Proceedings of the 1st Annual Regional Conference on Completed Crop Research Activities

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Amhara Regional Agricultural Research Institute
(ARARI) - Bahir Dar, Ethiopia

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FOREWORD

Following regionalization and political empowerment of regional states in 1991, three research centers (Adet, Debre Berhan or the then Sheno Research Centre and Sirinka) were transferred to Amhara National Regional State in 1995. By then, the centers were at a very low status and capacitating the centers to bring about agricultural research that can support the overall of agricultural development endeavors in the region was the main task. In about five years time after 1995, the research centers assumed relative strength and embarked on planning agricultural research that primarily reflect the region's interest. Eventually, some technology multiplication centers joined the research system and new centers/sub-centers were also opened in different agroecologies of the region. The scope of agricultural research in the region got impetus and this heralded the beginning of problem oriented and region specific agricultural research in almost all disciplines. This was verified by strong annual research program review at all levels with the participation of relevant stakeholders, complemented by field evaluation.

It was noticed, however, that the annual research program review forum focused more on evaluation of new research activities and overlooked completed research activities. This was the main reason to initiate annual regional conference to evaluate completed research activities and filter those research findings or technologies that can be transferred to the users and pass decision on those which are not. It is, therefore, hoped that the research findings included in this first proceeding are critically evaluated and is believed that the proceeding will serve as a useful means of communication with stakeholders. Moreover, the forum will serve as part of monitoring and evaluation system of research activities and due consideration will be given for its continuity.

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Food insecurity: extent, determinants and household coping mechanisms in Gera Keya woreda, Amhara region

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Abstract

A study was conducted in two selected peasant associations in Gera Keya wereda of Amhara Region to investigate the problem of food insecurity in terms of its extent, determinants and coping strategies of the peasants. A total of 161 sample households were selected from two peasant associations which represent highland and mid-altitude areas of the woreda. The results showed that more than half 53.4% of the households in the study sample are food insecure and significant variations in intake of per capita calories have been observed between the two sample kebeles. Seasonal food insecurity was also commonplace especially between June and October. The food poverty gap measure for the total sample households is 25.0%. The corresponding figure for Giragn and Kimir Dingay kebeles are 20.0% and 30.0%, respectively. Hence, the food poverty or insecurity situation at Kimir Dingay kebele is worse than at Giragn kebele. The regression analysis showed that family size, ownership of oxen and small ruminants and farmland size are the major determinants of household food security in the study area. Farmers have also indicated the cause of food insecurity to be drought (*belg* season rain failure), erratic rainfall, shortage of farmland due to population pressure, soil erosion, lack of oxen, low price of sheep, sheep diseases, frost, water logging and plant pests and diseases. Farmers reported that they devise different coping mechanisms to the problem of food shortage, which differ based on the degree of severity of the problem. An array of coping mechanisms have been pointed out by farmers which range from reducing the number and quantity of meals to eating wild plants, yet there is a tendency of reliance on relief food aid which is developed due to indiscriminate provision of relief food aid.

Introduction

The problem of food shortage in Ethiopia had been and still is the most important problem of the Ethiopian economy. Over the past three decades, the country had to depend on foreign food aid of a massive scale. In the last 17 years, the country has received an average of about 726,000 metric tones of food grain aid per annum [National Food Security Strategy (NFSS), 2002]. The 1984/85 season was one of the most severe periods of food crises and famine in the recent history of the country. About 10 million people faced critical food shortage (Desalegn, 1990). This famine had claimed the lives of one million people before the country got out of the problem by means of foreign emergency food aid amounting to 10 million tones (Desalegn, 1990). There were several other problems of food crises of a grand scale. At present, the country is under constant threat of famine; in 2003 about 12.6 million people were exposed to severe food shortage (USAID, 2003).

Many authors and government officials have given several reasons for this persistent problem of food insecurity. Drought is commonly mentioned. In fact, the root cause of food insecurity and famine cannot be attributed to one particular reason alone. A multitude of factors are involved. Poor economic policies have inhibited the development of agriculture based on comparative advantage. Intensification of agriculture and growing population pressure combined with depleting natural resource base all contribute their share to the problem of food insecurity.

In fact, recurrent drought, which have become very frequent recently (once in every two or three years), have significantly affected the country's subsistent agriculture significantly changing transitory food shortages into chronic food shortages and abject poverty, especially in the rural areas. Moreover, greatly increasing population pressure (about 3% per annum) together with high livestock population might have caused the carrying capacity of the fragile environment in some areas. Productivity is rapidly declining due to reduced fallow, severe livestock grazing, increasing soil erosion and deforestation. As a result, the food shortage, which previously was only limited to the eastern Ethiopia, are increasingly encroaching to other surplus producing and of high agricultural potential areas (NFSS, 2002).

While these are the facts at the macro (country) level, things seem to be worse at the micro (Wereda, Kebele and household) level. Certain eastern parts of the country have been experiencing frequent drought, crop failure, food shortage and famine since the turn of the 20th century. Areas like the former Wolo, Tigray, Hararge and parts of Shewa provinces have a long history of periodic food crises and famine.In fact, there are significant variations among regions and among weredas of a single region in the extent, cause, vulnerability and coping strategy for the problem of food insecurity. This can be attributed to variations in climatic and natural resource endowments, land availability and fertility as well as due to variations in cultural and socio-economic conditions. There are also significant variations regarding the extent, causes and consequences and coping strategies among households in a single wereda or kebele.

According to AIFSP (2000), forty-eight of the 150 weredas of the Amhara region are drought prone and suffer from frequent food shortages. Many households produce food that meets their requirmmt only for less than six months of the year. In the north Shewa zone of the Amhara region, four out of nineteen weredas have been classified as chronically food insecure. These weredas (districts) are namely Gera Keya, Lalo Mama, Angolelana Asagirt and Efratana Gidim. These weredas have been receiving food aid intermittently since the 1984/85 famine and are receiving food aid continuously since the early 1990s. With regard to the situations in Gera Keya Wereda, which is the focus of this study, farmers in the Wereda face difficulties in food security even in normal years, and mostly rely on food aid (North Shewa zone Disaster Prevention and Preparedness Desk, DPPD, 2003)?

As already indicated above, the problem of food security takes particular forms in its extent, causes and consequences at a lower level of analyses. Macro level analyses of the problem hid important differences at the micro level, which will result in blanket recommendations to widely varying problems. Survival strategies also differ according to the degree of severity of the problem, season and also by region, community, household, gender and age.Hence, identifying and analyzing the root causes of food insecurity, which takes a worms- eye-view of the problem, is very crucial to come up with viable ways of mitigating it.Taking this in to cognizance, the research question of this project focuses on the analyses of the problem of food insecurity at Gera Keya Wereda of North Shewa zone of the Amhara region in terms of its extent, major causes and coping strategies of the peasants residing in the Wereda.

The objectives of the study were to identify the extent of food insecurity (food shortage) in Gera keya wereda of the Amhara region; to analyze the determinants of food security/insecurity in the wereda; to identify the coping strategies of the peasants in the wereda; and to recommend viable means of mitigating the problem.

The study has the following limitations. Since, the data generated out of the formal survey was a cross-sectional data where agricultural yield, food purchase, sales and other household food economy data for the period between March 2003 and February 2004 were generated, it lacks longitudinal perspective of the problem under study. On top of this, the unit of analyses of this study was household level; i.e. intra-household food situation was not assessed.

Methodology

The population for the study is the set of entire households residing in Gera Keya wereda. First, Gera Keya wereda was selected deliberately for it is food insecure. Out of the thirty rural peasants associations in the wereda, two were selected-one representing mid altitude areas that make up 28 percent of the total area of the wereda and the other representing high altitude areas. Highland areas make up about sixty percent of the wereda. The Peasant association (kebele) selected for the study, to represent the mid-altitude areas, was Kimir Dingay kebele. The other peasant association included in the study is Giragn kebele, which represents the highland areas of the wereda.

A random sample of 161 households were selected by systematic sampling method using the list of land tax-payers and an exhaustive list of landless households in the two peasant associations as sampling frames. Sample size for each kebele was determined in such away that ten percent of the total households from each kebele are included in the sample. Hence, 91 households are selected from Giragn PA and the remaining 70 were selected from Kimir Dingay PA.

Semi-structured questionnaire with close- ended and open- ended questions were used; moreover an interview guide was used to focus group discussions. The questionnaire was tested prior to the data collection process on the spot from where the data was collected. In addition to this, the questionnaire was also evaluated by scientists, who have good knowledge and experience on the subject of study so as to make sure that the instruments used have content validity and also reliability.

Primary data were collected using a multitude of data collection techniques including structured questionnaire, semi-structured interview, and group discussion with different

Primary data were collected using a multitude of data collection techniques including structured questionnaire, semi-structured interview, and group discussion with different community members. All the necessary and available secondary data were collected from relevant sources in the wereda as well as from zonal offices. Following the compilation of the data collected, the sample household responses were coded and entered in SPSS version 9 software for statistical analysis. The different analytical techniques applied were t-test, chi-square test and logistic regression models. The t-test was run to investigate if there is any statistically significant difference in some selected household characteristics between households, which are food secure and those that are not. The chi-square was run to see if there is any systematic dependency or contingency relationship between food security/insecurity and some selected household characteristics. In addition to this a modified version of the Foster-Greer-Thorbeck class of poverty measures were used for the analyses of depth of food insecurity in the study samples. Finally, a logistic regression model was specified to identify the determinants of food security and assess their relative importance in determining the probability of being food secure.

Results and Discussion

Agro-ecological and farming systems characteristics of the study sites

Agro-ecological conditions of an area determine its farming systems, type and levels of agricultural production. Hence, the study sites were selected purposively to represent mid altitude and high altitude areas of the wereda. Low altitude areas were not represented in the study because they make up only 8% of the total area of the wereda. The mid-altitude areas were represented by Kimir Dingay peasant association (kebele) and the high altitude areas of the wereda were represented by Giragn kebele.

Kimir Dingay kebele is found within an altitude range of 1800 to 2500 meters above sea level. It has one cropping season, which is characterized by intensive rainfall between June and September. Its farming system is characterized by wheat and *tef* based crop-livestock mixed farming system where sorghum, chickpea, lentil and faba bean are also important in terms of area coverage and their role in the dietary habits of the population. Different livestock species are kept by households for different reasons. As in any other mixed farming system, oxen are kept for traction power and as a store of wealth. Among small ruminants goats are kept for they are very well adaptive to mid altitude areas.

Giragn kebele is found between altitudes ranging from 2700 to 3200 meters above sea level. It has two rainy seasons- *belg* (March to April) and *meher* (June to September). Hence, it has the possibility of producing twice a year. However, the *belg* (short rainy seasons) is becoming more and more unreliable. As a result, farmers are depending on the long rainy season, which they think is unsuitable for crop production because of intensive rainfall creating problem of water logging and also because of chilling frost.

The farming system of Giragn kebele is characterized by barley based mixed crop-livestock farming system. Unlike the mid altitude areas, the highlands have low crop diversity, hence the most important crops grown in these areas are only barley, faba bean and lentil. Here also different livestock species are kept for different purposes. In contrast to the mid altitude areas, sheep are kept in relatively large numbers for they are very adaptive to the cool chilly weather condition. Moreover, the existence of large areas of uncultivable range land and the chilly weather condition makes it suitable for sheep and wool production which farmers of the area are doing. More importantly sheep are kept as insurance from the risk of belg rain failures and the consequent food shortage. In addition to sheep, oxen are also kept for drought purposes. Though in small numbers, cows, chicken and equines are also kept by farm households of the area.

Constraints for agricultural production

The level of agricultural production of a household determines the food security status of a household. This is due to the fact that the greater share of household food energy available is derived from the household's own agricultural production. In fact, smallholder farmers in the study area and all over the country at large are 'jack-of-all-trades', i.e. they produce for their own consumption and very insignificant part of the household food economy is exchanged (or acquired through purchases).

Hence, problems that hinder the growth of agricultural production and productivity have immense implications on the household food security status and extent. In this regard, farm households included in the study sample are requested to identify and prioritize agricultural problems, which hold back the production and the growth of productivity.

A number of problems have been enumerated by the farmers which include pests, plant diseases, shortage of farmland and pastureland, drought, erratic rainfall, frost, weeds and soil fertility related problems. However, the intensity and severity of these problems differ by local agro-ecological conditions. Hence, the problems identified and prioritized by farmers in Giragn kebele are different from that of Kimir Dingay kebele.

At *Giragn* the most important and severe agricultural yield limiting factors are found to be frost, pests, land degradation, hailstorms and failure of belg season rainfall. At Giragn, next to the problem of frost, which happens in September and October with a final effect of sometimes total yield loss, pests are also important. The most frequently mentioned agricultural pests are aphids which have severe yield reduction effect on barley, faba bean and wheat production. Problems of soil erosion, loss of fertility and shallow depth of soils of the majority of the farmlands together with waterlogging and hailstorms have negative impacts on the farmers' effort to increase crop production and productivity.

Moreover, the frequent belg season rain failure increases the vulnerability of farmers at Giragn kebele to severe problem of food insecurity. This is for the reason that the greater proportion of the wereda, which is juxtaposed to the escarpment of the rift valley, depend on belg season agricultural production. Hence, when the belg season rain fall is not adequate or when it is absent, thousands of farmers face transitory food insecurity. The belg season rain fails to fall for over two consecutive years and in such cases farmers will be compelled to sale their assets in order to winter out the problem. As a result the transitory food insecurity turns into chronic and hence many more farm households would seek relief food aid as a last resort.

In contrast, the problems at Kimir Dingay kebele are quite different. Here the constraints to agricultural production identified by farmers according to their priority are pests, plant diseases, and shortage of farmland and pastureland as well as drought and weeds.

The most important pests causing damage to crop production are aphids, bollworm, armyworm, termites and vertebrate pests such as mice and apes. Of the plant diseases mentioned by the farmers rust and other fungal diseases are severe in reducing yield of wheat, sorghum, tef, chickpea and faba bean.

On top of these, shortage of farmland and pastureland are also identified as constraining factors for agricultural production especially at Kimir Dingay kebele unlike Giragn. In fact, the mean farmland holding at Kimir Dingay is higher than that of Giragn. However, at Kimir Dingay there are many land-less young peasants than at Giragn. The shortage of pasture land at Kimir Dingay erratic rainfall, which is manifested by late on-set and early off-set have severe yield reduction problem. Particularly the problem of land degradation and loss of soil fertility have been pointed out to be very severe problems during group discussion held with farmers. Land degradation and loss of soil fertility are related problems, which are the results of intensive cultivation of crop without the proper cultivation practices, and excessively ragged terrain of the area, which facilitates accelerated soil erosion.

Population pressure and the subsequent reduction in fallowing activities, as well as expansion of farmland to steep slopes and hillsides have also exacerbated the problem of soil erosion and loss of soil fertility. Moreover, the existing high population pressure in the wereda and the existence of extensive uncultivable land in the wereda raises the number of people per unit land and therefore the problem of shortag. of land and the consequent land degradation.

Agricultural input use

The use of modern agricultural inputs such as inorganic fertilizers, high yielding crop varieties, herbicides, insecticides, and modern agronomic practices undoubtedly boost agricultural production and productivity However, the use of crop and livestock production technological inputs in Gera Keya wereda is very limited.
For instance in the sample kebeles only 36% of the sample households have reported that they use modern inorganic fertilizers (DAP and Urea) and only 38.5% of them use improved crop varieties. The reasons behind the low level of adoption of fertilizer and high yielding varieties could be, on the one hand, lack of sufficient awareness about the importance of such technologies and on the other lack of financial capacity and fear of indebtedness as well as inappropriateness of the available agricultural technologies.

Surprisingly, despite the existence of high potential for livestock production in general and small ruminants production in particular, technological inputs available to the farmers to improve livestock production are non-existent. In fact very limited support is being given by the Debre Birhan Agricultural Research Center to improve the productivity of the local sheep breeds, which are known for their tasty mutton and reasonably good wool production.

Although, the problem of pest, diseases and weeds have been reported by farmers to be severe. none of the respondent farmers have pointed out that they use insecticides and pesticides.

Concerning agricultural extension service, it has also been very limited and the focus has been on crop production and very little effort is being geared to support the growth of livestock production and productivity. This focus on crop production technologies has also been limited that that the existing extension service is provided only on introduction of very few improved wheat varieties and inorganic fertilizers.

With regard to access to extension service, at *Giragn* kebele majority (80.2%) of the farmers have reported that they have regular contact with the extension agent assigned in their kebele. In contrast, at present, there is no extension agent assigned at *Kimir Dingay* kebele; thus, farmers have no access to extension service at present. The service being provided by the extension agents to the farmers is usually focused on distribution of inorganic fertilizer and improved wheat varieties and on soil conservation activities.

Food Habits

The food security status of a nation, a region, or any other unit of analysis has a lot to do with the dietary habits of the inhabitants of the area. Many research findings have indicated this fact, i.e., communities, which are food selective and which depend much on cereal are more vulnerable to food insecurity than those which have a habit of diversifying their food sources.

In the study area, cereals make up the greater part of the diets of the population. In general, in the high land parts of the wereda barley, wheat and sorghum are consumed in the form of local dishes like *Ingera, Qitta, Tiresho and Dabbo*. While pulses like faba bean, field pea and lentil are used for *Shiro* preparation and also for *Nifro* and *Qollo*. In the mid and lower altitude areas of the wereda, cereals like sorghum, teff, and wheat are consumed for the preparation of local dishes mentioned above. From the pulses field pea and chickpea are extensively used for *shiro* and *Qollo*. Hence, households depend much on cereals.

Extent of food security

The household food balance model is a modified version of the regional food balance model and has been used by Eshetu (2000) and also Degefu (2000) in their analyses of household food security. The model is expressed as:

$Nij = (Pij + Bij + Fij + Rij) - (Hij + Sij + Mij)$

Where: Nij is net food available for household i in year j expressed in kilocalories.

Pij = total grain produced by household i in year j expressed in kilocalories for each grain type;

Bij= total grain purchased by household i in year j expressed in kilocalories;

Fij = total grain obtained through relief food aid or food for work expressed in kilocalories;

Rij= total grain received by household i in year j as gift or remittance expressed in kilocalories;
Hij = total post harvest losses to household i in year j expressed in kilocalories;
Sij= total crop reserved for seed from the home by the household i in year j expressed in kilocalories and;
Mij = total marketed grain by household i in year j expressed in kilocalories.
All these data were collected during the household survey conducted in March 2004. The year refers to the time between March 2003 and February 2004. Each type of crop is converted in to kilocalories using Plat (1986) table of amount of kilocalories available from 100gm of grain of each crop. The resulting figure shows the amount of total food energy available for the household during the reference period (March 2003 to February 2004). Then, this figure was divided by the number of adult equivalents for each household and the number of days of a year that gives the per capita kilocalorie available for the household per adult equivalent per day.

The per capita kilocalorie available for the household per adult equivalent per day (here on ward referred as simply per capita kilocalorie) was compared to the minimum recommended allowance (2100 kilocalories). Households whose per capita kilocalorie was less than 2100 were categorized as food insecure and those households whose per capita kilocalorie was greater than 2100 kilocalories were set to be food secure.

The result of this computation reveled that 53.4% of the households in the study sites were facing food insecurity. The mean per capita kilocalorie available to the household per adult equivalent per day for the entire sample size was found to be 2227.38kcal with standard deviation of 915.8. A wide range in per capita kilocalorie has been observed with the minimum per capita kilocalorie being 845.29 and the maximum being 5125.16.

Out of the total sample households 5.6% of them had less than 1001 per capita kilocalories available per individual per day and 19.9% of the total households were with in the per capita kilocalorie range of 1001 and 1500. In general about 18.4% of the farm households have less than 2001 per capita kilocalorie available per adult equivalent per day.

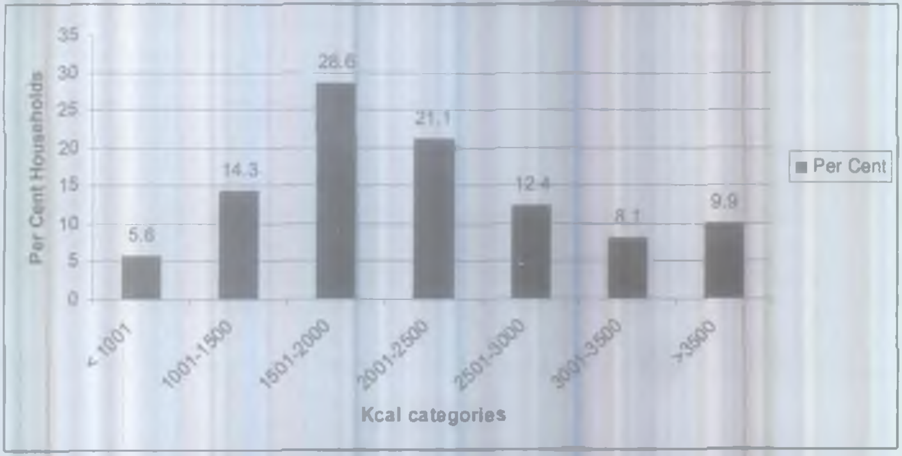

Fig. 1.Distrbution of households by kcal available

Significant variations have been observed between the two kebeles in per capita kilocalorie availability that *Giragn* kebele has average per capita kilocalorie of 2418.8, which is higher than the minimum recommended allowance. In contrast, the mean per capita kilocalorie available in *Kimir Dingay* kebele is 1978.53, which is much lower than the minimum recommended allowance. This difference in per capita kilocalorie has been found to be statistically significant (t = 3.104 ;P< 0.05). The higher amount of mean per capita kilocalorie for *Giragn* kebele can be attributed to the reasonably better harvest in this particular year due to good *belg* season rainfall which was not so usual as the *belg* rains are now becoming more and more unreliable. In the absence of *belg* rain the peasant associations located in the highland part of the wereda mostly rely on relief food aid. The available secondary data on food aid also support this fact that huge amounts of relief food aids are distributed in the wereda in the years such as 1999 and 2000 when *belg* rains had failed.

The total annual food energy available for the household in kilocalories was also divided by the number of adult equivalents for the household and the minimum recommended allowance of 2100 kilocalories to determine the number of days/ or months the household is able to feed adequately its family members. The result of this analysis showed that 5.6% of the total sample sizes were able to feed the family members adequately for less than six months of the year. 21.1% of the total households are able to cover the minimum food energy required for only less than 9 months of the year and only 46.6% of the sample households have annual food energy that could cover more than 12 months minimum food energy required for the entire household members.

Hence, the majority of the sample households face seasonal food insecurity even in normal years such as the year, which this study refers to. According to the survey results, July, August and September are the time when food shortage is very severe.

The extent of food security was also measured using an adapted version of the Foster-Greer-Thorbeck (FGT) class of poverty measures. Originally these measures were designed to compute depth of poverty. The FGT poverty measure is a class of poverty measure given by the following formula:

$$P^n = \frac{1}{d}\sum_{i=1}^{d}\left(\frac{povertline - income}{povertline}i\right)^n$$

where d=number of people below the poverty line
When n=0 P^0, gives the head count ratio or the percentage of people below the poverty line;
When n=1 P^1 gives the depth of poverty or the short fall from the poverty line;
When n=2 P^2 gives the squared depth of poverty which gives greater weight for the more destitute subjects.

This measure has been adapted to investigate the extent or depth of food insecurity simply by substituting food kilocalories available per day per individual for income and by substituting the poverty line by the minimum amount of kilocalorie necessary for an individual per day. Hence the adapted form of the FGT class of poverty measure takes the following form.

$$P^n = \frac{1}{d}\sum_{i=1}^{d}\left(\frac{mra - pcal}{mra} i\right)^n$$

Where 'pcal' is per capita kilocalorie available, 'mra' is the minimum recommended allowance and d is the number of food insecure households. Only those households which are food insecure or the difference between per capita kilocalorie and the minimum recommended allowance is negative are included in the computation. In other words, only those households whose per capita kilocalorie available is below 2100 kilocalories are included in this equation.

This adapted FGT measure revealed that out of the 161 sample households 56 of them or 53.4% are food insecure. At *Giragn* kebele out of the 91 households 40 or 44.0% of them are found to be food insecure and at *Kimir Dingay* 46 out of 70 households or 65.7% are found to be food insecure.

Table 1. FGT measure of food insecurity

	TOTAL	GIRAGN	K.DINGAY
FGT 0/P^0	0.53	0.44	0.66
FGT 1/P^1	0.25	0.20	0.30
FGT 2/P^2	0.09	0.06	0.12

Source: Computed from field survey data, March 2004

The FGT 1 or the P^1 measure shows the depth of the food insecurity or the average short fall of food energy from the minimum required for food insecure households. Hence, as shown in the table above, the food insecure households from the total sample were on average short of food energy by 25.1%. In other words, on average the food insecure households could get only 74.9% of the minimum recommended daily per capita food energy necessary for survival. The food insecure households from *Giragn* kebele were on the average short of the minimum recommended allowance by 20.00%, and the food insecure households from *Kimir Dingay* kebele are on average short of the minimum food energy recommended by 30.00%. Hence, the food insecurity in *Kimir Dingay* kebele is severe and deeper than that of *Giragn* kebele.

The FGT 2 or the P^2 measure of food poverty indicates the depth of food insecurity by giving more weight for the more destitute households, i.e; households with higher amount of food energy deficit from the recommended minimum allowance are given more weight in the computation of average level of shortfall of per capita kilocalorie. This is justified on the basis that it takes more resource to uplift those households, which are more destitute than those, which are closer to the minimum recommended allowance.

With this measure of food insecurity the average food energy shortfall of the food insecure households from the minimum amount of per capita kilocalorie recommended was 9.09%. Based on the FGT 2 measure the food insecure households from *Giragn* kebele were on the average short of the minimum recommended allowance by 5.76%, and the food insecure households from *Kimir Dingay* kebele were on average short of the minimum food energy recommended by 11.97%. Hence, once again, the food insecurity in *Kimir Dingay* kebele was severe and deeper than that of *Giragn* kebele.

Demographic characteristics and food security/insecurity

The demographic characteristics of households have impacts on food energy availability for the household. Thus in this section the study examines the existence of any systematic relationships between household demographic characteristics and food security. Certain important demographic characteristics such as age, sex, literacy status of the household head as well as dependency ratio, family size and their relationship to household per capita food kilocalorie availability have been examined thoroughly.

Sex of the household head is an important demographic variable that influences the food security status of a household head. This is for the reason that female-headed households are usually constrained by resources. They are mostly deprived in terms of resource endowment like land, labour and capital. Mostly they share crop their land to men farmers. Hence, it was hypothesized that female-headed households are more likely food insecure than male headed households.

The t-test was run to test this hypothesis. The mean per capita kilocalorie for female-headed households was 2190.85 (n=25) and that of male headed households was 2234.09(n=136). The t-test showed that there was no statistical difference in mean per capita kilocalorie available between male headed and female-headed households ($t = -0.219$, $P < .829$). Moreover, chi-square test was also run to test the existence of systematic relation between food security status and sex of the household head and the analyses showed that there was no significant systematic contingency relation between the two variables (chi square=0.250 and P=0.519). The reason behind the insignificant difference between male headed and female headed households might be due to the higher number of male headed households included in the sample.

Age of the household head is also regarded as an important variable with an impact on household food security status; i.e. older household are usually better than younger households (especially newly formed households) in terms of resource endowment. Thus it was hypothesized that younger households are more likely food insecure than older households. The t-test was run to test this hypothesis and the result showed that there was no statistically significant difference in mean age of the household heads between households, which were food secure and those which were not ($t = -0.337$; $P > 0.1$). The mean age of the household head for food secure and insecure households was 46.15 (n= 75) and 45.38 (n=86). T-test was also run to test the mean difference in per capita kilocalorie availability between households whose household head was younger than 45 and those with alder than 45 household head. The result showed that there was no statistically significant difference in mean per capita kilocalorie availability.

Though, there was no statistical difference between mean age of the food secure and insecure households, there was a clear difference in mean per capita kilocalorie available between household heads younger than 60 and those who were older than 60. For household heads older than 60, the mean per capita kilocalorie available for households for both kebeles and for the entire sample households were well above the minimum required 2100 kilocalories per day. Likewise the mean percentage of kilocalorie deficit for older households is positive (showing that there was no deficit).

The average family size for the overall sample households was 4.94 with standard deviation of 2.08 and with minimum and maximum family size being 2 and 11 respectively. It was hypothesized that family size has an impact on household food security status in such a way that large families tend to be food insecure than smaller families. As it is hypothesized, the statistical analysis showed a significant difference in family size between food secure and food insecure households ($t = 4.467$; $P<0.01$). The mean family size for food secure and food insecure households was 4.21 (n=75) and 5.58 (n=86) respectively.

In both the sample *Kebeles* and for the total sample also the mean per capita kilocalorie available per adult equivalent per day decreased with the increase in family size. In addition to this the mean kilocalorie deficit also increased with the increase in family size. The reason behind the negative relation between food security and family size might be that increased family number and therefore increased labour availability does not increase production, in contrary it increases only consumption. In other words, increase in family size does not lead to increase in production, which might be due to large number of farmers per unit land area. This means that the marginal productivity of labour might be negligibly low.

It was also hypothesized that dependency ratio has impact on household food security status. Hence, t-test was run to see if there is any difference in terms of dependency ratio between food secure and food insecure households. The result showed that the mean dependency ratio for food secure households was lower than that of food insecure households and there was statistically significant difference, at 10 percent level of significance, in the mean dependency ratio of food secure households (0.80, n=75) and food insecure households (0.99; n=86) ($t = 1.709$ and $P=0.089$).

Concerning education, the majority of the household heads included in the study have not attended basic education. Most of them respond that they have attended the education program provided by the Basic Education Campaign some 15 years ago. However, most of them do not read and write at present.
According to the survey results about 62.5% of the overall sample household heads do not read and write. About 22.4% of them have attended basic education and only 1.3% of them responded that they have had more than 8 years of basic education. Informal education programs are non-existent.

Literacy level of the household head is also an important variable mostly presumed to have impact on food security status of the household. Thus it was hypothesized that households which are headed by relatively more educated heads are in a better position in terms of food security than those whose heads are illiterate. The result of the t-test showed that there was no significant difference between food secure and insecure households in terms of years of schooling of the household head (t = 0.180, P= 0.857). The mean per capita kilocalorie available for households whose heads have less than 6 years of schooling was 2222.92 kilocalories per day and the corresponding figure for households whose heads have more than 6 years of schooling was 2301.37 kilocalories per day. This difference was found to be statistically not significant (t = -0.253, P>0.10). The reason behind this anomaly might be explained by the lack of other important productive resources

Asset ownership and extent of food security/insecurity

Asset ownership or farmers economic status affects the food energy availability for the household. Thus, the study examined the existence of any systematic relationship between asset ownership and food security/insecurity among sample farmers. In this regard, the relations between food security and variables such as land holding size, livestock holding, oxen holding, small ruminants holding, off-farm income generating activities and access to farm inputs are examined.

The average farmland holding for the entire sample was 1.008ha with standard deviation of 0.544 and the maximum farmland holding was 3.00ha while the minimum was 0.00. Landless farmers make up 2.5% of the total sample size, and 28.6% of them had less than 0.50ha of farmland. Out of the total sample farmers 65.8% of them had less than 1.00 ha of farmland and only 1.9% of them had greater than 2.00ha land. As farmland holding is a very important variable exhibiting the asset holding of a household, first, the t-test was run to see if there is any significant difference in farmland holding between the two kebeles. The result shows that the mean farm size for *Giragn* kebele is 0.8 ha and that of *Kimir Dingay* is 1.28ha and the mean difference in farm size between the two kebeles is statistically significant (t = -5.92 and P <0.01).

As it is evidenced from many empirical research findings, access to sufficient land is one of the critical factors determining food security. The result of this study also shows that per capita kilocalorie available increased with increase in land holding for the entire sample households except for land holding group with 1.01 to 1.50ha which might be due to lack of other productive resources. The mean per capita kilocalorie deficit percentage also showed the same pattern of increase with increase in land holding.

It was hypothesized that farm households which are food secure have larger farmlands than those which are not food secure. The t-test was run to test this hypothesis and the result showed that the average farmland holding for food secure households was 1.025ha and the corresponding figure for food insecure households was 0.992ha. This difference in farm size between food secure and food insecure households was not found to be significantly different (t = –0.375 and P = 0.10).

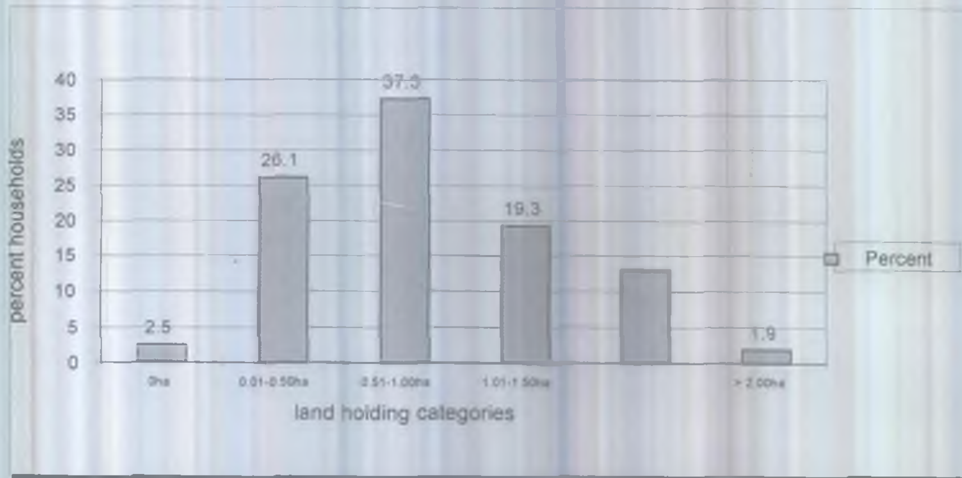

Fig.2. Distribution of sample households with land holding categories

Livestock holding in terms of tropical livestock units for the total sample households was approximately normally distributed with mean value of 2.163TLU and standard deviation of 1.131. The minimum amount of livestock holding in terms of total tropical livestock units was zero and the maximum amount was 6.22TLU.

As it can be evidenced from many studies concerning household food security, livestock possession is positively affects food security as it is the backbone of the farm economy especially in mixed farming systems. The result of this study showed that per capita kilocalorie invariably increases with increase in total livestock holding in terms of tropical livestock units. To test the hypothesis that food secure households have larger livestock possession than the food insecure households, t- test was run. The result of the test shows that the average livestock holding for food secure households was 2.43TLU and that of the food insecure households was found to be 1.93TLU. This difference in mean livestock holding in TLU was found to be statistically significant with t value of -2.854 and P value less than 0.05.

Oxen holding for the overall sample households were negatively skewed with mean value of 0.652TLU with standard deviation of 0.576. The minimum oxen holding were zero and the maximum amount was 2.80TLU. Out of the total sample households 34.8% were oxen less and 39.2% had only one ox. This shows that there was severe problem of shortage of oxen or traction for agricultural activities.

Of all livestock species, oxen play a very important role in the farm economy of the mixed farming system of rural Ethiopia. This is because that they provide traction power for different farm activities and they serve as a store of value. Hence, oxen holding show the wealth status of a farm household and are mostly positively related to food security. The data showed that per capita kilocalorie available for households increase with increase in oxen holding except for households with 3 and 4 oxen holding but these households are only two, thus it can not be concluded that increase in oxen holding was not associated with increase in per capita kilocalorie. The mean percentage kilocalorie available (the ratio of kilocalorie deficit or surplus to the minimum per capita kilocalorie needed) also increased with the increase in oxen holding.

T- test was run to test the hypothesis that food secure households have larger oxen holding than the food insecure households. The result of the test showed that the average oxen possession for food insecure households was 0.472TLU and that of the food secure households was found to be 0.8597TLU. This difference in mean oxen holding between the food secure and insecure households was found to be statistically significant ($t = -4.49$ and $P = 0.000$).

The average small ruminants (sheep and goat) holding for the entire sample size was 4.69 with standard deviation of 3.57. The minimum small ruminant holding was zero while the maximum was 15. About 19.3% of them had no sheep or goat, and 45.3% of them had small ruminant holding between 1and 5. Another 29.8% and 5.6% of the sample households had small ruminants holding between 6 to 10 and 11 to 15 respectively.

The average small ruminants holding for *Giragn* kebele was 5.47 which is higher than that of *Kimir Dingay* that is only 3.67. This difference in small ruminants holding was found to be statistically significant ($t = 3.40$ and $P = 0.01$). This variation in small ruminants holding between the two kebeles was due to variations in local sub agro-ecological conditions that the extensive savanna and cool temperature of *Giragn* kebele favours sheep production unlike the dry and extensively cultivated fields of *Kimir Dingay* kebele.

Small ruminants are reared by farmers for the purpose of store of asset and for sales in cases of immediate cash need. All the sample farmers who rear livestock responded that they keep the sheep and goat for the reason that they may be as a source of cash to purchase food grain at times of crop failure or low yield. They also responded that the sheep and goat are sold to settle debts. Thus, it was hypothesized that farmers with larger number of small ruminants are better off and food secure than those with minimum number or without. The amount of per capita kilocalorie available for the household increased invariably with increased in the number of small ruminants possession. The amount of kilocalorie deficit also decreased with increase in small ruminants holding.

The t-test also shows that there was significant difference in the mean number of small ruminant possession between food secure and insecure households at 0.05 significance level ($t = -2.485$, $P = 0.014$). The mean number of small ruminants for the food insecure households was 0.41TLU, which was lower than the corresponding figure of 0.54TLU for the food secure households.

Food security/insecurity and technological inputs

Farm inputs such as fertilizers, improved crop varieties, agricultural credit and extension services boost agricultural production and thus improve household food security status. Hence, it is important to see the relationship between the use of agricultural inputs and food security status of households.

Among the technological inputs, fertilizer use is one of the most important variables, which could have immense impact on household food security. In fact, the majority of the sample farm households do not use chemical fertilizers; only 36% of them use fertilizers. One of the reasons behind this low level of fertilizer adoption was farmers believe that the farm land gets used to it and it will be impossible to produce crops with out fertilizer for the future. The other reason is for fear that they might get indebted in case of crop failure because they get the fertilizer in credit.

Regarding the relationship between fertilizer use and food security, at *Giragn* the per capita kilocalorie available for households, which do not use chemical fertilizer, was higher than that of households, which do use chemical fertilizers. while the reverse was true for households from *Kimir Dingay* kebele. However, for the entire sample households, the mean per capita kilocalorie available for households that use chemical fertilizers is lower than corresponding figure for households, which do not use chemical fertilizers. This mean difference in per capita kilocalorie between households which use chemical fertilizers in their farmland and those who do not was not statistically significant with t value of 1.29 and P value of 0.198. The chi-square test also shows that there is no statistically significant systematic relationship between fertilizer use and food security, at lower than 0.05 level of significance with chi-value of .129 and P value of .099.

The reasons for the lack of statistically significant systematic relations between use of chemical fertilizer and food security might be due to the fact that households which use chemical fertilizers take credit in order to purchase it and they have to payback their debts right after crop harvest when prices for agricultural commodities fail, thus they have to sale large amount of their produce to settle their debts for fertilizer and other duties and this makes them to remain with meager amount of their produce. As a result, they will have relatively smaller amount of kilocalorie available for the household and become food insecure.

With regard to use of improved varieties, very few improved varieties of crops are available in the area. Of all the sample farmers only 38.5% of them have ever used high yielding varieties. One of the reasons behind this low level of adoption of high yielding crop varieties was lack of availability of the crop varieties in type and quantity. Concerning the relationship between uses of improved crop varieties and food security the chi-square test was run and the result shows that there was no statistically significant systematic relation between food security and use of improved crop varieties with chi-square value of 0.099, and P value of 0.208. The t-test also showed that there was no statistically significant difference in per capita kilocalorie availability between households, which use improved crop varieties and which do not, at lower than 0.05 level of significance ($t = 1.81$ and $P= 0.071$). The reason behind the lack of any significant systematic relations between food security status and use of improved varieties might be the same as that of the relation between use of chemical fertilizer and food security. However, the other reasons might also be lack of adaptive improved crop varieties for local sub agro-ecological conditions. Nevertheless, this particular problem needs further research to investigate the reasons behind.

Another important variable with immense implications to household food security is engagement in off-farm income generating activities. Off-farm income generating activities help farmers to diversify their income sources and thereby reduce risk of vulnerability to food insecurity.

As to the role of off-farm income activities to food security, attempts were made to see if there is any significant difference in food security between farmers who work off-farm activities and who do not. The result showed that for the households from *Giragn* kebele, the per capita kilocalorie of farmers engaged in off-farm activities was higher than that of the farmers who did not. And the result for *Kimir Dingay* kebele was contrary to what is expected, i.e. the per capita kilocalorie of farm households, which are engaged in off-farm income generating activities was lower than that of the household which did engage in off-farm income generating activities. The reason for this anomaly may be due to the fact that there are few opportunities for farmers in *Kimir Dingay* kebele and also the contribution of the income derived from these activities to household food security was negligible.

Chi square test was run to examine the existence of any systematic relation between food security and engagement in off-farm income generating activities. The result of the chi-square test showed that no statistically significant systematic relation exist between food security and off-farm activities (chi-square =0.045 and P>0.10).

T-test was also run to examine the existence of significant difference in per capita kilocalories between households which earn income from off-farm activities and which do not. The result of the t-test showed that the mean per capita kilocalorie available for households, which earn income from off-farm activities was 2175.77 kilocalories and the corresponding figure for households, which were not engaged in off-farm income generating activities was 2299.79 kilocalories. This mean difference was not statistically Significant (t =-0.846 and P>0.10). This shows that the income derived from off farm activities was negligible.

It was also hypothesized that farm households who rent-in land will have addition amount of cultivated land and hence additional amount of crop production, which can make them be food secure. To test this hypothesis, chi-square was run and contrary to what was expected there was no significant contingency relation between land renting and food security (chi-square = 0.075 and P=0.324). The t-test also showed that the mean per capita kilocalorie for households which rent-in land was 2102.33 and that of the households, which do not was 2378.13, but this difference in per capita kilocalorie was not statistically significant at 0.05 level of significance (t =-1.918 and P=0.064). The reason behind this scenario might be related to the fact that the farmers who rent-in land should share the crop produced with the owner of the land that leaves both parties with meager amount of output.

Access to market is also another important variable with implications to food security. Several household food security studies reveled that access to market, which is measured through indicators like proximity to nearby town, has impact on food security that households which are near to market and towns are in a better position in terms of food security than those which are far from market places and towns.

Comparison of the mean per capita kilocalorie of households which are with in two hours walk distance from the nearest market place to those which are located at more than two hours walk distance from the nearest market place showed statistically significant difference (t =-2.105, P=0.037). Those nearer to the market place have mean per capita kilocalorie of 2418.73, which was higher than the corresponding figure for the households which are located far away from the market place (2108.29 kilocalories).

With regard to access to credit, the credit service available in the study areas was only for purchase of chemical fertilizer and improved seeds. Only about 33.5% of the farmers have reported that they had taken from formal sources. In fact, access to credit service is another important variable with implications to household food security.

Hence it was hypothesized that households that take credit from formal sources will have better per capita kilocalorie than those, which do not take credit. T-test was run to test this hypothesis and it was found that the mean per capita kilocalorie for households which do not take credit from formal sources (2353.07) was higher than those which take credit (1978.32) and this mean difference in per capita kilocalorie was found to be statistically significant (t =2.49 and P = 0.05). The reason for this anomaly could either be lack of other important productive resources or because of heavy indebtedness of farmers who take credit that they had to sale part of their produce in order to settle their debts.

