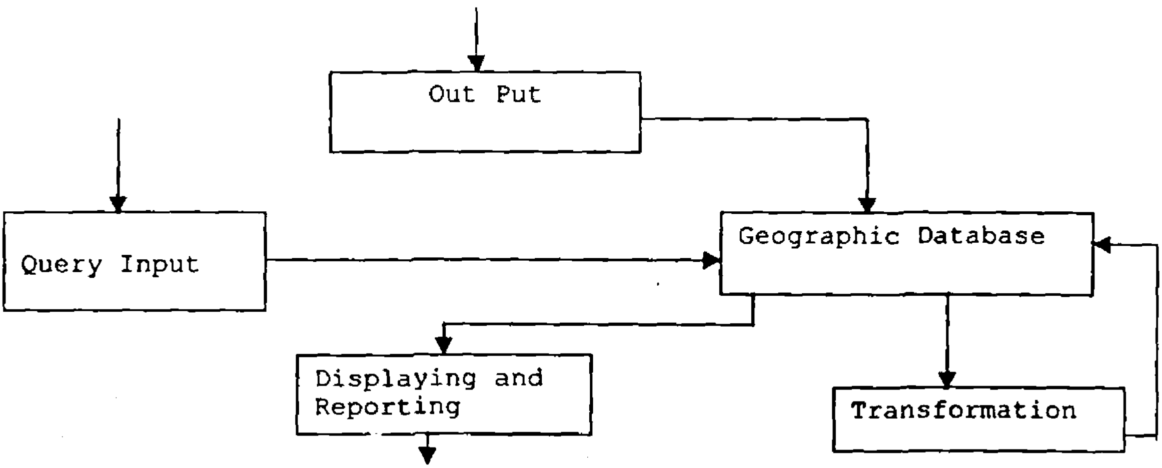


Fig 2. Software components for GIS (Burrough, 1993)

Data Input Components

Data input components converts data from their existing form into one that can be used by GIS (Aronoff, 1993). The existing data is usually in the form of existing maps, satellite images, aerial photographs, field observations and associated attribute data. Great attention should be placed on data input methods and data quality standards before data entry in terms of what types of process will be done, the kind of accuracy to be achieved and finally the form of output produced.

Data Storage and Database Management

Data storage and database management is concerned with the way positional data, attributes of geographical objects and topology are structured and stored (Fig. 3). Various methods on how to structure and store data are available. They will not be covered here because it is beyond the scope of this report, but just to mention that the method used will affect the system efficiency performance.

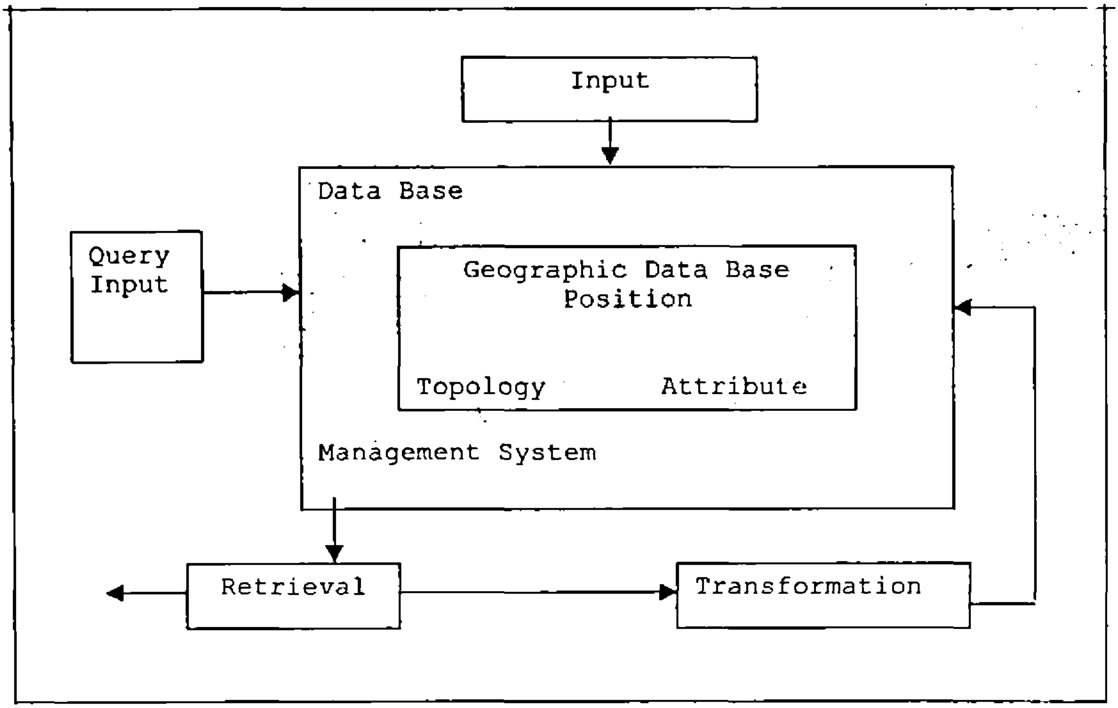


Fig. 3 components of the Geographical Database (Burrough, 1993)

Data Output and Presentation

Data output and presentation is the final product of any analysis carried out. It may be presented in one of many forms: Hard copy (maps, tables, charts etc.) or soft copy.

Data Transformation

Data transformation is concerned with updating procedures and analysis functions on spatial and non-spatial aspects. Burrough (1993) describes them as maintenance and utilization and analysis. Every kind of GIS should be able to answer the most general questions for example where is soil unit N? What is the result of intersecting soil units with land use units? What is at location X, Y, ...? Which units are associated with soil loss? GIS should also be capable of simulating scenarios of the real world.

The Last Module is Interaction with the User.

Query input is absolutely essential for the acceptance and use of any information system (Burrough, 1993). Previously the user was only able to make contact with the computer through punched paper tapes. Since the introduction of personal computers that have commands, operated programme chosen from the menu list users have a much more direct contact with the computer.

Data Sets

Data Sets are a named collection of logically related data records which represent a part of reality and arranged in a prescribed manner. These collection of data sets are useful in the performance of organisational activities. In order for the data sets to be of any use to the organisation they must be organised and, stored for efficient retrieval.

Organisational Context

The fourth component of GIS is the organisational aspect (Fig. 4). In order for GIS to function effectively not only must it possess the aforementioned components but it must be placed in a suitable organisational context. The organisation usually has a goal; objectives are defined to meet that goal and procedures employed by the personnel act upon the objectives which ultimately fulfils the goal. It is of utmost importance that the personnel and managers within the organisation are technically equipped to utilise GIS technology in an appropriate organisational context.