Food Aid and Food Security

The average amount of food aid received (by means of food for work or relief) by the total sample households between March 2003 and February 2004 was 0.8quintals. The standard deviation was 0.8 and the minimum and maximum amounts were 0.00 and 3.50 respectively. Out of the total households about 58% of them have received relief food aid during the above stated time. The mean per capita kilocalorie of households, which received food aid (2259.11kcal) was higher than that of the non recipients (2183.98Kcal) but this mean difference was not statistically significant (t =-0.513 and P=0.609). This shows that food aid has no statistically significant impact on household per capita kilocalorie availability.

Looking at the corresponding figures of the two kebeles one can observe that contrary to the case of Giragn kebele, at *Kimir Dingay* the mean per capita kilocalorie amount of households, which received food aid was lower than those households, which haven't received. The reason might be that because of stringent criteria of selecting food aid beneficiaries at *Kimir Dingay* that only the needy are provided with food aid. And since the poor are poor and deprived of many other productive resources, they do not have enough produce and also the amount of food aid was meager that they are unable to meet the minimum daily requirement of 2100 kilocalories.

Extent of food insecurity at 2400 minimum kilocalorie recommendation

Making the minimum per capita kilocalorie allowance 2400 kilocalories per person per day (which is the global minimum recommended kilocalorie required for an active and healthy life) reveled interesting results. If households which have less than 2400 kilocalories per adult equivalent per day are labeled food insecure and those above this figure to be food secure, about 66.5% of the sample households were food insecure and the remaining 33.5% were food secure.

Variations between the two sample kebeles have been observed in that 54 (59.3%) of the households from *Giragn* kebele and 53 (75.7%) of the households from *Kimir Dingay* kebele were found to be food insecure. These figures also show that the food insecurity situation in *Kimir Dingay* kebele is worse than *Giragn* kebele. Concerning the depth of food insecurity, out of the total sample households 8.8% of them have per capita kilocalorie available less than 50 % of the 2400 kilocalories recommended per person per day. Another 33.5% of them have per capita kilocalorie between 50 to 80% of the 2400 kilocalories necessary for an active and healthy life.

Decomposing these figures by kebele also shows that out of the total sample households 14 of them have per capita kilocalorie less than 50% of the 2400 kilocalories and out of these households 78.6% were from K*imir Dingay* while the remaining 21.4% were from *Giragn* kebele. Moreover, the data show that out of the 54 (34.0%) households that have per capita kilocalorie over 2400 kilocalories 37 (68.5%) were from *Giragn* kebele and 17 (31.5%) were from *Kimir Dingay*. Looking at the number of months a household's total kilocalorie could last if each member of the family consumes 2400 kilocalories per adult equivalent per day, the data reveled that about 13 (8.1%) of the entire sample households have food energy that could suffice the requirements for six months time only.

Regarding the adapted measure of food security calculated by making the threshold food energy requirement 2400 kilocalories, the table below shows that the FGT 0 for the total sample households is 107 and the head count ratio was 66.5%. The FGT 1 and FGT 2 measures of food poverty for the total sample were 0.289 and 0.114 respectively.

Table 2. Adapted FGT measure of food poverty at threshold level of 2400 kilocalories

	Head count	FGT0	FGT1	FGT2
Total	107	0.665	0.289	0.114
Kimir Dingay	53	0.757	0.343	0.150
Giragn	54	0.593	0.236	0.077

Source: Field Survey, March 2004

The table also shows that the adapted FGT measures for the two sample kebeles. The table shows that the head count ratio for *Giragn* kebele was lower than that of *Kimir Dingay*. The adapted FGT-1 and FGT-2 measures also showed that the average shortfall from the 2400 per capita kilocalorie at *Giragn* kebele for the food insecure households was 23.6% and the corresponding FGT-2 measure was 7.70%. The FGT-1 or the average per capita food energy shortfall for *Kimir Dingay* kebele was 34.3% and the FGT-2 figure was 15.0%.

Determinants of food security

The Model

According to Gujaratti (1998) the functional form of logistic regression model can be specified as:

$Ln [p(x)/ 1-p(x)]= B_0 + B_1X_1+ B_2X_2 + ... + B_nX_n$.

Where p(x) is the odds of being food secure. The logistic regression model takes a dummy variable as the dependent variable. The logistic regression applies maximum likelihood estimation after transforming the dependent into a logit variable (the natural log of the odds of the dependent occurring or not). In this way logistic regression estimates the probability of a certain event occurring.

Here, household food security status is the dependent variable where a value of zero is given for food insecure households and a value of one is given for food secure households. A household is said to be food secure if the total kilocalorie available to the household divided by the family size of the household and the number of days in a year exceeds 2100 cal per person per day.

Seventeen variables were entered in the model. Variables such as extension services were not included in the model due to lack of variability among sample households with respect to these variable.

On the other hand, certain variables such as amount of food aid in quintals received by the household, number of household members between the age of 15 and 65 and total livestock holding in TLU were not included in the model due to problems of multi-coliniarity with variables already included in the model.

The table below shows the logistic model estimates of the factors determining the state of food security at household level in Gera Keya wereda. It indicates that the fitted logistic model explains 78.34% of the total variation in the household food security. The model also correctly predicted the 83.33% of the food insecure households and 72.60% of the food secure households. The chi-square shows the parameters included in the model are significantly different from zero at less than 1% probability level with 17 degrees of freedom.

Among the seventeen factors included in the model four factors were found to have a significant impact in determining the state of food security. These were farm size, family size, oxen holding, and small ruminants holding.

Family size has a negative logit coefficient and odds ratio of 0.2988, which implies that the probability of a household to be food secure decrease by a factor of 0.2988 with a unit increase in family size.

Farm size was found to have positive and significant impact on the probability of being food secure. The probability of being food secure increased by a factor of 4.0983, with a unit increase in farm size.

Oxen holding had a positive and significant logit coefficient at 0.01 level of significance. This was due to the fact that households with more number of oxen have sufficient drought power and are able to rent-in land in addition to their own and thus produce more crops unlike those, which are ox less. The result of the regression result indicated that a unit increase in oxen holding increases the probability of being food secure by a factor of 13.0299.

Small ruminants holding had a positive and significant logit coefficient at 0.1 level of significance. This was for the reason that households with more number of small ruminants (sheep and goats) are able to sale them and buy food grain. The regression result suggested that a unit increase in the number of small ruminants increased the probability of being food secure by a factor of 4.4550.

Age of the household head was entered in the logistic model and the result of the regression analyses show that the age variable, although not significant, has a positive coefficient. This suggests that younger households have a lower probability of being food secure which might be related to the fact that younger household heads have lower amount of farmland and other asset holding.

The logistic regression analyses also showed that, though not significant, sex of the household head has a positive logit coefficient which implies that male headed households have a higher probability of being food secure than female headed households.

On the other hand the regression coefficients and the model were used to calculate predicted probabilities of the state of food security for change in the values of significant variables. The probabilities were calculated keeping the dummy variables at zero and the continues variables at their mean values.

The probability of being in food secure situation among farmers with the average values of continues variables and with value of zero for dummy variables is 14.6%.

The predicted probabilities of being food secure for the minimum and maximum amount of farmland holding are 3.7% and 73.9%. The predicted probabilities for farmland holdings of 0.25 and 0.5ha while all the other continues variables are kept at their mean value and all the dummy variables are kept as zero are found to be 5.5% and 7.7% respectively. As the farmland size increases the probability of being food secure increases invariably in the contrary it decreases with the increases in family size

The predicted probabilities of being food secure for the minimum and maximum amount of family size were found to be 85.6% and 0.01% respectively. The corresponding figures for minimum and maximum amounts of oxen holding in terms of tropical livestock units were 3.1% and 97.6% respectively, when all the other continues variables are kept at their mean values and all the dummy variables are kept at zero. As shown in the table 3, the maximum amount of predicted probability of being food secure is found for the hypothetical case with oxen holding of 2.8 TLU (equivalent to 4 oxen) and all the other continues variable kept at their mean value.

The predicted probabilities of being food secure for the maximum and minimum amounts of small ruminants holding in terms of tropical livestock units are found to be 7.8% and

44.3% respectively, when all the other continues variables are kept at their mean values and all the dummy variables are kept at zero.

Table 3. Parameter estimates of a logistic model for factors determining the state of food security among sample households in Gera Keya wereda of the Amhara region.

Variables	Parameter estimates	Wald statistic	Sign.	Exp (B)
Family size	-1.2080***	27.3256	.0000	.2988
Sex of the household head	0.9498	1.8806	.1703	2.5832
Age of the household head	0.0039	0.0368	.8478	1.0039
Dependency Ratio	0.1502	0.1755	.6753	1.1621
Educational level of the household head	-0.0106	0.0109	.9168	.9894
Farmland size	1.4106**	5.5660	.0183	4.0983
Land rent	0.3007	0.3194	.5719	1.3508
Fertilizer use	-0.5023	0.6111	.4344	.6052
Use of HYV	0.4564	0.6271	.4284	1.5783
Access to credit service	-0.3228	0.3335	.5636	.7241
Engagement in off farm activities	-0.3746	0.4783	.4892	.6876
Access to market	-0.8827	1.8954	.1686	.4622
Agro ecology	-0.8942	1.1595	.2816	.4137
Sales of livestock	0.0007	1.1231	.2893	1.0007
Food aid ratio to total calorie available	-0.8942	0.1014	.2257	.5636
Sales of livestock	0.0007	1.1231	.2893	1.0007
Small Ruminant holding in TLU	1.4940*	3.7776	.0519	4.4550
Oxen holding in TLU	2.5672***	20.2468	.0000	13.0299
Constant	1.4869	1.4469	.2290	
Model Chi-square	85.355***		.0000	
Overall cases correctly predicted	78.34%			
Correctly predicted food secure	72.60%			
Correctly predicted food insecure	83.33%			

*Note: ***=Statistically significant at 0.01; **= Statistically significant at 0.05;*
**= Statistically significant at 0.10 (Source: Computed from field survey, March 2004)*

In a group discussion with farmers, the most important causes of food insecurity are identified to be factors that are directly related to agricultural production. Of these factors, drought (*belg* season rain failure), erratic rainfall (late on-set and early off-set of *meher* season rain fall), shortage of farm land due to population pressure, soil erosion, lack of oxen and other important production inputs, low price of sheep and sheep diseases, frost, water logging and problem of pests (Aphids, Bole worms, army worms…) and plant diseases such as rust are found to be the most important ones. which differ based on the degree of severity of the problem

An array of coping mechanisms have been pointed out by farmers which range from reducing the number of meals to eating wild plants, yet there is a tendency of reliance on relief food aid which is developed due to indiscriminate

Concerning household copping mechanisms to the problem of food shortage, a number of strategies were reported by farmers provision of relief food aid and this has its own impact that other possible ways of mitigating the problem of food insecurity seem to be gradually being eroded.

Table 4. Predicted probabilities of food security status among sample farmers

Variables		Predicted Probability (%)
Land holding	0 (Minimum)	3.7
	0.25	5.5
	0.50	7.7
	1.000781 (mean)	14.6
	1.5	25.5
	3 (Maximum)	73.9
Family size	2 (Minimum)	85.6
	4.94 (mean)	14.6
	11 (Maximum)	0.01
Oxen holding	0 (Minimum)	3.1
	0.65 (mean)	14.6
	1.4	53.8
	2.1	87.5
	2.8 (Maximum)	97.6
Small ruminants holding	0 (Minimum)	7.8
	0.47 (mean)	14.6
	1.5 (Maximum)	44.3

Recommendations

1. Reducing the existing severe land degradation
   I. A lot of work has to be done to stop the accelerated soil erosion
   II. Proper land cultivation practices such as avoiding cultivation of steep slops should be adopted
2. Ameliorating the Problem of shortage of farmland
   I. The ever-increasing population pressure is the major cause behind the shortage of farmland. Hence, efforts should be geared towards controlling population growth through vigorous family planning education
   II. Efforts should be made to raise the level of agricultural production and productivity. This can be done only through use of modern agricultural technological inputs such as fertilizers, improved crop varieties and agronomic practices. Therefore, there is a need for an invigorated agricultural research and extension programmes.
   III. Other agricultural yield limiting factors such as pests and diseases should also be removed through problem solving agricultural research and extension.
   IV. Promotion and effecting of resettlement programs.
3. Since the major determinants of household food security in the wereda are found to be variables indicatingasset holding of farmers. efforts should be made to improve the asset holding of the farmers residing in the wereda through poverty reduction programs.
   I. Promotion of supplementary employment and income generating schemes by way of skill development training such as the enhancement of the existing tradition of making wool carpets and other products
   II. Enhancing rural credit services
   III. Enhancing agricultural marketing

4. Specialization in sheep production
   I. Utilization of the existing sheep production potential
   II. Enhancing their access to market in order to enable them to fetch better income from sales of sheep
5. Water harvesting and small scale irrigation development to get rid of problems associated with *belg* season rain failure as well as enabling the farmers to shift agricultural production to *meher* season.
6. Implementing stringent criteria for selection of relief food aid beneficiaries so as to avoid the problem of dependency on relief food aid.

References:

AIFSP.,2000. Amhara Integrated Food Security Program, USAID Food Security Project Study Report. Unpublished

Degefa Tollosa, 1996. Belg Crop Production as a Strategy for Household Food Security: A comparative Study of Belg Grower and Non-Belg Grower Framers in Munessa wereda, Arsi Zone. Unpublished M.A. thesis Department of Geography, Addis Ababa University.

Degefa Tollosa ,2000. Household Seasonal Food Insecurity in Oramia zone of Amhara Region

Desalegn Rahmato ,1990. 'Food aid and Food dependence in Ethiopia' in Eshetu Chole, Mlay, W. and Oyugi, W (eds.) .The Crisis of Development Strategies in Eastern Africa, OSSREA Book Series, Addis Ababa, Ethiopia.

Eshetu Bekele , 2000. Underlying causes of household food insecurity in legambo wereda South wello zone of Amhara Region. MA thesis, RLDS. Addis Ababa University.

Gujarati, D.N. ,1995. Basic Econometrics. Third Edition. McGraw-Hill, INC.

National Food Security Strategy (NFSS) ,2002. Unpublished Government Paper

Platt , 1985. Tables of Representative Values of Food Commonly Used in Tropical Countries. London School of Hygiene and Tropical Medicine

USAID, 2003.USAID/ETHIOPIA Drought Facts Sheet Number 9.

Crop production technology transfer efforts in North Shewa: achievements and constraints

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Abstract

Since the establishment of the Research, Extension and Farmers Liaison Division at the former Sheno Agricultural Research Center (now Debre Birhan Agricultural Research Center) in 1998, technology transfer efforts have been made in the North Shewa Zone of Amhara Region. Improved varieties of crops and their production technologies constitute much of the technology transfer. These include three wheat, four barley, two faba bean and two lentil varieties along with their production technologies. This paper is an attempt to examine and document the technology transfer efforts and their achievements in North Shewa zone.

Introduction

Investment in agricultural research can only be justified only if improved agricultural technologies would be developed and transferred to end users, eventually increasing agricultural production and productivity. In this regard, various studies on the performance of the Ethiopian agricultural research system proved that numerous improved crop production technologies have been developed by the federal and regional agricultural research centers. However, the level of their adoption by farmers has remained low. In order to reverse this trend, technology transfer efforts have been well underway by Research and Extension Liaison Divisions established in all the research centers across the country. With the same objective of transferring improved agricultural technologies in their mandate areas, the Research, Extension and Farmers Liaison Division was established at the former Sheno Agricultural Research Center (now Debre Birhan Agricultural Research Center) in 1998.

Since the establishment of the division, various efforts have been undertaken to transfer improved agricultural technologies to the farmers of North Shewa Zone in the Amhara Region. These efforts were largely concentrated on crop production technologies. This was due to lack of readily transferable technologies in other components of farming and lack of experience in livestock and natural resource technology transfer among the division staff.

On-farm pre-extension demonstrations, field days, trainings and Farmers Research and Extension groups (FREG) were the methods used in technology transfer.

This paper summarizes major achievements and constraints of past technology transfer efforts at Debre Birhan Agricultural Research Center.

Achievements

Bread wheat technology transfer

Bread wheat production is increasingly becoming an important cereal crop in the Highlands of North Shewa. It is mostly grown in areas between altitude of 2500 and 3000 m.a.s.l. The most important wheat production constraints in these areas are water-logging, frost, poor soil fertility, terminal moisture stress as well as lack of improved wheat varieties that adapt to these constraints.

In response to these production constraints, improved wheat varieties and crop management practices have been recommended by the respective research divisions of the center. Four improved bread wheat varieties, i.e., HAR 710, HAR 1709, HAR 604, and HAR 1899, and their production packages, i.e., agronomic recommendations comprising seed rate, drainage method and fertilizer rates were demonstrated to farmers of North Shewa highland areas.

In 1998, the improved Bread wheat variety HAR 710, which farmers named it *Fuabey,* and its production package, i.e., a seed rate of 175Kg/ha, 150Kg/ha Urea with 100Kg/ha DAP and hand made Broad Bed and Furrow drainage method, was demonstrated to farmers and an average yield of 27.4q/ha was harvested from three demonstration sites at Bakelo, Keyit and Mush areas while the local variety called *Shemet* with farmers' method of production gave an average yield of 12.6 q/ha from the above three sites. However due to the susceptibility of the improved variety HAR 710 to yellow rust observed around Kulumsa areas the demonstration of this variety was terminated and instead another two promising improved bread wheat varieties, HAR 1709 and HAR 604, were put under the demonstration program.

In 1999, demonstration of these varieties with their production packages were conducted at 7 sites around Keyit, Mush, Atakilt and Wishawshign areas and mean grain yields of 35.3q/ha and 23.3q/ha were observed from varieties HAR 604 (*Galama*) and HAR 1709 (*Mitike)* with their production packages, respectively. The local cultivar *Shemet* with farmers' method of production gave a mean grain yield of about 10.5q/ha. During the field evaluation, farmers appreciated the variety HAR 604 (*Galama*) for better palatability as animal feed and for better water logging and frost resistance. Moreover, farmers complained that HAR 1709 (Mitike) is short stalked, easily sheds, but matures early.

Demonstrating bread wheat varieties, Galama and Mitike, and their production package continued on fourteen farmers' fields around Debre Birhan zuria in 2000. The average yield obtained from Galama and Mitike was 28.5q/ha and 25.3q/ha, respectively. The unfertilized and fertilized local variety gave 12.8q/ha and 16.8q/ha, respectively. The marginal rate of return (MRR) by using Galama and Mitike with their package of production instead of the local variety and the practice associated with them was found to be higher, i.e., 121% and 86%, respectively. Despite higher yield compared with the traditional practice, the use of improved method of production with the local variety (Shemet) was not economical.

The same thing was done at Kotu, Faji, Enewari, and Seladingay areas in 2001, and an overall average of 26.28q/ha was harvested. The local variety here was ET-13 instead of *Shemet*. Many farmers were growing this variety with a name Global. The objective of the demonstration was to introduce the improved variety HAR 604 as an alternative to ET-13. The results showed that the new variety HAR-604 with its production package gave an average yield of 26.3q/ha. Yields ranged from 42.5q/ha at Enewari to 13.8q/ha at Faji. Et-13 gave an average yield of 22.0q/ha ranging from 41.5q/ha at Enewari to 13.1q/ha at Kotu. Farmers commended HAR-604 for its earliness compared with ET-13. It also had some resistance to frost and was more palatable as animal feed.

Once business was complete with HAR 604, work continued with an alternative, i.e., HAR 1899 (Katar), in 2003. The demonstrations were conducted on 12 farmers' fields around Enewari and Mehal Meda areas. The average yields of the new variety HAR 1899 at Enewari, Mehal Meda and the combined average yields were 36.1q/ha, 22.4q/ha and 29.3q/ha, respectively. The yield obtained from the unidentified improved variety used as a comparison at Enewari was 29.9q/ha and 25.1q/ha at Mehal meda while the combined average yield for the unidentified improved variety used for comparison was 27.5q/ha. However, as observed on the Field days conducted around Faji, the HAR-604 variety looked slightly susceptibility to rust.

In 2004, HAR 1899 gave the highest yield of 47.2q/ha at Enewari and the lowest of 8.9q/ha from Mehal Meda. The mean grain yield of HAR 1899 obtained from Mehal Meda area is about 12.3q/ha. At Mehal Meda, *Shemet* gave the least grain yield of 9.6q/ha. At Enewari, HAR 1899 and HAR 710 gave mean grain yields of 37.5q/ha and 31.7q/ha, respectively. At Molale, HAR 1899 and *Shemet* gave 17.4qt/ha and 12.4q/ha.

In 2005, demonstrating HAR 1899 and its production technologies continued around Molale, Mehal Meda and Deneba areas. Average yields of 23.0, 24.2 and 25.4q/ha was obtained, respectively. Yellow rust was observed in all locations. All existing varieties under production were found to be susceptible to the diseases except ET-13.

Presently, seven released bread wheat varieties from Kulumsa are under on-farm evaluation pfrograms by Farmers' Research and Extension Groups established around Deneba, Mehal Meda and Faji areas.

Table 1.Overall average yields obtained from demonstration sites for the improved and local varieties.

Variety	Yield in q/ha
HAR 710 (*Fuabey*)	27.4
HAR 604 (*Galama*)	29.7
HAR 1709 (*Mitike*)	26.0
HAR 1899 (*Katar*)	29.3
ET-13	26.2
Local variety (*Shemet*) with farmers' method of production	10.3
Shemet with improved production method	15.7

Future directions of wheat production technologies should focus on the following aspects. First of all, Farmers' Research and Extension Groups in all Woredas of North Shewa must be established and refined in the Zone so that technology evaluation and extension would be group based which will help to reach more farmers and increase the level of farmers' participation. Secondly, multiplication and dissemination of improved seeds by farmers themselves must be strengthened.

Food barley technology transfer

The cool highlands of North Shewa zone are suitable to barley production. In fact, barley is a traditional staple crop in these areas with high domestic demand. It is grown both in *Belg* and *Meher* seasons on fields fertilized with manure and manure-ash mixture. The major production constraints in these areas are frost, water-logging and poor soil fertility.

Following the release of the first barley variety Miserach, the demonstration of food barley has been conducted around Ankober, Asagirt, Debrebirhan Zuria, and Tarmaber since the 1999 cropping season. The demonstrations were conducted in both seasons. The belg demonstrations were conducted around Ankober and Asagirt that are known regions for higher belg production in area coverage and productivity. In Ankober area, demonstrations were conducted during both meher and belg seasons.

Field days were conducted in all these areas and farmers have given their opinion about the technologies. They chose Miserarch for high productivity, high tillering capacity, high weed suppression, better resistance to hail and frost damage, earliness, and white seed color. White seed color commands high price in the market.

The demonstrations were conducted in such away that the improved and farmers methods and varieties could easily be compared. The improved methods include varieties miserach *and shege*, seed rate (125Kg/ha), fertilizer rate (41/46 N-P2 O5), one hand weeding at 25-30 days after emergence, 2-3 times ploughing frequency and sowing date (around mid June). Whereas, the farmers method is use of local varieties without fertilizer and no weeding.

The results of indicated that the variety miserach and its production package gave higher yields. Misirach, shege and the local check gave mean grain yields of 28q/ha, 21.99 and 16.25qt/ha, respectively. Partial budget analysis showed that miserach and its production method gave an MRR of 68.3%. Shege was not found economical. Farmers chose misirach for the belg areas of Ankober for its earliness so that it will escape hail damage in July and August.

In 2000, Miserach and its production packages gave higher yields than others. Miserach and the local check *Nech Gebs* gave mean grain yields of 31.4q/ha and14.8q/ha, respectively.In 2001, demonstrations were conducted in both the *belg* and *Meher* seasons on 12 farmers' fields. Miserach, the local variety with improved technologies, and the local variety with no improved management gave 34.8q/ha, 30.2q/ha and 22.9q/ha, respectively.In 2002, Miserach was demonstrated only on the belg season around Asagirt and Mezezo on six farmers' fields. Miserach and the local variety with their production package gave 33.5q/ha and 20.5q/ha, respectively. In 2003, only extension activities were conducted.

In 2004, Debre Birhan Agricultural Research Center released another two food barley varieties namely *Basso* and *Mezezo* that were targeted to the belg season. Presently these varieties and their production packages are being demonstrated to farmers around Mezezo, Asagirt and Ankober areas. In due course, they were found to be susceptible to head smut of barley, which necessitates the use of seed dressing fungicides.

Farmers' evaluation of improved barley variety Mezezo and Basso shows that both of them have long spike and hence very good yield potentials. Their black seed colour is also preferred for home consumption. Basso is better in productivity but more susceptible to smut than Mezezo, and both of them are late maturing (over 160 days), which might expose them to damage by hail storm. The year by location combined performance of these varieties is shown in Table 2.

Table 2:Overall yield performance of barley varieties under demonstration in North Shewa

Barley varieties	Mean yield
Meher season	
Average yield of Miserach	26.03q/ha
Average yield of local variety with improved management	20.18q/ha
Average yield of local variety with traditional crop management	15.56q/ha
Belg season	
Average yield of Miserach	35.68q/ha
Average yield of improved variety Basso	26.1q/ha
Average yield of improved variety Mezezo	24.24q/ha
Average yield of local variety with improved management	22.7q/ha

Constraints

A number of constraints hamper the transfer of food barley technologies. Woreda agricultural development experts and development agents do not fully participate in the process. This is part of the national problem in which loose linkage among actors engaged in agricultural development in the country is to blame. Lack of seeds of the improved barley varieties due to the absence of organizations multiplying seeds of potato, barley, faba bean, etc.

Future directions

Establishing FREGs as for bread wheat.

- Strengthening multiplication and dissemination of improved seeds by farmers themselves.
- Adoption study to follow up the dissemination of demonstrated technologies.

Potato technology transfer

Potato is a very important food and cash crop. It is one of the cheapest sources of energy with a great potential to supply high quality food with in a relatively short period of time .The production of potato per unit area is the highest for potato among the major food crops such as maize, wheat and rice. However, potato production in the North Shewa highlands is severely constrained by many biotic and abiotic stresses such as diseases and low yield potentials of local cultivars. To avert this situation, a good deal of research endeavor has been made and some promising potato production technologies have been developed.

Since 2000, demonstration of improved potato varieties with their production package has been going on in the highlands of North Shewa around Ankober , Mehal Meda, Debre Birhan and Molale. The sizes of the demonstrations were 100 m^2 each. The package contained: sowing date (early June), spacing (75 cm × 30 cm between rows and between plants, respectively), fertilizer rate (110/90 $N-P_2O_5$). Farmers who have participated in the demonstration were given advice as to how to make diffused light store for potato. Field days were organized to attract more farmers to the technology. In 2000 and 2001 potato *Menagesha* and *Tolcha* had been demonstrated in the highlands of North Shewa, specifically around Ankober, Molale and Mehal Meda. Menagesha variety had shown very good yield in all the locations. It gave an average yield of 239.9q/ha ranging from 272.5 q/ha at Ankober to 207.4 q/ha at Molale in 2000. During 2001 cropping season, Menagesha had shown an average yield of 139 q/ha, ranging from 148.5 q/ha at Ankober to 133.3 q/ha at Molale. Also Tolcha variety was demonstrated at Ankober during the belg season of 2001 cropping season. But due to lack of sufficient rainfall, it gave only 56.5 q/ha.

Following the release of the improved potato varietes namely *Gorebella* in 2002 and *Gera* in 2003 by DBARC, several demonstrations were conducted around Mush, Molale, Mehal Meda, Ankober, Asagirt, Mezezo and Ataye. The results are presented in Table 3. The overall mean yield of Gorebella was 305.3q/ha, while that of Gera was 279.2q/ha.

All farmers commended the two potato varieties for their good yield and they expressed their interest for them. At present sufficient awareness has been created among farmers regarding the importance of these varieties and there is a huge demand for seeds of these varieties which is above the capacity of DBARC. Hence, other governmental and non-governmental organizatiohs should be involved in seed potato production and dissemination to meet the growing demand for seeds. Constraints discussed in barley apply here

Table 3. Potato demonstration by year and location

	2002	2003	2004	2005	Mean
Gorebela (yield kg/ha)	305.27	344.00	281.9	286.1	305.25
Gera (yield kg/ha)	-	320.40	265.1	231.9	279.17
Number of sites	6	12	15	6	
Locations	Ankober, Mush, Molale	Ankober, Mehal Meda, Ataye, Molale, Mush	Ankober, Mehal Meda, Ataye, Molale, Mush	Mezezo, Asagirt, Molale	

Future directions

- Strengthening informal potato seed production
- Training provision of potato utilization
- Scaling up of potato production technologies in the highlands
- Promoting the construction of food potato warehouses

Faba bean technology transfer

Faba bean is an important component of the mixed farming system of North Shewa because of its importance in crop rotation. It is also an important component in farmers' food habit. Yet, its production is constrained by biotic and abiotic stresses such as frost, wilt/root rot and poor genetic potential of the local varieties.

After the release of two faba bean varieties *Lallo* and *Dagm* by DBARC in 2002, the research-extension division of the center began to demonstrate these varieties and their improved production packages (120kg/ha seed rate, 100kh/ha DAP and one hand weeding 35 days after emergence) by forming farmers research groups in Enewari and pre-extension demonstrations in Ankober, Mehal Meda and Molale woredas. These varieties have high yielding potential and are resistant to black root rot which is a major yield limiting factor of faba bean grown in Vertisols.

Each farmer's plot was divided into three equal plots. On one of the three plots, the improved faba bean variety Lallo or Dagm was sown with all its recommended agronomic practices, while on the second plot the local faba bean variety was sown with the same agronomic practices like that of the improved varieties. On the third plot, the local variety was planted with the farmers' cultural practice.

From the demonstration plots, an overall mean grain yield of 22.6q/ha was obtained from Lallo with its production package. The minimum and maximum yields obtained were 13.0 and 57.3q/ha, respectively. The improved faba bean variety Dagm with its production package gave an overall mean yield of 20.6q/ha while the minimum and maximum yields obtained were 12 and 40q/ha, respectively. The local variety with improved method of production gave an average yield of 15.8q/ha, while the minimum and maximum yields obtained were 9.1 and 30.3q/ha, respectively. The mean yield for the local variety with the traditional method of production was 11.1q/ha., while the minimum and maximum yields were 5.6 and 28.9q/ha, respectively. Variations in soil fertility and rainfall and infestation by aphids in areas like Enewri in some years caused big variation in yield.Farmers' opinion about the varieties include good germination potential, good and vigorous stand, relative resistance to aphids' attack and good resistance to root rot are among the good qualities of the varieties. Farmers have also indicated that the varieties were relatively resistant to aphid and frost damage as compared to the local varieties. The demerits that farmers pointed out were that the improved varieties had fewer pods relative to stalk length.

At present, faba bean variety evaluation and evaluation of pesticides for aphid control are being conducted by FREG member farmers around Deneba, Faji and Mehal Meda areas.

Table 4. Results of the pre-extension demonstrations in the highlands of North Shewa in 2002 to 2005.

Location	Number of demonstrations	Yield of faba bean (q/ha)			
		Lallo	Dagm	Local variety with improved management	Local varieties
		2002			
Ankober	3	-	38.25	30.28	28.89
Mehal Meda	3	-	21.52	15.41	13.84
Molale	3	20.92	12.62	11.62	-
Enewari	4	18.90	19.50	-	-
		2003			
Molale	3	13	12.00	11.99	9.33
Mehal meda	3	57.33	40.00	23.67	27.00
Enewari	3	25.38	23.00	24.67	19.5
		2004			
Enewari	3	23.28	-	18.12	12.39
Molale	3	15.89	-	13.33	11.11
Ankober	3	20.67	-	17.56	14.00
Mehal Meda	3	14.83	-	11.03	10.33
Enewari	3	-	18.67	14.44	8.56
Molale	3	-	13.92	9.14	5.62
Ankober	3	-	17.44	17.22	13.33
Mehal Meda	3	-	17.11	12.61	6.88
		2005			
Molale	3	29.16	20.83	10.28	-
Mehal Meda	3	25.00	23.47	19.96	-
Ankober	3	13.04	17.37	12.44	
Enewari	3	17.00	13.75	9.64	
	Over all average	22.55	20.61	15.75	11.07

Lentil technology transfer

Lentil is an important component of the mixed farming system of North Shewa. It is used for crop rotation. It is also a good cash crop. Yet, its production is constrained by biotic and abiotic stresses such as aphids, terminal moisture stress, poor genetic potential, etc. Demonstration of lentil variety *Alemaya* and *Ada'a* was conducted around Enewari areas on seven farmers fields in 2003 and 2004. The demonstration was conducted using FREG (Farmers' Research and Extension Group). The group was composed of eight farmers in 2003 and 12 farmers in 2004.

In 2003 two lentil varieties called Ada'a and Alemaya were demonstrated on the plots of four of the group members. The demonstrations were conducted in such a way that each farmer's plot was divided into three equal plots. On one of the three plots, the improved variety Alemaya or Ada'a was sown with all its recommended agronomic practices, while on the second plot the local lentil cultvar was sown with the same agronomic practices like that of the improved varieties. On the third plot, the local cultivar was planted with farmers' cultural practice.

In 2004 the improved lentil variety Alemaya gave a mean grain yield of 17.2q/ha while the local lentil variety and the improved variety Ada'a gave 15.0 and 3.6q/ha, respectively. In 2004 only Alemaya and the local lentil variety were planted on three farmers' fields for the reason that farmers didn't want to plant the improved variety Ada'a for the reasons indicated below. The mean lentil yield obtained from the improved variety was only 9.3q/ha while the local variety gave 7.6q/ha. On average improved lentil variety Alemaya gave 18.0% yield advantage over the local lentil variety. This low level of yield of both varieties is because of heavy infestation of aphids in October 2004.

In 2005, demonstrations were undertaken on three farmers' fields and average yield of 17.9q/ha was obtained from Alemaya and its production package while the local lentil variety with improved method of production gave 15.8q/ha and the local variety with farmers method of production gave 13.2q/ha.

Though farmers in the group evaluated the demonstration at each stage of growth, at the end a field day was organized to show farmers, extension personnel and other development workers of the area. After hot discussion, Alemaya variety has got a greater appreciation than that of the Ada variety due to its higher productivity, dense straw for animal feed, relative resistance to frost damage and root rot/wilt. However, they have raised their fear of its lower market price due to its seed coat color that is new for the area. As far as the Ada variety is concerned it had lower productivity, some infertility problem, shatter its seed while harvesting. It also had wilting problem before seed setting and is susceptible to powdery mildew.

Moreover, farmers indicated that though most farmers use fertilizer to lentil, it only facilitates the time of maturity. The disadvantage is that this will result in lower seed weight. Therefore, farmers chose the Alemaya variety, which is productive without fertilizer. This idea corroborates the results of studies that lentil had no response to fertilizer application. In the study, three rates (45, 90, 135 kg/ha) and two sources of P_2O_5 (TSP and DAP) were used and neither the rates or the sources showed marked differences for seed yield (Asfaw T. et.al 1994).

General future directions

- Establish Farmers' Research and Extesion Groups in all Woredas of North Shewa Zone so that technology evaluation and extension would be participatory which involves a number of farmers.
- Start and strengthen the demonstration of livestock production technologies
- Strengthen the multiplication and dissemination of improved seeds by farmers themselves
- Train farmers and extension agents on various topics of technology transfer
- Undertake diffusion study to generate a feedback about the success or failure of the technology transfer efforts.

Reference:

Asfaw Telaye, Geletu Bejiga, Saxena, Mohan C., and Solh, Mahmoud B., 1994. Cool-season food legumes of Ethiopia. Proceedings of the first National Cool-season Food legumes Review Conference, 16-20 December1993, Addis Ababa, Ethiopia. ICARDA/ Institute of Agricultural Research. ICARDA: Allepo, Syria Vii + 440 pp.

Maize fertilizer response at the major maize growing areas of northwest Ethiopia

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Abstract

Two sets of on-farm maize fertilizer trials were carried out in major maize growing areas of northwest Ethiopia. The first set of experiment was conducted in Dera area, south Gonder, northwest Ethiopia. It was conducted for three consecutive years, 1999-2001. The second set of experiment was conducted for three years (200-2003) in Yilmana Denssa, Jabi Tenan, Basoliben, Ankesha, Mecha, Achefer, Huleteju Enebssie and Burie areas. The objective of the experiments was to determine optimum fertilizer rate for maize production in northwestern Amhara region. In the case of the first set of experiment a factorial combination of four nitrogen levels (0, 64, 128,192 N $kgha^{-1}$) and four phosphorous levels (0, 46, 92, 138 P_2O_5 $kgha^{-1}$) were tested. However, in the second set of experiment seven fertilizer rates (0-0, 60-46, 120-46, 120-92, 180-92, 180-138, and 100-75 N-P_2O_5 kg ha^{-1}) were tested. The results of the first set of experiment indicated that 128-92 N-P_2O_5 $kgha^{-1}$ fertilizer rate was an optimum profitable rate for maize production in Dera area. The statistical and economic analysis for the second set of experiment showed that fertilizer at a rate of 100-75 N-P_2O_5 kg ha^{-1} was found to be appropriate and recommendable for Yilmana Denssa and Basoliben areas. Similarly the 180-138 N-P_2O_5 kg ha^{-1} rate was found to be the most appropriate for maize production in Achefer, Huleteju Enebssie and Mecha areas. On the other hand for Jabi-Tenan and Ankesha areas 60-46 N-P_2O_5 kg ha^{-1} rate was observed to be recommendable. The 120-92 N-P_2O_5 kg ha^{-1} was the fertilizer rate identified to be appropriate for maize production in Burie area.

Introduction

Maize is among the principal cereal crops grown in northwestern Ethiopia. It ranks first in productivity and third in area coverage from the major cereal crops produced in the region (UNDP, 1996 and CSA, 1995). The production of maize in the area is in increasing tendency (CSA 1995; CSA, 1996; CSA, 1997; CSA 2000; CSA 2003 and Yigzaw 2004). Farmers used to cultivate maize around their homesteads, however; they are now cultivating maize as a field crop away from their residences. The farmers are very much interested in maize production since the crop has many uses. It has higher yield and is important for food as local bread, and green cobs alleviate the food shortage in August through September (Alelign *et al*, 1992).

Even though maize productivity ranks first in the region, the average yield of this ever increasingly demanded crop has remained at 15 q/ha which is lower than the national average, 17 q/ha, and is by far lower than the world average, 37 q/ha, (UNDP, 1996 and Benti, 1993). Various yield limiting factors attribute for the lower yield of maize in the area. Poor soil fertility is one of the principal factors which hamper maize production in maize growing areas of Ethiopia (Kebede *et al*, 1993 and Alelign *et al*, 1992). Soils in all major maize growing regions of the country are depleted of nutrients, thus demanding high soil amendments with nitrogen and phosphorous (Kebede *et al*, 1993). Research findings in Bako maize research center, indicated that a maximum yield of maize was obtained with the application of 125 kg ha^{-1} N and 100 kg ha^{-1} P_2O_5 at the tested locations (IAR, 1982). Similarly another experiment done at Alemaya University of Agriculture indicated that increasing the level of N up to 250 kg ha^{-1} and of P_2O_5 to 200 kg ha^{-1} has significantly increased grain yield of maize (IAR, 1982).

Since appropriate fertilizer rate is not made for maize production in northwestern Ethiopia, farmers use the national extension campaign recommendation, 100/100 kg ha^{-1} DAP/Urea, which is a blanket recommendation that is not specific to the area. Therefore, maize fertilizer experiments were conducted with the objective to determine the optimum fertilizer rate for maize productions in Dera, Huleteju-Enebssie, Basoliben, Mecha, Yilmana Denssa, Achefer, Burie, Jabi Tenan and Ankesha areas, northwest Ethiopia.

Materials and methods

Two sets of maize fertilizer experiments were conducted in the major maize growing areas of northwestern Ethiopia. The first set of experiment was carried out on farmers' field in Dera area, south Gondar. A total of ten sites in 1999, 2000 and 2001 main cropping seasons were sown for the experiment. The experiment consists of 16 factorial combinations of four nitrogen rates (0, 64, 128 and 192 N kg ha^{-1}) and four phosphorus rates (0, 46, 92 and 138 P_2O_5 kg ha^{-1}). The second set of experiment was carried out for three years (2000-2003) on farmers' field in Basoliben, Huleteju Enebssie, Mecha, Yilmana Denssa, Achefer, Burie, Jabi Tenan and Ankesha areas, in northwest Ethiopia. It was conducted by joint effort of Adet research center and the regional Bureau of Agriculture with participation of farmers. Seven fertilizer rates (0-0, 60-46, 120-46, 120-92, 180-92, 180-138, and 100-75 N-P_2O_5 kg ha^{-1}) were tested in the experiment. The fertilizer rates were systematically selected based on previous experiments of Adet and other agricultural research centers. All phosphorus and half of nitrogen levels were applied at planting time and the remaining N rates at knee height of the crop. Urea and DAP/TSP were used as sources of N and P_2O_5, respectively. The maize varieties used in the experiments were selected according to their adaptability in the specific areas. BH-540 maize hybrid variety was used for Dera, Basoliben, Mecha, Yilmana Denssa, Achefer and Ankesha areas. Similarly BH-660 was used at Burie, Jabi Tenan and Huleteju Enebssie Areas. The recommended 75 cm x 30 cm plant spacing was used for both varieties at all the locations. The design RCB with three replications was used for both sets of experiments. Five rows of maize each 5.1m long were planted per plot. The three central rows were considered as net plots and all agronomic data were collected from them. The gross and net plot sizes were therefore 3.75m x 5.1m (19.125 m^2) and 2.25m x 5.1m (11.47m^2), respectively. Soil sample prior to planting was collected at each location and analyzed.In the first set of experiment data were collected on grain yield, plant height and thousand seed weight while only grain yield data was collected for the vastly executed experiment set two. The agronomic data were subjected to analysis of variance (ANOVA) using MSTATC statistical software. In the case of the first experiment the agronomic efficiency for grain yield was also calculated in such away that the amount of grain yield produced per one kg of phosphorus/ nitrogen applied. Economic analysis had also been performed following the CIMMYT partial budget methodology (CIMMYT, 1988). The analysis was done in the first case with the normal prices of out puts and costs of inputs (Table 1). Sensitivity economic analysis was also performed by the assumption that the cost of fertilizer inputs increase by twenty five percent while the grain price remained constant (Table 1).

Table 1. Cost of fertilizers and price of maize grain for the economic analysis

	For the normal economic analysis:	For the sensitivity economic analysis:
Price of maize	Birr 1.33/ kg	Birr 1.33/ kg
Cost of DAP	Birr 3.74/ kg	Birr Birr 4.68/ kg
Cost of Urea	Birr 3.38/ kg	Birr 4.23/ kg

Maize grain yield was adjusted by 10% both for the normal and sensitivity economic analysis. The adjustment was made to narrow the yield gap between research plots and farmers plots (CIMMYT, 1988).

Result and discussion

Experiment-I

Results of combined analysis of variance across the ten sites for grain yield, plant height and thousand seeds weight revealed that nitrogen and phosphorous significantly affected the three parameters (Tables 2 and 3). Among the nitrogen levels, the highest mean grain yield (5153.8 kg/ ha) was obtained at the rate of 128 N kg/ ha. Though grain yield showed positive correlation both with phosphorous and nitrogen application, the relation was more pronounced to phosphorous application (Figure 1 and Figure 2). The comparison within the phosphorous levels indicated that the highest yield (5242.8 kg/ ha) was obtained at the 138 P_2O_5 kg/ ha rate. The agronomic efficiency (AE) of applied N (i.e. kg grain per kg N) was 33.6 for the first interval (i.e.; from 0 to 64 kg N/ha), 5.8 for the second interval (i.e. from 64 to 128 N kg/ ha) and -3.1 for the third interval (i.e. from 128 to 192 N kg/ ha). Similarly the AE of applied P also declined from 38.1 kg grain per kg P_2O_5 for the first interval, to 12.8 for the second and 3.6 for the third. The interaction of N by P did also significantly affected grain yield, plant height and thousand seeds weight (Tables 2 and 3). The highest mean grain yield, 6202.5 kg ha^{-1} was obtained with the application of 128-92 N-P_2O_5kg/ ha, representing an increase of 4546.8 kg ha^{-1} that is 274.6% over the control (unfertilized) treatment.

According to the statistical analysis the optimum rates of nitrogen and phosphorous fertilizers were 128-92, 128-138 and 192-138 N-P_2O_5 kg/ ha rates all resulting in grain yields that are statistically equivalent. However, the further economic analysis indicated that it was the 128-92 N-P_2O_5 kg/ ha level that was the most optimum profitable rate followed by the 64-46 N-P_2O_5 kg/ ha level (Table 3). The sensitivity economic analysis has also confirmed that the two rates are the first and second optimum levels for maize production in Dera area even if undesired increase in fertilizer cost by 25% occurred while the grain price remained constant (Table 4).

Table 2. Over sites combined analysis for maize grain yield, plant height and thousand seeds weight at Dera

Source of variation	Grain yield (kg ha^{-1})	Plant height (cm)	1000 seed wt. (g)
Site(S)	**	**	**
N	**	**	**
NxS	**	**	**
P_2O_5	**	**	**
P_2O_5 x S	**	**	**
N x P_2O_5	**	**	**
Mean value of 0/0 N/P_2O_5	1655.7	148.6	316.5
Highest mean value	6202.5	205.5	406.9
N/P_2O_5 comb. for highest value	128/92	128/138	128/92
CV%	28.81	12.28	10.12

Table 3. Effect of N and P fertilizer levels on the grain yield (kg ha^{-1}) of maize at Dera

Nitrogen (N) kg ha^{-1}	Phosphorous (P_2O_5) kg ha^{-1} 0	46	92	138	Mean
0	1655.7	2603.0	3013.7	3320.7	2648.3
64	3278.2	4992.9	5214.0	5665.6	4782.7
128	3181.7	5248.3	6202.5	5982.9	5153.8
192	2834.2	5108.8	5873.1	6001.9	4954.5
Mean	2737.5	4488.2	5075.8	5242.8	
C.V%			28.8		
LSD 5%	N	P_2O_5	N x P_2O_5		
	318.3	318.3	636.6		

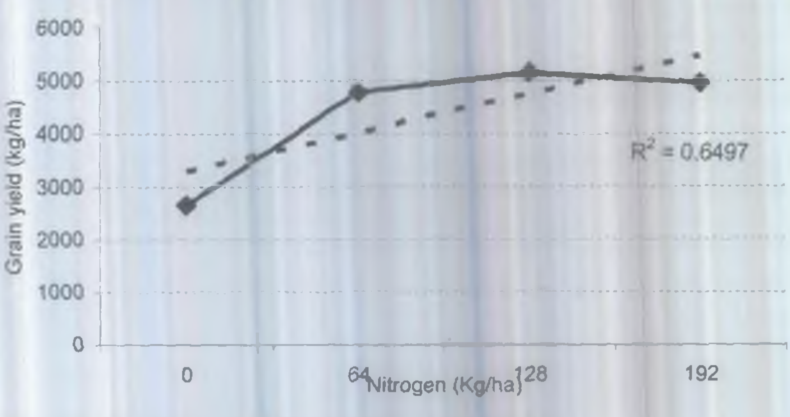

Fig. 1. Response of maize grain yield to nitrogen rates at Dera

Experiment-II

The statistical analysis indicated that maize grain yield significantly increased in response to fertilizer application (Table 5). The highest mean grain yields 10157 kg ha^{-1} at Mecha, 10975 kg ha^{-1} at Achefer, 7047 kg ha^{-1} at Yilmana-Denssa, 8806 at Huleteju Enebssie, 7089 kg ha^{-1} at Basoliben, 10322 kg ha^{-1} at Burie, 8025 kg ha^{-1} at Jabi Tenan and 7028 kg ha^{-1} at Ankesha were obtained with the application of the highest fertilizer rate (180-138 kg N-

P_2O_5/ha). The fertilizer rate exhibit a yield advantage of 6786 kg/ha, 7164 kg, 4150 kg/ha, 6181.8 kg/ha, 4319 kg/ha, 5461 kg/ha, 3702 kg/ha and 4844.8 kg/ha over the control treatment (0-0 kg N-P_2O_5/ha) in the respective localities (Table 5). The comparison among the test locations indicates that Burie area exhibited the highest mean grain yield for unfertilized treatment, 0-0 N-P_2O_5 kg ha^{-1}. This might be due to the inherent soil fertility status of the area. The soil analysis result (Table 6) supports such a conclusion since Burie had the highest total nitrogen (0.320 %) and a higher organic carbon content (4.001 %).

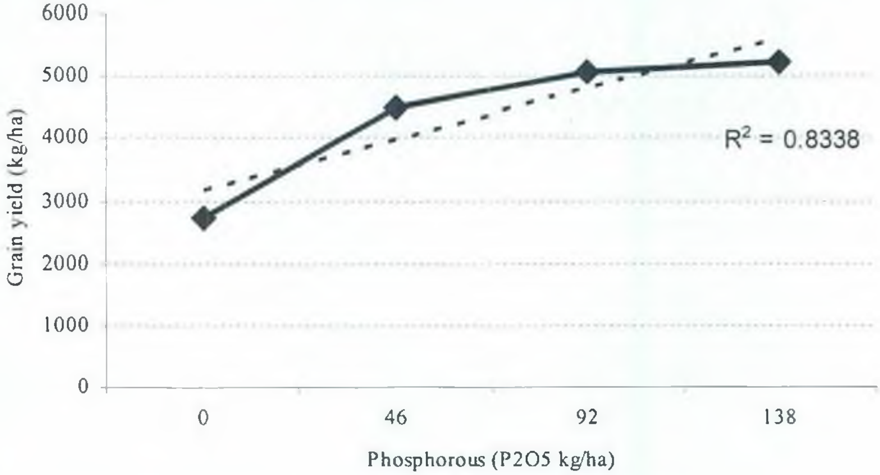

Fig. 2. Response of maize grain yield to phosphorous rates at Dera

Table 4. Economic and sensitivity economic analysis for maize grain yield at Dera

Normal Economic analysis					Sensitivity Economic analysis				
N-P_2O_5 (kg ha^{-1})	TVC (Birr/ha)	NB (Birr/ha)	MRR (%)	Rank	N-P_2O_5 (kg ha^{-1})	TVC (Birr/ha)	NB (Birr/ha)	MRR (%)	Rank
0-0	0.0	1981.9			0-0	0.0	1981.9		
0-46	374.0	2741.8	203.2		0-46	468.0	2647.8	142.3	
64-0	469.8	3454.2	743.5		64-0	588.0	3336.0	573.7	
0-92	748.0	2859.4	D		64-46	891.0	5085.5	577.3	2nd
64-46	712.0	5264.5	747.5	2nd	0-92	936.0	2671.4	D	
64-92	954.2	5287.0	9.3		128-0	1175.9	2632.6	D	
128-0	939.6	2868.9	D		64-92	1194.0	5047.1	D	
0-138	1122.0	2852.9	D		0-138	1404.0	2570.9	D	
128-46	1181.8	5100.4	D		128-46	1479.0	4803.2	D	
64-138	1196.4	5585.4	66.2		64-138	1497.1	5284.7	32.9	
192-0	1409.5	1983.1	D		192-0	1763.9	1628.6	D	
128-92	1424.0	6000.4	103.4	1st	128-92	1782.0	5642.4	92.5	1st
192-46	1651.6	4463.6	D		192-46	2066.9	4048.3	D	
128-138	1666.2	5495.4	D		128-138	2085.0	5076.5	D	
192-92	1893.8	5136.3	D		192-92	2370.0	4660.1	D	
192-138	2136.0	5048.3	D		192-138	2673.0	4511.3	D	

TVC= Total Variable cost in Birr/ha, NB= Net benefit in Birr/ha, MRR= Marginal Rate of Return.

The total nitrogen and organic carbon analysis results showed that Burie area has a medium level of nitrogen and organic carbon content (London, 1991), that resulted in higher mean grain yield than the other tested areas.

According to the economic analysis (Table 7), the profitable fertilizer level with acceptable Marginal Rate of Return (MRR) for maize production at Yilmana-Denssa and Basoliben areas was 100-75 $N\text{-}P_2O_5$ kg ha^{-1}. The sensitivity economic analysis (Table 8) for the stated locations indicated that the 100-75 $N\text{-}P_2O_5$ kg ha^{-1} fertilizer rate remained profitable even in worst economic situations. It is therefore appropriate to recommend 100-75 $N\text{-}P_2O_5$ kg ha^{-1} fertilizer rate for maize production at Yilmana-Denssa and Basoliben areas. On the other hand 60-46 $N\text{-}P_2O_5$ kg ha^{-1} was a second alternative to be recommended for both areas in cases where farmers face money shortage at planting time

Table 5. Effect of $N\text{-}P_2O_5$ fertilizer rates on maize grain yield (kg ha^{-1}) over different varieties at different locations

$N\text{-}P_2O_5$ Kg ha^{-1}	Varieties							
	BH-540					BH-660		
	Locations							
	Basoliben	Mecha	Yilmana Denssa	Achefer	Ankesha	Burie	Jabi T	Huleteju Enebsie
0-0	2770.3	3371.1	2896.8	3811.0	2183.2	4861.0	4323.2	2624.2
60-46	5665.8	7574.9	5234.4	7272.0	5547.1	7962.2	7188.0	5528.2
120-46	5813.0	8447.3	5595.7	8012.0	6084.6	8568.8	7405.8	6545.3
120-92	5847.9	8363.2	6026.2	9159.7	6091.4	9438.8	7621.0	7162.9
180-92	6071.9	9242.5	6051.1	9657.0	6906.0	9624.1	7888.1	7008.1
180-138	7089.3	10156.8	7047.5	10975.0	7028.0	10322.1	8024.8	8806.0
100-75	6567.4	8351.6	6021.2	8469.0	6084.5	8889.3	7484.0	6182.8
Mean	5689.4	7929.6	5553.3	8193.7	5703.5	8523.8	7075.2	6265.4
C.V (%)	16.99	15.05	17.26	14.56	17.4	10.31	13.77	18.19
$LSD_{0.05}$	554.0	496.4	637.0	533.7	412.8	449.4	502.3	935.4

Table 6. Different locations laboratory analysis of soil sample before planting

Location	Total N%	O.C%	O.M%	Available P (ppm)	P^H
Mecha	0.219	3.586	5.838	1.670	5.56
Burie	0.320	4.001	6.902	2.284	5.36
Jabi-Tenan	0.022	3.575	6.164	8.919	6.59
Basoliben	0.038	3.298	5.685	5.730	5.37
Achefer	0.029	4.215	7.269	0.234	5.39

In the case of Achefer and Huleteju-Enebsie areas 180-138 $N\text{-}P_2O_5$ kg ha^{-1} fertilizer rate was found to be the best recommended rate based on the economic and sensitivity analysis. In circumstances where there are farmers who face financial limitations during planting seasons for the purchase of fertilizers, the 120-92 $N\text{-}P_2O_5$ kg ha^{-1} could use as second alternative recommendation for both areas. Concerning Jabi-Tenan and Ankesha areas it was only the 60-46 $N\text{-}P_2O_5$ kg ha^{-1} fertilizer rate that was found to be appropriate to recommended. Regarding Mecha area, based on the normal and sensitivity economic analysis 180-138 $N\text{-}P_2O_5$ kg ha^{-1} is best recommended for maize production. In cases where farmers face financial shortage during the planting season 120-46 $N\text{-}P_2O_5$ kg ha^{-1} was found to be a second alternative recommendation for Mecha area. The 120-92 N-P_2O_5 kg ha^{-1} and 100-75 N-P_2O_5 kg ha^{-1} were found to be the first and second alternative recommendations, respectively, for maize production in Burie area.

Conclusion and recommendation

Different location specific recommendations had been made based on results of maize fertilizer experiments in the region. A fertilizer rate of 128-92 N-P_2O_5 kg ha^{-1} was best recommended to produce maize in Dera area while a rate of 100-75 N-P_2O_5 kg ha^{-1} is recommended for maize production at Yilmana Denssa and Basoliben areas. On the other hand a rate of 180-138 N-P_2O_5 kg ha^{-1} was found to be the most appropriate and recommended for maize production in Achefer, Huleteju Enebssie and Mecha areas. Regarding and Burie area, 120-92 N-P_2O_5 kg ha^{-1} was the best recommended fertilizer rate for maize production. Concerning Jabi-Tenan and Ankesha areas it was 60-46 N-P_2O_5 kg ha^{-1} fertilizer rate that was found to be appropriate to recommended for maize production in the areas.

Acknowledgment

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Table 7. Results of economic analysis of maize fertilizer trial at different Areas

N-P_2O_5 Kg ha^{-1}	TVC Birr/ha	Yilmana Denssa (NB) Birr/ha	Yilmana Denssa MRR%.	Huleteju E NB Birr/ha	Huleteju E MRR%	Jabi Tenan NB Birr/ha	Jabi Tenan MRR %	Basoliben NB Birr/ha	Basoliben MRR%	Mecha NB Birr/ha	Mecha MRR%	Achefer NB Birr/ha	Achefer MRR%	Burie NB Birr/ha	Burie MRR %	Ankesha NB Birr/ha	Ankesha MRR%
0-0	0.0	3467.4		3141.2		5174.9		3316.0		4035 2		4561 7		5818.6		2613.3	
60-46	682.6	5583.0	309.9	5934 7	409.2	7921 4	402.4	6099.3	407 7	8384 5	637.2	8022.0	506.9	8848.2	443.8	5957.3	489 9
120-46	1123.5	5574.6		6711.2	176.1	7741.2		5834.7		8988 0	136.9	8466 8	100.9	9133.1		6159 7	45 9
100-75	1365.2	6078 4	111.0	6271 8		7829 8		6732.2	141 8	8867 9	-	9008 4	9864.2	9511 6	148.6	6154.2	
120-92	1806 1	5848 2		7208 8	205.8	7757 1		5634 7		8645 6	-	9598 9	250 0	9933 0	178 4	5926 2	
180-92	2047 8	5437.1		6582.6		7636.0		5462.0		9257.2	-	9753.4		9713.9		6460 4	44.0
180-138	1129 0	6388 0	33.7	8493.0	188 1	7557 9		6438 1		10109 9	121.4	11089 3	218 4	10307 8	54.9	6364 7	

Table 8. Results of sensitivity economic analysis of maize fertilizer trial at different Areas

N-P_2O_5 Kg ha^{-1}	TVC Birr/ha	Yilmana Denssa NB Birr/ha	Yilmana Denssa MRR%	Huleteju E NB Birr/ha	Huleteju E MRR%	Jabi Tenan NB Birr/ha	Jabi Tenan MRR%	Basoliben NB Birr/ha	Basoliben MRR%	Mecha NB Birr/ha	Mecha MRR%	Achefer NB Birr/ha	Achefer MRR%	Burie NB Birr/ha	Burie MRR%	Ankesha NB Birr/ha	Ankesha MRR%
0-0	0.0	3467 4		3141 2		5174 9		3316 0		4035 2	-	4561 7		5818 6		2613 3	
60-46	854 2	5411 3	227 6	5763 1	306 9	7749 7	301 4	5927 7	305 7	8212 9	489 1	7850 4	385 0	8676 6	334 6	5785 7	371 4
120-46	1406 0	5292 1		6428 8	120 7	7458 8		5552 2		8705.5	-	8184 3		8850 6		5877 3	16 6
100-75	1708 4	5505 0	68 6	5988 0		7546 0		6448 4	93 2	8584 0	-	8724 5	156 5	9227 8	98.7	5827 3	
120-92	2260 2	4983 1		6865 6	144 4	7413 9		5291 4		8302.4	-	9255 7	179 7	9589 8	122 4	5583 0	
180-92	2562 6	5873.2		6128 5		7181 9		5007 9		8803.1	-	9299 3		9259 9		6006 3	15 1
180-138	1412 8	5794 6	6 8	7978 2	130 3	7043 1		5923.3		9595 0	80.9	10574 5	154 4	9793 0	23.8	5849 9	

D = Dominated treatment, the one with increasing TVC while NB is decreasing . TVC = Total Variable cost, NB = Net benefit . MRR = Marginal Rate of Return

REFERENCE

Alelign Kefyalew, and Regassa Ensermu. 1992. Bahir-Dar Mixed Farming Zone: Diagnostic Survey Report. Research Report No 18. Institute of Agricultural Research, Addis Ababa, Ethiopia.

Benti Tolessa. 1993. The need and objectives of the First National Maize Workshop. In: Benti Tolessa and Joel K. Ransom (eds.). 1993. Proceedings of the first National Maize Workshop of Ethiopia. 5-7 May 1992, Addis Addis Ababa, Ethiopia. IAR/CIMMYT, Addis Ababa.

CIMMYT. 1988. From agronomic data to farmer recomendations: An economic training manual. Revised Edition. Mexico, D.F.

CSA. 1995. Agricultural sample survey. Statistical Bulletin 132. Central Statistics Authority, Addis Ababa, Ethiopia.

CSA. 1996. Agricultural sample survey. Statistical Bulletin 152. Central Statistics Authority, Addis Ababa, Ethiopia.

CSA. 1997. Agricultural sample survey. Statistical Bulletin 163. Central Statistics Authority, Addis Ababa, Ethiopia.

CSA. 2000. Agricultural sample survey. Statistical Bulletin 227. Central Statistics Authority, Addis Ababa, Ethiopia.

CSA. 2003. Ethiopian Agricultural Sample Enumeration, 2001/02 (1994 E.C). Central Statistics Authority, Addis Ababa, Ethiopia.

IAR, 1982. Progress report. Institute of Agricultural research. Addis Ababa, Ethiopia.

Kebede Mulatu, Gezahagne Bogale, Benti Tolessa, Mosisa Worku, Yigzaw Desalegn and Assefa Afeta.1993. Maize Production Trends and research in Ethiopia. In: Benti Tolessa and Joel K. Ransom (eds.). 1993. Proceedings of the first National Maize Workshop of Ethiopia. 5-7 May 1992, Addis Addis Ababa, Ethiopia. IAR/CIMMYT, Addis Ababa.

London, J.R. 1991. Booker tropical manuals. A hand book fo soil survey and agricultural land evaluation in the tropics and sub tropics. UNDP. 1996. Sustainable Agricultural and Environmental Rehabilitation Program (SAERP). House Hold Level Socio-Economic Survey of the Amhara Region. Vol. 1. Produced by the Cooperative Endeavors of the Amhara Regional Council. Bahir Dar, Ethiopia

UNDP. 1996. Sustainable Agricultural and Environmental Rehabilitation Program (SAERP). House Hold Level Socio-Economic Survey of the Amhara Region. Vol. 1. Produced by the Cooperative Endeavors of the Amhara Regional Council. Bahir Dar, Ethiopia.

Yigzaw Dessalegn. 2004. Performance of F2 Generation of commercial Hybrid Maize Varieties at Adet, Northwest Ethiopia. In: Crop Science Society of Ethiopia. 2004. Sebil. Vol. 10. Proceedings of the Tenth Conference, 19-21 June 2001, Addis Abeba, Ethiopia.

The effect of time of split application of nitrogen fertilizer on the grain yield of maize

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Abstract

An experiment on time of nitrogen fertilizer application on maize was conducted for two consecutive cropping seasons in the years 2003 and 2004 at Adet Research station. Split plot design in RCB with three replications was used. Variety was the main plot and time of fertilizer application as sub-plot. Intermediate maturing and late maturing varieties, BH-540 and BH-660, respectively were used. Ten different times of nitrogen fertilizer application were studied. The application times were 1/2 at planting + 1/2 at knee height (control), all at planting, 1/2 at planting + 1/2 at near tasseling, 1/3 at planting + 1/3 at knee height + 1/3 near tasseling, 1/3 at planting + 2/3 at knee height, 1/3 at planting + 2/3 near tasseling, 1/4 at planting + 2/4 at knee height + 1/4 near tasseling, 1/4 at planting + 1/4 at knee height + 2/4 near tasseling, 1/4 at planting + 3/4 at knee height, and 1/4 at planting +3/4 near tasseling. The same rate of nitrogen, 128 N kg/ha, was used in all cases. Nitrogen was applied at hills around each plant. Phosphorous fertilizer at a rate of 92 kg/ha P_2O_5 was applied to all plots at planting. Results of statistical and economical analysis indicated that for the intermediate maturing BH-540 variety nitrogen application of 1/3 at planting and 2/3 at knee height was found to be the best method. The application method gave a yield advantage of 1005.4 kg/ha over the commonly practiced 1/2 at planting and 1/2 at knee height application system. Concerning the late maturing variety BH-660, nitrogen when applied 1/4 at planting and 3/4 at knee height gave the highest benefit and hence recommended with a yield advantage of 296.2 kg/ha over 1/2 at planting and 1/2 at knee height application. The present nitrogen split application recommendation could be used for maize growing areas which have similar ago-climate with that of Adet.

Introduction

Maize ranks first in productivity and third in area coverage from the major cereal crops produced in northwestern Ethiopia (Alelign *et al*, 1992; UNDP, 1996; CSA, 2000 and CSA, 2003). Even though maize productivity ranks first in the region, its average yield has remained at 15 q/ha which is lower than the national average, 17 q/ha, and is by far lower than the world average, 37 q/ha, (UNDP, 1996 and Benti, 1993). Various yield limiting factors attribute for the lower yield of maize in the area. Poor soil fertility is one of the principal factors which hamper maize production in maize growing areas of Ethiopia (Kebede *et al*, 1993 and Alelign *et al*, 1992). In high- and medium-altitude maize growing areas where rainfall is high, most of the nitrogen is lost through leaching and denitrification making the nutrient unavailable during the critical stages of crop growth (Muangai, *et al.* 1998). Split application of nitrogen has been reported to be one of the methods to improve nitrogen nutrient use by the crop while reducing the nutrient loss through leaching and volatilization (Mungai *et al.* 1998 and Tolessa *et al.* 1994). Therefore, split application of nitrogen is crucial for efficient utilization and optimum yields of maize. Most soils in Ethiopia are responsive to split application of nitrogen (Tolessa *et al.* 1994).

Presently, a blanket nitrogen split application recommendation of 1/2 of the total at planting while the remaining 1/2 at knee height is being widely used in northwestern Ethiopia. However, some farmers in the region have observed good responses of the crop by reducing the amount of nitrogen at planting and applying more at latter growth stages of the crop (personal communication). This study is therefore conducted with an objective of determining the optimum nitrogen fertilizer split application time for the intermediate and late maturing maize varieties BH-540 and BH-660, respectively.

Materials and methods

The experiment was conducted for two consecutive cropping seasons in the years 2003 and 2004 at Adet Research station. The altitude of the site is 2240 m.a.s.l receiving a mean total annual rainfall of 1156.9 mm of which about 70 % are received during the main cropping season in the months from June to September (Figure 1). It has average daily maximum and minimum temperatures of 26.1^{0}C and 9.7^{0}C, respectively (Figure 2). The station has a nitosol soil with an average soil P^H of 5.17 (Table 1). The design used was split plot with three replications. Variety was the main plot and time of fertilizer application as sub-plot. A medium maturing variety, BH-540, and a late maturing variety, BH-660, were used. Ten different times of nitrogen fertilizer application were studied. The application times were 1/2 at planting + 1/2 at knee height (control), all at planting, 1/2 at planting + 1/2 at near tasseling, 1/3 at planting + 1/3 at knee height + 1/3 near tasseling, 1/3 at planting + 2/3 at knee height, 1/3 at planting + 2/3 near tasseling, 1/4 at planting + 2/4 at knee height + 1/4 near tasseling, 1/4 at planting + 1/4 at knee height + 2/4 near tasseling, 1/4 at planting + 3/4 at knee height and 1/4 at planting + 3/4 near tasseling. The same rate of nitrogen, 128 N kg/ha, was used in all cases. Nitrogen was applied at hills around each plant. Phosphorous fertilizer at a rate of 92 kg/ha P_2O_5 was applied to all plots at planting. A gross and net plot sizes of 3.75 m X 4.8 m and 2.25 m X 4.8 m, respectively were used for each sub plots. Data was collected for labour (man days) needed for fertilizer application, grain yield, plant height, thousand seeds weight and soil sample at planting. Statistical analysis was performed for grain yield, plant height and thousand seeds weight. Economic analysis was also performed following the CIMMYT partial budget methodology (CIMMYT, 1988). A two years harvesting months (December-February) average price of Birr 0.72/kg maize grain and the prevailing labour cost in the area Birr 5/man day was taken for the economic analysis.

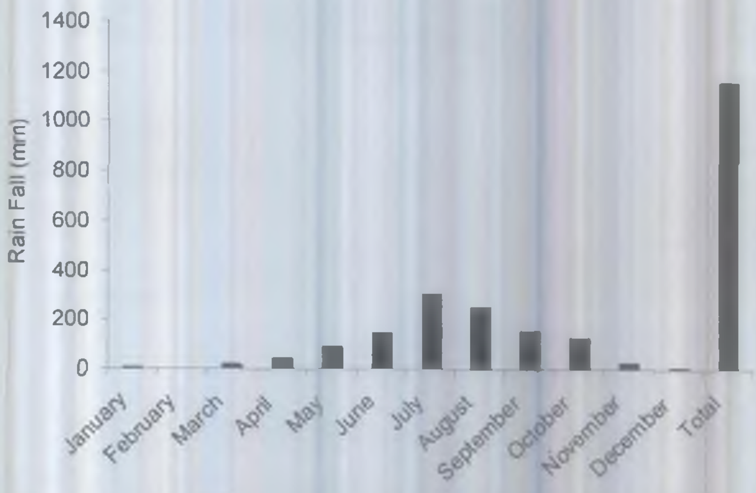

Fig. 1 Average Total Rain fall of Adet Research Station (1994-2004)

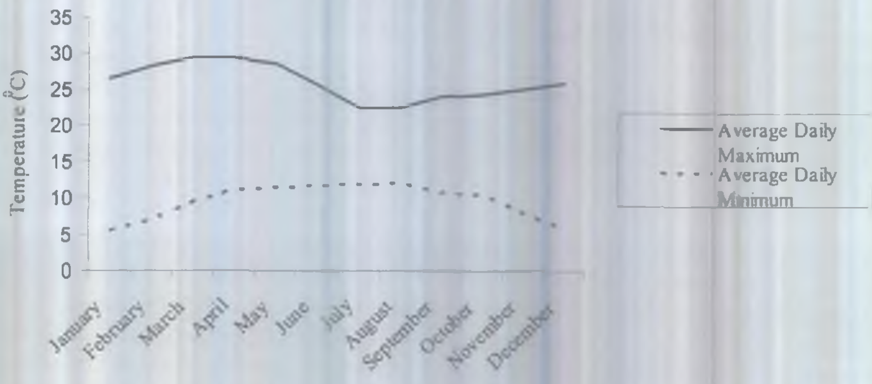

Fig. 2. Average Daily maximum and minimum temperatures of Adet Research Station (1994-2004)

Result and discussion

The experimental site had available P (Olsen) of 1.688 ppm, total nitrogen 0.0949%, soil organic matter of 1.898 % and P^{H} of 5.17 (Table 1). Application time caused significant variation in response of maize grain yield (Tables 2 and 3). In the first year of the experiment the highest grain yield for the variety BH-540 was obtained when the nitrogen was applied 1/4 at planting and 3/4 at knee height (Table 2). In the second year the highest grain yield was observed when nitrogen was applied 1/3 at planting and 2/3 at knee height. The combined over years analysis indicated that highest grain yield (7908.0 kg/ha) of BH-540 variety was obtained when nitrogen was applied in two splits 1/3 of it at planting and the remaining 2/3 at knee height (Table 2). The particular application exhibited a yield advantage of 1005.4 kg/ha over the control (1/2 at planting+1/2 at knee height).

Table 1. Some soil chemical charasteristics of sample taken before planting

Available P (Olsen)	1.688
Total N %	0.0949
Organic Matter %	1.898
p^H	5.17

Table 2. The effect of time of nitrogen fertilizer application on the grain yield of maize variety BH-540

Time of nitrogen fertilizer application	1st year		2nd year		Combined over two years	
	Yield Kg/ha	Yield advantage (kg/ha) over control	Yield Kg/ha	Yield advantage (kg/ha) over control	Yield Kg/ha	Yield advantage (kg/ha) over control
1/2 at planting + 1/2 at knee height	6018.5	0	7786.7	0	6902.6	0
All at planting	5154.3	-864.2	7771.3	-15.4	6462.8	-439.8
1/2 at planting + 1/2 at near tasseling	6358.0	339.5	5999.3	-1787.4	6178.7	-723.9
1/3 at planting + 1/3 at knee height + 1/3 at near tasseling	6481.5	463.0	8241.0	454.3	7361.2	458.6
1/3 at planting + 2/3 at knee height	6604.9	586.4	9211.0	1424.3	7908.0	1005.4
1/3 at planting + 2/3 at near tasseling	6512.3	493.8	8141.7	355.0	7327.0	424.4
1/4 at planting + 2/4 at knee height + 1/4 at near tasseling	6543.2	524.7	7967.0	180.3	7255.1	352.5
1/4 at planting + 1/4 at knee height+ 2/4 at near tasseling	6142.0	123.5	8381.7	595.0	7261.8	359.2
1/4 at planting + 3/4 at knee height	6666.7	648.2	7136.0	-650.7	6901.3	-1.3
1/4 at planting + 3/4 at near tasseling	6296.3	277.8	6495.0	-1291.7	6395.6	-507
CV%	11.96		12.09		12.10	
LSD $_{5\%}$	1288.0		1599.0		990.9	

In the case of the BH-660 variety, the highest grain yield in the first year was obtained when nitrogen was applied in three splits, 1/4 at planting, 1/4 at knee height and 2/4 at near tasseling, (Table 3). For the same variety, the second year result indicated that it was when nitrogen applied in two splits, 1/4 at planting and 3/4 at knee height, that the highest grain yield was gained. The two years combined analysis indicated that BH-660 gave the highest yield, 8182.0, when nitrogen was applied 1/4 at planting and 3/4 at knee height (Table 3).

The application exhibited a yield advantage of 296.0 kg/ha over the 1/2 at planting+1/2 at knee height application (control). The grain yield analysis indicated that both BH-540 and BH-660 need more of their nitrogen to be applied at knee height than at planting. It also indicate that the late maturing variety, BH-660, need most of its nitrogen at latter growth stages. At the time of planting, the medium maturing BH-540 need relatively more nitrogen (1/3) than the late maturing BH-660 which need 1/4 of the total nitrogen. Here it can be concluded that for medium maturing varieties like BH-540 nitrogen should be applied 1/3 of it at planting and the remaining 2/3 at knee height. Concerning late maturing varieties like BH-660, 1/4 of the nitrogen should be applied at planting while the rest 3/4 at knee height.

The results of this experiment differ from other recommendations given in the country. Tolessa et al. 2002 recommended that the best use of nitrogen would be obtained when 50% of the total requirement is applied at sowing and the remaining 50% is given as top dressing at knee height. Tolessa further elaborated that the other option is application of the total requirement in three equal splits at sowing, knee height and at flag leaf emergence. It is therefore justifiable to conclude that there should be location specific nitrogen fertilizer application timing.

Table 3. The effect of time of nitrogen fertilizer application on the grain yield of maize variety BH-660

Time of nitrogen fertilizer application	1st year		2nd year		Combined over two years	
	Yield Kg/ha	Yield advantage (kg/ha) over control	Yield Kg/ha	Yield advantage (kg/ha) over control	Yield Kg/ha	Yield advantage (kg/ha) over control
1/2 at planting + 1/2 at knee height	6851.9	0	8919.7	0	7885.8	0
All at planting	5185.2	-1666.7	9525.0	605.3	7355.1	-530.7
1/2 at planting + 1/2 at near tasseling	6728.4	-123.5	8681.0	-238.7	7704.7	-181.1
1/3 at planting + 1/3 at knee height + 1/3 at near tasseling	6759.3	-92.6	9430.3	510.6	8094.8	209.0
1/3 at planting + 2/3 at knee height	6635.8	- 216.1	9555.3	635.6	8095.6	209.8
1/3 at planting + 2/3 at near tasseling	6635.9	- 216.0	8982.0	62.3	7808.9	-76.9
1/4 at planting + 2/4 at knee height + 1/4 at near tasseling	6790.1	-61.8	9225.7	306.0	8007.9	122.1
1/4 at planting + 1/4 at knee height+ 2/4 at near tasseling	7407.4	555.5	8556.0	-363.7	7981.7	959
1/4 at planting + 3/4 at knee height	6759.3	-92.6	9604.7	685.0	8182.0	296.2
1/4 at planting + 3/4 at near tasseling	6975.3	123.4	8006.3	-913.4	7490.8	-395.0
CV%	9.49		9.51		9.61	
$LSD_{5\%}$	1086.0		1476.0		NS	

The statistical analysis for plant height indicated that plant height was significantly affected by timing and proportion of nitrogen fertilizer application (Table 4). The highest plant height in case of BH-540 variety was observed for nitrogen application of 1/3 at planting and 2/3 at knee height. In case of the variety BH-660, it was the 1/4 at planting and 3/4 at tillering application that exhibited the lowest plant height while the other treatments showed equivalent heights. Thousand seeds weight of the BH 660 variety but not of BH 540 was significantly affected by timing and proportion on nitrogen fertilizer application (Table 4). Though it was statistically non significant, the 1/3 at planting and 2/3 at knee height application resulted in the highest thousand seeds weight of BH-540 variety.

Table 4. The effect of time of nitrogen fertilizer application on plant height and thousand seeds weight of maize

Time of nitrogen fertilizer application	Plant height (cm)		Thousand seeds weight (g)	
	BH-540	BH-660	BH-540	BH-660
1/2 at planting + 1/2 at knee height	293.8	343.2	336.8	350.2
All at planting	282.8	341.3	342.1	356.6
1/2 at planting + 1/2 at near tasseling	272.8	326.3	332.5	325.1
1/3 at planting + 1/3 at knee height + 1/3 at near tasseling	284.1	335.5	346.4	336.3
1/3 at planting + 2/3 at knee height	299.9	339.5	354.2	344.8
1/3 at planting + 2/3 at near tasseling	264.8	326.9	333.6	329.8
1/4 at planting + 2/4 at knee height + 1/4 at near tasseling	282.7	338.2	327.7	343.4
1/4 at planting + 1/4 at knee height+ 2/4 at near tasseling	278.7	328.3	330.6	340.6
1/4 at planting + 3/4 at knee height	284.3	333.5	341.1	331.3
1/4 at planting + 3/4 at near tasseling	258.2	312.7	337.9	329.3
CV%	4.51	3.88	5.09	4.97
$LSD_{5\%}$	14.8	15.1	NS	21.98

Economic analysis was also performed to identify the profitable time of nitrogen fertilizer application taking into account the cost of fertilizer application and grain yield obtained (Table 5 and Table 6). In case of BH-540 the nitrogen application of 1/3 at planting and 2/3 at knee height was found to be the best method since it gave the highest net benefit (Table 5). Regarding BH-660, nitrogen when applied 1/4 at planting and 3/4 at knee height gave the highest net benefit and hence recommended (Table 6).

Table 5. Economic analysis for split application of nitrogen fertilizer using BH-540 variety

Time of nitrogen fertilizer application	Adjusted Grain yield (kg/ha)	Man power for fer appn	Labour cost for fer appn	Gross benefit	Net benefit
1/2p+1/2k	6212.3	20	100	4472.9	4372.9
All P	5816.5	10	50	4187.9	4137.9
1/2p+1/2t	5560.8	20	100	4003.8	3903.8
1/3 p+ 1/3 k+ 1/3 t	6625.1	30	150	4770.1	4620.1
1/3 p+ 2/3 k	7117.2	20	100	5124.4	5024.4
1/3 p+ 2/3 t	6594.3	20	100	4747.9	4647.9
1/4 p+ 2/4 k+ 1/4 t	6529.6	30	150	4701.3	4551.3
1/4 p+ 1/4 k+ 2/4 t	6535.6	30	150	4705.6	4555.6
1/4 p+ 3/4 k	6211.2	20	100	4472.0	4372.0
1/4 p+ 3/4 t	5756.0	20	100	4144.3	4044.3

Table 6. Economic analysis for split application of nitrogen fertilizer using BH-660 variety

Time of nitrogen fertilizer application	Grain yield (kg/ha)	Adjusted Gy (kg/ha)	Man power for fer appn	TVC (Labour cost for fer appn)	Gross benefit	Net benefit
1/2p+1/2k	7885.8	7097.2	20	100	5110.0	5010.0
All P	7355.1	6619.6	10	50	4766.1	4716.1
1/2p+1/2t	7704.7	6934.2	20	100	4992.6	4892.6
1/3 p+ 1/3 k+ 1/3 t	8094.8	7285.3	30	150	5245.4	5095.4
1/3 p+ 2/3 k	8095.6	7286.0	20	100	5245.9	5145.9
1/3 p+ 2/3 t	7808.9	7028.0	20	100	5060.2	4960.2
1/4 p+ 2/4 k+ 1/4 t	8007.9	7207.1	30	150	5189.1	5039.1
1/4 p+ 1/4 k+ 2/4 t	7981.7	7183.5	30	150	5172.1	5022.1
1/4 p+ 3/4 k	8182.0	7363.8	20	100	5301.9	5201.9
1/4 p+ 3/4 t	7490.8	6741.7	20	100	4854.0	4754.0

It can be concluded that it is wise to have specific nitrogen fertilizer application time recommendations for different maize growing areas (Tolessa *et al*. 2002). The present nitrogen split application recommendation could be used for maize growing areas which have similar amount of recommended fertilizer vis-à-vis soil and climatic condition with that of Adet. However, this research finding should be verified at the other major maize growing areas of the region so as to derive a dependable nitrogen fertilizer application recommendation.

Conclusion and recommendation

For BH-540 variety it was found that nitrogen should be applied 1/3 at planting and 2/3 at knee height. Similarly in the case of BH-660 it was found better to apply nitrogen 1/4 at planting and 3/4 at knee height. The present nitrogen split application recommendation could be used for maize growing areas which have similar amount of recommended fertilizer vis-à-vis soil and climatic condition with that of Adet. As a future research gap it is better to verify this research finding at the other major maize growing areas of the region so as to derive a dependable nitrogen fertilizer application recommendation.

References:

Alelign Kefyalew, and Regassa Ensermu. 1992. Bahir-Dar Mixed Farming Zone: Diagnostic Survey Report. Research Report No 18. Institute of Agricultural Research, Addis Ababa, Ethiopia.

Benti Tolessa. 1993. The need and objectives of the First National Maize Workshop. In: Benti Tolessa and Joel K. Ransom (eds.). 1993. Proceedings of the first National Maize Workshop of Ethiopia. 5-7 May 1992, Addis Addis Ababa, Ethiopia. IAR/CIMMYT, Addis Ababa.

CIMMYT. 1988. From agronomic data to farmer recomendations: An economic training manual. Revised Edition. Mexico, D.F.

CSA. 2000. *Agricultural sample survey. Statistical Bulletin* 227. Central Statistics Authority, Addis Ababa, Ethiopia.

CSA. 2003. Ethiopian Agricultural Sample Enumeration, 2001/02 (1994 E.C). Central Statistics Authority, Addis Ababa, Ethiopia.

Kebede Mulatu, Gezahagne Bogale, Benti Tolessa, Mosisa Worku, Yigzaw Desalegn and Assefa Afeta.1993. Maize Production Trends and research in Ethiopia. In: Benti Tolessa and Joel K. Ransom (eds.). 1993. Proceedings of the first National Maize Workshop of Ethiopia. 5-7 May 1992, Addis Addis Ababa, Ethiopia. IAR/CIMMYT, Addis Ababa.

Mungai, W.N.., Alice W. Kamau and Charles N. Macharia. 1998. The effect of organic and inorganic phosphorus, and time of split application of nitrogen on maize in Kenya. Maize Production Technology for the future: Challenges and Opportunities. Proceedings of the sixth Eastern and Southern Africa Regional maize conference, 21-25 September 1998. Addis Abeba, Ethiopia: CIMMYT (International Maize and Wheat Improvement Center) and EARO (Ethiopian Agricultural Research Organization).

Tolessa Debelie, Gemechu Gedano and Melakeselam Leul. 1994. Response of Maize to Split Application of Nitrogen Fertilizer at Bako. In: CSSE (Crop Science Society of Ethiopia). 1995. Sebil. Vol. 6. Proceedings of the Sixth Annual Conference. 3-4 May 1994, Addis Abeba, Ethiopia. Pp 56-60.

Tolessa Debelie, Tesfa Bogale, Wakene Negassa, Tenaw Workayehu, Minale Liben, Tewodros Mesfin, Birtukan Mekonen and Waga Mazengia. 2001. A review of fertilizer management research on maize in Ethiopia. Enhancing the Contribution of Maize to Food *Security in Ethiopia: Proceedings of the* Second National Maize Workshop of Ethiopia, 12-16 November 2001, Addis Ababa, Ethiopia: Ethiopian Agricultural Research Organization (EARO) and International Maize and Wheat Improvement Center (CIMMYT).

UNDP. 1996. Sustainable Agricultural and Environmental Rehabilitation Program (SAERP). House Hold Level Socio-Economic Survey of the Amhara Region. Vol. 1. Produced by the Cooperative Endeavors of the Amhara Regional Council. Bahir Dar, Ethiopia.

Evaluation of maize (*Zea mays*)-gomenzer (*Brasica carinata*) intercropping under different plant proportion and planting method of gomenzer

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Abstract

The experiment was conducted for three years, 1999-2001, at Adet Agricultural Research Center in northwestern Ethiopia. The objectives of the experiment were to assess the advantages and/ or disadvantages of maize-gomenzer intercropping and to determine the appropriate combinations of plant proportion and planting method for maize-gomenzer intercropping. It consisted a factorial combination of four gomenzer seed rates (4,3,2,1 kg/ha) and two planting methods (broadcasting the gomenzer on the row sown maize and planting gomenzer row in between two maize rows). There were also sole planting of maize and gomenzer for comparison purpose. The statistical analysis indicated that maize grain yield was significantly affected by gomenzer seed rate. Maize grain yield decreased with an increase in the seed rate of the intercropped gomenzer. However, the influence of planting method and its interaction with gomenzer seed rate on maize grain yield was non significant. Intercropping of gomenzer with maize either in row or by broadcasting caused higher reduction in maize yield. The economic analysis has also confirmed that intercropping of maize and gomenzer was not advantageous. However, it would be wise to conduct maize-gomenzer intercropping with a leaf topping practice so as to arrive at a comprehensive conclusion.

Introduction

Intercropping is the practice of growing two or more crops simultaneously on the same field (Willey, 1991). The system provides a potential for the sustenance to the majority of the farmers who operate in a low resource situation (Francis, 1986[a]). Insurance against the vagaries of weather, diseases and pests are the major reasons for the existence of intercropping (Papendic, 1983). By planting more than one crop at a time in the same field the farmer is also maximizing water use efficiency, maintaining soil fertility, and minimizing soil erosion which are the serious drawbacks of monoculture farming (Francis, 1986[b] and Hoshikawa, 199). It also hampers germination and growth of weeds (Palaniapan, 1985). In most instances intercropping offers the advantage of increased yield, nutritional diversity and highest possible net income (Pal *et al.*, 1981 and Aleman, 2000).

A survey in Northwestern Ethiopia, in the Amhara region, indicated that in the subsistence economy the farmer uses a combination of crops grown on a piece of land (UNDP, 1996). Farmers in the surveyed area gave different justifications for their practice among which shortage of land and risk avoidance are their prime reasons. Improvement of soil fertility, and yield advantage were other reasons (UNDP, 1996). The most common intercropping mixtures found in the area are maize-gomenzer (*Brasica carinata*), maize-potato, maize-sorghum, sorghum-finger millet, sorghum-faba bean, sorghum-barley, finger millet-gomenzer, finger millet-noug, whea-barley, faba bean-field pea and maize-faba bean (Alelign, 1988 and UNDP, 1996).