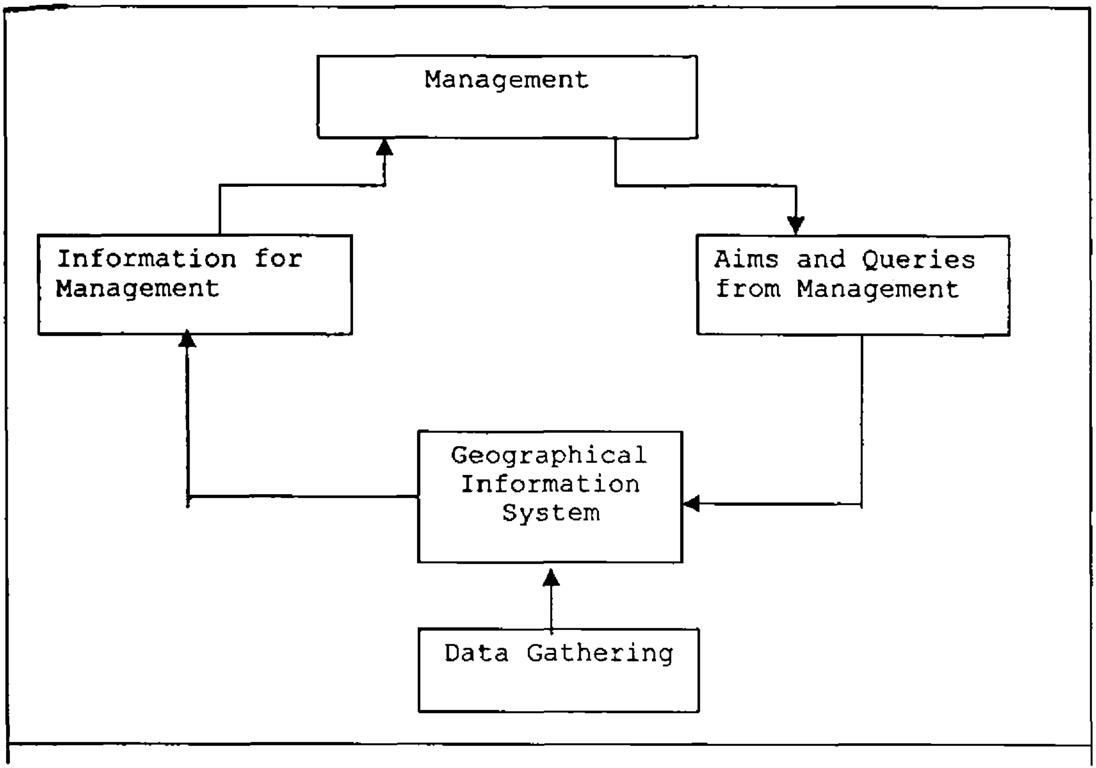


Fig. 4 Organisational aspects of GIS (Burrough, 1993)

Spatial Modelling Concepts

Geographic information describes conceptual objects that play a part in the earth's terrain description. The part objects play is composed of; (a) the relationship between them, and (b) over a time period their behaviour due to the objects intrinsic nature or influences from external force (Molenaar, 1994). A clear definition of objects, their behaviour and the different roles played by them is crucial for modelling within the GIS context. Terrain object definition is dependent on several aspects.

The first aspect is the respective disciplines of the users, whether the users are working in soil mapping, land use mapping or any other mapping discipline. The discipline of soil mapping will have its own definition of terrain objects, classes and attributes that will be different from the land use mapping discipline.

The second aspect is the mapping scale level. At each level different sets of elementary objects will be relevant. Elementary objects at regional level may be aggregates of elementary objects at community level.

The third aspects is the objective of the mapping which will address issues such as the purpose and use of the information i.e. will the information be used for land use allocation purposes, or environmental monitoring or is it purely for inventory purposes.

The forth aspect is the time of the terrain description. The relevance of data changes with time in many disciplines e.g. the process of land allocation present task is to identify and map land use units for different uses in the near future the task may most likely be restoration of used lands for other uses.

Each discipline utilising GIS will represent objects and their relationships in a structure that can be handled by the database system chosen. Several data modeling levels are recognised (Fig. 5).

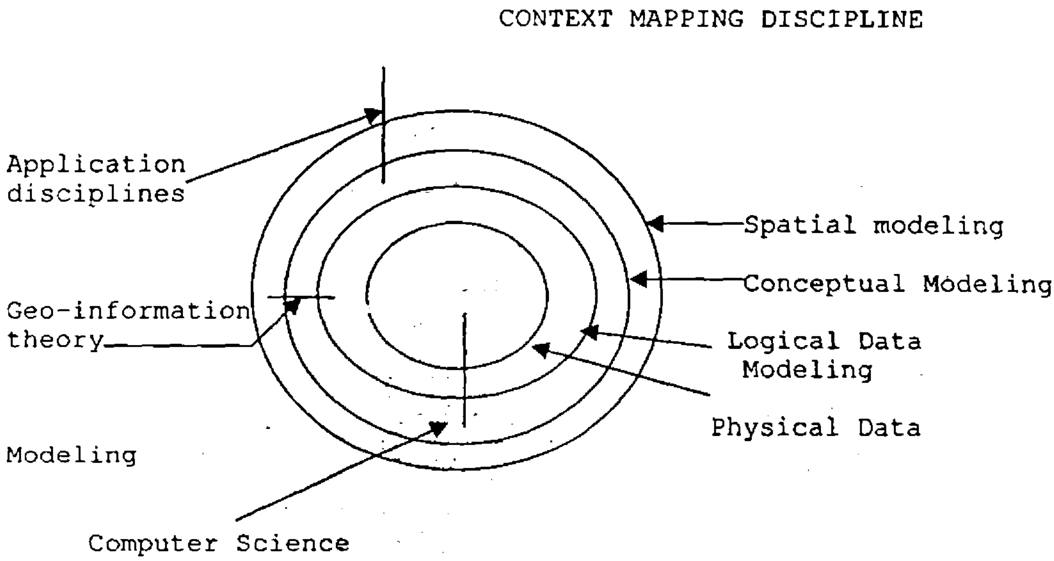


Fig. 5 Levels for Data Modelling (Molenaar, 1994)

Spatial Modelling

Spatial Modelling is the identification of objects role in terrain description. The application disciplines will identify their objects of interest for a particular application, all the relevant relationships between the objects and the means of representing them (vector or raster). Spatial Modelling is related to the geometric characteristics of objects; for example at a small scale one may represent a river as a line object, while at a larger scale the same river may probably be represented as an area object depending on the objectives.

Spatial or topological relationships among geographical objects are obtained from the geometric description of the objects. An example of a spatial relationship is how close is an allocated land area to the road? The relationships may be many and complex and are based on area definition /arcs that connect to surround are an area which defines a polygon/ contiguity

/arcs having direction and left and right sides/ and connectivity /arcs connecting to each other at nodes/ principals assigned to the primitive elementary objects arcs and nodes.

Conceptual Modelling

Conceptual Modelling is the representation of terrain features by their thematic and geometric description. Two important methods of terrain description are recognised (Molenaar, 1993);

i. to link values of some thematic attribute to position

ii. to identify terrain objects which have thematic and geometric characteristics.

Terrain objects in a GIS are structured as shown in Fig. 6.

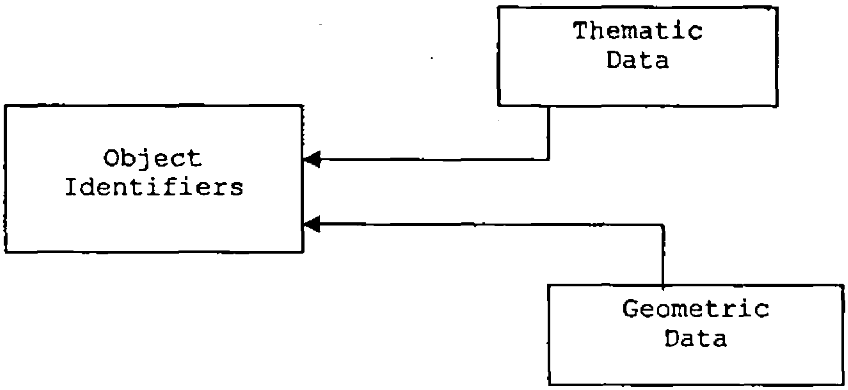


Fig. 6 The basic structure for representing terrain objects in GIS (Molenaar, 1994)

The object will be identified by an object identifier which is connected to thematic and geometric data. Geometric data have a quantitative nature and are used to represent co-ordinates, line equation etc. (Oosterom, 1990). Two basic formats are recognised: Raster and Vector: the report will see vector format. Three subtypes referred to as geometric primitives are distinguished within a 2 dimensional vector format: point (position, O-cell), polyline (line, arc, chain, 1-cell) and polygon (area, region, 2-cell).

Thematic data are alphanumeric data related to geographic objects (Oosterom, 1990) e.g. the name and age of geological unit, the name and parent material of a soil unit. These types of attributes are called non-spatial attributed because the attributes in themselves don't represent locational information.

Logical Data Modelling

Logical data modelling is a bridge between how users view the real world and how computer science disciplines will structure the view of that world in a machine. The logical model is easily understood by the data base users.

Physical Data Modelling

Physical Data Modelling is the lowest level of data structure, it is the process of structuring and organising data in the machine in the form of bits, bytes, blocks and pages. This part of the modelling is handled by computer science specialists and is represented by the inner circle of Fig. 5.

The disciplines have their own part to play in the creation of data models. There is no clear distinction between where the discipline begins and where one ends, overlapping of involvement is quite common.

Questions a GIS Can Answer

Spatial operations

Many software, such as spread sheets (Lotus 1-2-3, Quatro-pro), statistics packages (SAS, SYSTAT, SPSS), or drafting packages (AutoCad, AMFM) can handle simple geographic or spatial data. But these are not usually thought of as a GIS, because a GIS is only a GIS if it permits spatial operations on the data. For example, consider Table 1.

Table 1. Spatial data

Research Centre	Latitude	Longitude	Research Officers
Nazareth	8°45'N	39°3'E	32
Werer	9°30'N	40°15'E	27
Holeta	9°5'N	38°45'E	45
Bako	9°5'N	38°45'E	29
Adet	11°30'N	37°45'E	15
Jimma	7°40'N	36°50'E	37
Makalle	13°30'N	39°30'E	35
Gambella	8°10'N	37°40'E	20

The table shows the number of research officers working with the Institute of Agricultural Research (IAR) in specialised research activity of the listed centres.

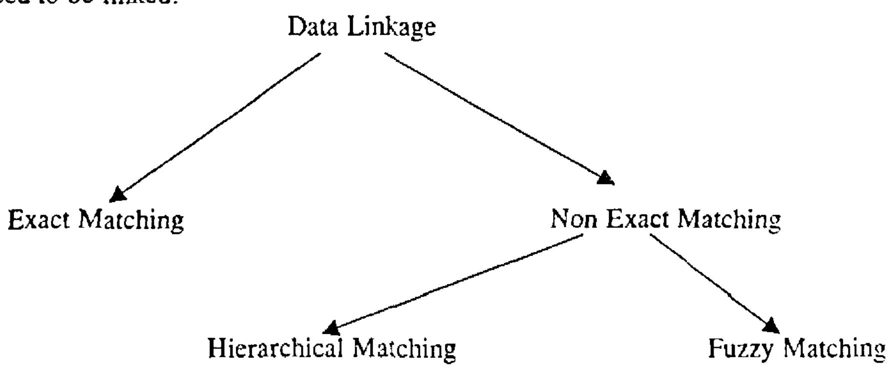
Spatial queries from Table 1 will be asking 'What is the average number of research officers working with IAR in each location?' The answer here doesn't require the stored value of latitude and longitude; nor does it describe where the places are in relation to each other.

Spatial queries will be "How many research officers work in IAR in the major centers of cereals? What is the ratio of researchers between major cereal centres and the livestock? Which centres lie within 500 km of each other? Which centres are part of the rift valley? What is the shortest route passing through all these centres?" These questions can only be answered using latitude and longitude data and other information, such as the radius of the earth. In such cases a GIS can readily answer such questions.

Data linkage

A GIS typically links data from different sets. As an example, suppose we need to know what percentage IAR's research station is used for maize trial. We have located the data we need, but our total area for each station is stored in one computer file, and the maize data is contained in a separate file. We must combine these files to solve the problem. Once the files are combined, it is a simple process to have the computer perform the arithmetic to produce the answer.

This may seem trivial-hardly needing a GIS. Consider the different ways in which data sets may need to be linked.



Exact matching

Exact matching occurs when we have information in one computer file about many geographic features (e.g. Research Centers) and additional information in another file about the same set of features. The operation to bring them together is easy, achieved by using a key common for both files - in this case, the name of the centre. So the record in each file with the same centre name is extracted and the two are joined and stored in another file.

Table 2 and 3. Total area and number of vehicles per research center

Research Centre	Total Area	Research Centre	No. of Vehicles
Nazareth	1500	Nazareth	12
Werer	1280	Werer	7
Holeta	930	Holeta	9
Bako	1200	Bako	11
Adet	750	Adet	3
Jimma	1500	Jimma	10
Makalle	780	Makalle	8
Gambella	830	Gambella	2

Table 4. Total area and number vehicles in each center

Research Centre	Total Area	No. of Vehicles
Nazreth	1500	12
Werer	1280	7
Holeta	930	9
Bako	1200	11
Adet	750	3
Jimma	1500	10
Makalle	780	8
Gambella	830	2

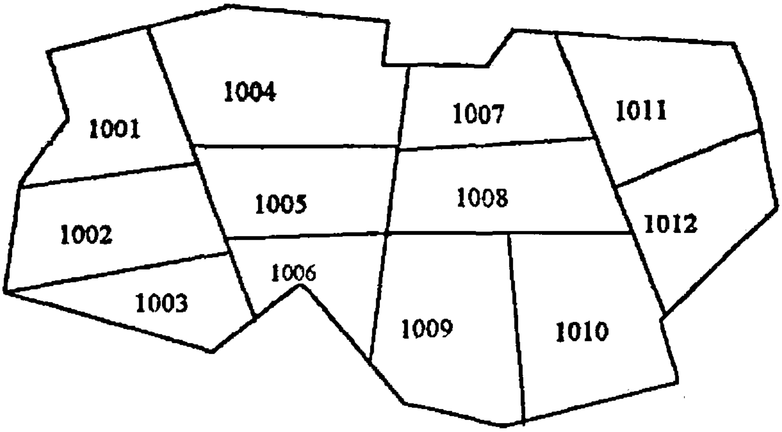
For this example we can see that Table 2 & 3 can be joined (Table 4) by performing an exact match on the name of the research centre.