Farmers reported that during maize-gomenzer intercropping they are using the gomen leaf as a relief food in the rainy season. Besides the gomen grain yield will help them in covering their fertilizer credit for maize (Aleligne and Regassa, 1992; UNDP, 1996; and personal communication). So far no systematic research effort has been made to asses the merits and demerits of the practice as well as with respect to plant density and planting pattern. The present study was designed and conducted to fill the information gap on advaantages and disadvantages of the maize-gomenzer intercropping and appropriate combinations of plant proportion and planting method for the cropping system

Materials and methods

The experiment was conducted for three years, 1999-2001 at Adet Agricultural Research Center in northwestern Ethiopia. Four gomenzer seed rates and two planting methods were factorially combined. The four seed rates were 2/3,1/2,1/3 and 1/6 of the gomenzer recommended rate for sole planting (4, 3, 2 and 1 kg/ha, respectively). The two planting methods were broadcasting the gomenzer on the entire plot of row sawn maize and inter row planting of the gomenzer to the row sown maize at a proportion of 1maize: 1gomenzer by placing one gomenzer row between two maize rows. The BH-540 hybrid and local gomenzer were used for the experiment. In all cases maize was planted at its 100 % rate with 75 cm x 30 cm spacing. There were two sole plantings: one for the maize at a spacing of 75cm x 30cm and one sole gomenzer planting broadcasted at seed rate of 6 kg/ha.

The two crops were planted simultaneously. In all the cases except for the sole gomenzer a fertilizer rate of 75-75 kg/ha N-P_2O_5 was used. All the P_2O_5 and half of the N were applied at planting. The other half of the N was applied at Knee height. For the sole gomenzer a fertilizer rate of 46-69 kg/ha N-P_2O_5 was used at planting. Urea and DAP served as sources of N and P_2O_5. A plot size of 4.5m x 4.8m (21.6m^2) was used. Each plot did accommodate six rows of maize of which the two extreme rows were considered as border rows in all the cases. Data was collected on date of emergence, stand count at maturity for both crops, plant height of the two crops at maturity, number of cobs/plant for maize, 1000 seeds weight for maize, date of maturity and grain yields of the two crops.

The agronomic data were subjected to analysis of variance (ANOVA) using MSTATC statistical software. The intercrop treatments were analyzed as two-factor experiment in RCB design. The intercrop yields were also analyzed and compared with respect to sole yields by considering all as single factor experiment in RCB design. Productivity of the intercropping system was also evaluated by economic analysis and by calculating the Land Equivalent Ratio (LER). Land Equivalent Ratio [the sole crop land area required to produce the intercrop yields] was calculated by equation (Willey, 1991):

LER = Yab/Yaa + Yba/Ybb, Where

Yab= yield per unit area of crop a in mixture

Yaa= yield per unit area of sole crop a

Yba= yield per unit area of crop b in mixture

Ybb= yield per unit area of sole crop b.

Economic analysis had also been performed following the CIMMYT partial budget methodology (CIMMYT, 1988). The yield of maize and gomenzer is adjusted by 10 % for the economic analysis. The analysis was performed by taking the current prices and costs of inputs and outputs as:

- Grain price: Birr 1.3/ kg maize, Birr 2.0/ kg gomenzer
- Seed cost: Birr 2.0/ kg gomenzer, Birr 6.62/ kg maize
- Labour cost for row planting of gomenzer = 4 man days/ha x 5Birr/ m. days= 20 Birr/ha
- Labour cost for broadcasting of gomenzer = 2 man days/ha x 5Birr/ m. days= 10 Birr/ha
- Cost of fertilizer: Birr 3.74/kg DAP, Birr 3.38/kg Urea

Result and discussion

The results of statistical analysis revealed that there were significant maize and gomenzer grain yield differences only due to plant proportion (gomenzer seed rate) in maize-gomenzer intercropping but not due to planting method and its interaction with plant proportion (Table 1). Neither plant proportion nor planting method but their interaction showed significant difference on thousand seed weight of maize (Table 2). Plant heights of both maize and gomenzer showed non-significant response to plant proportion, planting method and the interaction of plant proportion and planting method (Table 2). The comparison among gomenzer seed rates for the intercrop treatments indicate that the highest maize yield (6326.6 kg/ha) was obtained when the lowest gomenzer seed rate (1kg/ha) was intercropped with maize (Table 1). Maize grain yield was linearly increased as the proportion of gomenzer decreased with its decreased seed rate. However, the yield of gomenzer tend to increase with the increase in its proportion (Table 1). The highest gomenzer yield (877.3 kg/ha) was obtained when 3 kg/ha seed of gomenzer was intercropped to maize.

Table 1. Effect of plant proportion and planting method on the grain yield of maize and gomenzer

Gomenzer Seed rate (kg/ha) [Sr]	Maize Grain Yield (kg/ha) Planting Method (Pm)			Gomenzer Grain Yield (kg/ha) Planting Method (Pm)		
	Row planting	Broadcasting	Mean	Row planting	Broadcasting	Mean
1	6395.7	6257.6	6326.6	741.8	955.6	612.3
2	6047.9	6006.7	6027.3	774.2	980.4	791.7
3	6414.3	5258.5	5836.4	807.8	775.7	877.3
4	5251.9	4973.5	5112.7	594.5	630.1	848.7
Mean	6027.5	5624.1		729.6	835.4	
Sole mean yield		8114.1			1747.1	
For comparison within the intercrop treatments:						
	Pm	Sr	Pm x Sr	Pm	Sr	Pm x Sr
LSD 5%	NS	739.6	NS	NS	140.1	NS
CV %		18.87			26.62	
For comparing the intercrop treatments Vs the sole:						
		Treatments			Treatments	
LSD 5%		1044.0			215.4	
CV %		18.12			25.54	

Planting methods showed non-significant difference in maize and gomenzer grain yields. However, row planting of gomenzer provided higher yield of maize and lower yield of gomenzer than broadcasting of gomenzer due to less competition effect of gomenzer on maize. On the other hand broadcasting of gomenzer resulted in lower yield of maize and higher yield of gomenzer. Though it was statistically non-significant, row planting gomenzer in between maize rows resulted in 403.4 kg/ ha (7.2%) maize yield advantage over broadcasting gomenzer on the row sawn maize.

Table 2. Effect of plant proportion and planting method on thousand kernels weight and plant height of maize and plant height of gomenzer

Gomenzer Seed rate (kg/ha) [Sr]	Thousand kernels weight of maize (g)			Plant height of maize (cm)			Plant height of gomenzer (cm)		
	Planting Method (Pm)			Planting Method (Pm)			Planting Method (Pm)		
	Row planting	Broad-casting	Mean	Row planting	Broad-casting	Mean	Row planting	Broad-casting	Mean
1	4224.1	414.7	427.3	233.0	224.4	224.9	194.4	192.9	196.3
2	448.8	411.7	423.8	232.5	224.5	224.2	199.6	201.8	195.1
3	419.8	427.8	430.2	227.5	220.8	228.5	199.2	191.0	200.7
4	424.2	430.3	419.4	226.7	223.1	228.7	193.8	198.8	193.7
Mean	429.2	421.1		229.9	223.2		196.7	196.1	
CV %		4.33			3.71			6.35	
	Pm	Sr	Pm x Sr	Pm	Sr	Pm x Sr	Pm	Sr	Pm x Sr
LSD (5%)	NS	NS	17.52	NS	NS	NS	NS	NS	NS

The correlation analysis for maize and gomenzer grain yields vs gomenzer seed rates indicated that the grain yields are highly correlated with the seed rate (Figure 1). The grain yield of maize tend to decrease with increase in gomenzer seed rate. The comparison between the sole yield of maize vs. the intercrop yields of maize and the sole yield of gomenzer vs. the intercrop yields of gomenzer indicate that the sole yields were significantly superior to the respective intercrop yields (Table 1). The best yield of maize among the intercrop treatments (6414.2 kg/ ha) was obtained when 3 kg/ ha gomenzer seed was row planted in between the row planted maize. However, the stated highest intercrop maize yield was 1699.8 kg/ ha (26.5%) lower than the maize yield from sole planting (8114.1 kg/ ha). Similarly the sole gomenzer planting that gave a gomenzer yield of 1747.1 kg/ ha was 78.2 % (766.7 kg/ ha) superior over the best intercrop gomenzer yield (980.4 kg/ ha).

Land equivalent ratio (LER) analysis was carried out in order to assess the advantage of intercropping over the sole cropping. The LER is more than unity in almost all cases which shows that intercropping of maize and gomenzer is advantageous in many instances than planting each of the crops in sole (Table 3). The highest LER value (1.32) was recorded when gomenzer was planted by broadcasting it on the row sown maize at a seed rate of 1 kg/ha. This implies that an additional 0.32 unit of land would have been needed to get equal yield by planting of maize and gomenzer in pure stands.

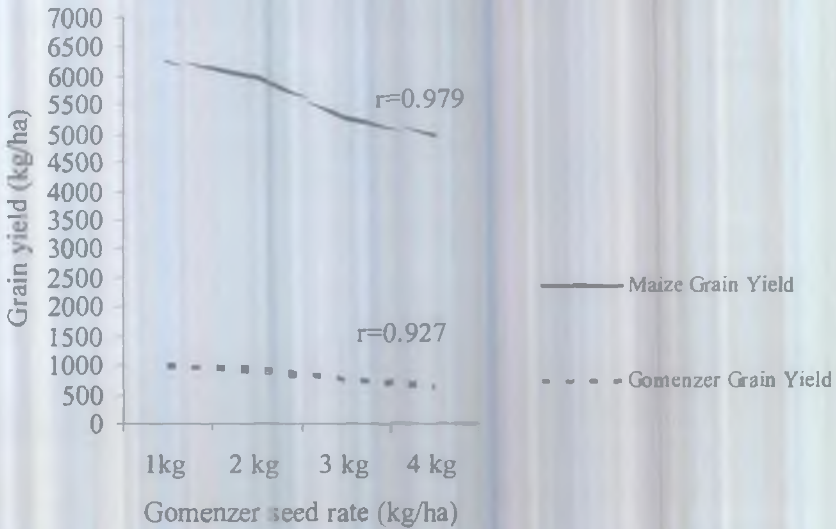

Fig. 1. Effect of gomenzer seed rate on the yield of maize during maize-gomenzer row intercropping

The treatment which gave the highest LER value (1.32) exhibited maize and gomenzer yields of 6257.6 and 955.6 kg/ ha, respectively. According to the interpretation of LER values for the stated treatment, a 1 ha land size will be enough to produce a maize yield of 6257.6 kg and 955.6 kg/ ha yield of gomenzer. However, if sole planting of the two crops was practiced, it would have required a 1.32 ha of land to produce the same 6257.6 kg maize and 955.6 kg gomenzer yields. The observed result indicate that intercropping of gomenzer at a seed rate of 1 kg/ha by broadcasting it on row sown maize provides a 32% (0.32ha) advantage over sole planting of the two crops in terms of land size.

The economic analysis indicates that none of the intercrop treatments were economically superior to maize sole planting (Table 4). All the intercrop treatments became dominated by the sole maize planting. Dominated treatments are the ones that have higher total variable cost but lower net benefit and are economically inferior to the one that dominate them (CIMMYT, 1988). Generally sole maize planting was found to be the most profitable among the tested treatments. Unlike the LER analysis, the economic analysis did not support the intercropping of maize and gomenzer. Though there was an advantage of maize-gomenzer intercropping in terms of land size, the advantage could have not been realized in economic terms. However, in order to arrive at a comprehensive conclusion, it would be wise to conduct maize-gomenzer intercropping with a leaf topping practice.

Table 3. Effect of plant proportion and planting method on the partial and total Land Equivalent Ratio (LER) of maize - gomenzer intercropping

Planting method	Seed rate of gomenzer (kg/ha)	Mean grain yield of maize	Mean grain yield of gomenzer	Land Equivalent Ratio (LER)		
				Maize	Gomenzer	Total
Row planting	4	5252.0	594.5	0.65	0.34	0.99
Row planting	3	6414.3	807.8	0.79	0.46	1.25
Row planting	2	6047.9	774.2	0.75	0.44	1.19
Row planting	1	6395.7	741.8	0.79	0.42	1.21
Broadcasting	4	4973.5	630.1	0.61	0.36	0.97
Broadcasting	3	5258.5	775.7	0.65	0.44	1.09
Broadcasting	2	6006.7	980.4	0.74	0.56	1.30
Broadcasting	1	6257.6	955.6	0.77	0.55	**1.32**
Sole maize		8114.1	0.0	1.00	0.00	1.00
Sole gomenzer	6	0.0	1747.13	0.00	1.00	1.00

If the farmer insist in his idea of maize-gomenzer intercropping, based on this investigation it would be possible to recommend intercropping of gomenzer by broadcasting it on the row sown maize at a seed rate of 1 kg/ha. In many instances the recommendations of LER and economic analysis coincide (Varughese and Iruthayaraj, 1996). However similar to the present investigation, many other findings indicate that though an intercrop is advantageous in terms of LER, it may not be economical given to the monetary values of the component crops (Rajkhowa et al., 1994).

Conclusion and recommendation

Maize-gomenzer intercropping is found to be uneconomicall compared to sole maize planting. It is economically disadvantageous to intercrop maize with gomenzer. However; if the farmer insist in his idea of maize-gomenzer intercropping for other advantages other than economic, it would be better to intercrop gomenzer by broadcasting it on row sown maize at a seed rate of 1 kg/ha. However, in order to arrive at a comprehensive conclusion, it would be wise to conduct maize-gomenzer intercropping with a leaf topping practice.

Table 4. Economic analysis of maize-gomenzer intercropping

Treatments in order of TVC increment	Mean grain yield of maize (kg/ha)	Mean grain yield of gomenzer (kg/ha)	Total variable cost (TVC)	Net Benefit Birr (NB)	Dominance analysis	MRR %
sole gomen	0.0	1747.1	722.6	2422.2		
sole maize	8114.1	0.0	1310.7	8183.0		979.6
MZ + 1 kg/ha Gz broadcasted	6257.6	955.6	1322.7	7718.7	D	
MZ + 2 kg/ha Gz broadcasted	6006.7	980.4	1324.7	7467.8	D	
MZ + 3 kg/ha Gz broadcasted	5258.5	775.7	1326.7	6221.9	D	
MZ + 4 kg/ha Gz broadcasted	4973.5	741.8	1328.7	5624.5	D	
MZ + 1 kg/ha Gz row planted	6395.7	741.8	1332.7	7485.5	D	
MZ + 2 kg/ha Gz row planted	6047.9	774.2	1334.7	7135.0	D	
MZ + 3 kg/ha Gz row planted	6414.3	807.8	1336.7	7622.0	D	
MZ + 4 kg/ha Gz row planted	5252.0	594.5	1338.7	5876.1	D	

D= Dominated treatment,Mz= Maize,Gz= Gomenzer

Reference

Aleligne Kefyalew, and Regassa Ensermu. 1992. Bahir-Dar Mixed Farming Zone: Diagnostic Survey Report. Research Report No 18. Institute of Agricultural Research, Addis Ababa, Ethiopia.

Aleman, F. 2000. Intercropping of common bean (Phaseolus vulgaris) and maize with different plant proportions, effects on land equivalent ratio, competitive ratio and monetary return. In: Studies on Bean/ Maize Production Systems in Nicaragua. Swedish University of Agricultural Sciences.

CIMMYT. 1988. From agronomic data to farmer recommendations: An economic training manual. Revised Edition. Mexico, D.F.

Francis, C.A. 1986[a]. Distribution and importance of multiple cropping. In: Francis, C.A (ed.), 1986. Multiple Cropping. Macmillan Publishing company, New York. pp 1-19.

Francis, C.A. 1986[b]. Perspectives for the future of multiple cropping. In: Francis, C.A (ed.), 1986. Multiple Cropping. Macmillan Publishing company, New York. pp 351-370.

Hoshikawa, K. 1991. Significance of legume crops in improving the productivity and stability of cropping systems. In: Johansen, C., Lee, K.K. and Saharawat, K.L. (eds.). Phosphorous Nutrition of grain legumes in the Semi-Arid Tropics. ICRISAT. pp 173-176

Pal, U.R., A.R. Rao, R. Singh and S.S. Verma. 1981. Intercropping with grain sorghum: Compatible inter-crops and spatial arrangements. Indian Journal of Genetics and Plant Breeding. 40: 44-50.

Palaniappan. 1985. Cropping Systems in the Tropics, principles and management. Wiley Eastern Limited. New Delhi. Tamil Nadu Agricultural University.

Papendic, R.I. 1983. Multiple Cropping. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America. 677 South Segoe Road Madison, Wisconsin 53711. pp 7-32.

Rajkhowa, D.J., S.R. Baroova and K. Dutta. 1994. Planting pattern and fertilizer management in wheat + rapeseed intercropping system under rain fed conditions. Annals of Agricultural Research. 15(3):270-273.

UNDP. 1996. Sustainable Agricultural And Environmental Rehabilitation Program (SAERP). House Hold Level Socio-Economic Survey Of The Amhara Region.Vol. 1. UNDP/ECA SAERP/WARDIS project No. Eth. 94001/B/01/99.

Varughese, K. and M.R. Iruthayaraj. 1996. Biological and economic indices for measuring resource utilization in maize-soybean intercropping. Madras Agricultural Journal. 83(9):556-559.

Willey, R.W. 1991. Evaluation and presentation of intercropping advantages. Experimental Agriculture. 21:119-123.

Determination of optimum rates of Nitrogen & Phosphorus fertilization for tef (*Eragrostis tef*) production in different agro ecological areas of northwestern Ethiopia

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Abstract

Tef is the major staple cereal of Ethiopia and highly adapted to diverse agro ecological zones. Its productivity, however, is very limited. Low soil fertility is one of the major constraints affecting tef production in northwestern Ethiopia. Tef fertilizer experiment was conducted from the year 2000 to 2003 on the major tef growing areas of northwestern Ethiopia on vertisol and nitosol of farmers' field on a total of thirteen major tef growing localities. It was carried out in collaboration with woreda agricultural offices. The objective of the experiment was to determine the economic optimum area specific fertilizer rate for tef production on vertisol and nitosol areas of northwestern Ethiopia. The experiment was designed in randomized complete block consisting of eight fertilizer rates with three replications. Fertilizer rates of 0/0, 41/46, 60/40, 60/60, 80/40, 60/80, 80/60, 100/80 kg N/P_2O_5 ha^{-1} were tested on vertisol and 0/0, 20/40, 41/46, 40/60, 60/40, 60/60, 80/40, 80/60 kg N/P_2O_5 ha^{-1} on nitosol. The result indicated for most localities of vertisols the highest grain yield was obtained with the highest fertilizer rate (100/80 kg N/P_2O_5 ha^{-1}) except at Belesa and Dembia where fertilizer rate of 60/60 and 80/60 kg N/P_2O_5 ha^{-1}, respectively exhibit the highest grain yields. Fertilizer rate of 60/60 kg N/P_2O_5 ha^{-1} give the highest grain yield in most localities of nitosols (Achefer, Gozamin, Denbecha, Dangla and Ebinat) where as at Estie and Bure areas the highest grain yield was obtained with the application of 80/60 kg N/P_2O_5 ha^{-1} and 40/60 kg N/P_2O_5 ha^{-1}, respectively. Fertilizer rates of 80/60 kg N/P_2O_5 ha^{-1} at Awobel and Huleteju-Enebssie; 60/60 kg N/P_2O_5 ha^{-1} at Achefer and Gozamen; 41/46 kg N/P_2O_5 ha^{-1} at Dejen, Belessa, and Ebinat; 20/40 kg N/P_2O_5 ha^{-1} at Bure, Denbecha and Dangla areas were economical rates and recommended to the respective localities. Similarly 80/40, 60/40 and 40/60 kg N/P_2O_5 ha^{-1} were recommended for Simada, Dembia and Estie areas, respectively.

Introduction

Tef is the major staple cereal of Ethiopia and highly adapted to diverse agro ecological zones including conditions marginal to the production of most of the other crops (Hailu and Seyfu, 2001). In the Amhara region tef contributes the highest share (26.16%) of production as compared to other crops; however, its productivity is limited to 9.12 q ha^{-1} (ANRS BOPED, 2002). Seifu 1993 and UNDP 1996 also reported the limited productivity of tef in the region. In northwestern Ethiopia, which is accompanied with divers agro ecologies, low soil fertility particularly nitrogen and phosphorous nutrients deficiencies are among the major constraints affecting crop productions (Taye *et al*, 1996). Continuous cropping, overgrazing, high soil erosion and removal of field crops residues without any soil amelioration mainly aggravate this poor soil fertility. Increasing of crop production must achieve largely high yield per unit area per unit time, which will require the applications of better technologies. Fertilizer application is a lead practice in the introduction of improved technologies. The region use blanket fertilizer application for tef production in the different agro ecologies. Application of the blanket fertilizer recommendation is not advisable since soil fertility is variable in different localities. Minale *et al* 2004 reported economically optimum location specific fertilizer rate for vertisol of Bichena (80/40 kg N/P_2O_5 ha^{-1}) and nitosol of Adet areas (40/60 kg N/P_2O_5 ha^{-1}). Since tef is adapted to diverse agro ecological zones, location specific fertilizer recommendations are very important to increase the productivity of the crop. Hence, to achieve the objective of recommending location based economically optimum fertilizer rate, this fertilizer experiment was conducted on vertisol and nitosol of the different localities of the sub region.

Materials and methods

Tef fertilizer experiment was conducted on vertisol and nitosol of farmers fields on a total of thirteen major tef growing localities of northwestern Ethiopia viz Awobel, Huleteju-Enebsie, Dejen,, Simada, Belesa and Dembia on vertisol where as Achefer, Bure, Denbecha, Gozamin, Dangla, Estie and Ebinat on nitosol. The experiment was executed in the year 2000 to 2003 in collaboration with respective woreda agricultural development offices. Training was given to the responsible woreda experts on how to manage the experiment and take the experimental data. The experiment was designed in randomized complete block consisting of eight fertilizer rates replicated three times. Fertilizer rates of 0/0, 41/46, 60/40, 60/60, 80/40, 60/80, 80/60 and 100/80 kg N/P_2O_5 ha^{-1} on vertisol where as 0/0, 20/40, 41/46, 40/60, 60/40, 60/60, 80/40 and 80/60 kg N/P_2O_5 ha^{-1} on nitosol were tested. A gross plot size of 4m x 5m (20 m^2) was used and seeds broadcasted at recommended rate of 30 kg ha^{-1}. On vertisol the variety DZ-01-354 was used except at Huleteju-Enebssie and Belessa areas where the local variety and Dz-Cr-37 were used, respectively. On nitosol the variety DZ-01-196 was used except at Denbecha where the local variety was used. Soil sample at the time of planting was collected for laboratory analysis. DAP and urea were the sources of N and P_2O_5. All P_2O_5 and half N applied at planting and the other half of N applied at tillering. Experimental sites were visited and evaluated once to twice in the season by the researchers and feedbacks were collected. Reliable data were collected from a total of 118 sites (Table 1). The data collected from a net plot size of 3 m x 3 m (9 m^2) were subjected to analysis of variance using MSTATC Statistical software.

Average fertilizer costs of the localities for 2005 year and average grain price (January to March) of 2006 were used for the economic analysis. Sensitivity analysis was made based on the trend of market prices of the grain and fertilizers cost with the assumption that cost of fertilizers increased by 20% and grain price remain constant (Table 2).

Table 1. Number of sites with reliable data at test locations

Location	Number of sites	Location	Number of sites
Esie	8	Simada	14
Ebinat	5	Dejen	13
Achefer	7	Awobel	12
Bure	7	Huleteju-Enebssie	13
Denbecha	4	Belessa	8
Gozamin	7	Dembia	11
Dangla	9		

Table 2. Cost of fertilizer inputs and price of tef grain for the economic analysis

Cost/Price of input/output	Current situation (Birr/kg)	Sensitivity analysis (Birr/kg)
Cost of DAP	3.74	4.49
Cost of Urea	3.38	4.06
Average price of tef grain for all localities	2.57	2.57

Mean grain yield data over sites for each location was adjusted down by 10% and subjected to partial budget and sensitivity economic analysis following CIMMYT methodology (CIMMYT, 1988).Total costs that varied (fertilizer cost) for each treatments was calculated and treatments were ranked in order of ascending total variable cost (TVC) and dominance analysis was used to eliminate those treatments costing more but producing a lower net benefit than the next lowest cost treatment. The marginal rate of return (MRR) was calculated for each non-dominated treatment. Experiences and empirical evidences have shown that the minimum rate of return acceptable to farmers will be between 50 to 100%. If the technology simply represents an adjustment in current farmer practice, then a minimum rate of return as low as 50% may be acceptable (CIMMYT, 1988). Given the situation of small-scale farmers in Ethiopia and their practice in fertilizer application to tef, a minimum MRR of 70% was assumed.

Results and Discussion

The vertisols result

Results of soil sample analysis of the localities indicated in Table 3. According to the fertility classification of Landon 1991, the result revealed low to medium OC and available P, very low total N and acidic to neutral pH. Grain yield difference was significant among the fertilizer rates in all the locations (Table 4). The lowest grain yield at all locations was obtained from the unfertilized treatment. The highest grain yield at Simada, Awabel, Dejen and Huleteju-Enebsie was obtained from the highest fertilizer rate (100/80 kg N/P_2O_5 ha^{-1}). Where as at Belesa and Dembia the highest grain yield was recorded from fertilizer rate of 60/60 and 80/60 kg N/P_2O_5 ha^{-1}, respectively. Lowest to highest grain yield ranged from 950 to 2048 kg/ha at Simada, 947 to 1952 kg/ha at Awobel, 842 to 1692 kg/ha at Dejene, 661 to 1982 kg/ha at Huleteju-Enebssie, 293 to 859 kg/ha at Belesa and 671 to 1343 kg/ha at Dembia. The increase in grain yield over the control varies from 100% at Dembia to

200% at Huleteju-Enebssie indicating the highest fertilizer response at Huleteju-Enebssie area. Fertilizer rate of 80/60 kg N/P_2O_5 ha^{-1} was economical rate at Huleteju-Enebssie and Awobel where as 80/40 and 60/40 kg N/P_2O_5 ha^{-1} at Simada and Dembia area, respectively. Fertilizer rate of 41/46 kg N/P_2O_5 ha^{-1} was the economical rate for Dejen and Belessa (Table 5). The sensitivity analysis indicated the recommendation will change for Simada, Awobel and Dembia areas if fertilizer cost increased by 20%, therefore, the rates could be used with careful follow up of future price and cost changes. Where as for other localities the recommendations remain unchanged though the fertilizer cost increased by 20% (Table 6).

The nitosols result

Results of soil sample analysis of the localities indicated in Table 7. According to the fertility classification of Landon 1991, the result revealed low to medium organic carbon (OC), acidic soil pH, low available phosphorus (P), and total nitrogen (N) ranged from very low to high. A significant response on grain yield was observed due to differences on fertilizer rates in most of the locations (Table 8).

Table 3. Mean value of some parametrs of soil samples taken at planting on vertisol

Soil characteristics	Simada	Awabel	Dejen	Belesa	Dembia
pH	6.59	5.53	6.11	7.22	6.30
Organic carbon (%)	2.418	4.681	4.652	2.127	2.411
Total N (%)	0.012	0.038	0.034	0.015	0.074
Available P (ppm)	8.919	5.295	11.674	4.913	0.989
O.M (%)	4.090	8.071	8.021	3.667	4.156

Table 4. Grain yield of tef as affected by nitrogen and phosphorus rates on vertisol at different localities

N/P_2O_5 kg ha^{-1}	Simada	Awabel	Dejen	Hulet eju-Enebssie	Belesa	Dembia
0-0	950^{D}	947^{F}	842^{E}	661^{D}	293^{C}	671^{F}
41-46	1712^{C}	1570^{E}	1403^{CD}	1394^{C}	789^{A}	1104^{E}
60-40	1746^{C}	1649^{DE}	1347^{D}	1660^{B}	781^{AB}	1197^{CDE}
60-60	1752^{C}	1712^{CD}	1406^{CD}	1740^{B}	859^{A}	1173^{DE}
80-40	1918^{AB}	1802^{BC}	1559^{B}	1734^{B}	688^{B}	1285^{ABC}
60-80	1752^{C}	1737^{CD}	1450^{C}	1656^{B}	836^{A}	1244^{BCD}
80-60	1909^{B}	1894^{AB}	1551^{B}	1956^{A}	857^{A}	1343^{A}
100-80	2048^{A}	1952^{A}	1692^{A}	1982^{A}	779^{AB}	1313^{AB}
C.V.(%)	18.59	14.38	15.13	16.70	21.55	15.70
$LSD_{5\%}$	138	111	95	119	91	89

Numbers followed by different letters indicate significant differences at 5% level of significance.

Table 5. Economic analysis of nitrogen and phosphorus fertilizers rates on tef grain yield on vertisol production system at different localities

		Simada		Awabel		Dejen		Hulet Eju Enebssie		Belesa		Dembia	
N/P_2O_5 (kg ha^{-1})	TVC (Birr ha^{-1})	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)
0/0	0	2198		2191		1948		1530		678		1551	
41/46	543	3416	224	3089	166	2701	139	2682	212	1283	111	2011	85
60/40	651	3388 D		3164	*	2464 D		3189	470	1155 D		2118	98
60/60	756	3296 D		3203	*	2496 D		3269	76	1231 D		1958 D	
80/40	798	3637	87	3371	110	2809	42	3212 D		792 D		2173	37
60/80	861	3190 D		3156 D		2493 D		2969 D		1072 D		2016 D	
80/60	903	3512 D		3477	101	2685 D		3620	239	1080 D		2204	30
100/80	1155	3581 D		3359 D		2755 D		3430 D		646 D		1882 D	

In all of the locations the lower grain yield obtained from unfertilized treatment ranged from 314 kg/ha at Dangla to 940 kg/ha at Bure. The fertilizer response was poor at Bure which may be due to the better soil fertility status of the location though the soil sample analysis didn't support it. The grain yield response is different at different locations. In case of Achefer, Gozamin, Denbecha, Dangla and Ebinat the highest grain yield was obtained with the application of 60/60 kg N/P_2O_5 ha^{-1}. Where as at Estie and Bure areas it was obtained with the application of 80/60 kg N/P_2O_5 ha^{-1} and 40/60 N/P_2O_5 ha^{-1}, respectively.

Table 6. Sensitivity analysis of nitrogen and phosphorus fertilizers rates on tef grain yield on vertisol production system at different localities

		Simada		Awabel		Dejen		Hulet Eju Enebssie		Belesa		Dembia	
N/P_2O_5 (kg ha^{-1})	TVC (Birr ha^{-1})	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)
0/0	0	2198		2191		1948		1530		678		1551	
41/46	652	3307	170	2980	121	2592	99	2573	160	1174	76	1902	54
60/40	782	3258 D		3033	*	2333 D		3059	374	1025 D		1987	65
60/60	908	3144 D		3051	*	2344 D		3117	*	1079 D		1806 D	
80/40	959	3477	56	3210	75	2648	18	3052 D		632 D		2013	15
60/80	1034	3018 D		2983 D		2320 D		2796 D		899 D		1844 D	
80/60	1085	3332 D		3295	68	2504 D		3439	126	899 D		2023	8
100/80	1387	3350 D		3127 D		2523 D		3198 D		414 D		1650 D	

** MRR is less than acceptable level , TVC = total variable cost NB = net benefit, birr/ha MRR = marginal rate of return*

In general the highest grain yield among the locations ranged from 764 kg/ha at Dangla to 1564 kg/ha at Estie. The highest yield increase (289%) at Estie and lowest increase (57%) at Bure recorded over the unfertilized. This indicates the heterogeneity of the locations in fertility status. Keeping the advantage of location specific fertilizer recommendation, fertilizer rate of 60/60 kg N/P_2O_5 ha^{-1} is the first option to be used as an economical rate at Achefer and Gozamen where as 40/60 and 41/46 kg N/P_2O_5 ha^{-1} are for Estie and Ebinat areas, respectively. Fertilizer rate of 20/40 kg N/P_2O_5 ha^{-1} can be recommended as location specific fertilizer rate for Bure, Denbecha and Dangla (Table 9). The sensitivity analyses further indicated the first option fertilizer rates remains profitable in all of the locations except Achefer area (Table 10).

Table 7. Mean value of some parametrs of soil samples taken at planting time on nitosols

Soil characteristics	Burie	Gozamen	Denbecha	Dangila	Ebinat
pH	5.06	4.77	5.24	4.72	6.31
Organic carbon (%)	4.029	3.317	4.295	3.101	2.499
Total N (%)	0.144	0.553	0.398	0.146	0.037
Available P (ppm)	1.925	2.146	1.890	0.741	1.899
O.M (%)	6.945	5.728	7.405	5.346	4.309

Table 8. Grain yield of tef as affected by nitrogen and phosphorus rates on nitosol at *different localities*

N/P_2O_5 kg ha^{-1}	Estie	Achefer	Burie	Gozamen	Denbecha	Dangila	Ebinat
0/0	402^{D}	628^{D}	940^{B}	506^{F}	613^{B}	314^{D}	495^{D}
20/40	1299^{C}	1031^{C}	1347^{A}	990^{E}	1004^{A}	674^{BC}	954^{C}
41/46	1468^{B}	1280^{B}	1461^{A}	1212^{CD}	973^{A}	724^{ABC}	1204^{AB}
40/60	1532^{AB}	1270^{B}	1476^{A}	1163^{D}	989^{A}	741^{AB}	1091^{BC}
60/40	1514^{AB}	1335^{AB}	1374^{A}	1288^{BC}	994^{A}	677^{BC}	1198^{AB}
60/60	1534^{AB}	1445^{A}	1374^{A}	1430^{A}	1058^{A}	764^{A}	1268^{A}
80/40	1487^{AB}	1388^{AB}	1374^{A}	1315^{ABC}	983^{A}	658^{C}	1183^{AB}
80/60	1564^{A}	1398^{AB}	1423^{A}	1408^{AB}	1052^{A}	707^{ABC}	1249^{A}
CV(%)	11.16	18.13	15.72	17.47	15.31	19.99	17.59
$LSD_{5\%}$	92	147	130	125	120	71	138

Numbers followed by different letters indicate significant differences at 5% level of significance.

Table 9. Economic analysis of nitrogen and phosphorus fertilizers rates on tef grain yield on nitosol production system at different localities

N/P_2O_5 (kg ha^{-1})	TVC (B ha^{-1})	Estie		Achefer		Burie		Gozamen		Denbecha		Dangila		Ebinat	
		NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)
0/0	0	930		1452		2174		1169		1418		726		1146	
20/40	357	2648	481	2028	161	2757	163	1932	214	1966	153	1201	133	1851	197
41/46	543	2853	110	2417	209	2837	43	2261	177	1707 D		1132 D		2243	211
40/60	609	2934	121	2329 D		2804 D		2080 D		1679 D		1104 D		1915 D	
60/40	651	2850 D		2437	*	2526 D		2328	*	1649 D		914 D		2120 D	
60/60	756	2793 D		2587	80	2423 D		2551	136	1691 D		1011 D		2176 D	
80/40	798	2641 D		2413 D		2380 D		2243 D		1476 D		725 D		1939 D	
80/60	903	2713 D		2330 D		2387 D		2355 D		1530 D		733 D		1986 D	

Table 10. Sensitivity analysis of nitrogen and phosphorus fertilizers rates on tef grain yield on nitosol production system at different localities

N/P_2O_5 (kg ha^{-1})	TVC (B ha^{-1})	Estie		Achefer		Bure		Gozamen		Denbecha		Dangila		Ebinat	
		NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)	NB (B ha^{-1})	MRR (%)
0/0	0	930		1452		2174		1169		1418		726		1146	
20/40	429	2576	384	1956	118	2686	119	1861	161	1894	111	1130	94	1779	148
41/46										1598		1023		2134	159
	652	2744	75	2308	158	2728	19	2152	130	D		D			
40/60				2207		2682		1958		1557		982		1793	
	731	2811	85	D		D		D		D		D		D	
60/40		2720		2306		2396				1518		783		1990	
	782	D		D		D		2197	*	D		D		D	
60/60		2641			49	2271				1539		860		2024	
	908	D		2435		D		2399	97	D		D		D	
80/40		2481		2252		2220		2082		1315		565		1779	
	958	D		D		D		D		D		D		D	
80/60		2532		2148		2206		2173		1349		552		1805	
	1085	D		D		D		D		D		D		D	

** MRR is less than acceptable level ,TVC = total variable cost NB = net benefit, birr/ha MRR = marginal rate of return*

Conclusion and recommendation

In all of the locations significant grain yield difference was observed due to differences in fertilizer rates. The response on grain yield to fertilizer rates varies for the locations indicating heterogeneity in soil fertility status among the major tef growing areas of the sub region which further realized location specific fertilizer recommendation is very important. Fertilizer rates of 80/60 kg N/P_2O_5 ha^{-1} at Awobel and Huleteju-Enebssie; 60/60 kg N/P_2O_5 ha^{-1} at Achefer and Gozamen; 41/46 kg N/P_2O_5 ha^{-1} at Dejen, Belessa and Ebinat; 20/40 kg N/P_2O_5 ha^{-1} at Bure, Denbecha and Dangla areas were economical rates and recommended to the respective localities. Fertilizer rates of 80/40, 60/40 and 40/60 kg N/P_2O_5 ha^{-1} were recommended for Simada, Dembia and Estie areas, respectively.

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References:

ANRS BOPED (Amahara National Regional State Bureau of Planning and Economic Development). 2002. Annual Statistical Bulletin 2001/2002. Bahir Dar Ethiopia.

CIMMYT. 1988. From agronomic data to farmer recommendations: An economics training manual. Completely revised edition. Mexico, D.F.

Hailu Tefera and Seyfu Ketema. 2001. Production and importance of tef in Ethiopia agriculture. In Hailu Tefera, Getachew Belay and Mark Sorrels (eds.) Tef

Research and Development. Proceedings of the "International workshop on tef genetics and improvement", Debre Zeit, Ethiopia. 16-19 October 2000.

Landon, J.R. (Ed). 1991. Booker Tropical Mannual. A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics.

Minale Liben, Alemayehu Assefa, Tilahun Tadesse and Abrham marye. 2004. The response of tef to nitrogen and phosphorus application at Bichena and Yilmana-Densa areas, north-western Ethiopia. Crop Science Society of Ethiopia (CSSE). 2004. Sebil. Vol. 10. Proceedings of the Tenth conference, 19-21 June 2001, Addis Ababa, Ethiopia.

Seifu Ketema. 1993. Tef (*Eragrostis Tef*): Breeding, genetic resources, Agronomy, utilization and role of Ethiopian agriculture. IAR, Addis Ababa

Taye Bekele, Yeshanew Ashagrie, Balesh Tulema and Girma Gebrekidan. 1996. Soil fertility Management in Barley. In: Hailu Gebre and Toop van Leur (eds.). Barley Research in Ethiopia: Past Work and Future Prospects. Proceedings of the First Barley Research Review Workshop, 16-19 October 1993, Addis Abeba, Ethiopia.

UNDP. 1996. Sustainable Agricultural and Environmental Rehabilitation Program (SAERP). House Hold Level Socio-Economic Survey of the Amhara Region. V.1 Produced By the Cooperative Endeavors of the Amhara Regional Council. Bahir Dar, Ethiopia

The effect of tillage frequency and weed control on the yield of tef (*Eragrostis tef*) in Yielmana-Densa Area, Northwestern Ethiopia

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Abstract

Tef is the major crop and contributes the highest share of grain production. However, its productivity is limited to 896 kg/ha. An experiment was conducted on nitosols in Yielmana-Densa area of northwestern Ethiopia in the main cropping seasons of 2002-2004. The objective of the experiment was to determine the optimum tillage frequency, time and weeding frequency for tef production in Yielmana Densa area. The experiment was designed in a factorial split plot using tillage as a main plot and weeding as sub plot. The tillage consisted of four frequencies (seven plows, five plows, three plows and one plow + roundup) and the weeding consisted of four levels (no weeding, weeding once at tillering, weeding once at stem elongation and weeding twice at tillering and stem elongation stages of the crop). Grain yield increased linearly as tillage frequency increased. Twice weeding increased yield by 39% over un-weeded. The highest grain yield was obtained when seven times plow is combined with weeding twice which resulted in an increase of yield by 96% over the lowest yield treatment (one plow + roundup + un-weeded). However, three times plowing combined with hand weeding at tillering was found to be economical practice with the highest marginal rate of return and net benefit. It is, therefore, recommended to small-scale farmers around Yielmana Densa to promote sustainable crop production with less unfavorable effect on the environment.

Introduction

Tef is the major staple cereal crop of Ethiopia and highly adapted to diverse agro ecological zones including conditions marginal to the production of most of the other crops (Hailu and Seyfu, 2001). Seyfu (1991) stated that Ethiopian farmers prefer to grow tef because of its multiple advantages such as high market value, reduced post harvest management cost, low risk crop and the straw is preferable animal feed than other cereals. In the Amhara region tef contributes the highest share (21%) of grain production as compared to other crops; however, its productivity is limited to 896 kg/ha (CSA, 2002). Because of the morphological nature of the crop, especially its short and delicate stem, small leaves and shallow fibrous root system, tef offers less competition to weeds. About 48 to 49% yield loss of tef had been reported due to weed competition in the western Amhara (Rezene and Zerihun, 2001). Farmers around Adet mostly practice twice hand weeding for tef from 30 to 60 days after planting. Most surveys reported that hand weeding in tef remains to be one of the most expensive, time and energy consuming practice under all growing conditions (Rezene and Zerihun, 2001). Seyfu (1997) reported that the small size of tef seed poses problem during sowing and indirectly during weeding, and farmers find it difficult to use mechanical weeding implements and are forced to either hand weed or to use chemical herbicides.

Most of the farmers in northwestern Ethiopia practice fine tef seedbed preparation with an average seven times oxen plow (Aleligne, 1988). The reason for fine seedbed preparation is to get weed free environment and good crop germination. On the contrary, the traditional tillage (excessive tillage) had unfavorable effect on the environment due to accelerated soil erosion (Reddy, 2000) and also increased cost of production.

An experiment conducted at Debre Zeit Research Center indicated that hand weeding once at early tillering or twice at early tillering and stem elongation stage depending on the degree of weed infestation of the crop was profitable (Seyfu, 1993). However, no single weed control method gives satisfactorily results and hence an experiment consisting of tillage frequency, time and frequency of hand weeding was conducted in Yilmana Densa area to determine optimum tillage frequency, time and frequency of weeding for tef production in the locality.

Materials and methods

The experiment was carried out on nitosol of farmers' field in Yilmana-Densa (Adet), northwestern Ethiopia in the main cropping seasons from 2002 to 2004. Adet is located at $11^{0}17'$N and $37^{0}43'$E, altitude 2240 m a.s.l. The dominant soil type is nitosol, exhibiting clay, sand and silt contents approximately 70, 10 and 20%, respectively. Based on climatic data recorded at Adet site over the past 8 years (1997-2004), mean monthly maximum and minimum temperatures are 26.0 and 9.6^{0}C, respectively. The mean maximum temperature ranges from 22.4^{0}C in August to 29.4^{0}C in March while the mean minimum temperature ranges from 5.5^{0}C in January to 12.2^{0}C in August. The rainfall pattern of the area is essentially unimodal. Effective rainy period extends from May to October with a peak during July. Total annual precipitation is 1161 mm, and that received during the May–October growing season is 1067 mm.