Non Exact Matching

These has two forms.

Hierarchical – Some type of information, however, are collected in more detail or more frequently than other types of information. For example, crop type, pest and disease prevalence, input used etc. in the research centres is collected frequently in reference to each research plot. Research plots are divided into blocks, where these smaller /blocks/ areas nest /i.e. fit exactly/ within the research centre's total area, then the solution for matching these data is to use hierarchical matching.

For illustration reasons we will assume that Nazareth research centre has 1500 hectares, which is divided into 12 blocks are assumed to nest within the total areal boundary.



Map 1 – Nazareth Research Centre

The numbers enumerated in each polygon are assumed to represent the block number. The block numbers are codes (can also be character string) useful to handle our data in the data base. Information related to the map is handled as follows.

Table 5 – Size of blocks in the centre.

Block Number	Area in Hectares
1001	115
1002	135
1003	75
1004	183
1005	107
1006	67
1007	103
1008	135
1009	140
1010	168
1011	162
1012	110
Total Area	1500

The hierarchical structure illustrated in this diagram shows that Nazareth centre is composed of 12 blocks, to obtain meaningful values for the station, the value for each block must be added. On each block a spatio-temporal data can also be collected and put in relation to the hierarchy. For example, if we take only one block, all attributes investigated according to the research theme of the centre can be handled. Suppose we are looking on sorghum improvement, and since 1963 block 1OO1 was used for the purpose, the spatio-temporal data is handled as follows.

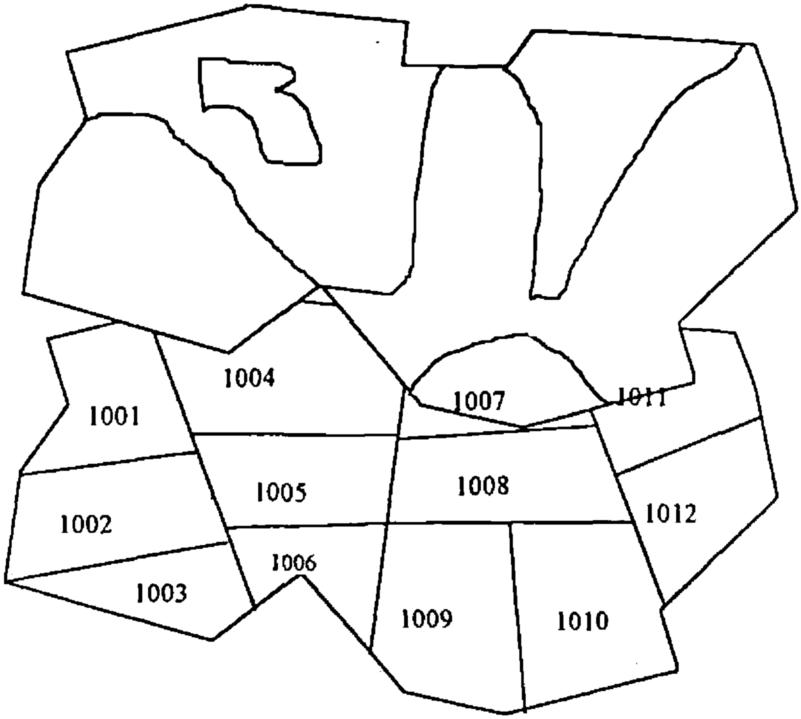
Table 6 - Crop yield data.

Year	Crop Type	Variety	Yield/Ha	Biomass	Block Number
1963	Sorghum	Seredo	45		1OO1
1964	Sorghum	Serena	49		1OO1
1965	Fallow	-	-	-	1OO1
....	...	...	...	...	1OO1
...	...	...	...	...	1OO1
1984	Sorghum	G-1107	65		1OO1
1985	Maize	Abo-Bako	135		1OO1
1986	Sorghum	Bako-Mash	115		1OO1
1987	Maize	A-511	165		1OO1

At the lower hierarchical level an extended data is captured that describes the temporal crop research activity of the centre. Here the data linkage is achieved by the block number.

Fuzzy matching - On many occasions, the boundaries of areas of the research centre in one data set don't match with those of other data sets. This is especially true when dealing with environmental data. For example, the crop boundaries, in the research centre, are defined by the field edges of the blocks, rarely match the boundary between soil types. If we want to determine the most productive soil type for a particular crop, we need to overlay the two data sets and compute crop productivity for each and every soil type. In principle, this is like laying one map over another and noting the combinations of soil and crop productivity.

When data boundaries between layers do not match, the layers can be joined, creating a new layer containing the characteristics of both. A GIS can perform all these operations because it uses geo-reference, or space, as the common key between the data sets. Information is linked only if it relates to the same geographic location.



Map 2 – Nazareth research centre soils and research plots map overlay.

Linking our data sets is important in a situation where we have two or more data sets for the same area (geographic location), such as yearly yield/ha/crop for every research station and average cost of production, yearly yield/ha/crop and soil type etc. Each data set might be analysed and mapped individually. Alternatively, they can be combined to produce one valid combination. If, however, we have 10 data sets for the research centre, we have hundredth of thousands of possible combinations. Although not all combinations are useful, we can answer many more questions than if the data sets are kept separate. Combining them adds value to the data base. To do this analysis, then we need a GIS.

Some Applications of a GIS

Applications for a GIS technology is widely developed in the world. Many of the early applications built land registration systems and environmental data bases. GIS was also used to develop utility systems and creating a comprehensive national topographic data base. Some countries developed an important forestry application to plan the volume of timber to cut, identify access to the timber, and report to the management. Application in some countries emphasised monitoring and modelling possible environmental changes. In Ethiopia, the then the Land Use Planning and Regulatory Department (LUPRD) of the Ministry of Agriculture developed a custom oriented GIS software for the application of land evaluation, land capability and suitability classification and land use planning purposes with special reference to the highlands of the country. National housing and population census, geological surveys can also use GIS technology for the topologically integrated geographic encoding and referencing.

Today, the number and variety of applications for GIS are increasing. The amount of geographic data that has been gathered is staggering and includes volumes of satellite imageries collected from space. Governments can use GIS for planning and zoning, property assessment and land records, parcel mapping, public safety, and environmental planning. Resource managers rely on GIS for fish and wildlife planning, management of forested, agricultural, and coastal lands, and energy and mineral resource management.