The experiment was conducted in a total of four sites. It was designed in a factorial split plot using tillage as a main plot and weeding as sub plot with three replications. The tillage consisted of four frequencies (seven plows, five plows, three plows and one plow + roundup) and weeding consisted of four levels (no weeding, weeding once at tillering stage, weeding once at stem elongation and weeding twice at tillering and stem elongation stages of the crop). The variety DZ-01-196 was used at seed rate of 30 kg ha^{-1}. The gross and net plot size were 6m x 3m (18 m^2) and 5m x 2m (10 m^2), respectively. The first plowing, for all plots except untilled plot, was done immediately after the harvest of the precursor crop. The herbicide, roundup, was sprayed once at a rate of 3 l/ha on the untilled plot at about 10 days before planting of tef. The first weeding at tillering stage of the crop was done at about one month after planting and the second weeding at stem elongation was done one month after the first weeding. Weed count is taken twice; firstly for untilled plots at the time of roundup spray and secondly for all plots at tillering stage of the crop using a quadrant size of 50 cm X 50 cm at two randomly selected spots in each plot. Plant height of five randomly selected plants in each plot were measured and the average plant height was calculated. The straw yield was calculated by subtracting the grain yield from total crop dry biomass of the net plot. Data collected were subjected to analysis of variance using MSTATC Statistical soft ware. Labor data for tillage and weeding and herbicide cost were considered as variable costs for economic analysis. An average market price of tef grain during the experimental periods 2003 and 2004 of the three months (Dec. to Feb.) was used. Sensitivity analysis was made through the assumption that variable costs and tef grain prices increased and decreased, respectively by 20% (Table 1).

Table 1. Cost of inputs and price of tef grain for the economic analysis

Cost/Price of input/output	Current situation	Sensitivity analysis
Cost of weeding (Birr/man days)	5.00	6.00
Cost of plowing (Birr/ha)	80.00	96.00
Cost of herbicide (Birr/l).	60.00	72.00
Price of tef grain (Birr/kg)	2.29	2.09

The mean grain yield data was adjusted to10% lower and subjected to partial budget and sensitivity analysis (CIMMYT, 1988). Total costs that varied for each treatments were calculated and treatments were ranked in order of ascending total variable cost (TVC) and dominance analysis was used to eliminate those treatments costing more but producing a lower net benefit than the next lowest cost treatment. The marginal rate of return (MRR) was calculated for each non-dominated treatment.

Results and Discussion

Generally, low weed infestation was recorded during the experimental periods. Weeds are emerged late and weed infestation at the time of herbicide spray for untilled plot was not as it was expected. However, the herbicide (roundup) totally devastated the emerged weeds on that particular plot. Sixteen weed species are recorded on the untilled plot with a total number ranged from 926 to 1962/m^2 depending up on the experimental sites. *Cyperus esculentus, Commelina subulata and Setaria pumila* were the major weeds of the untilled plots at the time of pre-sowing. The late emergence of weeds was due to inadequate precipitation for weed emergence on April and May of the experimental years as compared to the previous years (Fig.1). Generally the average annual precipitation during the experimental years was 1001.2 mm which is less than the previous 5 years average annual precipitation of 1257.28 mm. The low annual precipitation during the experimental years contributed for low weed infestation during the crop growing season. Twenty one weed species are recorded at tillering stage of the crop with total weed population ranged from 685 for seven plows treatment to 802/m^2 for one plow plus roundup treatment (Table 2). This suggested that frequent tillage decreased the weed population during crop growing season through enhancing weed emergence at the time of pre-sowing and there by reducing the weed seed bank in the soil. This is in line with findings of Yeshanew *et al* (1996). The increase in weed species from 16 at pre-sowing on untilled plot to 21 at tillering stage of the crop is due to the fact that tillage favored more number of weed species to emerge as compared to no-tillage system.

Table 2. Count of some major weed species (number/m^2) at tillering stage of tef on the nitosol of Yilmana-Densa

Weed species	Plowing frequency				
	P_7	P_5	P_3	P_1 + R	Mean
Corrigiola capensis	164	191	186	252	198
Polygonum nepalence	198	181	171	222	193
Commelina sabulata	69	68	66	79	71
Cyperus esculentus	58	68	84	31	60
Setaria pumila	50	56	65	31	51
Erucastrum arabicum	21	33	29	32	29
Guizotia scabra	23	16	15	22	19
Other minor weeds	102	119	104	133	115
Total	685	732	720	802	

P_7 = Seven plows, P_5 = Five plows, P_3 = Three plows, P_1 = One plow, R = roundup

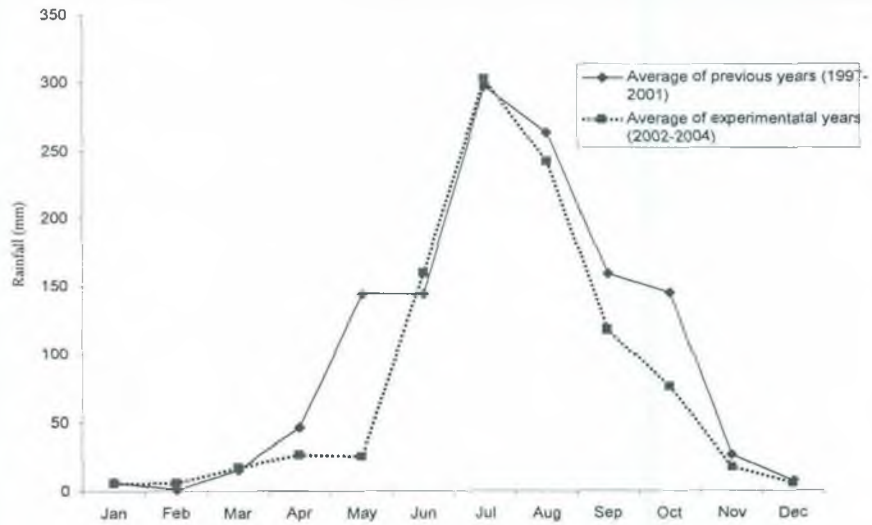

Fig. 1 Monthly mean rainfall of the experimental years in relation to the previous years at Adet Agricultural Research Center

Analysis of variance for individual sites on plant height, grain and straw yield was indicated (Table 3). Plant height and straw yield showed non significant responses to plowing frequency in almost all sites except site 3 for plant height and site 1 for straw yield. Grain yield response to plowing frequency was significant in site 1 and site 4. All crop parameters showed significant responses to weeding and weeding by plowing frequency interaction in all the sites. In general, the sites showed similar responses to all crop parameters.

Table 3. Analysis of variance for individual sites on plant height, grain and straw yield of tef on nitosols in Yilmana-Densa

Source of variation	Site 1			Site 2			Site 3			Site 4		
	Plant height (cm)	Grain yield (kg/ha)	Straw yield (kg/ha)	Plant height (cm)	Grain yield (kg/ha)	Straw yield (kg/ha)	Plant height (cm)	Grain yield (kg/ha)	Straw yield (kg/ha)	Plant height (cm)	Grain yield (kg/ha)	Straw yield (kg/ha)
Plowing (P)	NS	*	*	NS	NS	NS	*	NS	NS	NS	*	NS
Weeding (W)	*	**	*	**	**	**	**	**	**	**	**	**
PxW	**	**	**	**	**	**	**	**	**	*	**	**
CV% (main plot)	7.87	14.76	19.15	6.30	18.84	22.63	5.49	28.94	19.49	4.02	16.42	26.87
CV% (sub plot)	3.59	5.47	11.00	4.92	11.18	16.13	4.39	17.07	11.81	5.34	11.23	11.46

*, ** *Significant at 5 and 1% level of significance, respectively* NS *Non-significant*

The combined analysis of plant height, grain and straw yield over sites (Table 4) indicated non-significant difference of site by plowing frequency for all crop parameters. On the other hand, site by weeding interactions showed significant differences in all of the crop parameters, showing variations in weed infestations among the sites. Grain and straw yield showed significant responses to plowing, weeding and their interactions whereas plant height showed significant responses only to weeding. The highest plant height was recorded in the plot of highest plowing frequency combined with un-weeded treatment (Table 5). This may be due to the fast vertical growth of the crop to successfully compete with weeds for light.

Table 4. Combined analysis over sites on plant height, grain and straw yield of tef On nitosols in Yilmana-Densa

Source of variation	Plant height (cm)	Grain yield (kg/ha)	Straw yield (kg/ha)
Plowing (P)	NS	**	**
PxS	NS	NS	NS
Weeding (W)	*	**	**
WxS	**	**	**
PxW	NS	**	*

* ** *Significant at 5 and 1% level of significance, respectively* NS *Non-significant , S = Site*

Table 5. Plant height, grain yield and straw yield of tef as affected by tillage frequency and weeding on nitosols in Yilmana Densa

Plowing frequency	Plant height (cm)					Grain yield (kg/ha)					Straw yield (kg/ha)				
	W_0	W_1	W_S	$W_1 + W_S$	Mean	W_0	W_1	W_S	$W_1 + W_S$	Mean	W_0	W_1	W_S	$W_1 + W_S$	Mean
P_7	98.2	96.8	90.0	95.6	95.1	1394	1609	1475	1771	1562	4723	4583	3658	4279	4311
P_5	95.8	96.2	84.1	92.2	92.1	1226	1589	1269	1575	1415	4074	4445	2997	3850	3841
P_3	96.4	94.3	87.9	93.2	92.9	1120	1441	1257	1557	1344	3880	4026	3110	3776	3698
P_1 + roundup	97.1	96.5	89.2	93.5	94.1	904	1439	1216	1528	1272	3513	4336	2917	3706	3618
Mean	96.8	95.9	87.8	93.6		1161	1519	1304	1608		4047	4348	3171	3903	
		P	W	PxW			P	W	PxW			P	W	PxW	
CV%		6.14	4.59	4.59			18.89	10.40	10.40			21.85	12.70	12.70	
$LSD_{5\%}$		NS	2.4	NS			111	59	118			356	199	398	

P_7 = Seven plows, P_5 = Five plows, P_3 = Three plows, P_1 = One plow, R = roundup , W_0 = Unweeded, W_1 = Weeding at tillering, W_S = Weeding at stem elongation

The highest and lowest grain yield of tef was obtained on plots of highest and lowest plowing frequency, respectively (Table 5). There was a linear increase in grain yield as plowing frequency increased which may be due to increased competitive capacity of the crop with decreased weed population. Previous research results at different tef growing areas of the country also indicated increased tef grain yield as plowing frequency increased (Fufa *et al*, 2001). Grain yield increase of 23% was recorded in the seven times plow over the one plow + roundup spray. In case of weeding, the highest grain yield was obtained in plots hand weeding twice at tillering and stem elongation and the lowest was in un-weeded plots. Yield increase of 39% was recorded in plots weeded twice over un-weeded. Generally the highest grain yield (1771 kg/ha) was obtained when seven times plow combined with hand weeding twice at tillering and stem elongation. A yield increase of 96% was achieved over the lowest yield treatment (one plow + roundup + un-weeded).

Similarly, straw yield linearly increased as plowing frequency increased (Table 5). Straw yield increase of 19% was recorded in the seven times plow over the one plow + roundup spray. Unlike grain yield, the highest straw yield (4723 kg/ha) was obtained when seven times plow combined with un-weeded treatment. The highest straw yield in the un-weeded treatment as compared to weeded treatments is may be due to the inseparable mixtures of some weed plants with the total crop biomass at the time of harvesting.

Economic analysis on grain yield for the single factor effect was indicated (Table 6). Seven times plow gave the highest net benefit (NB) as compared to the other plowing frequencies. However, marginal rate of return (MRR) for seven times plow was below the acceptable level. Weeding once at tillering gave the highest NB as compared to the other weeding levels. Weeding at tillering had acceptable level of MRR both under the current situation and sensitivity analysis. However, economic analysis on grain yield for the interaction effect (Table 7) showed better NB and MRR than the single factor effect. The highest NB was obtained when five times plow combined with hand weeding at tillering stage but the MRR was below the acceptable level. Since frequent plow aggravate soil erosion (Reddy, 2000), low plow frequency with the highest MRR is advisable. Three times plow combined with hand weeding at tillering exhibited the highest MRR (343%) and NB (birr 2470 ha^{-1}). The sensitivity analysis even under the worst economic situation is inline with the result of the current situation (Table 7). Previous research results did not also show the necessity of plowing more than three times (Fufa *et al*, 2001).

Conclusion

Three times oxen plow combined with hand weeding at tillering was found the best choice to be recommended to small-scale farmers for tef production and also to promote sustainable crop production with less unfavorable effect on the environment. The plowing frequency to be performed in such away that the first plow immediate after precursor crop harvested, the second plow in June about a week before planting and the third plow at the time of planting. Under seasons of high annual precipitation, the second weeding at stem elongation may be necessary depending on the intensity of weed infestation. Further research on tillage frequency in reference to vertisols and precursor crops need to be worked out in Yielmana Densa area.

Table 6. Economic analyses of plowing frequency and weeding on tef grain yield

Plowing frequency	Current cost and price situation TVC (Birr/ha)	Net Benefit (Birr/ha)	MRR (%)	Weeding	Current cost and price situation TVC (Brr/ha)	Net Benefit (Birr/ha)	MRR (%)	Sensitivity analysis TVC (Birr/ha)	Net Benefit (Birr/ha)	MRR (%)
P_3	240	2530		W_0	0	2393		0	2184	
P_1 + roundup	260	2362 D	-	W_t	260	2871	184	312	2545	116
P_5	400	2516 D	-	W_s	415	2273 D	-	498	1955 D	-
P_7	560	2659	40	W_tW_s	490	2825 D	-	588	2437 D	-

D = dominated treatment, NB = net benefit, TVC = total variable costs, MRR = marginal rate of return, P_7 = Seven plow, P_5 = Five plow, P_3 = Three plow, P_1 = One plow, R = roundup ,W_0 = Unweeded, W_t = Weeding at tillering, W_S = Weeding at stem elongation

Table 7. Economic analysis of plowing frequency and weeding interaction on tef grain yield

Plowing frequency by Weeding interactions	Current situation TVC (Birr/ha)	Net Benefit (Birr/ha)	MRR (%)	Sensitivity analysis TVC (Birr/ha)	Net Benefit (Birr/ha)	MRR (%)
P_3W_0	240	2068		288	1819	
P_1 R W_0	260	1603 D		312	1388 D	
P_5W_0	400	2127	37	480	1826	4
P_3W_t	500	2470	343	600	2111	237
P_1RW_t	520	2446 D		624	2083 D	
P_7W_0	560	2313 D		672	1950 D	
P_3W_s	655	1936 D		786	1578 D	
P_5W_t	660	2615	91	792	2197	45
P_1RW_s	675	1831 D		810	1477 D	
$P_3W_tW_s$	730	2479 D		876	2053 D	
$P_1RW_tW_s$	750	2399 D		900	1974 D	
P_5W_s	815.0	1800 D		978	1409 D	
P_7W_t	820.0	2496 D		984	2043 D	
$P_5W_tW_s$	890.0	2354 D		1068	1893 D	
P_7W_s	975.0	2065 D		1170	1604 D	
$P_7W_tW_s$	1050.0	2600 D		1260	2071 D	

References:

Aleligne Kefyalew. 1988. Diagnostic Survey Report of Adet Mixed Farming Zone. Research Report No. 4/88. IAR. Addis Ababa. Ethiopia.

CIMMYT (International Maize and Wheat Improvement Center). 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely Revised Edition. CIMMYT. Mexico. D.F.

CSA (Central Statistical Authority). 2002. Crop Production Forecast Sample Survey 2002/03. Report on Forecast of Area and Production of Major Crops (For Rural Private Peasant Holdings). Statistical Bulletin No. 271. Addis Ababa. Ethiopia.

Fufa Hundera, Tesfa Bogale, Hailu Tefera, Kebebew Assefa, Tiruneh Kefyallew, Abera Debelo and Seifu Ketema. 2001. Agronomy Research in Tef. *In*: Hailu Tefera, Getachew Belay and Mark Sorrels (eds.). Tef Research and Development. Proceedings of the International Workshop on Tef Genetics and Improvement. 16-19 October 2000. Debre Zeit, Ethiopia. PP. 167-176.

Hailu Tefera and Seyfu Ketema. 2001. Production and Importance of Tef in Ethiopia Agriculture. *In*: Hailu Tefera, Getachew Belay and Mark Sorrels (eds.). Tef Research and Development. Proceedings of the International Workshop on Tef Genetics and Improvement. 16-19 October 2000. Debre Zeit, Ethiopia. pp.3-7.

Reddy S.R. 2000. *Principles of crop production*. 1st edition. Kalyani publishers. New Delhi-110 002. India.

Rezene Fessehaie and Zerihun Tadele. 2001. Weed Research in Tef. *In*: Hailu Tefera, Getachew Belay and Mark Sorrels (eds.). Tef Research and Development. Proceedings of the International Workshop on Tef Genetics and Improvement. 16-19 October 2000. Debre Zeit, Ethiopia. pp. 201-213.

Seyfu Ketema. 1991. Germplasm Evaluation and Breeding Work on Tef (*Eragrostis tef*) in Ethiopia. *In*: J.M.M. Engels, J.G. Hawkes and Melaku Worede (eds.). Plant Genetic Resources of Ethiopia. Cambridge University Press. Cambridge. UK. 323-328.

Seyfu Ketema. 1993. Tef (*Eragrostis tef*): Breeding, Genetic Resources, Agronomy, Utilization and Role of Ethiopian Agriculture. IAR, Addis Ababa. Ethiopia.

Seyfu Ketema. 1997. Tef. *Eragrostis tef* (Zuuc.) Trotter. Promoting the Conservation and Use of Underutilized and Neglected Crops. 12. Institute of Plant Genetics and Crop Plant Research. Gatersleben/International Plant Genetic Resources Institute. Rome. Italy.

Yeshanew Ashagrie, Alemayehu Assefa and P.R.Gowda. 1996. Preliminary Results of Weed Management Research in Barley Production Areas of North Western Ethiopia. *In*: Rezene Fessehaie (ed.). Arem Vol.1. Proceedings of the First Annual Conference of the Ethiopian Weed Science Society. 24-25 Nov. 1993. Addis Ababa. Ethiopia. pp. 59-64.

Effect of tef-safflower mixed cropping system on yield and productivity of component crops at Waghimra and Bugna, Northeastern Ethiopia

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Abstract

Field experiment was conducted at research sites of Sekota Dry land Agricultural Research Centre (Aybra and Woleh) during 2003-04 cropping seasons and at Bugna site during 2003-05. The objectives of the experiment were to determine plant population of component crops that are to be successfully grown in mixtures and evaluate whether mixed cropping system has a yield benefit over that of sole cropping system. The result indicated that mixed cropping had significantly affected both tef and safflower biomass and grain yield but the effect on grain yield of tef at Aybra and biomass yield of tef at Bugna were not significant. The total land productivity (LER) was ranged from 1. 33 to 1.55 at Aybra, 1.06 to 1.52 at Woleh and 1.24 to 1.51 at Bugna compared to sole cropping. The highest total land equivalent ratio (LER) (1.55 & 1.52) were obtained from tef + 6 kg/ha safflower at Aybra and Woleh, respectively where as at Bugna tef +4 kg/ha safflower gave the highest total LER of 1.51. The economic analysis result showed that at Aybra and Woleh tef + 6 kg/ha safflower gave a gross monetary value of 3546.0 ETB/ha and 2387.00 ETB/ha, respectively while at Bugna tef+4kg/ha safflower gave the highest GMV of 6148.8 ETB/ha. This finding indicated that mixed cropping of tef and safflower is agronomically advantageous and economically profitable under dry land areas of Waghimra and Bugna areas.

Introduction

Increasing production per unit area is now becoming a preferable strategy to maintain food security relative to extensive farming that uses more land using improved cropping system and management practices (Reddy and Kidane, 1991). Agronomic practice such as fallowing or shifting cultivation is currently impractical in most areas due to the ever-increasing population growth that resulted in land scarcity. Thus, using of agronomic practices, which focus on soil and water conservation, soil fertility management, increasing biomass production, and cropping systems increasing production per unit area are very important strategies to attain sustainable development in agriculture.

Moisture deficit, poor soil fertility, pest, lack of improved varieties, weeds and arable land scarcities are major bottlenecks for the existing farming system of Sekota (Sekota farming system survey, unpublished). As a result, yields of most crops are very low and variable between years and across seasons. In some years, there is a possibility of complete crop failure due to drought. The majorities of the farmers in the areas are resource poor and have strong fear to risks. As a result, farmers in the area are using different coping mechanisms like intercropping to minimize production risks and increasing production per unit area of land. Tef and safflower are the major crops often grown in association in Wagemhira zone. Intercropping is traditionally practiced in most parts of Ethiopia (Adjei-Twum *et al*, 1986).It has many advantages like risk minimization, higher total yield, yield stability, weed suppression, soil erosion control and soil fertility maintenance, control spread of disease and pest and efficient use of scarce resources. Hunshal and Malic (1987) also reported that intercropping gave higher yield over sole cropping.

Yield advantage in intercropping systems is mainly due to differential use of growth resources by the component crops and it is associated with a fuller use of environmental resources over time (Willey *et al*, 1986). Intercropping system involves two or more crop species with the assumption that they could exploit the natural resources better than the mono cropping system. If the two crop species grow together are mutually beneficial then there is cooperation. On the contrary, competition results when they tend to be mutually harmful and this competition is mainly for water, light and nutrient. The relation ship for cooperation and competition are density dependent. According to Donald (1963) at lower densities, there is cooperation and finally active competition comes in to play as the density increases.

Although farmers are traditionally aware of the advantages of intercropping, they do not use a definite proportion of component crops which results in the decrease of total yields that could be obtained from a given area. Therefore determination of the appropriate densities of component crops that could give optimum returns per unit area of land with out affecting the yield of the main crop to a greater extent is crucial.

Materials and methods

Field experiment was conducted on research sites of Sekota Dry land Agricultural Research Center (Aybra and Woleh) during 2003/04 while the experiment was conducted at Bugna site during 2003/05 cropping seasons. The experimental sites have a mean annual rainfall of 700-1000 mm and an altitude of 800-1000 m.a.s.l. The treatments were tested in Randomized Complete Block Design (RCBD) in three replications in a plot size of 5m*5m ($25m^2$). The treatments were: (1) Sole tef; (2) Sole safflower; (3) Tef +2 kg/ha safflower; (4) Tef + 4 kg/ha safflower; (5) Tef + 6 kg/ha safflower; (6) Tef +8 kg/ha safflower; (7) Tef + 10 kg/ha safflower and (8) Tef + 12 kg /ha safflower. In all treatments where the two crops grow together, Safflower was sown first by broadcasting and covered with oxen plowing and tef was sown at the surface. The sole crops were planted at their recommended seed rate of 25 kg/ha for tef and 20 kg/ha for safflower. In addition tef in all mixtures was kept at the recommended population in additive series while the population of safflower was varied according to the treatments. Fertilizer at a rate of 50kg/ha Urea and 100kg/ha DAP was applied based on the recommendation of the major crop (tef). For the economic analysis 372 ET Birr/100 kg DAP and 352 ET Birr/100 kg Urea and seed costs of both tef and safflower were considered. To estimate the monetary value of component crops, tef grain yield was valued at an average open market price of ET Birr 420/100 kg and safflower at ET Birr 150/100 kg for year 2003-2005 in Northern Ethiopia (Waghimra). Net monetary value (NMV) was computed from the yield of tef and safflower component crops by multiplying the yields with their respective unit price and finally fertilizers and seed costs were reduced.

The Land Equivalent Ratio was calculated using the formula described by Willey (1979): $\sum_{i}^{n} YiI / YiM$, YiI is the yield of i th species in intercropping and YiM is the yield of i th species in monocropping. The analysis of variance was made using SAS computer software (V.8) and mean comparison was made using Fisher's LSD test.

Result and discussion

The analysis of variance indicated that there were significant differences on tef and safflower grain yields due to mixed cropping system except tef grain yield at Aybra. (Table1). Although there was no a linear trend, the grain yield of safflower increased as the proportion of safflower increased in the mixed cropping system (Table 1).The increase in safflower yield due to the increase in its proportion could be attributed to its high stands which enables it to take up more nutrients and water from the soil against the companion crop tef. In most of the treatments grain yield of tef decreased as the proportion of safflower increased in the mixed cropping system. This could be due to the fact that competition effects exerted on the component crop (tef) for the limited growth resources (moisture and nutrients). At Aybra, the highest tef grain yield (886.7kg ha^{-1}) was obtained from sole tef followed by tef+ 2 kg safflower (800kgha^{-1}). Similarly at Woleh the highest tef grain yield (693.33kgha^{-1}) was recorded from sole tef but followed by teff+4kg/ha safflower (440.0kgha^{-1}). In Similar fashion at Bugna, the highest tef grain yield (1530.7kgha^{-1}) was recorded from sole tef followed by tef + 4 kg safflower (1230.2kgha^{-1}) (Table 1). As the proportion of safflower increase in the mixed cropping system, the grain yield of tef decreased. This indicated that the two crops are complementary only at lower population densities. According to Donald (1993) at low densities there is cooperation and finally active competition comes in to play as the density increase. The non -significant difference among treatments with respect to tef grain yield at Aybra at different proportion of safflower in the mixed cropping system could be due to the complementary growth habit between the component crops at the specific site. However, tef grain yield was significantly varied due to mixed cropping at Weleh and Bugna. The variation could be due to the difference in the availability of growth resources in the given locations.

Plant height and number of branch per plant of safflower were not significantly affected at Aybra and Woleh but the effect was significant at Bugna (Table 2). Safflower total biomass yield was significantly affected at the three locations (Table 2). Similar to grain yield of safflower the biomass yield also increase as the proportion of safflower increase in the mixed cropping system. The number of branches/ safflower plant showed significant response only at Bugna (Table 2). Tef biomass yield showed significant response at Aybra and Woleh (Table 3). The biomass yield of tef decreased as the proportion of safflower increase. This could be attributed to the increase in inter specific competition for the limited resources and the larger canopy of safflower which could suppress tef growth. The highest biomass yield of tef (3013.3 kg ha^{-1}) at Aybra and (2626.7kg ha^{-1}) at Woleh were recorded from sole tef.

Table1. Effect of tef -safflower mixed cropping on mean grain yield of component crops, total LER and net monetary value (NMV) at Aybra, Woleh and Bugna

Treatments	Aybra				Woleh				Bugna			
	Tef gra yield (kg/ha	Staff flow grain yiel (kg/ha)	Total LER	NMV (Birr/ha	Tef grain yield (kg/ha	Safflower grain yiel (kg/ha)	Total LER	NMV (Birr/ha	rain yield g/ha)	flower n yield g/ha)	al R	(Birr/h
Sole tef	886.7	-	1.00	3071.0	693.33	-	1.00	2259.0	530.7	-	1.00	͡6.4
Sole safflower	-	1040	1.00	982.0	-	1366.7	1.00	1472.0	-	1894.1	1.00	͡53.2
Tef + 2 kg/h: safflower	800	526.7	1.47	3494.0	406.67	620.0	1.19	1982.0	190.7	917.5	1.36	͡7.6
Tef + 4 kg/h: safflower	780.0	486.7	1.36	3347.0	440.00	786.7	1.49	2369.0	230.2	1013.6	1.51	͡8.8
Tef + 6 kg/h: safflower	740.0	733.3	1.55	3546.0	386.67	950.0	1.52	2387.0	194.7	905.3	1.39	͡0.5
Tef + 8 kg/h: safflower	740.0	620.0	1.46	3373.0	346.67	883.3	1.30	2116.0	129.8	873.0	1.44	͡0.0
Tef + 10 kg /ha safflower	646.7	728.0	1.33	2958.0	243.33	980.0	1.21	1824.0	064.0	1221.2	1.24	͡8.1
Tef + 12kg/ha safflower	700.0	713.3	1.50	3339.0	210.00	906.7	1.06	1571.0	͡86.9	1212.9	1.43	͡9.4
Mean	756.2	691.7	-	3013.8	389.5	927.6	-	1997.5	191.6	1148.2	-	͡55.5
LSD.05	NS	226.7	-	-	96.4	228.5	-	-	͡300.4	499.98	-	-
CV (%)	23.2	27.1	-	-	20.9	20.8	-	-	26.2	45.7	-	-

NS= Non significant

Table 2. Effect of Tef Safflower Mixed Cropping on Mean Performance of Safflower at Aybra, Woleh and Bugna

	Aybra		Woleh		Bugna		
Treatments	Total biomass (kg/ha)	1000 seed weight(gm)	Total biomass(kg/ha)	1000 seed weight(gm)	Plant height/ plant (cm)	Number of branch/ plant	Total biomass(kg/ha)
Sole safflower	5560.0	33.67	8573.3	38.17	104.7	11.7	12751
Tef + 2 kg/ha Safflower	1613.3	40.17	3253.3	39.50	87.5	11.11	3529
Tef +4 kg/ha Safflower	1933.3	39.50	3653.3	39.67	90.9	10.07	4653
Tef +6 kg /ha Safflower	2813.3	39.83	4146.7	38.17	86.0	7.9	3902
Tef +8 kg/ha Safflower	2653.3	38.00	4426.7	38.50	85.0	7.44	4520
Tef +10 kg/ha Safflower	3040.0	36.83	4920.0	38.83	89.	10.42	6249
Tef + 12 kg/ha Safflower	2946.7	36.50	5026.7	37.17	91.o	9.58	6804
Mean	2937.1	37. 78	4857.1	38.57	90.7	9.76	6058.4
LSD.05	949.66	3.70	1268.8	NS	7.022	2.34	2068.2
CV (%)	27.2	8.3	22.0	5.1	8.1	25.2	35.8

NS= Non significant

Table 3. Effect of tef safflower mixed cropping on total tef biomass yield of tef

Treatments	Aybra	Woleh	Bugna
Sole tef	3013.3	2626.7	6575.6
Tef+ 2 kg /ha Safflower	2706.7	2413.3	5408.9
Tef +4 kg /ha Safflower	2466.7	2283.3	5764.4
Tef +6 kg /ha Safflower	2333.3	1960.0	5773.3
Tef +8 kg /ha Safflower	2480.0	1880.0	5360.0
Tef + 10 kg/ha Safflower	2026.7	1746.7	5511.1
Tef + 12 kg/ha Safflower	2040.0	1326.7	5173.3
Mean	2438.095	2033.81	5652.4
LSD 0.05	585.86	395.05	Ns
CV (%)	20.2	16.4	24.4

NS= Non significant

The total land productivity in tef safflower mixed cropping system was assessed by calculating the Land Equivalent Ratio (LER). Although the yield of component crops in the mixed cropping system were low as compared to their respective sole crop yields, the LER value showed that the total land productivity was improved in all mixed cropping treatments i.e. (LER>1) as shown in Table 1. The total land equivalent ratio (LER) from mixed cropping was ranged from 1.33 to1.55 at Aybra, 1.06 to 1.52 at Woleh and 1.24 to 1.51 at Bugna than the sole cropping (Table1). This could be due to efficient utilization of limited resources compared to sole cropping. One of the advantages of intercropping system is its efficient and complete use of growth resources such as solar energy, soil nutrients, and water (Francis, 1986a; Siva Kumar, 1993). Better use of limited resources was probably the reason for yield advantage in mixed cropping system. For instance, moisture is the most limiting factor in dry land areas. In an intercropping experiment Morris and Garrity (1993a) computed that mono cropped cowpea used 172 mm, mono cropped sorghum 135mm, the intercrops 162 mm, and fallow 121mm of water. Mean water use efficiency by monocropped cowpea, mono cropped sorghum, and the intercrops was 11.3, 12.4 and 16.5 kg glucose /ha/mm, respectively and hence the intercrops used water more efficiently.

Large difference in rooting pattern exists between tef and safflower. Tef has shallow and massive fibrous root system while Safflower is a thistle-like plant with a strong central branch stem with varying number of branches, and tap-root system. The taproot of safflower can penetrate to depths of 8 to 10 feet if subsoil temperature and moisture permit. Different rooting patterns can explore a greater total soil volume because of the roots being at different depths (Palaniappan, 1985; Francis, 1986a). Another possibility is that component crops may have different peak demand for nutrients due to differences in growth stages. In this experiment tef matured earlier than the safflower that could create the time dimension of the system .This difference could lead to efficient utilization of resources by lessening competition among the intercrop components. The higher over all yields of component crops at Bugna could be traced back to the availability of better growing condition (soil nutrient and moisture).

Only agronomic advantages are not sufficient enough to compare the advantages from mixed cropping system. Economic evaluation of the mixed cropping system was also necessary. The economic analysis result indicated that at Aybra and Woleh sole tef + 6 kg safflower gave highest gross monetary values of 3546.0 and 2387.0 ET Birr/ha, respectively and at Bugna sole tef+4 kg safflower gave the highest gross monetary value of 6148.8 ET Birr/ha (Table 1).

Conclusions and recommendations

Mixed cropping of tef and safflower resulted in increased productivity per unit area. The reason could be due to efficient utilization of growth resources. The result of the current finding can lead to a conclusion that mixed cropping of tef + 6kg safflower is both agronomically and economically advantageous at Aybra and Woleh areas while at Bugna tef + 4 kg safflower is agronomically advantageous and economically profitable. However, soil fertility amendment using proper rotation and application of both organic and inorganic sources of fertilizers after the harvest of the component corps are very essential as both the component crops are non nitrogen fixers and explore more soil nutrients extensively.

References

Adjei-Twun, D.C., Kidane Georgis and Nigussie Tesfamichael. 1986. Effect of intercropping sorghum with legumes on the growth and yield of component crops. p. 225-234. In proceedings of the 18th National crop improvement conference. Nazret, Ethiopia, 24-26 April1986. IAR, Addis Ababa.

Donald, C.M., 1963, competition among crop and pasture plants. Advances in Agronomy 15:1-118.

Francis, C.A. 1986a. Distribution and Importance of Multiplying Cropping .In: Francis, C.A (ed.), 1986.Multiple Cropping. Macmillan Publishing Company, New York. PP. 1-19.

Hunshal, C.S and Malic, D.S., 1987. Dry matter and yield of sorghum as influenced by different plant densities and intercrops. Journal of Maharasatra Agricultural universities, 12:199-202.

Moris, R.A and D.P. Garrrity. 1993a. Resource Capture and Utilization in intercropping: Water. Field Crops Research, 34(3): 303-317.

M.S Reddy and Kidane Georgis, 1991. Development of technologies for dry land farming areas of Ethiopia. Proceedings of the first National Workshop on Dry land farming in Ethiopia 26-28 November 1991 Nazret, Ethiopia.

Palaniapan, S.P., 1985. Cropping Systems in the Tropics, Principles and Management. Wiley Eastern Limited. Tamil Nadu Agricultural University. PP. 75-80.

Papendic, R.I. 1983. Multiple Cropping. American Society of Agronomy, Crop Sciences Society of America, Soil Science Society of America. 677 South Segoe Road, Madison, Wisconsin. PP. 7-32.

Participatory Farming Systems Characterization and Intervention Options for Sekota Woreda, Waghimra Zone (Amhara Region), 2000.

Siva Kumar, M.V.K. 1993. Growth and Yield of Millet and Cowpea in Rely and intercrop Systems in the Sahelian Zones in Years when the On Set of the Rainy Season is Early. Experimental Agriculture. 29 (4): 417-427.

Trenbath, B.R., 1986. Resource Use by Intercrops .In: C.A. Francis. (Ed.), Multiple Cropping. Macmillan Publishing Company, New York. PP. 57-81.

Willey, R.w., Natarajan, M., Reddy, M.s and Rao, M.R., 1986. Cropping systems with Groundnut, resource use and productivity. Proceeding of International Symposium. International Crop Research Institute for the semiarid Tropics, Sahelian center. 21-26 August 1985, Patanchure, Hyderabad, India.

Willey, R.W.1979. Intercropping, its Importance and Research Needs. Part1. Competition and Yield Advantages. Field Crop Abstr.32: 1-10.

Effect of Nitrogen and phosphorus fertilizers on the yield of bread wheat (*Triticum aestivum*) in major wheat growing areas of northwestern Ethiopia

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Abstract

Bread wheat is one of the major staple cereal crops in northwest Ethiopia; however, its productivity is very limited. Low soil fertility is one of the major constraints affecting the productivity of the crop. Fertilizer experiment was carried out in major wheat growing areas of in northwestern Ethiopia; Gozamen, Awabel, Machakel, Gonchasiso-Enebssie, Enarge-Enawga and Debay-Tilatgin, Burie, Banja and Wogera for three consecutive years (2000-2003). The principal objective of the experiment was to determine economically optimum fertilizer rate for the production of semi dwarf improved bread wheat variety (HAR-1685). The experiment was designed in randomized complete block consisting of seven nitrogen and phosphorous combination rates; 0-0, 64-46 92-46, 92-92, 138-46, 138-92 and 184-92 kg N-P_2O_5/ha replicated three times. The result revealed that the highest biological grain yield was obtained with the application of the highest fertilizer rate (184-92 kg N-P_2O_5/ha) at all locations. However, according to partial budget analysis 138-46 kg N-P_2O_5/ha is economically profitable and the best recommendation at Awabel, Machakel, Goncha-Sisoenebsie, Enarge-Enawga, Banja and Wogera conditions. Where as at Gozamen, Debay-Tilatgin and Burie areas the highest grain yield was obtained with the application of 184-92, 92-46 and 64-46 kg N-P_2O_5/ha are the best economical recommended fertilizer rates, respectively for bread wheat production. Those farmers having cash constraint in Awabel, Goncha-Sisoenebsie, Enarge-Enawga, Banja and Wogera 92-46 kg N-P_2O_5 ha^{-1} and in Gozamen 138-46 kg N-P_2O_5 ha^{-1}, Machakel and Debay-Tilatgin 64-46 kg N-P_2O_5 ha^{-1}rates would be used as the second alternative recommendation

Introduction

Wheat (Triticum spp.) is one of the major cereal crops in the Ethiopian highlands, and is grown at altitudes ranging from 1,500 to 3,000 m a.s.l. The most suitable areas for wheat production, however, are situated between 1,900 and 2,700 m a.s.l (Hailu, 1991) with soil types varying from well-drained sandy loams to water-logging prone clays, including Vertisols. In diverse agro-ecologies of northwestern Ethiopia low soil fertility, particularly N and P nutrients deficiencies are among the major biophysical constraints affecting agricultural productions (Taye et al, 1996). This poor soil fertility is mainly aggravated by continuous cropping, overgrazing, high soil erosion and removal of field crops residues without any soil amelioration. Particularly at farmers' level increasing of crop production must achieve largely high yield/ unit area/unit time, which will require the applications of better technologies. Fertilizer application is a lead practice in the introduction of improved technologies. Farmers in the region use blanket fertilizer application for the crop in the different agro ecologies. This blanket fertilizer recommendation may not be suitable for different localities due to the variations of fertility status of the soils. According to Minale et al, 2005, fertilizer rates of 138-46 kg N-P_2O_5 ha^{-1} at Farta and 123-46 kg N/P_2O_5 ha^{-1} at Laie-Gaient were found economically feasible with net benefit (NB) of Ethiopian Birr 3538 and 3062, respectively. Since wheat is adapted to diverse agro ecological zones, location specific fertilizer recommendations are very important to increase the productivity of the crop. Hence, to achieve the objective of location based economically optimum fertilizer rate, a fertilizer experiment was conducted on major bread wheat growing areas of northwest part of Ethiopia.

Materials and methods

The experiment was carried out in major wheat growing areas of farmers' fields in Gozamen, Awabel, Machakel, Gonchasiso-Enebssie, Enarge-Enawga and Debay-Tilatgin (East Gojam), Burie (West Gojam), Banja (Awi) and Wogera (North Gondar) in northwest Ethiopia for three consecutive years (2000-2003). A total of 135 sites in 9 locations, 15 sites in each location, were sown for the experiment, however 30 sites were abandoned due to improper management of the experiment (Table 1). It was conducted by the joint effort of the Adet Agricultural Research Center and Bureau of Agriculture. Training was given to the responsible woreda experts on how to manage the experiment and take the experimental data. The experiment was designed in randomized complete block with three replications. It consists of seven nitrogen and phosphorous combination rates, of which five rates were selected based on the result of previous experiments while for comparison purpose blanket recommendation currently being used for the extension and unfertilized treatment as are included. The treatments were 0-0 kg N-P_2O_5, 64-46 (blanket recommendation) kg N-P_2O_5, 92-46 kg N-P_2O_5, 92-92 kg N-P_2O_5, 138-46 kg N-P_2O_5, 138-92 kg N-P_2O_5 and 184-92 kg N-P_2O_5/ha fertilizer levels. All P_2O_5 and half of each N rate were applied at planting and the remaining N applied at tillering stage of the crop. The gross and net plot size were 4 m x 5 m ($20m^2$) and 3 m x 3 m ($9m^2$), respectively. The variety"Qubsa" (HAR-1685) was broadcasted at a seed rate of 175 kg/ha. Soil sample at 0-20cm.depth prior to planting was collected at each location and analyzed to perceive the soil fertility status of each location.

Table 1. List of Locations and number of effective experimental sites

Locations	Number of Sites
Burie	14
Gozamen	12
Awabel	14
Machakel	14
Gonchasiso-Enebssie	12
Enarg-Enawga	9
Debay-Tilatgin	5
Banja	13
Wogera	12
Total Sites	105

The data collected from a net plot size of 3 m x 3 m (9 m^2) were subjected to analysis of variance using MSTATC Statistical software. The mean grain yields of the treatments were also subjected to discrete economic analysis using partial budget methodology (CIMMYT, 1988). The analysis included by considering the market prices of the grain and the fertilizers cost at the current market condition of the year 2005/06 (Table 2).

Table 2. Cost of inputs and price of out puts

Cost/Price of input/output	Current situation (Birr/kg)	Sensitivity analysis (Birr/kg)
Cost of DAP	3.74	4.49
Cost of Urea	3.38	4.06
Price of wheat grain	2.0	2.0

Marginal rate of return greater than or equal to 100% was considered as an acceptable level (CIMMYT 1988). Experience and empirical evidence have shown that maximum rate of return to farmers will be between 50 and 100% (CIMMYT, 1988). Given the situation of small-scale farmers in Ethiopia, a MRR of 100% is realistic (Amanuel., et al. 1991). Sensitivity analysis was made based on the trend of market prices of the grain and cost of fertilizers with the assumption that price of grain remain constant and cost of fertilizers increased by 20%.

Results and Discussion

The soil analysis indicate that the locations have total N of 0.031-0.325%, O.C of 2.998-5.025%, O.M of 5.169-8.663%, available P of 1.670-10.301 ppm and pH of 4.86-6.68 (Table 3). The result of analysis for each location indicated that there was significant grain yield difference among the fertilizer rates (Table 4). The linear increase in grain yield was observed as the fertilizer levels increased in all locations. The grain yield obtained from unfertilized treatment ranged from 1321 to 2241kg/ha across the locations. The highest mean grain yield was manifested in the highest fertilizer rate (184-92 kg N-P2O5/ha): It ranged from 3548 to 5004 kg/ha. The highest mean grain yield 4644 at Goncha-Siso Enebssie, 4742 at Enarg-Enawga, 4476 at Debay-Tilatgin, 4332 at Awabel, 4819 at Gozamen, 3548 at Machakel, 4137 at Burie, 5004 kg/ha at Banja and 4876 kg/ha at Wogera were obtained with the application of the highest fertilizer rate (184-92 kg N-P_2O_5 /ha) representing an increase of 2730, 2986, 2267, 2622, 3030, 2227, 1896, 3451 and 2929 kg over the control (0-0 kg N-P_2O_5 /ha) in the respective localities (Table 4).