GIS supports the daily activities of automated mapping and facilities management with application for electricity, water, sewer, gas, telecommunication, and cable television utilities, using capabilities such as load management, trouble call analysis, voltage drop, base map generation and maintenance, line system analysis, sitting, network pressure and flow analysis, leak detection, and inventory. Demographers use GIS for target market analysis, facility sitting, address matching and geo-coding, as well as product profiles, forecasting and planning. GIS also has an increasing role in supporting education and research in the class room, the computer lab, the research institute, and the public library.

The most important point to note is that these diverse applications are carried out using similar software and techniques - a GIS is truly a general-purpose tool.

Epilogue

So far, a GIS has been described in two ways:

i. through formal definitions and
ii. through its ability to carry out spatial operations, linking data sets using location as the common key. We can, however, also distinguish a GIS by listing the types of questions it can, or should be able to, answer. For any application there are five generic questions that a GIS can answer.

Location - What is at ....?

This question seeks to find out what exists at a particular location. A location can be described in many ways using, for example, a place name, a street name, a block number or a geographic reference, such as latitude and longitude or 'X, Y and Z.

Condition - Where is it ?

This is the converse of the first and requires spatial analysis to answer. Instead of identifying what exists at a given location, you want to find a location where certain conditions are satisfied.

Trends - What has changed since...?

This question might involve both the first two and seeks to find the differences within a given area over time.

Patterns - What spatial patterns exist?

We might ask this question to determine whether **'quelea'** is the major cause of low productivity among the varieties of sorghum in the research centre. Just as important, you might want to know how many anomalies there are that do not fit the pattern and where they are located.

Modelling - What if ...?

'What if ....?' questions are posed to determine what happens, for example, if a new technology is introduced to the farming system, or if the technologies previously used manifest some effects. Answering this question requires locational as well as other information.

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AGRO-METEOROLOGICAL SERVICE AND RESEARCH: CURRENT STATUS AND FUTURE PROSPECT IN THE INSTITUTE OF AGRICULTURAL RESEARCH

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Abstract

Agriculture is an economic activity which is directly linked with climate and soil resources. The important application of agro-meteorology must then be used to determine whether these natural resources are being properly utilized. In this context, the historical development of agro-meteorology division of the Institute of Agricultural Research (IAR) is reported. Currently IAR has about 32 observatory stations of varied standards, across a range of agro-ecologies. It was also reported that data recording, standardization and establishment of network of the IAR's met stations were possible only after the establishment of a national coordination office at Nazareth Research Center. Current status, major strength, drawbacks and future potential benefit of agro-meteorology is outlined. Possible recommendations and base line strategic scenarios as derived from the framework of the entire report are also presented herein, so that the role of agro-meteorology in Ethiopian agriculture may stand by its own right.

Introduction

Ethiopia is endowed with diverse agricultural crops, livestock and agro-ecological settings which ideally suit for various farming systems. The country has about 14 million hectare of arable land of which most are under rain-fed agriculture and only 3% is under actual irrigation. Moreover, some 46% of this arable land is located in the semi-arid regions, where sustained and increased agriculture is hampered by short and unpredictable rainy season and intensive rainfall interspersed with prolonged drought and thus contributes only to 10% of the total food production per annum. On the other hand, the population growth rate in Ethiopia is rapidly escalating (3.2% per annum) and paradoxically the country is unable to feed this ever increasing mouth (Belay, 1994).

Successful agriculture depends on the proper understanding and inter-relationships of four basic factors; the genetic potential of plants, soils, weather and management. All these factors are not simple physical variables of one dimension but very complicated ones. Neither are they independent of one another. On the contrary, they often are strongly correlated (Belay, 1994). Of all gifts of nature, agriculture is clearly the economic activity which is strongly linked with climatic and soil variables. Climate and soils are, therefore, regarded as natural resources and that the important application of agro-meteorology must then be used to determine whether these resources are being properly used.

Agro-meteorology is an applied science which provides information on meteorological conditions that affect agricultural production. The need for agro-meteorology service to generate climatic data catering almost exclusively to the needs of agricultural researchers of the Institute of agricultural research has long been felt. The service was first established at Melka Werer Research Station in 1965, and later on, at Bako Research Station in 1976. Then it was working in fragmented fashion. Since then, the mission of establishing observatory stations across a range of geographic regions, in collaboration with the National Meteorological Service Agency (NMSA), was fairly accomplished. Nazareth Agricultural Research Center (NARC) has played a Coordination role for the IAR's Weather Observatory Stations network development since

1980. Currently there are some 32 agricultural met stations of varied standards mostly located at the IAR research centers. After the coordination responsibility was vested in NARC, it was possible to standardize data recording & archiving for uniform data processing and mean monthly summary reports (Hailu Adnew, yearly mean monthly reports production and distribution). It also ensured data security and integrity.

It is worth stressing that no clear long ranging strategic research scenario was visioned, as yet. As a result, except, offering service at shallow profile, no significant head way could be made in terms of advanced agro-meteorological research and appreciation of its role in the highly variable Ethiopian agriculture. Moreover, those generated information are not readily available to users. It seems, as if agro-climatic information in agricultural research and development is needless beyond appending the mean monthly summaries or simple report of it, at the end of findings in an ivory tower manner.

The objective of this paper is, therefore, to summarize and report the current status, future potential and operational scale of agro-met research in Ethiopia. While agro-met is equally valid in livestock research, a more restricted view with regard to crops research will be considered in this report. It is hoped that, this paper will stimulate discussion on how to build a national capability and identify areas where agro-meteorological/climatological research is needed most in terms of priorities, possibilities and resource requirements.

Current Status

During the earliest days, only four agro-meteorology stations were installed, following the eldest agricultural research centers of the Institute (Table 1). Gradually, about 28 met stations of varied standards were established after the NARC assumed the coordination responsibility (Tables 2 and 3).

It is a great wonder that, after a long history of establishment, the service couldn't reveal significant head way, particularly in terms of exploiting the already piled climatic data in current and future agricultural decision making. Parts of the difficulties are lack of minimum critical mass of effective research resources and imprecise goals and objectives; which stifled the steady state growth of the division to the full scale operation level.

Consequently, only simple climatic analyses such as long term monthly averages, analyses of variance or linear correlation techniques have bean commonly used in agricultural research data interpretation. However, such data sets are of limited significance since the response of crops to weather and soil changes is not so simple as to be defined by such descriptive statistics alone. In such cases, the problems apparently come after the analyses and interpretation, when data needs to be interpreted with the farming systems perspective, where simple treatment differences may not be enough for farmers to adopt improved technologies. The issues dominating the biological and socio-economic performance of the farming community such as rainfall or soil fertility variabilities should be entertained in treatment senses not to end up as experimental error Moisture conservation studies must attach importance to the water/energy balance and evpo-transpiration balance. Diseases and pest epidemiology, and management research should appreciate the importance of meteorological information.

Table 1. Locational features of the agro-meteorology stations established during pre- coordination Period

Met Station	Geographic Location	General Environmental Characteristics	Year of establishment	Latitude	Longitude	Altitude (m.a.s.l)	Data Base
Bako	W.Shoa	Humid climate	1976	9°8 N0	37°5 E	1550	1976-95
Jimma	South west	Humid "	1968	7°40 N	36°7 E	1750	1968-95
M.Werer	W.Hararghe	Very dry	1965	9°29 N	40°7 E	750	1965-95
Holetta	Centeral Shoa	Humid Climate	1969	9°3 N	38°30E	2390	1969-95
Kulumsa	South East	" "	1967	9°1 N	39°9 E	2130	1967-95

Table 2. Location features of third class met stations established during post coordination period

Met Station	Geographic Location	General Environmental characteristics	Year of establishment	Latitude	Longitude	Altitude (m.a.s.l.)	Data base
1. Bedessa*	W. Hararghe	Warm humid	1982	8°55	N39°20E	1820	1982-85
2. Mechara*	" "	" "	1989	-	-	2500	incomplete
3. Koka*	Centeral shoa	" "	-	-	-	-	-
4. Sinana	Bale	Humid climate	1989	-	39°20E	2800	1989-95
5. Metu	South Western	Warm humid	1967	8°19 N	35°35E	1940	1967-95
6. Dhera*	Central shoa	" "	1982	9°10 N	39°20E	1680	1982-95
7. D/zeit	" "	Semi Humid	1990	8°44 N	38°58E	1900	1990-95
8. Wenago	Southern	" "	1990	6°20 N	38°20E	1670	1990-95
9. Tepi	South Western	Hot low land	1974	7°20 N	38°20E	1500	1974-95
10 Endibre**	West Shoa	Humid Climate	1978	-	-	-	1978-84

* = Provisionally not functional ** = Terminated

Table 3 Location features of principal (1st class) agro- met stations established during the post Coordination period

Met Stations	Location	Geographic Environmental characters	Year of establishment	Latitude	Longitude	Altitude (m.a.s.l.)	Data base
1 Adami T.	South Shoa	Semi arid	1981	7°48 N	38°7 E	1650	1981-95
2 Awassa	South	Warm Humid	1982	7°05 N	38°29 E	1700	1972-95
3 Gera	South west	Cold humid	1981	7°5 N	37°0 E	1710	1981-95
4 Melkassa	CRV	Semi arid	1977	8°24 N	39°21 E	1550	1977-95
5 Mekele	Northern	Semi arid	1977	13°5 N	39°6 E	1970	1977-88
6 Kobo*	North East	" "	1977	12°2 N	39°5 E	1500	1977-89
7 Sheno	North shoa	Cold humid	1988	9°10 N	39°21 E	2800	1982-95
8 Abobo*	Western	Warm humid	1988	7°50 N	39°19 E	750	Incomplete
9 Adet	North West	Warm Humid	1988	7°50 N	37°30 E	2060	1988-90
10 Pawe*	North West	Warm humid	1987	11°3 N	34°35 E	1650	1987-90
11 Bekoji	South East	Cool humid	1988	7°15 N	39°30 E	2750	1981-95
12 Ginchi	West shoa	Cool humid	1981	9°2 N	38°12 E	2290	1988-95
13 Mieso	W. Hararghe	Semi arid	1984	9°20 N	41°11 E	1470	1986-93
14 Sirinka	North East	Semi Arid	1988	7°20 N	38°20 E	-	1981-95
15 Areka	Southern	Cool Humid	1988	7°02 N	37°40 E	1750	1988-95
16 Assosa*	Western	Warm Humid	1988	10°04 N	34°33 E	1550	Incomplete
17 Ambo	West shoa	Warm humid	1995	-	-	-	1995-

Table 4. Net Work of Agro-meteorological Observatories in IAR

Data record	Observatories* (Number)	Instrument used
Rain fall (mm)	32	Ordinary rainguage/Automatic
Max temperature	32	
Min temperature	32	
Dry bulb temperature	24	Thermometer
Wet bulb temperature	24	
Wind Speed	23	Anemometer (1 and 2m)
Wind direction	23	Wind vane (1 and 2m)
Soil temperature	23	Soil thermometer at various depth)
Radiation	18	Actino- graph, solarimeter
Evaporation	22	Class- A pan
Evapo-transpiration	-	-
Grass minimum temperature	1	Grass minimum thermometer
Sunshine	18	Sunshine recorder
Dew	-	Dew guage
Relative humidity	24	Hygrograph
Cloud	18	Oktas

* Time of observations were at 06, 09, 12, 15 and 18 hours

Current Strength of Agro-meteorology Division of the IAR

The existing massive daily climatic data have many interesting and flexible features of potential utility as and when desired, in terms of completeness, representativeness, length of record period and quality (Table 4). The observatory stations are visited 5 times a day at 0600, 0900, 1200, 1500 and 1800 hours, data which can even be used for real time analyses and more refined report generation. Those data collected from all the IAR centers are summarized and archived at Nazareth Research Center, for uniform data processing and utility purposes.

Currently, collection of meteorological data, crops phenology and soil variables on sorghum, maize, tef and haricot bean varieties have bean started at Melkassa and few other stations for data base construction and management and utility, such as in probability analyses and modeling. Though more is expected from it, the Agromet Division of the NMSA, with its fairly available research resources is addressing the agricultural problems of the country to a limited extent, as well.

Current Weakness of Agro-meteorology Division of the IAR

Lack of trained human resource in agro-meteorology and data management, especially in the use of modern data base software packages.

Lack of clear long term vision/strategies.

Lack of effective communication and coordination between responsible parties such as between IAR and National Meteorological Agency.

Lack of appreciation and continued under estimation of the usefulness of agro-climatic information.

Problems in coordination and especially in managing major climatic observation network.

Continued emphasis on maintaining data records in written form under unsuitable storage conditions leading often to loss and ruin of data.

Lack of electronic processes of data and continued lack of a data base management perspective.

Difficulties in maintenance of operational observatory stations and production of good quality and uniform data sets due to lack of infrastructure.

Lack of capacity to assemble/analyse the agro-climate related information that have been generated in the IAR research centers.

Future Emphasis and Potential Utility Areas of Agro-met

One of the limitations of agricultural experiment is that it is undertaken at specific location and that to carry out research at more locations it is never possible to extend the sites to the range of environments that it should cover. Under such conditions modeling various agricultural problems to extrapolate more precise technologies and information to the ranges beyond the experimental sites is by far rewarding, than seeking expensive crop research across locations. Currently, a great deal of modeling work has been directed at a world scale to individual processes involved in crop growth and development such as modeling evaporation (Ritchie, 1972), photosynthesis (Duncan et al, 1967), respiration (Baker et al, 1972), potential evapo-transipition (Penman, 1948), water balance (Bayer et al, 1978), probability of occurrence of particular weather event (Virmani et al, 1978) and growth simulation model (Arkin et al, 1976).