Table 3. Mean value of important soil parameters measured from soil sample taken at planting (before fertilizer application) at the experimental locations

Location	Total N (%)	O.C (%)	O.M (%)	Available P (ppm)	PH
Banja	0.287	4.263	7.350	8.397	4.86
Machakel	0.131	3.400	6.272	10.301	5.62
Burie	0.325	4.105	7.077	2.229	5.12
Gozamen	0.302	2.998	5.169	3.313	5.15
Goncha-Sisoenebsie	0.219	3.586	5.838	1.670	5.56
Enarji-Enawga	0.031	4.293	7.402	8.349	6.68
Debay-Tilatgin	0.034	5.025	8.663	4.085	6.31
Awabel	0.036	4.687	8.081	4.159	5.72

Table 4. Effect of fertilizer application on grain yield of bread wheat in different wheat growing areas

N-P_2O_5 (kg ha^{-1})	Goncha-Sissoenebsie	Enarg-Enawga.	Debay-Tilatgin.	Awabel	Gozamen	Machakel	Burie	Banja	Wogera
0-0	1914^{E}	1756^{F}	2210^{E}	1710^{E}	1789^{E}	1321^{D}	2242^{D}	1554^{E}	1947^{D}
64-46	3173^{D}	3090^{E}	3796^{D}	3204^{D}	3217^{D}	2759^{C}	3781^{C}	3117^{D}	3525^{C}
92-46	3548^{C}	3572^{D}	4051^{D}	3493^{C}	3444^{D}	2914^{C}	3881^{BC}	3717^{C}	3777^{BC}
92-92	3639^{C}	3969^{C}	3921^{D}	3719^{B}	3851^{C}	3183^{B}	4046^{AB}	3658^{C}	4031^{B}
138-46	4237^{B}	4181^{BC}	4204^{BC}	3934^{B}	4038^{C}	3390^{AB}	4032^{AB}	4448^{B}	4096^{B}
138-92	4085^{B}	4410^{B}	4442^{AB}	4185^{A}	4421^{B}	3418^{AB}	4141^{A}	4702^{B}	4552^{A}
184-92	4644^{A}	4742^{A}	4476^{A}	4332^{A}	4819^{A}	3548^{A}	4137^{A}	5004^{A}	4876^{A}
CV%	22.5	18.8	16.0	14.3	16.9	20.6	10.6	15.5	20.6

Numbers followed by different letters indicate differences at 5% level of significance.

The results of economic analysis in all locations (excluding Debaye-ilatgin, Burie and Gozamen) indicated that the application of 138-46 kg N-P_2O_5/ha gave the highest net benefit with acceptable level of Marginal Rate of Return, (MRR). Besides, those farmers having cash constraint in Gonchasiso-Enebsie, Awabel, Banja and Wogera 92-46 and 64-46 kg N-P_2O_5/ha rates would be used as the alternative recommendation rates for bread wheat production. However, for Gozamen 184-92 kg N-P_2O_5/ha was the best recommendation and for Debaye-Tilatgin and Burie areas the above fertilizer rates (184-92 kg N-P_2O_5/ha and 138-46 kg N-P_2O_5/ha) was not effective (Table 5). According to Landon (1991), the mean Organic Matter (OM) (8.663 & 7.077%) concentrations of the soil were relatively medium in the two locations (Table 3). Therefore, application of 64-46 kg N-P_2O_5/ha in Burie and 92-46 kg N-P_2O_5 /ha in Debay-Tilatgin were the best profitable rate for wheat production. Moreover, sensitivity analysis was made to see the sensitivity of the recommended rate when subjected to input and out put price changes at the locations. The two alternative recommendations (138-46 and 64-46 kg N-P_2O_5/ha for Awabal, Gozamen, Machakel, Enarg-Enawga, Goncha-Sisoenebssie, Banja and Wogera and 64-46 kg N-P_2O_5/ha for Debay-Tilatgin and Burie are remain constant profitable even if the inputs, DAP and UREA, cost rise by 20% and which the price of out put (grain) remain constant (Birr 2.00/kg) (Table 6).

Conclusion and recommendation

Bread wheat was found to be very responsive to fertilizer (N and P). The highest biological grain yield was obtained with the application of the highest fertilizer rate (184-92 kg N-P_2O_5/ha). However, according to partial budget analysis 138-46 kg N-P_2O_5/ha for Awabel, Machakel, Goncha-Sisoenebsie, Enarge-Enawga, Banja and Wogera and184-92 kg N-P_2O_5/ha for Gozamen is economically profitable and the best recommendation for bread wheat production. While 92-46 kg N-P_2O_5/ha for Debay-Tilatgin and 64-46 kg N-P_2O_5/ha for Burie is also economical recommended fertilizer rates. Those farmers having cash constraint in all the locations (except Debay and Burie), 92-46 and 64-46 kg N-P_2O_5/ha rates would be used as an the alternative recommendation

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References:

Amanuel Gorfu, Asefa Taa, Tanner, D.G. and Mwangi, W. 1991. On-Farm Research to Derive Fertilizer Recommendations for Small-Scale Bread Wheat Production: Methodological Issues and Technical Results. Research Report No. 14. IAR, Addis Ababa, Ethiopia. 37 Landon, J.R. (Ed). 1991. Booker Tropical Manual. A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics.

CIMMYT. 1988. From agronomic data to farmer recommendations: An economics training manual. Completely revised edition. Mexico, D.F.

Hailu Gebre-Mariam, Tanner, D.G., and Mengistu Hulluka. 1991. Wheat Research in Ethiopia: A historical perspective. Addis Ababa: IAR/ CIMMYT

Minale Liben, Alemayehu Assefa and Tilahun Tadesse. 2005. The response of bread wheat to nitrogen and phosphorous fertilizers at different agro-ecologies of northwestern Ethiopia. M.G. Kinyua, J.Kamwaga, J.O.Owuoche, A.C. Ndiema, P.N. Njau, D.K.Friesen, D.Ouya (Eds). 2005. Proceedings of the 12th Regional Wheat Workshop for Eastern, Central and Southern Africa, Nakuru, Kenya, 22-26 Nov 2004. KARI and CIMMYT

Taye Bekele, Yeshanew Ashagrie, Balesh Tulema and Girma Gebrekidan. 1996. Soil fertility Management in Barley. In: Hailu Gebre and Toop van Leur (eds.). 1996. Barley Research in Ethiopia: Past Work and Future Prospects. Proceedings of The First Barley Research Review Workshop, 16-19 October 1993, Addis Abeba, Ethiopia.

Effect of Nitrogen and Phosphorus fertilizers on the yield of food barley (*Hordeum vulgare*) in major barley growing areas of northwest Ethiopia

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Abstract

Food barley is one of the major staple cereal crops in Ethiopia; however, its productivity is very limited. Low soil fertility is one of the major constraints affecting the productivity of the crop in northwestern Ethiopia. Two sets of experiments were conducted on farmers' fields in Laie-Gaient, Estie, Enarg-Enawga, Machakel, Gozamen, Debay-Tilatgin, Banja, Chillga and Wogera areas of northwest Ethiopia in main cropping seasons of 2000-2002. The principal objectives of the experiments were to determine economic optimum fertilizer rate for the production of local food barley cultivar in major barley growing areas. Both sets of the experiments were designed in RCB with three replications. The first set of the experiment was conducted at Laie-Gaient contained 4 x 4 factorial combinations treatment of four nitrogen(N) rates (0, 32, 64 & 96 kg/ha) and four P_2O_5 rates (0, 23, 46 & 69 kg/ha), and the second set of the experiment conducted at the rest above mentioned areas, which consisted of eight nitrogen and Phosphorous combination rates (0-0, 46-23, 46-46, 46-69, 69-23, 69-46, 69-69 and 92-69). In case of Laie-Gaient condition, the results indicated that there was a drastic increase in response to N as compared to P in grain yield, plant height and fertile spike/m^2. Fertilizer rate of 96-46 N-P_2O_5 kg/ha is the best economical optimum fertilizer rate to be recommended for food barley production in this area. However, for those farmers who have less economic power to purchase fertilizer, 64-69 or 64-23 N-P_2O_5 kg/ha could used as an alternatives though the farmers are going to loose some benefit as compared to the first recommended option at Laie-Gaient condition. Fertilizer rate of 46-46 kg N-P_2O_5/ha is recommended at Enarg-Enawga, Machakel and Debay-Tilatgin areas. On the other hand, a rate of 69-69 kg N-P_2O_5/ha for Gozamen and Chillga areas while 69-23 kg N-P_2O_5 ha^{-1} for Estie area were found to be the most profitable and recommended. Regarding Wogera area, the 69-46 kg N-P_2O_5/ha fertilizer rate was confirmed to be the recommendable rate for food barley production. Application of inorganic fertilizers for barley production in Banja area was found to be uneconomical.

Introduction:

Food barley (Hordeum vulgare) is one of the most important cereal crops mainly grown by smallholder farmers in mid and high altitude areas of northwest Ethiopia. Predominantly, it is grown between altitudes range of 2000 and 3000 m.a.s.l (Asmare et al, 1998). It has a number of attributes, which makes it desirable by resource poor farmers. Despite its importance, the productivity at farm level has remained low, which is even lower than the national average (1 t/ha) (Asmare et al, 1998). One of the reasons for this low productivity of the crop is poor soil fertility of the farmland. This poor fertility status of the soil is mainly aggravated by continuous cropping, overgrazing, high soil erosion and removal of field crops residues without any soil amelioration. As a result the productivity of the major crops of the region is very limited (Hailu et al 1991, Seifu 1993, UNDP 1996, Asmare et al 1998, ANRS BOPED 2000, Aleligne and Regassa 1992; and Fasil and Abera 1997). Nitrogen and phosphorous are deficient in most of the Ethiopian highland soils (Taye et al, 1996). Particularly at farmers' level increasing of crop production must achieve largely high yield/ unit area/unit time, which will require the applications of better technologies. Fertilizer application is a lead practice in the introduction of improved technologies. Farmers in the region use blanket fertilizer application for barley production in the different agro ecologies. This blanket fertilizer recommendation may not be suitable for different localities due to the variations of fertility status of the soils.

Results of previous research activities in northwest Ethiopia indicated a fertilizer rate of 46-46 kg N-P_2O_5 ha^{-1} in Yilemana-Denssa, 69-23 kg N-P_2O_5 ha^{-1} in Farta and 46-23 kg N-P_2O_5 ha^{-1} in Huleteju-Enebssie areas were found to be economically optimum for local early maturing food barley cultivar (Yeshanew et al, 1992 and Minale et al, 2001). This result emphasized variations in soil fertility status of the different localities.
Thus, it was necessary to conduct on farm fertilizer experiment to determine specific fertilizer recommendations under farmers' management practice for different localities, so as to increase productivity of the crop.

This paper therefore, presents results of on-farm fertilizer trials conducted at major barley growing areas of northwest Ethiopia with the specific objective to determine economically optimum fertilizer rate for food barley production.

Materials and methods

Two sets of experiments were conducted on Nitosols of farmers' fields with the altitude range of 2600 to 3100 m.a.s.l. at the main cropping season of 2000 to 2002. Both sets of the experiments were designed in RCB with three replications. The first sets of experiment was conducted at Laie-Gaient which consisted of 4 x 4 factorial combinations of nitrogen rates (0, 32, 64 & 96 kg/ha) and P_2O_5 rates (0, 23, 46 & 69 kg/ha), and the second set was carried-out at Estie (South Gondar), Chillga, Wogera (North Gondar), Enarg-Enawga, Machakel, Gozamen, Debay-Tilatgin (East Gojam) and Banja (Awi) it consisted of eight nitrogen and phosphorous combination rates (0-0, 46-23, 46-46, 46-69, 69-23, 69-46, 69-69 and 92-69 kg N-P_2O_5/ha), which are selected based on the results of previous experiments. Seed of local barley cultivar was broadcasted on a plot size of 5 m x 4 m (20 m^2). The source of nitrogen and phosphorous were Urea, DAP and TSP. All P_2O_5 and half of the N were applied at planting and the remaining N at tillering stage of the crop. Soil sample was collected at planting (before fertilizer application) to estimate the soil fertility status of the locations. Planting, weeding and other operations were executed as per farmers' practices. Grain yield and other yield component parameters were collected and subjected to statistical analysis using MSTATC computer software.

Economic analysis had been performed following the CIMMYT partial budget methodology (CIMMYT, 1988) in order to evaluate the monitory advantages of the fertilizer treatments. The analysis was done with the current (normal) cost/prices of inputs and out puts, which were averaged over the current market price (2005/06). Sensitivity analysis was also performed in order to assess the fate of the profitable rate in worst economic situations. The analysis was conducted by the assumption that the cost of fertilizer increased by 20% while the grain price was remaining constant. The following prices and costs were used for the economic analysis (Table 1):

Table 1. Cost of inputs and price of out puts

Cost/Price of input/output	Current situation (Birr/kg)	Sensitivity analysis (Birr/kg)
Cost of DAP	3.74	4.49
Cost of Urea	3.38	4.06
Average price of food barley grain	1.80	1.80

Marginal rate of return (MRR) greater than or equal to 100% was considered as an acceptable level (CIMMYT 1988). Experience and empirical evidence have shown that maximum rate of return to farmers will be between 50 and 100% (CIMMYT, 1988). Given the situation of small-scale farmers in Ethiopia, a MRR of 100% is realistic (Amanuel, et al. 1991).

Results and discussion

Experiment-I

The results of fertility status of the soil based on the laboratory analysis at the time of planting in the locations indicated in Table 6. The results of analysis of variance (ANOVA) revealed that in all the sites, except one, grain yield was significantly influenced by nitrogen application where as the effect of phosphorus application on grain yield was significant on four sites (Table 2). The grain yield obtained from unfertilized treatment ranged from 568 to 2402 kg/ha. The highest grain yield potential of the location is manifested in the fertilized plot of 96 or 64 kg N/ha combined with 46 or 69 kg P_2O_5 /ha with grain yield ranged from 1684 to 4324 kg/ha. Coefficient of variation for grain yield varied from 20.7 to 47.4%.

The results of combined analysis of variance (i.e. across sites) for grain yield, plant height, tiller count/m^2, fertile spike/m^2 and 1000 kernel weight are presented in Table 3. The result revealed that grain yield and plant height significantly affected by N, P, N x P and N by site interaction where as tiller and fertile spike/m^2 showed significant responses to N and N x P interaction.

Table 2. Analysis of variance on grain yield of food barley for individual sites at Laie-Gaient.

Source of variation	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7	SIte-8
N	**	**	**	NS	**	**	**	**
P_2O_5	NS	*	NS	NS	**	**	NS	*
N X P_2O_5	NS	*	NS	NS	**	*	NS	*
Mean yield ($kgha^{-1}$) of 0/0 N/ P_2O_5	2229	903	2402	1467	568	852	723	639
Highest mean yield ($kgha^{-1}$)	4324	2699	3954	2353	1684	2130	1814	2255
N/ P_2O_5 comb. for highest yield	96/46	64/69	96/46	96/46	96/46	96/69	64/46	64/69
CV(%)	20.72	47.42	26.29	42.25	25.91	36.01	37.42	34.77

**, ** Indicate significance at the 5 &1% levels, respectively. NS Indicate non-significance*

Table 3. Combined analysis of variance on grain yield and other yield components of food barely at Laie-Gaient

Source of variation	Grain yield (kg/ha)	Plant height (cm)	Tiller /m^2 at maturity	Fertile spike/m^2	1000 kernel wt.(g)
Site (S)	**	**	**	**	**
N	**	**	**	**	NS
N x S	*	**	NS	NS	NS
P_2O_5	**	**	NS	NS	NS
P_2O_5 x S	NS	NS	NS	NS	NS
N x P_2O_5	*	*	*	*	NS
Mean value of 0/0 N/P_2O_5	1223	83.87	208	168	41.17
Highest mean value	2470	108.36	274	237	42.5
N/P_2O_5 comb. for highest value	96/46	96/46	96/46	96/46	0/69

**, ** Indicate significance at the 5 &1% levels, respectively. NS Indicate non-significance*

There was a continuous increase in grain yield as nitrogen and phosphorus rates increased (Table 4.). Grain yield increased from 1246 kg/ha to 2188 kg/ha in response to N application and from 1535 kg/ha to 1869 kg/ha in response to P application. The agronomic efficiency (AE) of applied N (i.e. kg grain per kg N) was 8.5 for the first interval (0 to 32 kg N/ha), 10.4 for the second interval (0 to 64 kg N/ha) and 9.8 for the third interval (0 to 96 kg N/ha). While the AE of P declined from 6.1 kg grain per kg P_2O_5 for the first interval to 5.4 for the second, and 4.8 for the third; therefore, grain yield response to N appeared a better way than P. In general the highest mean grain yield (2470 kg/ha) was obtained with the application of 96-46 kg N-P_2O_5/ha that exhibit a yield advantage of 1247 kg over the control treatment (0-0 kg N-P_2O_5/ha). Plant height showed significant responce both to nitrogen and phosphorous while number of fertile spike/m^2 and tiller count significantly respond only to nitrogen application (Table 3). The growth parameters were linearly and positively correlated with grain yield at Laie-Gaient condition (Fig 1 and 2).

The normal economic analysis indicated that the 96-46 kg N- P_2O_5/ha fertilizer rate was the most profitable over the other rates (Table 5). It gave a net benefit of birr 2863 with acceptable level of MRR (153%). Fertilizer rate of 64-69 and 64-23 kg N-P_2O_5/ha could be used as alternative recommendations under the case in which farmers face economic difficulty to purchase fertilizer at the time of planting.

Table 4. Effect of nitrogen and phosphorus on grain yield and number of fertile spike/m^2 (kg/ha)of food barley at Laie-Gaient

N levels kg/ha	Grain yield (kg/ha)				
	P_2O_5 levels (kg/ha)				
	0	23	46	69	Mean
0	1223	1191	1245	1323	1246
32	1426	1421	1588	1640	1519
64	1644	1911	1826	2255	1909
96	1846	2177	2470	2258	2188
Mean	1535	1675	1782	1869	
			33.5		
		N	P	N x P	
LSD(5%)		163.4	163.4	326.8	

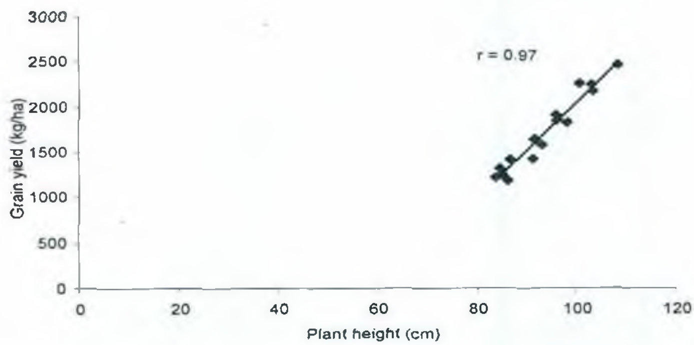

Fig. 1. Inter relationship between grain yield and plant height of food barley at Laie-Gaient

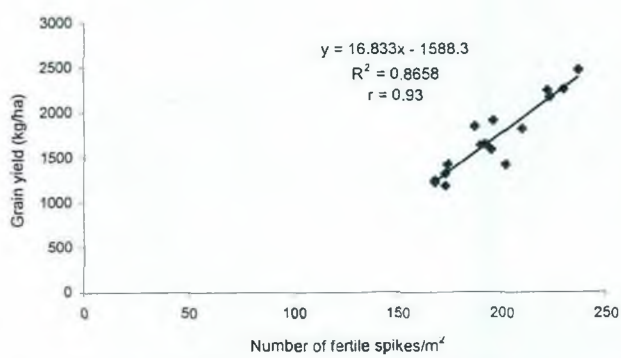

Fig.2. Inter relationship between grain yield and fertile spike of food barley at Laie-Gaient

The sensitivity economic analysis, the analysis considering worst economic situations had also indicated that the fertilizer rates 96-46 kg N-P_2O_5/ha and 64-69 kg N-P_2O_5/ha remained profitable and can confidentially be recommended for food barley production in Laie-Gaient area.

Table 5. Economic analyses on grain yield of food barely for non-dominated treatments

	Scenario 1 (at current situation)			Scenario 2 (sensitivity)		
N-P2O5 (Kg/ha)	TVC	Net benefit (birr)	MRR (%)	TVC	Net benefit (birr)	MRR (%)
0-0	0	1980		0	1980	
32-0	235	2075	39	282	2027	16
64-0	470	2193	50	564	2098	25
64-23	591	2504	257	710	2385	197
96-23	826	2701	83	992	2535	52
64-69	832	2819	1796	999	2652	1528
96-46	947	3053	204	1137	2863	153

TVC - Total variable cost, NB - Net benefit, MRR- Marginal Rate of Return

Experiment II

The result of analysis in each location indicated that there was significant grain yield difference among the fertilizer rates (Table 7). The grain yield obtained from unfertilized treatment ranged from 665 kg/ha to 2095 kg/ha across the locations. While, the highest mean grain yield ranged from 1588 kg/ha to 3511 kg/ha which is manifested in the highest treatments (application of 92-69 kg N-P_2O_5/ha). Amongst the locations the highest grain yield for the application of all fertilizer levels even the control treatment (0-0 kg N-P_2O_5/ha) were obtained at Debay-Tilatgin (Table 7). This indicated that the fertility status of the location was in better condition. According to Landon (1991), mean Organic Matter (OM) and total nitrogen (N_{tot}) concentrations of the soils were relatively low at all locations. However, the mean available Phosphorous (P_{ava}) concentration and P^H level of the soil were relatively at medium conditions at Debay-Tilatgin and Enarg-Enawega districts (Table 6). Therefore, due to the medium level of the parameters in the two districts higher grain yield was obtained as compared to other locations. Where as, in other locations the two parameters (P_{ava}. and P^H) were low as of N_{tot} and OM, as a result the yield obtained in the locations relatively low in all treatments (Table 6 & 7). The highest mean grain yield 2153 kg/ha at Estie, 1795 kg/ha at Machakel, 2049 kg/ha at Gozamen, 3511 kg/ha at Debay-Tilatgin and 1588 kg/ha at Banja were obtained at the application of the highest fertilizer rate treatments (92-69 kg N-P_2O_5/ha) which resulted in yield increase by 159%, 149%, 208%, 68% and 60% over the control treatment in the respective locations (Table 7). Where as 2849 kg/ha at Enarg-Enawga and 1784 kg/ha at Chillga were obtained at the application of 69-69 kg N-P_2O_5/ha, which resulted in yield increase by 90% and 159%, respectively. While mean grain yield, 3115 kg/ha at Wogera was obtained at the application of 69-46 kg N-P_2O_5/ha with a yield advantage of 79 % over the control treatment.

Table 6. Mean value of important soil parameters measured from soil sample taken at planting (before fertilizer application)

Location	Total N (%)	O.C (%)	O.M (%)	Avail P(ppm)	PH
Banja	0.376	4.241	7.311	2.55	4.81
Machakel	0.156	3.685	6.354	3.494	5.04
Gozamen	0.403	3.243	5.592	9.936	6.05
Enarg-Enawga	0.028	3.747	6.553	6.954	6.74
Debay-Tilatgin	0.023	3.606	6.216	8.256	6.45
Laie-Gaient	0.28	0.30	0.517	0.59	5.76

Table 7. Effect of fertilizer application on grain yield of food barley in different localities

$N\text{-}P_2O_5$ kg ha^{-1}	Estie	Enarg-E	Machakel	Gozamen	Debay-T	Banja	Chillga	Wogera
0-0	833^{D}	1497^{C}	720^{D}	665^{F}	2095^{C}	995^{C}	690^{E}	1738^{C}
46-23	1742^{C}	2418^{B}	1424^{C}	1290^{E}	3125^{B}	1350^{B}	1385^{D}	2401^{B}
46-46	1802^{C}	2589^{AB}	1629^{B}	1475^{D}	3321^{AB}	1425^{AB}	1510^{CD}	2627^{AB}
46-69	1840^{C}	2644^{AB}	1710^{AB}	1426^{DE}	3207^{B}	1477^{AB}	1521^{CD}	2741^{AB}
69-23	1965^{B}	2476^{B}	1644^{AB}	1343^{DE}	3317^{AB}	1485^{AB}	1515^{CD}	2840^{AB}
69-46	1998^{B}	2618^{AB}	1706^{AB}	1666^{C}	3341^{AB}	1582^{A}	1623^{BC}	3115^{A}
69-69	2109^{A}	2849^{A}	1770^{AB}	1857^{B}	3249^{AB}	1549^{A}	1784^{A}	3100^{A}
92-69	2153^{A}	2651^{AB}	1795^{A}	2049^{A}	3511^{A}	1588^{A}	1730^{AB}	2969^{AB}
CV%	13.95	19.10	18.85	15.26	14.39	21.86	19.97	31.51

Numbers followed by different letters indicate differences at 5% level of significance

However, the economic a..alysis indicated that 92-69 kg $N\text{-}P_2O_5$/ha was not profitable at current market situation for all locations. At Enarge-Enawga, Machakel and Debay-Tilatgin 46-46 kg $N\text{-}P_2O_5$/ha was found to be the only most profitable fertilizer rate for local food barley production at current market conditions (Table 8). Similarly the most profitable fertilizer rate for Gozamen and Chillga areas were 69-69 kg $N\text{-}P_2O_5$/ha while 69-23 kg $N\text{-}P_2O_5$/ha for Estie area. Where as 46-46 kg $N\text{-}P_2O_5$/ha for Gozamen and 46-23 kg $N\text{-}P_2O_5$ /ha for Estie, Enarge-Enawga, Machakel, Debay-Tilatgin and Chillga could also be used as a second alternative. Regarding Wogera area 69-46 kg $N\text{-}P_2O_5$ /ha was the first profitable rate followed by 69-23 and 46-46 kg $N\text{-}P_2O_5$ /ha as alternatives accordingly (Table 8). In this study application of inorganic fertilizers for barley production in Banja area was found to be uneconomical at the current market situations. This is probably due to the acidic nature of the soil and the nature of crop at Banja area (Table 6 and 7). Sensitivity analysis was made to see the reliability of the recommended rates when subjected to input and output price changes at the respective locations. The analysis confirmed that the 46-23 kg $N\text{-}P_2O_5$ /ha rate remained profitable exhibiting a MRR value with the acceptable level at Estie, Enarg-Enawga, Debay-Tilatgin, Machakel and Chillga. The sensitivity analysis for Gozamen indicated that the 69-69 kg $N\text{-}P_2O_5$ /ha remain profitable in worst economic situations. Concerning Wogera area, both the economic and sensitivity analysis indicated that 69-46 kg $N\text{-}P_2O_5$ /ha is the best recommended rate for barley production (Table 9).

Conclusion and recommendation

The fertilizer rate of 96-46 kg N- P_2O_5 /ha achieved the highest grain yield, plant height and number of fertile spike/m^2. In all the crop parameters there was a drastic increase in response to N as compared to P. Fertilizer rate of 96-46 kg N- P_2O_5 /ha is the best economically optimum fertilizer rate to be recommended for food barley production at Laie-Gaient area. For those farmers who have less economic power to purchase fertilizer at plating time, 96-23 or 64-69 kg N-P_2O_5/ha could used as an alternatives though the farmers are going to loose some benefit as compared to the first recommended option. Fertilizer rate of Enarg-Enawga, Machakel and Debay-Tilatgin 46-46 kg N-P_2O_5/ha was found to be the only most profitable fertilizer rate for local food barley production at current market conditions. On the other hands, a rate of 69-69 kg N-P_2O_5/ha for Gozamen and Chillga while 69-23 kg N-P_2O_5 /ha for Estie area were found to be the most profitable and recommended fertilizer rate. Regarding at Wogera area, the 69-46 kg N-P_2O_5/ha fertilizer rate was confirmed to be the recommendable rate for food barley production. In this study application of inorganic fertilizers for barley production in Banja area was found to be uneconomical.

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The authors acknowledge The Amhara regional agricultural research institute and Bureau of Agriculture in creating favorable environment to conduct a collaborating research, and the respective area agricultural development experts for the follow up of the experiment.

Table 8. Economic analysis of fertilizer application on food barley grain yield at different localities

		Estie		Gozamen		Enarg-Enawga		Machakel		Debay-T		Chillga		Banja		Wogera	
N-P_2O_5 kg ha^{-1}	TVC Birr/ha	NB Birr/ha	MRR %	NB Birr/ha	MRR %	NB Birr/ha	MRR %	NB Birr/ha	MRR %	NB Birr/ha	MRR %	NB Birr/ha	MRR %	NB Birr/ha	MRR %	NB Birr/ha	MRR %
0-0	0	1348		1077		2425		1166		3394		1117		1612		2815	
46-23	468.46	2363	221	1630	120	3458	225	1848	148	4604	293	1785	145	1727	25	3431	134
46-46	596.96	2339D		1810	149	3614	129	2058	173	4800	162	1866	67	1728	1.1	3675	201
69-23	638.46	2555	113	1548 D		3382D		2035D		4745D		1826D		1778	30	3972	617
46-69	725.42	2280D		1610 D		3582D		2069	8	4495D		1763D		1692D		3739D	
69-46	766.96	2488D		1950	83	3493D		2015D		4664D		1880	7	1814	26	4297	268
69-69	895.42	2546D		2139	156	3742	44	1997D		4394D		2021	116	1639D		4152D	
92-69	1065.42	2448D		2280	84	3256D		1869D		4648D		1764D		1534D		3771D	

Table 9. Sensitivity analysis of fertilizer application on food barley grain yield at different localities

N-		Estie		Gozamen		Enarg-Enawga		Machakel		Debay		Chillga		Banja		Wogera	
P_2O_5 kg ha	TVC Birr/ha	NB Birr/ha	MRR%	NB Birr/ha	MRR%	NB Birr/ha	MRR%	NB Birr/ha	MRR%	NB Birr/ha	MRR%	NB Birr/ha	MRR%	NB Birr/ha	MRR%	NB Birr/ha	MRR%
0-0	0.00	1348		1077		2425		1166		3394		1117		1612		2815	
46-23	538	2271	167	1538	83	3365	170	1756	107	4512	202	1693	104	1635	4	3338	95
46-46	686	2223D		1693	107	3498	91	1942	128	4684	118	1750	39	1612D		3558	151
69-23	733	2429	78	1421D		3256D		1909D		4619D		1700D		1651	8	3845	495
46-69	833	2140D		1469D		3442D		1928D		4354D		1622D		1552D		3598D	
69-46	881	2337D		1799	52	3342D		1865D		4513D		1729D		1664	8	4146	207
69-69	1028	2371D		1964	113	3567	20	1822 D		4219D		1846	27	1465D		3977D	
92-69	1224	2240D		2071	52	3047D		1661D		4439D		1555D		1326D		3562D	

D= Dominated treatment, the one with increasing TVC while NB is decreasing. TVC = Total Variable Cost. NB= Net Benefit. MRR= Marginal Rate of Return

References:

Aleligne Kefyalew, and Regassa Ensermu. 1992. Bahir-Dar Mixed Farming Zone: Diagnostic Survey Report. Research Report No 18. Institute of Agricultural Research, Addis Ababa, Ethiopia

ANRS BOPED (Amahara National Regional State Bureau of Planning and Economic Development). *2000. Annual Statistical Bulletin* , Bahir Dar Ethiopia.

Asmare Yallew, Alemu Hailiye, Alemayehu Assefa, Melkamu Ayalew, Tessema Zewudu, Berihane Assayegn and Halima Hassen. 1998. Barley production practices in Gojam and Gondar. pp. 67-89. In: Chilot Yirga, Fekadu Alemayehu and Woldeyesus Sinebo(eds.) Barley based farming system in the high lands of Ethiopia. . Addis Abeba, Ethiopia

CIMMYT. 1988. From agronomic data to farmer recommendations: An economic training manual. Revised Edition. Mexico, D.F.

Fasil Reda. and Abera Debelo. 1997. Melkasa Agricultural Research Center Profile, IAR, Addis Ababa Ethiopia.

Hailu Gebre-Mariam, Tanner, D.G., and Mengistu Hulluka. 1991. Wheat Research in Ethiopia: A historical perspective. Addis Ababa: IAR/ CIMMYT

Landon, J.R. (Ed). 1991. Booker Tropical Manual. A Handbook for Soil Survey and Agricultural Land Evaluation In The Tropics And Subtropics

Minale Liben, Alemayehu Assefa, Tilahun Tadess and Alemu Hailiye. 2001. Effect of nitrogen and phosphorus fertilizers rate on the yield of early maturing barley at Farta and Huletejue-Enebssie areas- Northwestern Ethiopia. Crop Science Society of Ethiopia (CSSE). SEBIL Vol 9. Proceedings of the ninth biannual conference, 22-23 June 1999. Addis Ababa, Ethiopia.

Seifu Ketema. 1993. Tef (Eragrostis Tef): Breeding, genetic resources, Agronomy, utilization and role of Ethiopian agriculture. IAR, Addis Ababa

Taye Bekele, Yeshanew Ashagrie, Balesh Tulema and Girma Gebrekidan. 1996. Soil fertility Management in Barley. In: Hailu Gebre and Toop van Leur (eds.). 1996. Barley Research in Ethiopia: Past Work and Future Prospects. Proceedings of The First Barley Research Review Workshop, 16-19 October 1993, Addis Abeba, Ethiopia.

UNDP. 1996. Sustainable Agricultural and Environmental Rehabilitation Program (SAERP). House Hold Level Socio-Economic Survey of the Amhara Region. V.1 Produced By the Cooperative Endeavors of the Amhara Regional Council. Bahir Dar, Ethiopia

Yeshanew Ashagrie, Tilahun Geleto, Regassa Ensermu, Asgelil Dibabe and Aleligne Kefyalew. 1992. The effect of N and P fertilizer application on the yield of food barley. A Bulletin of the crop science society of Ethiopia. SEBIL. Vol 4. Dec. 1992.

Effect of nitrogen and phosphorous fertilizers on the yield of rice in Fogera and Metema Areas, Northwestern Ethiopia

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Abstract

Rice is becoming an important crop in some areas of northwestern Ethiopia. It becomes the dominant crop in the farming system of the Fogera plain. A fertilizer rate trial was conducted in 2002, 2003 and 2004 cropping seasons at Fogera and Metema areas with the objective of recommending appropriate fertilizer rates for rice production in these areas. Factorial arrangement of five nitrogen and three phosphorous fertilizer rates in Randomized complete Block Design with three replications were used for the experiment. Similar levels of N (0, 46, 69, 92 and 115 N kg/ha) were used both for Metema and Fogera. Regarding phosphorous 0, 46 and 69 P_2O_5kg/ha at Metema; and 0, 23 and 46 P_2O_5 kg/ha at Fogera were studied. The statistical analysis for rice grain yield at Fogera indicated that phosphorous application did not significantly affect rice grain yield. However nitrogen fertilizer application and its interaction with phosphorous significantly affected the rice grain yield at Fogera. The analysis for Metema showed that the single effect of nitrogen and phosphorous fertilizers moreover the interaction of the two nutrients significantly affected rice grain yield. Highest biological yield of 3726.5 kg/ha at Fogera and 3682.0 kg/ha at Metema were obtained with the application of 115-46 N-P_2O_5 kg/ha. Based on the economic analysis 69-23 N-P_2O_5 kg/ha and 115-46 N-P_2O_5 kg/ha fertilizer rates were recommend for rice production in Fogera plain and Metema area, respectively.

Introduction

Rice (*Oryza sativa* L.) is a leading food crop in the world. It is the principal staple food in the diet of more than half of the world population and its grain production exceeded only by that of wheat and maize (Dowswell *et al*, 1996). Rice is the staple food in many countries of Africa and constitutes a major part of the diet in many others (Norman and Otoo, 2003). During the past three decades the crop has shown a steady increase in demand and its growing importance is evident given its important place in the strategic food security planning policies of many countries. In northewestern Ethiopia, rice research and production activities have been started some years back. Currently at Fogera and Metema areas of the Amhara region, rice production is increasing from year to year. The number of households involved in rice production and its area coverage is also increasing (Tesfaye *et al*., 2005). Considerable efforts have been exerted to popularize the production, processing, and consumption aspects of the crop.

Soil nutrient management has a great role in rice production (Doberann and Fairhurst, 2000). Urea is the major N fertilizer for rice in most rice growing countries in Asia (Lee *et al*, 1998). Research results in India indicated incremental rate of N increased grain yield significantly up to 90 kg N/ha after which the grain yield declined (Singh *et al*, 1994). A fertilizer observation trial on rice was conducted at Fogera,Woreta, (Mulugeta 1997). The results indicated that response to N was higher and gave highest grain yield as compared to unfertilized and phosphorus fertilized treatment. This indicated that there is a need to apply fertilizer for rice crop in Fogera plain. No detail fertilizer trial has been done on rice in Fogera and Metema areas, northwest Ethiopia. Therefore, this trial was carried out to determine the optimum fertilizer rate for rice production in Fogera and Metema areas, northwest Ethiopia.

Material and methods

A rice fertilizer trial was conducted in the main cropping seasons of 2003 and 2004 at Fogera and in 2002, 2003 and 2004 at Metema areas. Factorial arrangement of nitrogen and phosphorous fertilizer rates in Randomized complete Block Design with three replications was used for the experiment. In case of Metema, five levels of nitrogen (0, 46, 69, 92 and 115 N kg/ha) and three levels of phosphorous (0, 46 and 69 P_2O_5kg/ha) were studied. While the same five levels of nitrogen (0, 46, 69, 92 and 115 N kg/ha) and other three levels of phosphorous (0, 23 and 46 P_2O_5 kg/ha) were used for Fogera. The rice variety X-jigna was used in case of Fogera while Kokit (IRAT-209) was used for the experiment at Metema. The seeds were broadcasted at a rate of 100 kg/ha. The gross and net plot sizes were 4m x 5m and 3m x 4m, respectively. All other cultural practices were executed according to the farmers' recommendations. In case of Fogera, the experimental fields were mostly planted with rice and some with tef and grass pea in the preceding year. On the other hand the field history of the preceding year indicated that some of the experimental fields in Metema were left fallow, some planted with rice, tef, sorghum or sesame. Composite soil sample were collected before planting and analyzed for each experimental area. Data was collected on grain yield, thousand seeds weight, plant height and fertile panicles. The data was subjected to analysis of variance (ANOVA) using MSTAC microcomputer software. Economic analysis had also been performed following the CIMMYT partial budget methodology (CIMMYT, 1988). The economic analysis was done in the first case with the normal prices and costs of inputs and out puts (Table 1). Sensitivity economic analyses were also performed by the assumption that the cost of fertilizer inputs increase by twenty five percent while the grain price remained constant (Table 1).

Table 1. Cost of fertilizers and price of grain for the normal and sensitivity economic analysis

	Cost or Price (Birr/kg) for the normal economic analysis:	Cost or Price (Birr/kg) for the sensitivity economic analysis:
Price of rice grain	2.9	2.9
Cost of DAP	3.74	4.68
Cost of Urea	3.38	4.23

For the purpose of the economic analysis the unhulled rice grain yield was converted into paddy (milled) rice using the formula: Paddy rice= Unhulled rice x 0.72 (AICAF, 1992).

Result and Discussion

Laboratory analysis for soil sample collected at the time of planting indicated that Fogera is better than Metema in its phosphorous, nitrogen and organic matter status (Table 2). The laboratory difference in soil quality is also supported by the field result hence Fogera showed a higher rice grain yield (2750.5 kg/ha) than Metema (1902.9 kg/ha) at 0-0 N-P_2O_5 fertilizer level (Table 5). Due to its better soil fertility status Fogera requires less amount of supplemental fertilizer than Metema.

Table 2. Some soil chemical charasteristics of sample taken before planting

	Fogera	Metema
Available P (Olsen)	12.639	3.482
Total N %	0.1602	0.120
Organic Matter %	3.20	2.396
P^H	5.48	6.105

The individual site analysis indicate that most of the sites at Fogera and Metema showed significant responce in grain yield to nitrogen application (Table 3 and 4). The combined sites statistical analysis for rice grain yield at Fogera indicated that Nitrogen fertilizer and its interaction with phosphorous significantly affected the rice grain yield (Table 5). Among the nitrogen rates, the highest grain yield was obtained with the application of 115 N kg/ha. Rice grain yield increased linearly with increase in nitrogen and phosphorous fertilizers. Concerning the interaction effect of nitrogen and phosphorous, the 115-46 N-P_2O_5 kg/ha application gave the highest grain yield, 4076.4 kg/ha, with a yield advantage of 1325.9 kg/ha over the unfertilized (0-0 N-P_2O_5 kg/ha) level at Fogera. On the other hand the statistical analysis for Metema showed that the single effect of nitrogen and phosphorous fertilizers besides the interaction of the two nutrients significantly affected rice grain yield (Table 5). Among the nitrogen rates, the 115 N kg/ha level exhibited the highest grain yield. Regarding phosphorous fertilizer, the 69 P_2O_5 kg/ha level gave the highest yield compared to the other rates. Rice grain yield showed a linear responce to increase in nitrogen and phosphorous fertilizers. The 115-69 N-P_2O_5 kg/ha fertilizer combination resulted in the highest biological grain yield, 3862.0 kg/ha, with a yield advantage of 1959.1 kg/ha over the unfertilized treatment (0-0 N-P_2O_5 kg/ha).

Table 3. Results of analysis of variance for mean grain yield of individual sites at Fogera

Source of variation	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7
N	**	NS	NS	**	**	**	**
P_2O_5	NS	NS	NS	**	NS	NS	NS
N x P_2O_5	NS	NS	NS	NS	NS	NS	NS
Mean yield (kg/ha) of 0-0 N- P_2O_5 kg/ha	4717.6	1421.3	4049.8	1623.3	2742.6	3166.0	1532.6
Highest mean yield (kg/ha)	8257.9	3173.6	4650.5	3583.9	4682.4	5241.2	3116.7
N- P_2O_5 kg/ha for the highest mean yield	115-46	69-46	92-0	92-46	46-46	115-46	69-46
CV%	21.51	23.84	23.47	27.21	28.38	20.63	35.82

Table 4. Results of analysis of variance for mean grain yield of individual sites at Metema

Source of variation	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7	Site-8	Site-9
N	NS	NS	**	NS	**	**	**	NS	**
P_2O_5	NS	**	NS	NS	**	**	**	NS	NS
N x P_2O_5	NS	**	NS	NS	NS	NS	NS	NS	NS
Mean yield (kg/ha) of 0-0 N- P_2O_5 kg/ha	1779.2	718.4	1429.3	2858.7	958.2	949.9	3721.8	3663.2	1047.8
Highest mean yield (kg/ha)	3087.6	2614.2	3777.4	4585.2	3307.1	5147.9	6557.7	5614.0	4089.1
N- P_2O_5 kg/ha for the highest mean yield	115-0	115-69	115-46	115-46	92-69	115-69	115-46	46-46	115-69
CV%	33.43	38.34	23.38	27.15	28.18	28.24	21.41	23.39	23.75

Table 5. Effect of Nitrogen and Phosphorous Bertilizers on the Grain Yield (kg/ha) of Rice at Fogera and Metema

Nitrogen (N kg/ha)	Fogera Phosphorous (P_2O_5 kg/ha)				Metema Phosphorous (P_2O_5 kg/ha)			
	0	23	46	Mean	0	46	69	Mean
0	2750.5	2925.5	3325.7	3000.5	1902.9	2143.1	2187.2	2077.7
46	3466.8	3524.1	3790.6	3593.8	2583.2	2960.2	2962.6	2835.3
69	3595.0	3922.4	3851.2	3789.5	2935.9	2909.3	3236.2	3027.1
92	3912.6	3694.7	3746.1	3784.5	3006.5	3116.7	3470.5	3197.9
115	3750.2	3938.2	4076.4	3921.6	2918.9	3766.3	3862.0	3515.7
Mean	3495.0	3601.0	3758.0		2669.5	2979.1	3143.7	
	N	P_2O_5	N x P_2O_5		N	P_2O_5	N x P_2O_5	
$LSD_{5\%}$	345.5	NS	598.5		245.5	190.2	425.2	
CV%			27.18				27.07	

The results of the statistical analysis for plant height, number of tillers, number of fertile panicles, panicle length and thousand seeds weight for Fogera and Metema is presented in Table 6 and Table 7, respectively. Plant height had shown significant response to nitrogen and phosphorous application both at Fogera and Metema. Tiller count significantly responded only to nitrogen at Fogera while it responded to nitrogen and phosphorous at Metema. Number of fertile panicles was significantly affected by nitrogen at Fogera whereas at Metema it was affected by nitrogen and the interaction of nitrogen and phosphorous (Table 6 and 7). At Fogera panicle length showed significant variation to the interaction of nitrogen and phosphorous while in contrast it was affected only by phosphorous at Metema. Thousand seeds weight at Fogera was affected by nitrogen though it was affected neither by nitrogen nor by phosphorous at Metema. The response of grain yield, plant height, tiller count and number of fertile panicles to nitrogen and phosphorous application both at Fogera and Metema was linear.