Crop growth and development models are useful in planning alternative strategies for proper land use and water management in semi arid regions. In this case information on different aspects of plant growth can often be brought together, providing a unified picture and sometimes a valuable stimulus to collaboration and team work. An attempt at model construction can help in pin pointing areas where knowledge and data are lacking. The pre-harvest forecast of crop yields, based on crop weather models will enable government agencies to make policy decisions on food imports/exports and on internal food distribution. However, it should be remembered that modeling is not a substitute for experimentation, but it may provide a more rational basis for experimentation.

Increased interest of professionals and agricultural policy makers in and application of remotely/satellite sensed or geographic information system (GIS) for monitoring vegetation, crop growth and drought, yield prediction; agro-ecological zonation, prediction of soil loss, monitoring erosion, salinization etc., is another new vistas in the specific application of scientific knowledge to agricultural planning. Currently a number of GIS soft wares are available, but too expensive for us to make use of them now. Nevertheless, it is interesting to note that the importance of agro-meteorological information in GIS application to agricultural development justify the dynamic nature of the science.

Recommendation

With this premise, it is essential that solution be sought to make use of the past and future meteorological data in conjunction with the crop data, before the enormous increase in volume of this data poses complex problems of storage, retrieval or before its benefit ends within itself than offering service to us. This would entail the need for operational data base/bank construction, maintenance and management system through dedicated software such as QPRO, DBASE, INSTAT and STATGRAGH. Hence, the following recommendations are being drawn from the entire framework of the report for the possible follow up action.

It would be of historic importance that networks be strengthened between IAR and NMSA to undertake nationally coordinated agro-meteorological research of particular relevance to priority agricultural problems from the farming community perspective.

Inter-disciplinary studies involving agro- meteorologist, crop physiologist, soil physicist, and crop simulators should be evolved.

Currently, the agro-meteorology research of IAR exists at its pre-operational stage in terms of manpower and infrastructure. Trained and capable research personnel should be recruited and training on data base management should be organized for the stations' observers.

In developing operational agro-met network, especially in regions with highly variable ecological settings, data making, transmission, verification, analyses and dissemination of information to users must be facilitated.

Specific clients-oriented research strategies of short, medium and long term should be devised and users must provide sufficient assistance both for national capability building of the division and its application to areas of their own interest.

The blue print for further regional agro-meteorological problems-focused research strategy should be started at least by our agronomists/crop physiologists of each research centers.

The operational national commodity programmes' (Wheat, Sorghum, Maize and others) multi-site experimentation effort should be taken into an advantage in enhancing the met service to an advanced level.

To this end, a general strategic scenarios/objectives that are open-ended to constructive criticisms from all corners are outlined as follows.

develop an efficient data provision service to clients by adapting suitable data base construction and management and information dissemination systems through operational network.

derive an optimal crop-based model of land use, which will assure the most rational and sustainable use of natural resources for agricultural development, both at present and in the future. This will be possible through undertaking various research in the inter-disciplinary field of agro-meteorology, in order to quantitatively define the relationship between the environment and the corresponding agricultural production processes.

Only then, might the knowledge of agro-meteorology serve the Ethiopian Agriculture by its own right and not through other disciplines.

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GENOTYPE X ENVIRONMENT INTERACTION IN 13 INBRED LINES OF SORGHUM (*Sorghum bicolar* L.Monech) TESTED AT MELKASSA FOR FOUR YEARS (1986-1989)

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Abstract

Environmental sensitivity in 13 sorghum inbred lines was studied at low elevation testing site, representing moisture stress areas of the major lowland sorghum producing regions in the country for four years with the objective of identifying sorghum lines which are stable in performance over the years. Regression coefficients were conducted by regressing mean values for each genotype at a location on the means of all genotypes in an environment. The analysis of variance showed that there was significant differences for days to 50% anthesis and plant height. The inbred lines responded inconsistently for days to anthesis and plant height over the years. Significant differences were detected for grain yield. Further partitioning of the genotype x year interactions indicated that the non-linear part accounted for variety x year interaction for both days to anthesis and plant height. On the basis of good mean performances for the desired traits and low sensitivity to environmental changes, three varieties IS 2284, OZ x 26/F5/5/E/3, and 148 x Framida have been identified as stable for low elevation sorghum growing areas.

Introduction

Unlike the classical Mendelians traits which are easily classified in to distinct categories, many of the agriculturally important traits such as plant height, days to 50% anthesis and grain yield forms a spectrum of phenotypes which blend imperceptively from one type to another (4). These traits are quantitative in nature and are governed by polygenes or Quantitative Trait Loci (QTLs) (1).

The phenotypic variability expressed in most quantitative traits have a relatively large environmental component and a correspondingly small genetic part so when varieties are compared in different years their performance relative to each other may not be the same. One variety may have the highest performance in some years and a second may excel in other. These differences could be attributed to changes in an unpredictable factors such as rainfall, temperature and relative humidity (3).

Thus, it is the task of the plant breeder to identify genotypes that have a higher mean performance for the desired traits and low regression coefficient or sensitivity to environment.

Materials and Methods

Eleven improved varieties of sorghum selected on the basis of various desirable attributes and two standard checks were used in this study (Table 1). The lines were arranged in Randomized Complete Block Design with four replications in all years. Plot size of five rows of 5 m length spaced 0.75 m apart was used. All the necessary management practices (thinning, weeding, hoeing, etc.,) were applied as per recommendations.

Table 1. Desirable characteristics of the 13 inbred lines of sorghum used in this study.

Entry Number	Pedigree	Characteristics
1	M-36121	Grain quality
2	148 x Framida	Striga resistant
3	Dj1195	Earliness
4	OZ x 26/F_5/5/E/3	Early and bird resistant
5	Ozx4/F_5/6/3/E/3 Bulk	Early and bird resistant
6	IS 2284	Drought tolerance
7	(148 x E-35-1)-4-1-1 x CS3541 derive-5-4-2-1	Yield and grain quality
8	(SC 423 x CS3541 x E-35-1)-2-1-2	Yield and grain quality
9	M-90411	Yield potential
10	(148 x E-35-1)-4-1 x CS3541 derive-5-2-1	" "
11	ICSV 83386	" "
12	76 T_1 #23	Early (check)
13	Gambella 1107	Medium (check)

Agronomic data such as days to anthesis was recorded as the number of days from planting to 50% flowering. Plant height was measured in cm as a distance from the ground level to the apex of the panicle. Grain yield in g/plot was recorded from the center three rows.

Analysis of variance was computed and environmental stability of individual genotypes were estimated by regressing mean performances of the genotypes at each environment on the environmental index (2).

The general model used was given as;

$$Yij = u + di + ej + gij + Eijk$$

where u is general mean

di is line effect

ej an environmental index

gij is the genotype x environment interaction of the ith genotype and the jth environment

Eijk is random effect

To test whether the linearity differs among the 13 genotypes we used the model.

$$Yij = u + di + (1+bi)\, ej$$

Where u + di is the mean performance of the inbred lines and (1+bi) ej is the linear sensitivity of the 13 inbred lines.

Results and Discussions

The analysis of variance showed that there was significant difference between lines for days to 50% anthesis and plant height over the years. No significant difference was detected between lines for grain yield. Genotype x year interaction component revealed that both the effects of years and variety x year interactions were highly significant for both days to 50% anthesis and plant height indicating the inconsistency of performances of these genotypes over the years (Table 2). The non-linear part attributed to significant effects of the genotype x year interactions for both days to flowering and plant height indicating the presence of residual part which are not accounted for by the linearity.

Table 2. Genotypes x year analysis for days to anthesis and plant height of 13 inbred lines of sorghum planted at Melkassa (1986-1989).

Source	DF	Mean squares	
		Days to anthesis	Plant height
Varieties (V)	12	98.23**	1772.08**
Year (Y)	3	213.46**	1582.53**
V x Y	36	12.96**	154.42**
Regression	12	4.49ns	61.83ns
Reminder	24	16.23**	202.60**
Error	156	6.92	66.07
C.V. (%)		5.03	8.74

** Significant at 0.01 level of probability.

A wide range of adaptation in days to flowering was observed among the inbred lines (Table 3). The earliest variety took 56 days to flower while the latest one took 86 days. Of the total number of entries tested, 30% flowered earlier or as early as the earliest flowering check variety, $76T_1$ #23. On the basis of mean performance across years, three varieties IS 2284, OZ x $26/F_5/5/E/3$, and 148 x Framida had flowered earlier and showed low environmental sensitivity (Table 4). Inbred lines which are early in flowering are highly desirable for areas where moisture stress, as a result of erratic and unreliable rain fall, is a serious threat to sorghum production.

Differences for plant height between varieties were highly significant. These varieties showed a wide range of variation (96-190 cm) for plant height. Three varieties IS 2284, OZ x $26/F_5/5/E/3$, and 148 x Framida had low environmental sensitivity (Table 5). Close to 61% of the varieties grew shorter than the check, $76T_1$ #23. These short stature plants are highly desirable for low elevation moisture stress areas where lodging as a result of terminal moisture stress is a serious set back.

The over all mean performances of the 13 inbred lines showed that the highest yield of 33 q/ha was obtained in 1989 while the lowest was recorded in 1986 (Table 6). These mean performances was related to the amount of rainfall received during the growing period (June-October). Of the total amount of rain fall received, close to 80% was distributed within the growing season in 1988 and 1989 (Table 7).

On the basis of better mean performance for the desired traits and low sensitivity to environmental changes, three varieties IS 2284, OZ x 26/Fs/5/E/3, and 148 x Framida have been identified as stable for low elevation sorghum growing areas.

Table 3. Mean, range and standard deviations for grain yield, days to flowering and plant height of the 13 inbred lines tested at Melkassa (1986- 1989).

Variable	Mean	Minimum	Maximum	Standard deviation
Grain Yield (q/ha)	30.4	14.0	55.0	7.9
Days to anthesis	69.4	56.0	86.0	6.7
Plant height (cm)	142.3	96.0	190.0	21.9

Table 4. Regression analysis for mean performances of each variety on environmental index for days to 50% anthesis at Melkassa (1988-1989).

Entry number	Mean m+di	Linear regression coefficient 1 + Bdi	SP x Y (12d.f)	Regn ss (10 d.f)	Rem ss (11 d.f)
1	66.00	1.00	49.54	49.82	12.75
2	69.75	0.88	43.36	38.17	0.58
3	60.25	0.98	48.28	47.26	12.99
4	64.25	0.83	41.09	34.28	16.47
5	66.25	1.32	65.18	86.24	14.50
6	67.25	0.23	11.40	2.64	110.00
7	73.25	1.51	74.38	112.32	128.44
8	72.50	1.24	61.20	76.02	12.98
9	72.25	0.82	40.71	33.64	17.11
10	72.00	0.97	47.93	46.64	19.36
11	71.50	1.09	53.93	59.04	13.96
12	66.50	1.03	50.50	51.77	27.73
13	79.50	1.07	52.89	56.71	2.21

Table 5. Regression analysis for mean performances of each variety on environmental index for plant height at Melkassa (1988-1989).

Entry number	Mean m+di	Linear regression coefficient 1 + Bdi	SP x Y (12 df)	Regn ss (10 df)	Rem ss (11 df)
1	161.25	1.03	377.60	390.41	162.34
2	135.25	1.65	602.99	995.58	513.17
3	113.25	0.76	280.07	215.69	684.30
4	132.25	0.76	261.06	186.61	216.14
5	127.25	0.41	150.67	62.16	102.59
6	175.25	0.81	295.29	238.76	133.99
7	142.00	1.11	404.62	448.28	109.72
8	146.00	0.77	283.85	220.62	257.38
9	124.00	0.55	202.70	112.50	105.50
10	142.25	0.79	289.91	230.14	124.67
11	141.75	1.41	516.64	730.86	131.89
12	144.75	1.38	507.40	704.95	2136.80
13	163.00	1.57	574.23	902.88	215.11

Table 6. Mean grain yield of the 13 inbred lines of sorghum tested at Melkassa (1986-1989).

	Grain yield (q/ha)				
Pedigree	1986	1987	1988	1989	Mean
M-36121	27	30	38	36	32.75
148 x Framida	24	14	40	30	27.00
DJ1195	20	31	20	31	25.50
OZ x 26/F5/5/E/3	38	42	26	55	40.25
OZx4/F5/6/3/E/3BULK	30	37	27	46	35.00
IS 2284	29	28	26	35	29.50
(148 x E-35-1)-4-1-1 xCS3541 derive-5-4-2-1	23	30	42	30	31.25
(SC 423 x CS3541 x E-35-1)-2-1-2	32	26	35	24	29.25
M-90411 (148 x E-35 1)-4-1 x	24	20	28	24	24.00
CS3541 derive-5-2-1	34	33	38	29	23.50
ICSV 83386	20	29	40	41	32.50
76 T1 #23	18	23	36	24	25.25
Gambella 1107	35	19	34	30	29.50
Mean	27.2	27.2	33.1	33.5	
St. dev.	6.35	7.58	6.89	9.20	
CV (%)	23	27	21	2	

Table 7. Mean monthly rainfall data for Melkassa (1987-1989).

Month	Rainfall (mm) 1986	1987	1988	1989
January	0.0	0.0	35.4	0.0
February	55.7	13.1	12.2	15.7
March	67.6	87.7	2.4	34.0
April	53.4	44.2	29.9	61.6
May	25.6	145.4	26.2	1.2
June	103.4	3.3	59.3	83.5
July	147.0	102.4	188.7	147.4
August	88.5	227.5	186.2	273.2
September	76.6	60.0	132.1	66.2
October	10.2	0.6	14.0	10.7
November	0.0	0.0	0.0	0.0
December	2.6	0.0	4.5	6.0

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