Table 6. Effect of nitrogen and phosphorous fertilizers on plant height, tiller count, fertile panicle, panicle length and thousand seeds weight of Rice at Fogera

Nitrogen (N) kg/ha	Plant height (cm)				Tiller count/m²				Number of fertile panicles/ m²				Panicle length (cm)				Thousand seeds weight (g)			
	Phosphorous (P_2O_5kg/ha)				Phosphorous (P_2O_5kg/ha)				Phosphorous (P_2O_5kg/ha)				Phosphorous (P_2O_5kg/ha)				Phosphorous (P_2O_5kg/ha)			
	0	23	46	Mean	0	23	46	Mean	0	23	46	Mean	0	23	46	Mean	0	23	46	Mean
0	86	85	90	87	289	300	314	301	392	388	418	399	18.2	17.6	18.7	18.2	27.2	27.1	27.6	27.3
46	90	93	93	92	323	295	351	323	429	394	447	423	17.8	18.3	18.3	18.1	27.4	28.2	28.1	28.0
69	92	89	95	92	350	355	350	352	443	449	448	446	18.3	18.5	18.6	18.5	27.7	27.5	28.0	27.7
92	94	97	95	95	351	339	333	341	453	449	424	442	18.1	18.8	18.2	18.4	27.8	27.5	27.7	27.7
115	97	96	97	97	355	363	381	366	443	461	486	463	18.8	18.4	18.1	18.4	27.7	27.2	27.2	27.4
Mean	91	92	94		334	330	346		432	428	445		18.2	18.3	18.4		27.6	27.5	27.7	
CV %		8.18				21.78				18.91				6.2				3.88		
	N	P_2O_5	NxP_2O_5		N	P_2O_5		NxP_2O_5	N	P_2O_5	NxP_2O_5		N	P_2O_5		NxP_2O_5	N	P_2O_5	NxP_2O_5	
LSD 5%	3.745	4.496	NS		36.27	NS		NS	40.69	NS	NS		NS	NS		0.8077	0.529	NS	NS	

Table 7. Effect of nitrogen and phosphorous fertilizers on plant height, tiller count, fertile panicle, panicle length and thousand seeds weight of Rice at Metema

Nitrogen (N) kg/ha	Plant height (cm)				Tiller count/m²				Number of fertile panicles/ m²				Panicle length (cm)				Thousand seeds weight (g)			
	Phosphorous (P_2O_5kg/ha)				Phosphorous (P_2O_5kg/ha)				Phosphorous (P_2O_5kg/ha)				Phosphorous (P_2O_5kg/ha)				Phosphorous (P_2O_5kg/ha)			
	0	46	69	Mean	0	46	69	Mean	0	46	69	Mean	0	46	69	Mean	0	46	69	Mean
0	102	108	106	105	131	131	132	131	183	183	168	178	17.9	18.6	18.4	18.3	31.6	31.5	32.1	31.8
46	114	118	118	116	142	160	167	156	193	210	213	205	17.9	18.7	18.9	18.5	31.5	32.4	32.0	32.0
69	114	122	122	119	152	166	169	162	198	212	219	210	18.4	18.6	18.2	18.4	32.3	32.0	32.0	32.1
92	119	122	126	123	160	159	177	165	205	197	221	207	18.3	19.0	18.6	18.6	31.3	31.6	31.9	31.6
115	121	128	130	126	163	167	156	162	208	217	200	208	19.0	19.2	18.9	19.1	30.7	31.9	32.1	31.6
Mean	114	120	121		150	156	160		197	204	204		18.3	18.8	18.6		31.5	31.9	32.0	
CV %		5.95				22.98				18.92				9.57				6.24		
	N	P_2O_5	NxP_2O_5		N	P_2O_5		NxP_2O_5	N	P_2O_5	NxP_2O_5		N	P_2O_5		NxP_2O_5	N	P_2O_5	NxP_2O_5	
LSD 5%	3.062	3.675	NS		15.57	18.69		NS	16.65	NS	23.96		NS	0.499		NS	NS	NS	NS	

The economic analysis for Fogera indicated that it was the 69-23 N-P_2O_5 kg/ha rate that was found the first profitable rate followed by 46-46 N-P_2O_5 kg/ha and 46-0 N-P_2O_5 kg/ha fertilizer rates in the normal as well as sensitivity economic analysis (Table 8). In cases where farmers face economic difficulty, money shortage at the time of planting, the 46-46 N-P_2O_5 and 46-0 N-P_2O_5 rates could be used as a second and third alternatives, respectively. In case of Metema the normal as well as sensitivity economic analysis indicated that 115-46 N-P_2O_5 kg/ha fertilizer rate was the best profitable and hence recommended rate for rice production (Table 9). The rate exhibited the highest net benefit as compared to the other fertilizer rates. If farmers at Metema are not economically capable at the time of planting to buy the amount of fertilizer needed for the first recommended rate, they could use 92-69 and 69-0 N-P_2O_5 kg/ha fertilizer rates as second and third alternatives, respectively. However; they are going to loose some profit if they use the second and more if the third alternative is used. Hence it is better to use the first recommendation, 115-46 N-P_2O_5 kg/ha, as far as possible.

Table 8. Results of Economic Analysis of rice fertilizer trial at Fogera

Normal Economic analysis

Dominance Analysis

N-P_2O_5 (kg/ha)	TVC	NB	
0-0	0.0	5224	
0-23	187	5351	
46-0	338	6352	
0-46	374	6026	D
46-23	459	6255	D
69-0	507	6384	
46-46	580	6721	
69-23	628	6806	
92-0	676	6855	
69-46	749	6583	D
92-23	797	6363	D
115-0	845	6504	D
92-46	918	6189	D
115-23	966	6602	D
115-46	1087	6694	D

MRR Analysis

N-P_2O_5 (kg/ha)	TVC	NB	MRR (%)	Rank
0-0	0	5224		
0-23	187	5351	67 5	
46-0	338	6352	663 2	
69-0	507	6384	19 2	
46-46	580	6721	463 2	3rd
69-23	628	6806	175.0	2nd
92-0	676	6855	102 6	1st

Sensitivity economic analysis

Dominance Analysis

N-P_2O_5 (kg/ha)	TVC	NB	
0-0	0	5224	
0-23	234	5304	
46-0	423	6267	
0-46	468	5932	D
46-23	574	6140	D
69-0	635	6257	D
46-46	725	6576	
69-23	786	6648	
92-0	846	6685	
69-46	937	6395	D
92-23	997	6162	D
115-0	1058	6292	D
92-46	1148	5958	D
115-23	1209	6359	D
115-46	1360	6421	D

N-P_2O_5 (kg/ha)	TVC	NB	MRR (%)	Rank
0-0	0	5224		
0-23	234	5304	33.8	
46-0	423	6267	509 7	3rd
46-46	725	6576	102 1	2nd
69-23	786	6648	119 7	1st
92-0	846	6685	61 8	

Table 9. Results of Economic Analysis of rice fertilizer trial at Metema

Normal Economic analysis

Dominance Analysis

N-P_2O_5 (kg/ha)	TVC	NB	
0-0	0	3821	
46-0	338	4911	
0-46	374	3869	D
69-0	507	5302	
0-69	561	3887	D
46-46	580	5357	
92-0	676	5518	
46-69	701	5270	D
69-46	749	5084	D
115-0	845	5119	D
69-69	870	5578	
92-46	918	5630	
92-69	1039	5958	
115-46	1087	6601	
115-69	1208	6399	D

MRR Analysis

N-P_2O_5 (kg/ha)	TVC	NB	MRR(%)	Rank
0-0	0	3821		
46-0	338	4911	322 5	
69-0	507	5302	231.1	
46-46	580	5357	76.1	
92-0	676	5518	167.2	
69-69	870	5578	31.0	
92-46	918	5630	107 5	
92-69	1039	5958	271.7	2nd
115-46	1087	6601	1336.4	1st

Sensitivity economic analysis

Dominance Analysis

N-P_2O_5 (kg/ha)	TVC	NB	
0-0	0	3821	
46-0	423	4826	
0-46	468	3775	D
69-0	635	5174	
0-69	702	3746	D
46-46	725	5211	
92-0	846	5348	
46-69	877	5094	D
69-46	937	4896	D
115-0	1058	4906	D
69-69	1088	5359	
92-46	1148	5399	
92-69	1300	5697	
115-46	1360	6328	
115-69	1511	6095	D

N-P_2O_5 (kg/ha)	TVC	NB	MRR (%)	Rank
0-0	0	3821		
46-0	423	4826	237 6	
69-0	635	5174	164 5	
46-46	725	5211	40.8	
92-0	846	5348	113.4	
69-69	1088	5359	4 7	
92-46	1148	5399	65.7	
92-69	1300	5697	197 0	2nd
115-46	1360	6328	1047 2	1st

**TVC=Total Variable Cost (Birr/ha), **NB= Net Benefit (Birr/ha)*

Conclusion and recommendation

The fertilizer rate 69-23 N-P_2O_5 kg/ha is found to be the best recommended rate for rice production in Fogera plain. In case farmers face money shortage at the time of planting, the 46-46 N-P_2O_5 and 46-0 N-P_2O_5 rates could be used as a second and third alternatives. Regarding Metema area it is 115-46 N-P_2O_5 kg/ha fertilizer rate which is recommended for rice production in the area. Metema area farmers could use 92-69 N-P_2O_5 rate as second alternative. Concerning the time of application, in Fogera as well as Metema areas all the recommended P_2O_5 and half of the recommended nitrogen should be applied at planting and half of the remaining nitrogen at tillering stage of the crop. However further study on timing of nitrogen fertilizer application for rice production is vital.

Reference

AICAF.1992. Hand book of tropical rice cultivation. Association for International Cooperation of Agriculture and Forestry (AICAF), Japan.

CIMMYT. 1988. From agronomic data to farmer recomendations: An economic training manual. Revised Edition. Mexico, D.F.

Doberann, A. and T. Fairhurst. 2000. Rice Nutrient Disorders and Nutrient Management. Potash & Phosphate institute (PPI), Potash & Phosphate institute of Canada (PPIC) and International Rice Research Institute (IRRI).

Dowswell, C.R, R.L Paliwall and R.P. Cantrell. 1996. Maize in the Third World. West View press. New York.

Lee, K.S., J.H. Jun and H.T.Shin. 1998.Effective amount of nitrogen fertilizer for direct seeding on wet surface of reclaimed soil in Korea. IRRN. 23:2. PP.29.

Singh, S. P. and K.G. Pillai. 1994.Response to Nitrogen in semidwarf scented rice varieties. IRR Notes vol.19 No. 4.

Tesfaye Zegeye, Befekadu Alemayehu and Aklilu Agidie. 2005. Rice Production, Consumption and Marketing: The Case of Fogera, Dera and Libokemkem Districts of Amhara Region. Paper Presented at Rice Research and Promotion Workshop, June 3-4, 2005. Bahir Dar, Ethiopia.

Mulugeta Seyoum. 1997. Uptake and Response of Rice (Oryza sativa L.) to Nitrogen and Phosphorous Fertilization under Rainfed Lowland Condition of the Fogera Plain, Northern Ethiopia. MSc Thesis. Alemaya University, Ethiopia.

Norman, J.C and E. Otoo. 2003. Rice development strategies for food security in Africa. FAO CorporateDocumentRepository. Proceedings ofthe20th Session of the International Rice Commission. Bangkok.

Determination of Optimum Rates of Nitrogen & Phosphorus Fertilization for Sorghum (*Sorghum bicolor*) Production in Alefa Takusa Area, North Gondar

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Abstract

Information on the response of sorghum to nitrogen and phosphorous fertilizers in north Gonder areas is scanty. Low soil fertility particularly nitrogen and phosphorous nutrients deficiencies are among the major biophysical constraints affecting cereal crops including sorghum production. Field experiment was conducted at Alefa Takusa for three consecutive years to investigate the economic optimum fertilizer rate for sorghum production. Seven treatments of nitrogen and phosphorous fertilizers (0/0, 41/46, 55/23, 64/46, 87/46, 96/69 & 110/46 N/P2O5 kg ha^{-1}) were studied in randomized complete block design with three replications. The results revealed that the higher grain yield was obtained with the application of 96/69 kg N/P_2O_5 ha^{-1}. However, fertilizer rate of 41/46 kg N/P2O5 ha-1 was found an economical rate with a net benefit of Eth. birr 2357 ha^{-1}.

Introduction

Sorghum (*Sorghum bicolor*) is one of the most important cereal crops grown in north Gondar. Both the seed and the stalk are used in diversified ways. Alefa Takusa is one of the potential areas of north Gondar zone where sorghum is largely produced. Sorghum contributes the highest share (43.74 %) of production as compared to other crops grown in the zone (ANRS BOPED 2002). Low soil fertility particularly nitrogen and phosphorous nutrients deficiencies are among the major biophysical constraints affecting cereal crops including sorghum production (Taye *et al*, 1996). Continuous cropping, overgrazing, high soil erosion and removal of field crops residues without any soil amelioration mainly aggravate the poor soil fertility. As a result the productivity of the major crops in northwestern Ethiopia is very limited (UNDP 1996, Fasil and Abera 1997). Increase of crop production require the applications of better technologies. Fertilizer application is a lead practice in the introduction of improved technologies. Increased productivity of sorghum can be achieved by adopting improved agronomic practices and cultivars. Under favorable conditions the yield of sorghum can exceed 100 q/ha (Murty *et al* 1994). Sorghum showed responses to N and P application through out the whole India. Improved varieties and hybrids of sorghum responded to N rates ranging from 60 to 150 kg N ha^{-1}, where as a response to P application was observed up to 40 kg P ha^{-1} (Pal *et al*, 1982). Asfaw *et al*, 1997 reported good responses of sorghum grain yield to N and P application in Ethiopia. Though, a blanket fertilizer application was recommended for sorghum production across different agro ecologies of the region, farmers in the Alefa Takusa area still didn't apply fertilizer for sorghum. Information on the response of sorghum to N and P fertilizers in north Gonder areas is scanty. Hence, this experiment was conducted to determine the economic optimum fertilizer rate for sorghum production in Alefa Takusa area, North Gondar.

Materials and methods

Sorghum fertilizer experiment was conducted on vertisol of farmers fields in Alefa Takusa area in the year 2001 to 2003. The experiment was carried out in collaboration with woreda agricultural development office. Training was given to the responsible woreda agricultural experts on how to manage the experiment and take the experimental data. It was designed in randomized complete block with three replications. Seven fertilizer rates (0/0, 41/46, 55/23, 64/46, 87/46, 96/69 & 110/46 kg N/P_2O_5 ha^{-1}) were used. Plants of the late maturing local variety (known as *Bule*) was grown on with a space of 75 cm between rows and 15 cm between plants on a plot size of 3.75 m x 4.8 m (18 m^2). DAP and Urea were used as sources of nitrogen and phosphorus. All P_2O_5 and half N applied at planting and the other half of N applied at knee height growth stage of the crop. Grain yield data was collected andsubjected to analysis of variance using MSTATC statistical software. Cost of fertilizers of the year 2005 and average grain price of the three months (January, February and March) of the year 2006 were used for the economic analysis. Sensitivity analysis was made based on the trend of market prices of the grain and fertilizers with the assumption that cost of fertilizers increased by 20% and grain price remain constant (Table 1).

Table 1: Cost of fertilizer inputs and price of sorghum grain for the economic analysis

Cost/Price of input/output	Current situation (Birr/kg)	Sensitivity analysis (Birr/kg)
Cost of DAP	3.74	4.49
Cost of Urea	3.38	4.06
Price of sorghum grain	1.60	1.60

Mean grain yield data over sites was adjusted down by 10% and subjected to partial budget and sensitivity economic analysis following CIMMYT methodology (CIMMYT, 1988). Total costs that varied (fertilizer cost) for each treatment was calculated and treatments were ranked in order of ascending total variable cost (TVC). Dominance analysis was used to eliminate those treatments costing more but producing a lower net benefit than the next lowest cost treatment. The marginal rate of return (MRR) was calculated for each non-dominated treatment. Experiences have shown that the minimum rate of return acceptable to farmers will be between 50 to 100%.

Results and discussion

Results of soil sample analysis indicated 0.01% of total nitrogen (N), 2.401% of organic carbon (OC), 4.139% of organic matter (OM), 1.602 ppm of available phosphorus (P) and pH of 7.02 According to the soil classification of Landon 1991, the area, Alefa Takusa, was found to have low OC and available P, very low total N and neutral soil.

Out of the six sites, four sites showed significant responses in sorghum grain yield to fertilizer application (Table 2). In all of the sites the lowest yield was recorded without fertilizer application where as the highest grain yield for the three sites out of six sites was obtained with the application of 96/69 kg N/P_2O_5 ha^{-1}. As it was observed in most of the experimental sites it seems that stalk borer infestation was positively correlated to fertilizer application. This is an indication for further study on stalk borer infestation in relation to fertilizer rates and its control measures shall be investigated. In all the three years and combined over years significant responses on grain yield observed due to differences in fertilizer rates (Table 3). The lowest and highest grain yields were obtained on the unfertilized plot and with fertilizer application of 96/69 kg N/P_2O_5 ha^{-1}, respectively. Results on combined analysis over years revealed a yield increase of 968 kg/ha (77%) over the unfertilized plot with application 96/69 kg N/P_2O_5 ha^{-1}.

Table 2: Analysis of variance on grain yield of sorghum for individual sites in Alefa Takusa area

Source of varaition	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6
N X P_2O_5	*	**	NS	*	NS	**
Mean yield (kgha^{-1}) of 0/0 N/ P_2O_5	1037	815	1204	852	1944	1636
Highest mean yield (kgha^{-1})	2148	1944	1815	1870	3417	2407
N/ P_2O_5 comb. for highest yield	96/69	41/46	96/69	110/46	96/69	41/46
CV (%)	24.59	11.34	26.54	21.70	18.80	9.28

*, ** Significant at 5 & 1% level of significance, respectively [NS] Non-significant

Table 3. Grain yield of sorghum as affected by nitrogen and phosphorus rates in Alefa Takusa area

N/P_2O_5 kg ha^{-1}	2001	2002	2003	Combined over years
0/0	1037	957	1790	1248
55/23	1296	1420	2511	1763
41/46	1278	1735	2802	2014
64/46	1704	1395	2509	1818
87/46	1519	1784	2333 .	1923
110/46	1667	1340	2593	1812
96/69	2148	1784	2897	2216
CV(%)	24.59	21.02	15.93	19.32
$LSD_{5\%}$	665.3	298.9	472.9	234.6

The partial budget analysis at the current situation indicated that fertilizer rate 41/46 kg N/P_2O_5 ha^{-1} was economical rate with acceptable MRR (1908%) and highest net benefit of Eth. birr 2357 ha^{-1} (Table 4). An increase in net benefit of Eth. birr 560 was recorded over the unfertilized one. The sensitivity analysis further indicated the same fertilizer rate recommendation with a net benefit of Eth. birr 2248 ha^{-1}. Hence from the present investigation based on the normal and sensitivity economic analysis the 41/46 kg N/P_2O_5 ha^{-1} could be recommended for the production of late maturing sorghum varieties in Alefa Takusa area.

Conclusion and recommendation

The highest sorghum grain yield was recorded with the application of 96/69 kg N/P_2O_5 ha^{-1}. However, the economic analysis indicated 41/46 kg N/P_2O_5 ha^{-1} was the most profitable rate in Alefa Takusa area. Fertilizer rate of 41/46 kg N/P_2O_5 ha^{-1} could be used as the optimum recommended rate under the conditions where stalk borer is not a sever problem for sorghum production. Further study on stalk borer infestation in relation to fertilizer rates shall be investigated in the locality.

Table 4. Economic analysis of nitrogen and phosphorus fertilizers rate on grain yield of sorghum in Alefa Takusa area

	Scenario 1 (at current situation)			Scenario 2 (sensitivity)		
N/P_2O_5 ($kgha^{-1}$)	TVC (Eth. birr)	NB (Eth. birr)	MRR (%)	TVC (Eth. birr)	NB (Eth. birr)	MRR (%)
0/0	0	1797		0	1797	
55/23	525	2014	41	631	1908	18
41/46	543	2357	1908	652	2248	1581
64/46	712	1906 D		855	1763 D	
87/46	881	1888 D		1058	1711 D	
110/46	1050	1559 D		1261	1348 D	
96/69	1068	2123 D		1283	1909 D	

NB = net benefit TVC = total variable cost MRR = marginal rate of return

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References

ANRS BOPED (Amahara National Regional State Bureau of Planning and Economic Development). 2001/2002. Annual Statistical Bulletin 2001/2002. Bahir Dar Ethiopia.

Asfaw Belay, Heluf Gebrekidane, Yohannes Uloro and Eyelachew Zewdie. 1997. Effect of crop residue grain yield response of sorghum (Sorghum bicolor) to application of N and P fertilizer. Nutrient Cycling in Agroecosystems. 46(3), 191-196.

CIMMYT. 1988. From agronomic data to farmer recommendations: An economics training manual. Completely revised edition. Mexico, D.F.

Fasil Reda. and Abera Debelo. 1997. Melkasa Agricultural Research Center Profile, IAR, Addis Ababa. Ethiopia.

Landon, J.R. (Ed). 1991. Booker Tropical Mannual. A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics.

Murty D.S, Tabo R and Ajayi O. 1994. Sorgum hybrid seed production and managment. Information bulletin no. 41. ICRISAT, India

Taye Bekele, Yeshanew Ashagrie, Balesh Tulema and Girma Gebrekidan. 1996. Soil fertility Management in Barley. In: Hailu Gebre and Toop van Leur (eds.). 1996. Barley Research in Ethiopia: Past Work and Future Prospects. Proceedings of The First Barley Research Review Workshop, 16-19 October 1993, Addis Abeba, Ethiopia.

UNDP. 1996. Sustainable Agricultural and Environmental Rehabilitation Program (SAERP). House Hold Level Socio-Economic Survey of the Amhara Region. V.1 Produced By the Amhara Regional Council. Bahir Dar, Ethiopia.

Pal,U.R., UC. Upadhyay, SP. Singh and NK. Umrani. 1982. Mineral nutrition and fertilizer response of grain sorghum in India – A review over the last 25 years. Nutrient Cycling in Agroecosystems. 3(2).

Response of Triticale to Nitrogen and Phosphorus Fertilizers on the Different Agro-Ecologies of Northwestern Ethiopia

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Abstract

A multi-location fertilizer response trial was conducted on representative farmers' fields at Laie-Gaient, Farta, Banja and Snan areas of northwestern Ethiopia during 2002 to 2004 cropping seasons. The principal objective of the trial was to investigate the response of triticale to nitrogen and phosphorus nutrients and to determine the economical optimum fertilizer rate. The experiment was designed in a complete factorial arrangement in RCB with three replications. It consisted of 15 factorial combinations of five nitrogen (N) rates (0, 23, 46, 69 and 92 kg N/ha) and three phosphorous (P_2O_5) rates (0, 23, and 46 kg P_2O_5/ha). The result revealed that N, P, N by P interaction significantly affected most crop parameters at all the locations. The highest mean grain yields of 3818 kg/ha at Laie-Gaient, 2686 kg/ha at Farta, 2680 kg/ha at Snan and 2988 kg/ha at Banja were obtained with the application of 92-46 kg N-P_2O_5/ha, representing an increase of 107, 104, 159 and 139% over the unfertilized treatment at the respective locations. Fertilizer rate of 92-46 kg N-P_2O_5/ha remains economically profitable with acceptable marginal rate of return 428% in Laie-Gaient, 263% in Farta and 153% in Snan areas. In Banja 92 kg N/ha was the most profitable rate with acceptable marginal rate of return 670%. If the input cost increased by 10% and output price decreased by 40% the above recommendations remains profitable for Farta and Banja areas while for Laie-Gaient 46-23 kg N-P_2O_5/ha found to be recommended and for Snan fertilizer rate of 69-46 kg N-P_2O_5/ha will be the most profitable economical rate.

Introduction

Triticale (*Triticosecale wittmack*) is wheat-rye (*Triticum aestivum - Secale cereale*) hybrid. The name triticale derived from the genus name of its parental lines that comprise Triticum from wheat and secale from rye crop. It possesses the yield potential of wheat and hardiness of rye. It is well adapted to cold, drought, acidic soils, and wider geographic ranges. It is resistance to disease and pests as compare to wheat and barley. Consequently, triticale is successfully grown in almost all environments where its parental species are grown (Stoskopf, 1985; NRC, 1989). In favorable environmental condition its yield equals that of wheat; however, under poor conditions its yield exceeds that of wheat. Triticale has a multipurpose use for human consumption and animal feed. It is rich in protein (10%-16%) and lysine (3.1%-4.0%) than wheat (Inagaki et al., 1997; Varughese et al., 1996). Triticale has a very extensive root system and can mine the soil more efficiently in conditions where fertility is poor (Salmon D.P. et al., 2004).

Subsistence farmers living in marginal highland areas of the Amhara Region, such as Lay-Gaient, Banja and Snan(Robu Gebeya) are suffering from a year-to-year food shortage mainly due to soil degradation, frost and as a result of which declining of crop yields. Poor soil fertility is the major yield limiting factor in the highland areas of the region. To mitigate the effects of climate change and chronic food shortage, the region encourages crop diversification and the introduction of highly adaptable crops, such as triticale. Therefore, to alleviate the chronic food shortage, Adet Agricultural Research Center has released two promising triticale varieties in 2002 known as USGEN19 ("Minet") and 95T62 A-P-L 9-m ("Snan"). Even though these varieties are ready for dissemination in the marginal highland areas of Gaient, Banja and Snan, the production packages, such as proper cultural practices and optimum rate of fertilizer recommendations for the areas are not available. Results of fertilizer studies at CIMMYT indicated that application of N at the rate of 0, 75, 150 and 500 kg/ha increased triticale grain yield by 1.6, 5.0, 7.0 and 7.5 tones/ha, respectively(Mergoum M., et al., 2004). Fertilizer recommendation is very specific to climatic and soil condition. Thus the experiment was conducted to investigate the response of triticale crop to nitrogen and phosphorus nutrient and to determine economic optimum rate of fertilizer for triticale production in the highland areas of northwest Ethiopia.

Materials and methods

The experiment was conducted on Luvisols of farmers' fields in Farta and Laie-Gaient (south Gondar), Acrisols of Banja (Awi zone) and Snan (east Gojam) in the year 2002 to 2004 main cropping seasons. It was executed in a total of seven sites at Laie-Gaient, eight at Farta, seven at Snan and six sites at Banja. The altitude of the locations ranged from 2600 to 2860 m.a.s.l. The rainfall distribution at Laie-Gaient and Farta areas were erratic (late onset and early cease) during the experimental seasons. The rainfall received during the growing season usually causes severe erosion, which hamper the production of the major crops.

The experiment consists of 15 factorial combinations of five nitrogen rates (0, 23, 46, 69 and 92 kg N/ha) and three phosphorous rates (0, 23, and 46 kg P_2O_5/ha). The design was a complete factorial arrangement in RCB with three replications. Seeds of the triticale variety, "minet" at Laie-Gaient, Farta and Banja and "snan" at Snan were broadcasted at the seed rate of 175 kg/ha. All sowing dates were in the middle of June in each year. Urea and DAP/TSP were used as a source of N and P, respectively. All P and half of N fertilizers were applied at sowing, and the remaining N was top dressed at the early to mid-tillering stage of the crop. The gross and net plot sizes were 5 m x 4 m (20m^2) and 4 m x 3 m (12m^2), respectively. Data were collected on grain yield, plant height and number of fertile spike per m^2. All the data were subjected to analysis of variance (ANOVA) using MSTATC statistical software. The mean grain yields for the fifteen N by P combinations were also subjected to discrete economic analysis using partial budget methodology (CIMMYT, 1988). Since the crop is recently introduced to the region, the price of the grain has taken depending on farmers to farmers' seed exchange rate for the seeding purpose (not as grain purpose) at Farta local market conditions (Messfin, 2005).Two cost/price scenarios were used during the experimentation period. In the first case mean cost of input (fertilizer) and mean price of triticale grain was considered at peak period (output). In the second

scenario it was assumed that the cost of fertilizer increased by 20% while the price of the grain fall by 40%. The following cost and prices were considered for economic analysis (Table 1).

Table 1. Fertilizer costs and grain price for the economic analysis

Grain and Fertilizer costs	For the normal/current market cost/price	For the sensitivity cost/price[b]
Grain price[a] (EB/kg)	2.12	1.27
Urea cost (EB/kg)	3.38	4.06
DAP cost (EB/kg)	3.74	4.49

[a] *Prevailing farmer price during peak sales (i.e. Dec. to Feb.); Cost of fertilizer increased by 20% & grain price decreased by 40%*

Results and discussion

The soil samples were collected from each experimental site, in each location at planting time. The samples were mixed as one sample for each location. The results of laboratory analysis of the soil during planting time were indicated moderately acidic with medium to low levels of organic matter; total N and available P were observed. While at Banja acidity of the soil was found to be higher than other locations (Table 2).

Table 2. Soil characteristics of the four locations at the time of planting

Soil properties	Banja	Snan	Farta	Laie-Gaient
pH	4.81	6.05	5.17	5.76
Organic carbon (%)	4.24	3.24	3.20	3.60
Total N (%)	0.37	0.40	0.08	0.28
Available P (ppm)	2.55	9.93	3.70	0.59

The results of ANOVA for grain yield at each site of the locations are presented (Table 3-5). Triticale grain yield exhibited statistically significant difference to nitrogen almost in all sites of the locations. Grain yield response to phosphorus varied according to the locations. In Farta and Snan areas majority of the sites showed significant grain yield response to phosphorus where as in Laie-Gaient and Banja it was the reverse. The mean grain yield obtained from the unfertilized treatment ranged from 1277 to 2355 kg/ha in Laie-Gaient, 561 to 2479 kg/ha in Farta, 377 to 1981 in Snan and 517 to 2562 in Banja. The high yield potential of the locations is manifested in the fertilized plots. The mean yields ranged from 3347 to 4492 kg/ha in Laie-Gaient, 2106 to 4339 kg/ha in Farta, 1697 to 4013 kg/ha in Snan and 2205 to 3924 kg/ha in Banja.

The results of the combined analysis of variance (i.e., across the experimental sites in each location) for grain yield, plant height and fertile spike/m^2 are presented in Table 5 and 6.

The result revealed that N, P, N x P and site by N interaction are significantly affected most crop parameters at all the locations except site by N interaction at Laie-Gaient area.

Table 3. Aanalysis of variance on grain yield of triticale for individual sites at Laie-Gaient and Farta

Source of variation	Laie-Gaient							Farta							
	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7	Site-8
N	*	**	*	*	NS	**	**	**	**	**	NS	**	*	**	**
P_2O_5	**	NS	NS	NS	*	NS	NS	**	**	**	*	**	NS	**	NS
N X P_2O_5	NS	NS	NS	NS	NS	NS	NS	*	NS	*	NS	*	NS	*	NS
Mean yield ($kgha^{-1}$) of 0/0 N/ P_2O_5	1740	1844	1642	2307	1727	2355	1277	812	1007	866	2479	561	2463	1027	1340
Highest mean yield ($kgha^{-1}$)	4357	3347	3362	4176	4171	4492	3940	2543	2531	3238	4339	2109	3564	2322	2106
N/ P_2O_5 comb for highest yield	92/46	46/23	69/23	92/46	69/46	92/46	92/23	92/46	92/23	92/46	92/46	92/23	92/46	92/46	69/23
CV(%)	28 74	23.62	34.55	25 06	34 72	14.58	30.21	25 93	24 91	23 91	22 07	23 37	19 48	29 11	19.41

*, ** *Indicate significance at the 5 % and 1% levels, respectively. NS Indicate non-significance*

Table 4. Analysis of variance on grain yield of triticale for individual sites at Snan and Banja

Source of variation	Snan							Banja					
	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6
N	**	**	**	**	**	**	**	**	**	**	**	**	**
P_2O_5	NS	NS	**	NS	*	**	**	NS	NS	NS	*	NS	NS
N X P_2O_5	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean yield ($kgha^{-1}$) of 0/0 N/ P_2O_5	1345	935	443	686	377	1462	1981	1889	619	1283	627	2562	517
Highest mean yield ($kgha^{-1}$)	3811	2359	2060	1697	1780	3640	4013	3597	2590	3699	2413	3924	2205
N/ P_2O_5 comb for highest yield	92/46	69/46	69/46	69/46	92/0	69/46	92/46	92/0	92/0	92/46	92/0	69/46	92/46
CV(%)	27.08	24 10	25.86	19 88	23 75	18.76	17 61	22 54	24 81	22.79	12 59	17 77	27.30

*, ** *Indicate significance at the 5 % and 1% levels, respectively.. NS Indicate non-significance*

Significant site by N interaction suggest that heterogeneity for initial soil N levels among the site may have exerted a differential effect on the response of the crop to N application. It has been reported that the N use efficiency of crops is enhanced due to important soil factors that may affect the availability of applied P, soil moisture, available P, and the nature and amount of clay in the soil (Desta, 1988).

Grain yield increased linearly in response to applied nitrogen and phosphorus (Table 6) in all the locations. The highest mean grain yields 3818 kg/ha in Laie-Gaient, 2686 kg/ha in Farta, 2680 in Snan and 2988 kg/ha in Banja were obtained from the application of 92-46 kg N-P_2O_5/ha, representing an increase of 107, 104, 159 and 139% over the unfertilized treatment at the respective locations. The agronomic efficiency for N application ranged from13.1-16.4, 8.26-9.67, 11.9-12.4 and 13.7-17.7 kg of grain yield per 1 kg of N applied for the different treatment intervals in Laie-Gaient, Farta, Snan and Banja areas, respectively. Similarly the agronomic efficiency for P ranged from 16.1-21.6, 11.4-15.6, 9.8-10.8 and 6.6-3.8 kg of grain yield per 1 kg of P applied for the different treatment intervals in Laie-Gaient, Farta, Snan and Banja areas, respectively. This realized that higher grain yield response to P than N in Laie-Gaient and Farta areas where as lower grain yield response to P than N in Snan and Banja areas. Grain yield was positively and linearly correlated with plant height and fertile spike in all the locations (Fig.2-3). Plant height was increased in response to applied nitrogen (Fig.1). It showed significant response to phosphorus application in all the locations where as number of fertile spike showed significant response to N in all locations except at Banja.

Table 5. Combined analysis of variance across sites at each location on grain yield and other yield components of triticale at Laie Gaient, Farta, Snan and Banja

Source of variation	Laie Gaient			Farta			Snan			Banja		
	Grain yield (kg/ha)	Plant height (cm)	Fertile spike/m^2	Grain yield (kg/ha)	Plant height (cm)	Fertile spike/m^2	Grain yield (kg/ha)	Plant height (cm)	Fertile spike /m^2	Grain yield (kg/ha)	Plant height (cm)	Fertile spike/m^2
Site (S)	**	**	**	**	**	**	**	**	**	**	**	**
N	**	**	*	**	**	NS	**	**	**	**	**	*
NxS	NS	NS	NS	NS	**	NS	**	NS	NS	**	*	NS
P_2O_5	**	**	*	**	**	NS	**	**	**	*	*	NS
P_2O_5 x S	NS	NS	NS	NS	**	NS	NS	*	NS	NS	NS	NS
N x P_2O_5	*	*	*	**	*	NS	*	*	*	*	*	NS
Mean value of 0/0 N/P_2O_5	1841	94.1	250	1319	85.2	309	1033	68.0	281	1249	83.9	338
Highest mean value	3818	116.9	334	2686	108.0	348	2680	95.2	355	2988	109.3	391
N/P_2O_5 comb. for highest value	92/46	92/46	92/46	92/46	92/46	46/46	92/46	92/46	92/0	92/46	92/0	69/46
CV%	27.30	7.16	21.27	23.81	5.59	22.84	22.69	7.78	22.60	21.98	6.69	17.93

*, ** *Indicate significance at the 5 % and 1% levels, respectively.; NS Indicate non-significance.*

Table 6. Effect of nitrogen and phosphorus on the grain yield of triticale in different localities

N levels (kg/ha)	*Laie-Gaint* P_2O_5 levels (kg/ha)				Farta P_2O_5 levels (kg/ha)				Snan P_2O_5 levels (kg/ha)				Banja P_2O_5 levels (kg/ha)			
	0	23	46	Mean	0	23	46	Mean	0	23	46	Mean	0	23	46	Mean
0	1841	2063	2272	2059	1319	1364	1522	1402	1033	1285	1350	1223	1249	1201	1357	1269
23	1934	2611	2563	2369	1417	1687	1672	1592	1305	1489	1697	1497	1451	1706	1704	1620
46	2248	3074	3119	2814	1448	1918	2049	1806	1575	1769	2031	1792	1806	2009	1880	1898
69	2712	2824	3350	2962	1732	2110	2364	2069	1754	1964^C	2455	2058	2250	2667	2558	2492
92	2686	3331	3818	3278	1758	2386	2686	2277	2059	2350	2680	2363	2861	2794	2988	2881
Mean	2284	2781	3024		1535	1893	2059		1545	1771	2042		1924	2076	2097	
CV (%)		27.30				23.81				22.69				21.98		
	N	P	N x P_2O_5		N	P	N x P_2O_5		N	P	N x P_2O_5		N	P	N x P_2O_5	
$LSD_{(5\%)}$	258.6	200.3	448.0		143.0	110.8	247.7		142.5	110.3	246.7		169.7	131.5	294.0	

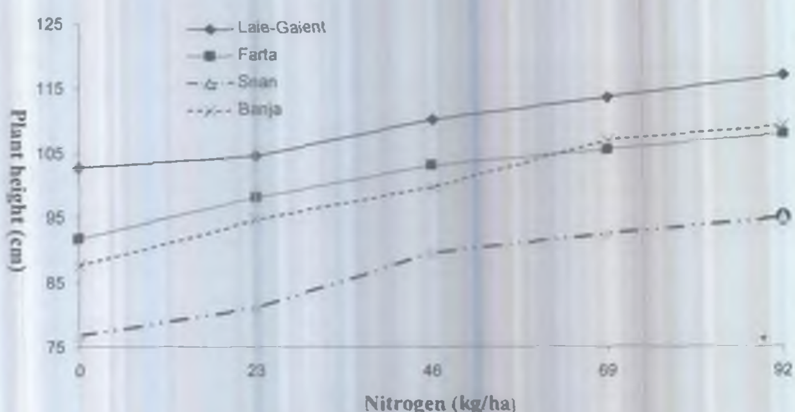

Fig1. Triticale plant height response to nitrogen application at 46 kg/ha of phosphorous

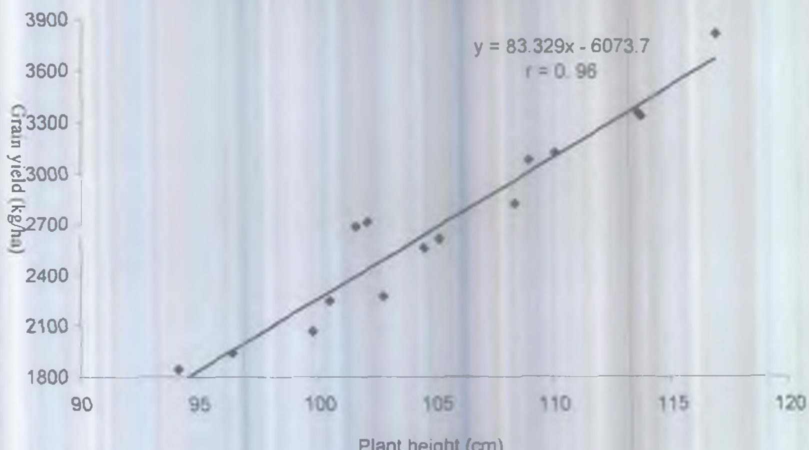

Fig.2. Inter relationship between grain yield and Plant heght of triticale in Laie-Gaient

The results of partial budget analysis are given in Table 7 and 8. According to the results of the economic analysis the most profitable fertilizer rate with acceptable marginal rate of return (MRR) for triticale production in Laie-Gaient, Farta and Snan areas is 92-46 kg N-P_2O_5/ha. This rate exhibited MRR of 428% in Laie-Gaient, 263% in Farta, 153% in Snan, which are by far higher than the assumed minimum acceptable MRR of 100%. While 92-0 kg N-P_2O_5/ha. at Banja is the most profitable rate with acceptable MRR (670%). However, if farmers have cash constraint to purchase the fertilizer during planting time, 69-46 kg N-P_2O_5/ha could be used as alternative recommendation in Farta and Snan. Where as 46-23 kg N-P_2O_5/ha for Laie-Gaient and 69-23 kg N-P_2O_5/ha for Banja could be used as alternative recommendations.

Moreover, sensitivity analysis was made to see the sensitivity of the recommended fertilizer rate when subjected to input and output price changes. The above most profitable recommendation, 92-46 kg N-P_2O_5/ha does not remain profitable for Laie-Gaient, Farta and Snan areas. While, for Farta and Snan the second alternative recommendation (69-46 kg N-P_2O_5/ha) and 46-23 kg N-P_2O_5/ha remains profitable. While, for Banja area the first most profitable recommendation (92-0 kg N-P_2O_5/ha) is still profitable even if the cost of inputs, (DAP and urea) rise by 20% and the price of output (grain) falls by 40%.

Table 7. Economic analysis on grain yield of triticale for non-dominated treatments for Laie-Gaient and Farta

	Laie-Gaient						Farta						
	At the current cost/price of input and output			Sensitivity analysis			At the current cost/price of input and output				Sensitivity analysis		
Treatments N-P_2O_5 kg/ha	TVC (ET Birr)	NB (ET Birr)	MRR (%)	TVC (ET Birr)	NB (ET Birr)	MRR (%)	Treatment N-P_2O_5 kg/ha	TVC (ET Birr)	NB (ET Birr)	MRR (%)	TVC (ET Birr)	NB (ET Birr)	MRR (%)
0-0	0	3514		0	2105		0-0	0	2517		0	1508	
23-0	169	3520	3	203	2007 D		23-0	169	2534	10	203	1416 D	
0-23	187	3748	1267	224	2133	12	23-23	289	2929	326	348	1580	20
23-23	289	4692	917	348	2636	407	46-23	458	3200	160	551	1640	29
46-23	458	5406	422	551	2962	160	46-46	579	3330	107	696	1646	3
69-46	748	5642	81	899	2929 D		69-23	627	3398	141	754	1657	20
92-46	917	6366	428	1102	3261	54	69-46	748	3761	300	899	1803	100
							92-46	917	4208	263	1102	1968	81

D - dominated treatment, TVC - Total variable cost, NB - Net benefit, MRR - Marginal Rate of Return

Table 8. Economic analysis on grain yield of triticale for non-dominated treatments for Snan and Banja

	Snan						Banja						
	At the current cost/price of input and output			Sensitivity analysis			At the current cost/price of input and output				Sensitivity analysis		
Treatments $N-P_2O_5$ kg/ha	TVC (ET Birr)	NB (ET Birr)	MRR (%)	TVC (ET Birr)	NB (ET Birr)	MRR (%)	Treatment $N-P_2O_5$ kg/ha	TVC (ET Birr)	NB (ET Birr)	MRR (%)	TVC (ET Birr)	NB (ET Birr)	MRR (%)
0-0	0	1971		0	1180		0-0	0	2384		0	1428	
23-0	169	2321	207	203	1289	53	23-0	169	2599	127	203	1455	13
23-23	289	2550	189	348	1353	44	23-23	289	2965	302	348	1602	101
46-0	338	2667	243	406	1394	70	46-0	338	3107	293	406	1657	96
23-46	410	2826	218	493	1446	59	46-23	458	3375	221	551	1745	60
46-23	458	2916	186	551	1470	42	69-0	507	3786	853	609	1962	374
46-46	579	3295	313	696	1625	106	69-23	627	4461	558	754	2294	228
69-46	748	3935	378	899	1906	138	92-0	676	4783	670	812	2458	283
92-46	917	4195	153	1102	1960	26							

Conclusion and Recommendation

Triticale was found very responsive to nitrogen fertilizer in all locations. It was also responsive to phosphorus fertilizer in the three locations except Banja. Fertilizer rate of 92-46 kg $N-P_2O_5$/ha for Laie-Gaient, Farta and Snan areas and 92-0 kg $N-P_2O_5$/ha for Banja area are economical recommended rate for triticale production at the current market situation. If the cost/price of input and output changes, 69-46 kg $N-P_2O_5$/ha for Snan and Farta, 46-23 kg $N-P_2O_5$/ha for Laie-Gaient and 92-0 kg $N-P_2O_5$/ha for Banja could be economically recommended.

References

CIMMYT. 1988. From agronomic data to farmer recomendations: An economic training manual. Revised Edition. Mexico, D.F.

Desta Beyene. 1988. Soil fertility assessement of Ethiopian vertisols soil. PP. 223-231. In Jutzi, S.C., Haque, I.,McIntire, J and Stares, J.E.S (eds). Management of Vertisols in Sub-Saharan Africa. Addis Ababa. Ethiopia: ILCA.

Inagaki, M. N., Pfeiffer, W. H., Mergoum, M., Mujeebkazi, A. and Lukaszewski, A. J. 1997. Effects of D-genome chromosomes on crossibility of hexaploid triticale with maize. Plant Breeding. 116:387-389

Mergoum, M. W.H. Preiffer, R.J. Pena, K Ammar, S.Rajaram. 2004. Triticale crop improvement and management. In: Mohamed Mergum and Helena Gomez(Ed.), Triticale improvement and production. FAO, Plant production and protection paper-179.

Mesfin Astatkie. 2005. Analysis of factor influenced adoption of triticale and its impact: The case of Farta woreda. An M. Sc. Thesis presented to the School of Graduate Studies of Alemaya University, Ethiopia.

NRC (National Research Council). 1989. Triiticale: A promising Addition to the World's Cereal Grains. National Academy Press, National Research Council, Washington, DC

Salmon D.P., Mergoum M, H.Gomez Marcpherson. 2004. Triticale production and management. In: Mohamed Mergum and Helena Gomez(Ed.), Triticale improvement and production. FAO, Plant production and protection paper-179.

Stoskopf, N. C. 1985. Triticale, In Cereal Grain Crops. Reston Pub. Reston, VA

Varughese, G., Pfeiffer, W. H. and Pina, R. J. 1996. Triticale: A successful alternative crop (part 1 and 2). Cereal foods world. 41 (6/7): 474-645.

The Influence of Seed Rate on the Grain Yield and Yield Components of Triticale (*Triticosecale wittmack*)

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Abstract

Triticale is the introduced crop that possesses the yield potential of wheat and hardiness of rye. It adapts in extreme cold, drought, and acidic soil conditions. The seed rate trial was conducted on Luvisols of farmers' fields in Farta, Laie-Gaient and Snan areas in the year 2003 and 2004 main cropping seasons. The principal objective of the experiment was to determine optimum seed rate for triticale production. The design was a complete factorial arrangement of RCB with three replications. It consists of a factorial combinations of five seed rates (125, 150, 175, 200 and 225 kg/ha) and two released varieties ('Snan' and 'Minet'). The result revealed that the highest mean grain yield, 2981 kg/ha for "Minet" variety was obtained with the use of 200 kg/ha seed rate while for 'Snan' variety the data was inconsistent. According to economic analysis seed rate of 175 and 200 kg/ha produced 422 and 377% marginal rate of return (MRR), respectively which are by far higher than the assumed minimum acceptable MRR of 100%. Therefore, seed rates ranging from 175 to 200 kg/ha were found profitable and recommended rates for triticale production in Snan, Laie-Gaient and Farta areas.

Introduction

Crop diversification and use of introduced adaptable crops are the systems, which could alleviate the food shortage in drought-affected areas. Triticale (Triticosecale wittmack) is one of the introduced crops that possess the yield potential of wheat and hardiness of rye. It can adapt easily in extreme cold, drought, and acidic soils conditions. Triticale could successfully grow in almost all environmental conditions where its parental species are grown (Stoskopf, 1985; NRC, 1989). In addition, triticale has a multipurpose use for human consumption and animal feed (Inagaki et al., 1997; Varughese et al., 1996). Subsistence farmers living in marginal highland areas of the Amhara Region, such as South Gondar and East Gojam (Snan) are suffering from food shortage mainly due to soil degradation, drought, and lack of improved package of crop production.

For such areas two triticale varieties namely USGEN19 ('Minet') and 95T62 A-P-L 9-m ('Snan') were released in 2002 by Adet Agricultural Research Center in collaboration with GTZ. Even though these varieties are ready for dissemination to the users in the marginal highland areas of South Gondar, East Gojam and Awi zones, their production packages are not available. Among the production packages appropriate seed rate is one of the major yield-limiting factors. This paper therefore, presents results of seeding rate trial conducted at Laie-Gaient, Farta and Snan environmental conditions to determine the appropriate seed rate for triticale production.

Material and Methods

The experiment was conducted on Luvisols of farmers' fields in Farta and Laie-Gaient (South Gondar) and Snan (East Gojam) in the year 2003 and 2004 main cropping seasons. It was executed in a total of seven sites where two sites at Laie-Gaient, three sites at Snan and two sites at Farta. The altitude of the locations ranged from 2600 to 2860 m.a.s.l. The rain received during the growing season usually causes severe erosion, which hamper the production of the major crops.

The experiment was executed in a total of seven sites; where two sites at Laie-Gaient, three sites at Snan and two sites at Farta. The design of the experiment was in randomized complete block with three replications. It consists of 10 factorial combinations of five seed rates (125, 150, 175, 200 and 225kg/ha) and two released varieties ('Snan' and 'Minet'). Seeds of the triticale varieties were broadcasted for the respective seed rates. Urea and DAP as a source of fertilizer with a rate of 92/46 kg N/P_2O_5/ha were used. All P and half of N were applied at sowing, and the remaining N was top dressed at the early to mid-tillering stage of the crop. Gross and net plot size was 5 m x 5 m ($25m^2$) and 4 m x 4 m ($16m^2$), respectively. Data were collected on grain yield, plant height, number of fertile spike, tiller count and spike length. All the data were subjected to analysis of variance (ANOVA) using MSTATC statistical software. The mean grain yields for the ten treatment combinations were also subjected to discrete economic analysis using partial budget methodology (CIMMYT, 1988). Cost/price of triticale seed and grain were used during the experimentation period. Since the crop is recently introduced to the region, cost of the seed and grain price (birr 2.12 /kg) have been taken depending on farmers to farmers seed exchange rate for the seeding purpose (not as the grain purpose) at Farta local market conditions (Messfin, 2005) and sensitivity analysis was made with the assumption that cost of the seed and price of the grain decreased by 40%.

Results and Discussions

The results of the ANOVA for grain yield at each site of the location are presented in Table 1. Two of the three sites grain yield was significantly affected due to seed rate and the interaction of seed rate by variety in Snan. While in Laie-Gaient at one of the two sites grain yield was affected significantly due to variety and interaction of seed rate by variety. In Farta area, none of the sites exhibited significant difference due to treatments.

Table 1: Analysis of variance on grain yield of triticale for individual sites in the three locations

Source of variation	Snan			Laie-Gaient		Farta	
	Site-1	Site-2	Site-3	Site-1	Site-2	Site-1	Site-2
variety(V)	NS	NS	NS	**	NS	NS	NS
seed rate(Sr)	**	**	NS	NS	NS	NS	NS
Sr x V	*	*	NS	*	NS	NS	NS
CV (%)	16.48	16.03	29.48	15.89	29.28	23.42	21.77

**, ** Indicate significance at the 5 &1% probability levels, respectively. NS -Indicate non-significance difference*

The combined analysis of variance over the sites in each location on grain yield and other yield components are presented in Table 2. The significant difference in grain yield among the sites in each of the locations realized the variability of the sites. Grain yield was significantly affected by seed rate in Snan where as in Laie-Gaint and Farta areas neither of the variety, seed rate nor their interaction significantly affected grain yield. Plant height, number of fertile spike and length of spike were significantly affected by all the factors (variety, seed rate and their interaction) in Snan. At Laie-Gaient plant height was significantly affected by variety, where as grain yield, number of fertile spikes and spike length were not affected by any of the factors. In Farta area spike length showed significant difference to variety and seed rate while plant height for variety only. Grain yield and fertile spike respond for none of the factors. The "Minet" variety is out- standing as compared the "Snan" variety in all the measured crop parameters in all of the locations. Even though the difference in grain yield among the seed rates were not significant, almost linear grain yield increment was recorded in 'Minet' variety from the lower to higher seed rate except at the highest seed rate (225 kg/ha) in all the locations (Table 3). However, in case of 'Snan' variety the yield increment was inconsistent and therefore it was not considered. In general in case of 'Minet' variety the highest grain yield 2471 kg/ha in Snan, 3387 kg/ha in Laie-Gaient and 3532 kg/ha in Farta was obtained at the seed rate of 225 and 200 kg/ha, respectively. For the combined analyses over the three locations the highest mean grain yield, 2981 kg/ha for "Minet" variety was obtained with the use of 200 kg/ha seed rate, representing an increase of 333 kg over the lowest seed rate (125kg/ha). Where as in case of "Snan" variety the highest mean grain yield, 2917 kg/ha and 2600 kg/ha was obtained with the seed rates of 225 kg/ha and 150 kg/ha, respectively, but, the grain yield obtained with the 200 and 175 kg/ha (which are in between 150 & 225 kg/ha seed rates) were lower. This shows that the data was still inconsistent.

Table 2: Combined analysis of variance on grain yield and other yield components of triticale in the three locations

Source of variation	Snan				Laie-Gaient				Farta			
	Grain yield (kg/ha)	Plant height (Cm.)	Fertile spike/ m^2	Spike length (Cm.)	Grain yield (kg/ha)	Plant height (Cm.)	Fertile spike/m^2	Spike length (Cm.)	Grain yield (kg/ha)	Plant height (Cm.)	Fertile spike/ m^2	Spike length (Cm.)
Site (S)	**	**	**	**	*	*	**	**	*	*	**	**
Variety(V)	NS	*	**	**	NS	*	NS	NS	NS	*	NS	*
S x V	NS	NS	*	NS	NS	*	NS	NS	NS	*	NS	*
Seed rate(Sr)	**	*	*	**	NS	NS	NS	NS	NS	NS	NS	*
S x Sr	NS	*	*	NS	*	NS	NS	NS	NS	NS	NS	NS
Sr x V	NS	*	*	*	NS	NS	NS	NS	NS	NS	NS	NS
C.V%	19.15	7.11	22.28	8.13	24.39	6.90	30.13	11.59	24.97	3.83	20.88	7.15

**, ** Indicate significance at the 5 &1% probability levels, respectively.; NS -Indicate non-significance difference*

The over all response curves of 'Minet' variety to the different seed rates is shown in Fig.1. Grain yield slowly increased on the interval of 125 to 150 kg/ha seed rate and sharp increased in grain yield was observed as seed rate increased from 150 to 200 kg/ha and then slightly decline after the seed rate of 200 kg/ha. The yield components, fertile spike and spike length, showed response to seed rates (Fig.2).

Table 3. Effect of seed rate and variety on grain yield of triticale in the three locations

		Snan			**Laie-Gaient**			**Farta**			Combined over locations	
Seed rate (kg/ha)	Snan	Minet	Mean	Snan	Minet	Mean	Snan	Minet	Mean	Snan	Minet	Mean
125	1765	2211	1988	2505	3136	2820	2385.9	2817.9	2601.9	2153.8	2648.7	2401.2
150	1905	2413	2159	3122	2662	2892	3121.5	3063.9	3092.7	2600.3	2669.8	2635.1
175	1951	2472	2211	2871	3110	2990	2581.2	3077.8	2829.5	2393.9	2827.4	2610.7
200	2110	2456	2283	2930	3218	3075	2922.9	3532.2	3227.6	2577.0	2981.4	2779.2
225	2154	2471	2313	3705	3387	3546	3272.7	3250.1	3261.4	2916.8	2955.5	2936.1
Mean	1977	2405		3027	3103		2856.8	3148.4		2528.4	2816.7	
C.V (%)		19.15			24.39			24.97			23.54	
	Sr	V	Sr x V	Sr	V	Sr x V	Sr	V	Sr x V	Sr	V	Sr x V
$LSD_{5\%}$	NS	177.3	280.4	NS	NS	NS	NS	NS	NS	NS	NS	NS

As seed rates increased number of fertile spikes/m^2 and the grain yield almost linearly increased where as spike length decreased, this is due to the competition effect of the population among themselves. Therefore, the correlation analysis (Fig.3) revealed significant linear relationship of grain yield with number of spikes. Grain yield was positively correlated with number of spikes.For partial budget analysis the grain yield data of 'Minet' variety was considered. The partial budget analysis at the current market conditions and the sensitivity analysis revealed that same seed rate was recommended but different net benefit. Seed rate of 175 and 200 kg/ha produced 422 and 377% marginal rate of return (MRR), respectively which are by far higher than the assumed minimum acceptable MRR of 100% (Table 4). However, in case of 'Snan' variety could not be done economic analysis due to the conflicting agronomic data.

Conclusion and recommendations

The yielding potential of triticale varied according to the locations. The variety "Minet" was more outstanding than 'Snan' variety in all crop parameters in all of the locations and was responsive to seed rates. Seed rates ranging from 175 to 200 kg/ha were found profitable and are recommended rates for triticale variety "Minet". Therfore, at Snan, Laie-Gaient and Farta areas this seed rate can be used with the variety "minet" while the earlier seed rate should be used for the variety sinan untill further rate is determined for this variety.

Table 4: Economic analysis for grain yield combined over the three locations

	current cost/price of seed and grain (birr 2.12/kg)			cost/price of seed and grain decreased by 40% (birr 1.27/kg)		
Seed rate (kg/ha)	TVC (ET Birr)	NB (ET Birr)	MRR (%)	TVC (ET Birr)	NB (ET Birr)	MRR (%)
125	265	4684.1		158.8	2806.0	
150	318	4714.8	58.1	190.5	2824.5	58.1
175	371	4938.7	422.4	222.3	2958.6	422.4
200	424	5138.9	377.8	254.0	3078.6	377.8
225	477	5047.1 D		285.8	3023.5 D	

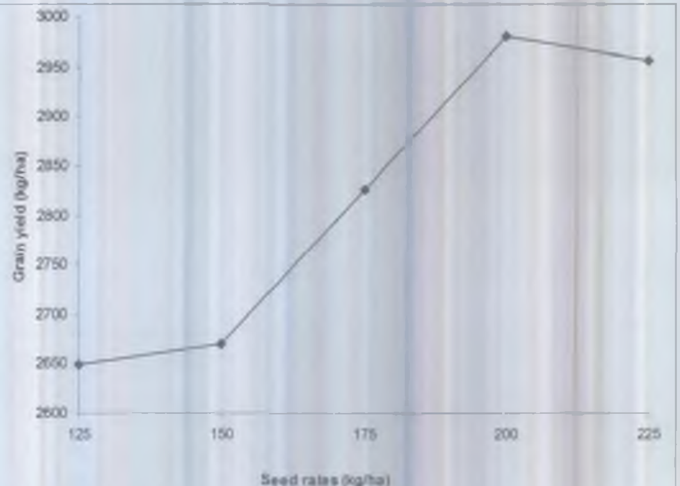

Fig.1. Grain yield response of triticale to different seed rates (over locations)

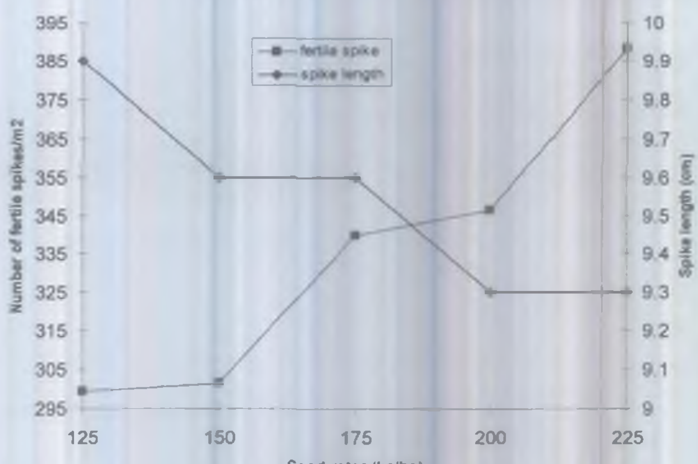

Fig.2. Response of triticale yield components to different seed rates (over locations)

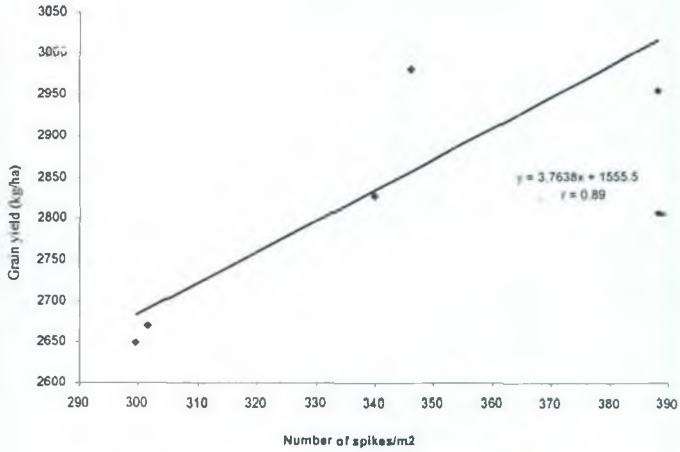

Fig.3. Interrelationship between grain yield and number of spikes

References

CIMMYT. 1988. From agronomic data to farmer recommendations: An economic training manual. Revised Edition. Mexico, D.F.

Inagaki, M. N., Pfeiffer, W. H., Mergoum, M., Mujeebkazi, A. and Lukaszewski, A. J. 1997. Effects of D-genome chromosomes on crossibility of hexaploid triticale with maize. Plant Breeding. 116:387-389

Mesfin Astatkie. 2005. Analysis of factor influenced adoption of triticale and its impact: The case of Farta woreda. An M. Sc. Thesis presented to the School of Graduate Studies of Alemaya University, Ethiopia.

NRC. 1989. Triiticale: A promising Addition to the World's Cereal Grains. National Academy Press, National Research Council, Washington, DC

Stoskopf, N. C. 1985. Triticale, In Cereal Grain Crops. Reston Pub. Reston, VA

Varughese, G., Pfeiffer, W. H. and Pina, R. J. 1996. Triticale: A successful alternative crop (part 1 and 2). *Cereal foods world.* 41 *(6/7): 474-645*

The response of Faba bean (*Vicia faba*) to nitrogen and phosphorus fertilizers in Northwestern Ethiopia

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Abstract

Poor soil fertility is one of the major production constraints for faba bean production. So as to determine the optimum fertilizer rates for faba bean production in northwestern Ethiopia, an experiment was conducted in Yilmana-Densa, Farta and Dabat areas for three consecutive years (1997-1999) in a total of 25 sites where wheat or barley were grown as precursor crops. Three nitrogen (0, 18 & 27 kgha^{-1}) and four phosphorous levels (0, 23, 46 & 69 P_2O_5 kgha^{-1}) were factorially arranged in RCBD replicated three times. Significant grain yield response was observed to phosphorus application in all locations. There was a linear increase in grain yield in response to the increase in phosphorus rates. Significant response on grain yield to nitrogen application was observed in Dabat area. The highest grain yields 1746, 2399 and 1878 kgha^{-1} in Yilmana-Densa, Farta and Dabat, respectively were obtained from the highest fertilizer rate (27/69 kg N/P_2O_5 ha^{-1}). Agronomic parameters such as plant height, 100 seeds weight, number of pods and seeds per plant linearly increased in response to an increase in phosphorus rates in all of the locations. All these agronomic parameters were positively and significantly correlated with grain yield. The economic analysis indicated fertilizer rate of 18/23 kg N/P_2O_5 ha^{-1} is recommendable for faba bean production at Yilmana-Denssa and Dabat areas. Where as 27/69 kg N/P2O5 ha^{-1} for Farta area was found economical rate. The sensitivity analysis further indicated the same recommendation as to current situation. In Farta area fertilizer rates of 18/46 or 18/23 kgha^{-1} could be used as alternatives for those farmers who are deficit in cash.

Introduction

Faba bean is among the major grain legumes cultivated in Ethiopia. It has various benefits to Ethiopian agriculture and daily diet (Asfaw and Mahmould, 1994). It is the most important crop as an export food legume. It is an important low input 'break' crop and good preceeding for cereals and when grown in association resulted in increased land productivity per unit area (Amare and Adamu 1994). Of the pulses, faba bean stands first in area, production and yield (Hailu *et al*, 1994). Ethiopia is considered as the world's second largest producer of the crop, next to China. However, the productivity is still low. This low productivity is due to traditional methods of production and different production constraints (Asfaw *et al*, 1994). Poor soil fertility is one of the major production constraints for faba bean production in North Western Ethiopia (Hailu *et al*. 1994).

Angaw and Asnakew (1994) reported that faba bean responded significantly to fertilizers when cropped after cereals than high land oil seeds. Previous fertilizer trials on faba bean at different faba bean producing areas indicated different responses. There was no significant response to either nitrogen or phosphorus or to their interaction at Kulumsa and Debrezeit but significant yield response to phosphorus application was shown under Sinana conditions. At Holetta, results showed that faba bean yield was highly significantly affected by the application of both nitrogen and phosphorus but not by their interaction (Amare and Adamu 1994). It can be concluded that there is the need to develop location specific faba bean fertilizer recommendations. Therefore, the fertilizer experiment was conducted on the different localities of northwestern Ethiopia so as to see the response of the crop to fertilizers and to determine economically optimum rate(s) of nitrogen and phosphorus fertilizers.

Materials and methods

The experiment was conducted on nitosols, luvisols and cambisols of Yilmana-Densa (west Gojam), Farta (south Gondar) and Dabat (north Gondar) areas, respectively for three consecutive years (1997-1999). It was conducted on sites where wheat or barley were grown as precursor crops. Three nitrogen (0, 18 & 27 Nkg/ha) and four phosphorous levels (0, 23, 46 & 69 P_2O_5 kg/ha) were factorially arranged in RCBD replicated three times. DAP, urea and TSP were the sources of N and P_2O_5. Soil sample at the time of planting was collected for laboratory analysis. The variety CS-20 DK was broadcasted at seed rate of 250 kg/ha on plot size of 5m x3m (15 m^2). Grain yield and other yield parameters (plant height, 100 seed weight, seeds/pod, pods & seeds/plant) were collected on the net plot size of 8 m^2 (2m x4m) and then subjected to analysis of variance using MSTATC statistical software. The agronomic efficiency for grain yield was also calculated in such away that the amount of grain yield produced per one kg of phosphorus applied.

Average fertilizer costs of the localities for 2005 year and average grain price (January to March) of 2006 were used for the economic analysis. Sensitivity analysis was made through the assumption that fertilizer cost increased by 20% and grain price remains constant (Table 1).

Table 1. Cost of fertilizer inputs and price of faba bean grain for the economic analysis

Cost/Price of input/output	Current situation (Birr/kg)	Sensitivity analysis (Birr/kg)
Cost of DAP and TSP	3.74	4.49
Cost of Urea	3.38	4.06
Price of faba bean grain	2.35	2.35

The mean grain yield data over sites for each location was adjusted down by 10% and subjected to partial budget and sensitivity analysis (CIMMYT, 1988). Total costs that varied (fertilizer cost) for each treatments was calculated and treatments were ranked inorder of ascending total variable cost (TVC) and dominance analysis was used to eliminate those treatments costing more but producing a lower net benefit than the next lowest cost treatment. The marginal rate of return (MRR) was calculated for each non-dominated treatment and a minimum acceptable MRR of 100% was assumed.

Results and discussion

Results on soil sample analysis of the three locations indicated on Table 2. According to the fertility classification of Landon 1991, the result revealed low total N, medium available P and acidic soils in all of the locations where as organic carbon is very low at Dabat and low at Yilmana-Densa and Farta areas.

Table 2. Soil properties of the three locations at the time of planting

Soil properties	Yilmana-Densa	Farta	Dabat
pH	5.74	5.13	5.56
Organic carbon (%)	3.54	2.17	1.64
Total N (%)	0.16	0.19	0.14
Available P (ppm)	5.61	6.97	7.02

Analysis on seed yield of individual sites on the two locations (Yilmana-Densa and Farta) indicated highly a significant response to phosphorus in most of the sites where as responses to nitrogen was negligible (Table 3a and 3b). This is because of nitrogen fixing capacity of the crop. It was reported that faba bean fixes more nitrogen (135 kg N/ha) than lentil and chickpea (Murinda and Saxena 1983). Small starter nitrogen doses resulted better nodulation and higher nitrogenas activity implying that improved early growth and improved subsequent activity of the rhizobium bacteria. Of the 9 sites in Yilmana-Densa, 6 sites showed significant difference to phosphorus and only two sites to nitrogen application.Similarly, of the 8 sites in Farta, 5 sites showed response to phosphorus and only one site to nitrogen application. In Dabat none of the sites showed responses either to N or P (Table 3c). The highest grain yield in almost all sites was obtained with the application of both nitrogen and phosphorous. There was a yield increase ranging from 27.36 to 279.06% in Yilmana-Densa, 33.53 to 154.32% in Farta and 2.85 to 111.69% in Dabat as compared to unfertilized treatment. The increase was lowest at Dabat area indicating poor response to fertilizers.

Table 3a. Analysis of variance on grain yield of faba bean for individual sites (Yilmana-Densa)

Source of varaition	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7	Site-8	Site-9
N	NS	*	NS	**	NS	NS	NS	NS	NS
P_2O_5	NS	NS	*	**	*	**	NS	**	**
N X P_2O_5	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean yield ($kgha^{-1}$) of 0/0 N/P_2O_5	2271	1411	946	340	234	1145	1569	1103	808
Highest mean yield (kg ha^{-1})	3175	1797	1799	737	887	2120	2433	2670	177υ
N/P_2O_5 comb. for highest yield	27/18	27/69	18/46	18/69	18/69	27/46	18/0	27/69	0/69
CV (%)	20.02	23.8	29.56	43.10	27.81	19.77	41.83	18.24	23.05

**, ** Significant at 5 & 1% level of significance, respectively. NS Non-significant*

Table 3b. Analysis of variance on grain yield of faba bean for individual sites (Farta)

Source of varaition	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7	Site-8
N	NS	NS	*	NS	NS	NS	NS	NS
P_2O_5	*	**	**	NS	NS	NS	**	*
N X P_2O_5	NS	NS	*	NS	NS	NS	NS	NS
Mean yield (kgha^{-1}) of 0/0 N/P_2O_5	1876	1052	1285	702	1589	2684	1438	1382
Highest mean yield (kgha^{-1})	2692	2307	3268	1082	2174	3584	3560	2643
N/P_2O_5 comb. for highest yield	27/69	0/69	18/46	27/69	27/46	18/69	27/69	27/46
CV(%)	23.20	30.86	20.31	28.53	19.97	23.07	28.43	28.97

Table 3c. Analysis of variance on grain yield of faba bean for individual sites (Dabat)

Source of varaition	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7	Site-8
N	NS	NS	NS	NS	NS	NS	NS	NS
P_2O_5	NS	NS	NS	NS	NS	NS	NS	NS
N X P_2O_5	NS	NS	NS	NS	NS	NS	NS	NS
Mean yield (kgha^{-1}) of 0/0 N/P_2O_5	952	1892	1993	640	1448	753	2071	1317
Highest mean yield (kgha^{-1})	1477	1946	2476	1129	2557	1594	2848	2226
N/ P_2O_5 comb. for highest yield	18/69	27/69	0/69	0/23	27/23	27/69	27/69	27/69
CV(%)	29.81	31.94	28.78	39.38	42.73	38.82	26.52	27.05

Results of combined ANOVA (Table 4) revealed the significant response of grain yield to phosphorus application in the three locations and to nitrogen application in Dabat area only. Significant differences on grain yield to phosphorus by site interaction also indicated the heterogeneity of the sites in fertility levels. Generally, there was a linear increase in grain yield in response to the increase in P rates in all the locations (Table 5). This is in line with findings of Gizaw *et al*, 1999. The result revealed agronomic efficiency of 7.29, 10.67 and 4.01 kg of grain yield per one kg of phosphorus applied at Yilmana Densa, Farta and Dabat, respectively. This indicates the highest grain yield response to phosphorus application at Farta than the other two locations. The highest grain yield 1746, 2399 and 1878 kgha^{-1} in Yilmana-Densa, Farta and Dabat, respectively was obtained on the interaction of 27/69 kg N/P_2O_5 ha^{-1}. The maximum grain yield on nitrogen by phosphorus interaction is due to the uptake enhancement effect of one nutrient by the other. Taye *et al* (2002) observed the enhanced uptake of nitrogen by the crop through the application of phosphorus and vice versa. There was an increase in grain yield of 59.89, 58.83 and 35.79% in Yilmana-Densa, Farta and Dabat areas, respectively over the unfertilized.

Agronomic parameters such as plant height, 100 seed weight, pods and seeds per plant showed significant responses to phosphorus application in Yilmana-Densa and Farta areas where as in Dabat area only plant height and pods per plant showed significant responses to phosphorus (Table 3). Response of agronomic parameters to nitrogen application was not significant in all of the locations except plant height at Yilmana-Densa. Seeds per pod were not significantly affected by either of the nutrients in all locations. All these agronomic parameters were linearly and positively correlated with grain yield (Fig. 1-4). There was a strong correlation of grain yield with plant height in Yilmana Densa and grain yield with number of pods per plant in Farta area.

Table 4. Combined analysis of variance on grain yield and other yield components of faba bean for the three locations

	Yilmana-Densa					Farta					Dabat				
Source of variation	Grain yield (kg/ha)	nt height (cm)	Pods/plant	100 seed wt (g)	Seeds/plant	Grain yield (kg/ha)	Plant height (cm)	Pods/plant	100 seed wt (g)	Seeds/plant	Grain yield (kg/ha)	Plant height (cm)	Pods/plant	100 seed wt (g)	Seeds/plant
Site(S)	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
N	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS
NxS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P_2O_5	**	**	**	**	**	**	**	**	*	**	*	*	*	NS	NS
P_2O_5 x S	*	*	*	*	NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS
N x P_2O_5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean value of 0/0 N/P_2O_5	1092	80.7	4.4	44.9	10.9	1501	97.1	5.3	47.1	15.1	1293	89.6	9.2	48.3	32.6
Highest mean value N/P_2O_5	1746	98.9	5.8	49.3	14.0	2399	114.6	7.4	49.2	18.2	1878	99.5	11.3	48.9	38.7
comb. for highest value	27/69	18/69	18/69	27/46	18/69	27/69	27/69	27/69	18/69	27/69	27/69	27/69	0/69	27/69	18/69

Table 5. Effect of nitrogen and phosphorus fertilizer application on grain yield of faba bean

P_2O_5 levels (kg/ha)	Yilmana-Densa N levels (kg/ha) 0	18	27	Mean	Farta N levels (kg/ha) 0	18	27	Mean	Dabat N levels (kg/ha) 0	18	27	Mean
0	1092	1274	1188	1185	1501	1590	1522	1538	1383	1332	1556	1424
23	1340	1481	1471	1431	1596	1851	1800	1749	1419	1679	1607	1568
46	1607	1581	1608	1599	1937	2140	1978	2018	1473	1398	1629	1500
69	1704	1614	1746	1688	2167	2255	2399	2274	1532	1694	1878	1701
mean	1436	1488	1503		1800	1959	1925		1452	1526	1667	
CV (%)		28.06				27.52				33.63		
	N	P_2O_5	N x P_2O_5		N	P_2O_5	N x P_2O_5		N	P_2O_5	N x P_2O_5	
LSD (5%)	NS	128	NS		NS	172	NS		136	171	NS	
(1%)	NS	169	NS		NS	226	NS		NS	NS	NS	

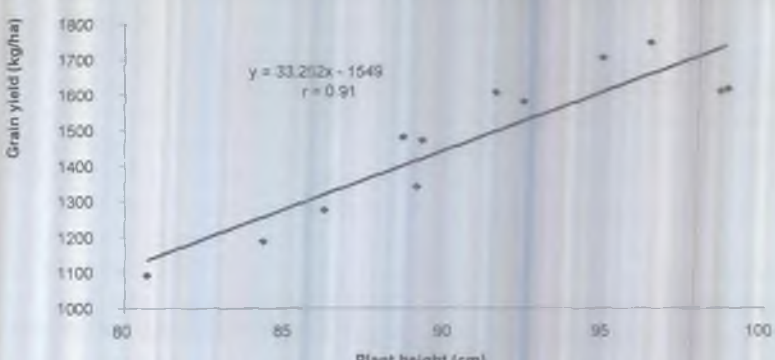

Fig.1. Interrelationship between grain yield and plant height of faba bean at Yilmana Denssa

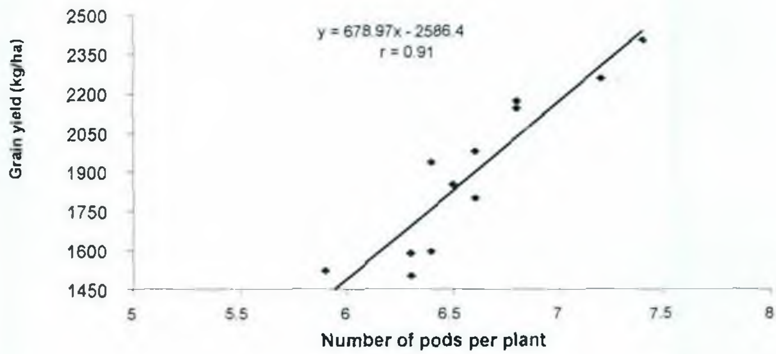

Fig.2. Interrelationship between grain yield and pods per plant of faba bean at Farta

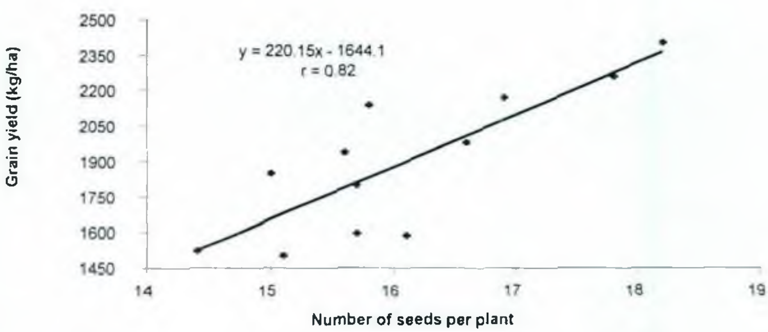

Fig.3. Interrelationship between grain yield and seeds per plant of faba bean at Farta

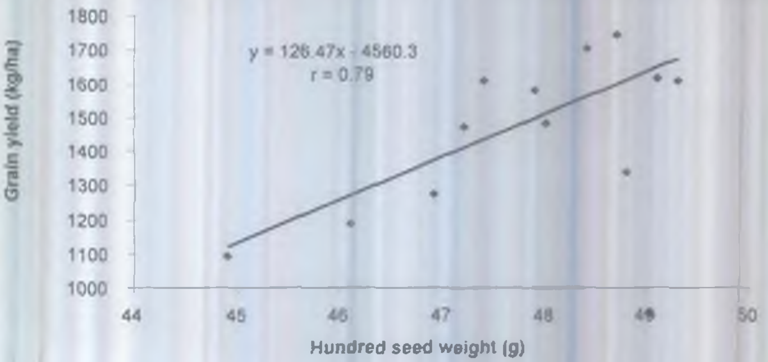

Fig.4. Interrelationship between grain yield and hundred seeds weight of faba bean at Yilmana Denssa

The economic and sensitivity analysis indicated that a fertilizer rate of 18/23 kg N/P_2O_5 ha^{-1} is optimum recommendable rate for faba bean production at Yilmana-Denssa and Dabat areas (Table 6a, 6c). Where as fertilizer rate of 27/69 kg N/P2O5 ha^{-1} were found more profitable and recommended for Farta area (Table 6b). In Farta area fertilizer rates of 18/46 or 18/23 $kgha^{-1}$ could be used as alternatives for those farmers who are in deficit of cash.

Table 6a. Economic analysis of nitrogen and phosphorus fertilizers rate on grain yield of faba bean at Yilmana-Densa

	Current cost of fertilizer and price of grain			Fertilizer cost increased by 20% and grain price remain constant		
N/P_2O_5 ($kgha^{-1}$)	TVC (Eth. birr)	NB (Eth. birr)	MRR (%)	TVC (Eth. birr)	NB (Eth. birr)	MRR (%)
0/0	0	2310		0	2310	
18/0	132	2562	191	159	2536	142
0/23	187	2647	155	225	2610	113
18/23	253	2879	351	304	2828	275
0/46	374	3025	120	449	2950	84
0/69	561	3043	10	674	2931 D	
27/69	561	3132	57	674	3019	31

D dominated treatment

NB = net benefit, TVC = total variable cost, MRR = marginal rate of return

Table 6b. Economic analysis of nitrogen and phosphorus fertilizers rate on grain yield of faba bean at Farta

	Current cost of fertilizer and price of grain			Fertilizer cost increased by 20% and grain price remain constant		
N/P_2O_5 ($kgha^{-1}$)	TVC (Eth. birr)	NB (Eth. birr)	MRR (%)	TVC (Eth. birr)	NB (Eth. birr)	MRR (%)
0/0	0	3158		0	3158	
0/23	187	3487	176	225	3449	130
18/23	253	3613	191	304	3562	142
18/46	374	4194	481	449	4119	384
27/69	561	4528	178	674	4415	132

Table 6c. Economic analysis of nitrogen and phosphorus fertilizers rate on grain yield of faba bean at Dabat

	Current cost of fertilizer and price of grain			Fertilizer cost increased by 20% and grain price remain constant		
N/P_2O_5 ($kgha^{-1}$)	TVC (Eth. birr)	NB (Eth. birr)	MRR (%)	TVC (Eth. birr)	NB (Eth. birr)	MRR (%)
0/0	0	2735		0	2735	
27/0	198	2862	64	238	2822	37
18/23	253	3040	325	304	2989	254
27/69	561	3134	31	674	3021	9

Conclusion and recommendation

Grain yield and most of the yield parameters showed significant responses to phosphorus. Though there is no significant response of faba bean to nitrogen, application of a small amount as a starter is important to exploit the yielding potential of the crop. Yield increase observed in all of the locations as nitrogen and phosphorus rates increased. It is recommended that 27/69 kg $N/P_2O_5ha^{-1}$ at Farta and 18/23 kg $N/P_2O_5ha^{-1}$ at Yilmana-Denssa and Dabat areas are economical fertilizer rates for faba bean production. In Farta area fertilizer rates of 18/46 or 18/23 $kgha^{-1}$ could be used as alternatives for those farmers who are deficit in cash.

References

Amare Ghizaw and Adamu Molla. 1994. Faba bean and fieldpea agronomy research. Asfaw Tilaye, Geletu Bejiga, Saxena Mohan C. and Solh Mahmoud B. (eds.) Cool season food legumes of Ethiopia. Proceedings of the first national cool season food legumes review conference, 16-20 Dec., Addis Ababa, Ethiopia.

Angaw Tsigie and Asnakew Woldeab. 1994. Fertilizer response trials on high land food legumes. Asfaw Tilaye, Geletu Bejiga, Saxena Mohan C. and Solh Mahmoud B. (eds.) Cool season food legumes of Ethiopia. Proceedings of the first national cool season food legumes review conference, 16-20 Dec., Addis Ababa, Ethiopia.

Asfaw Tilaye and Mahmowd Solh. 1994. Overview of achievements in cool season food legume research in Ethiopia. Asfaw Tilaye, Geletu Bejiga, Saxena Mohan C. and Solh Mahmoud B. (eds.) Cool season food legumes of Ethiopia. Proceedings of the first national cool season food legumes review conference, 16-20 Dec., Addis Ababa, Ethiopia.

Asfaw Tilaye, Geletu Bejiga and Alem Berhe. 1994. Role of cool season food legumes and their production constraints in Ethiopian agriculture. Asfaw Tilaye, Geletu Bejiga, Saxena Mohan C. and Solh Mahmoud B. (eds.) Cool season food legumes of

Ethiopia. Proceedings of the first national cool season food legumes review conference, 16-20 Dec., Addis Ababa, Ethiopia.

CIMMYT. 1988. From agronomic data to farmer recommendations: An economics training manual. Completely revised edition. Mexico, D.F.

Ghizaw A., Mamo T., Yilma Z., Molla A. And Ashagre A. 1999. Nitrogen and Phosphorus Effects on Faba Bean Yield and Some Yield Components. Journal of Agronomy and Crop Science 182(3), 167-174.

Hailu Beyene, Workneh Negatu and Shelemew W/mariam. 1994. Small holder production practices and constraints in Ethiopia. Asfaw Tilaye, Geletu Bejiga, Saxena Mohan C. and Solh Mahmoud B. (eds.) Cool season food legumes of Ethiopia. Proceedings of the first national cool season food legumes review conference, 16-20 Dec., Addis Ababa, Ethiopia.

Landon, J.R. (Ed). 1991. Booker Tropical Mannual. A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics.

Murinda M.V. and Saxena M.C. 1983. Agronomy of faba beans, lentils and chickpeas. Saxena M.C. and Varm S. (eds.) Proceedings of faba beans, kabuli chickpeas and lentils in the 1980's. An international workshop 16-20 May 1983. The international center for agricultural research in the dry areas (ICARDA), Aleppo, Syria.

aye Bekele, Yesuf Assen Sahlemedhin Sertsu, Amanuel Gorfu, Mohammed Hassena, D.G. Tanner, Tesfaye Tesemma and Takel Gebre. 2002. Optimizing fertilizer use in Ethiopia. Correlation of soil analysis with fertilizer response in Hetosa woreda, Arsi zone. Addis Ababa: Sasakawa-Global 2000.

Chickpea variety development for moisture stress areas of Wollo, Ethiopia

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Abstract

Eight promising Kabuli type chickpea genotypes were evaluated during 2002 to 2005 cropping seasons at Sirinka, Chefa and Kobo. Farmers were involved in the evaluation of the candidate genotypes on farmers' fields. Highly significant difference among chickpea genotypes was revealed in days to flowering, days to maturity, number of pods per plant, 100 seeds weight. Genotypes FLIP-93-22C and ICC-14808 were found outstanding in all agronomic and yield performance and fulfilled the required standard of 100 seeds weight (35-37 g) for export. Based on its' performance, ICC-14808, named as 'Yelbe', was released for Sirinka, Chefa, Kobo and similar agro-ecologies. Similarly, twelve promising desi type chickpea genotypes were evaluated for their earliness and seed yield at Mersa and Kobo. Genotypes 41210, ICCV-91212 and ICCV-92069 matured within 83-87 days and gave the seed yield of 600-1700, 900-1100 and 800-2100 kg ha^{-1}, respectively, at the research station. Genotypes 41210, ICCV-91212 and ICCV-92069 had the yield advantage of 44 %, 18 % and 54 % over the standard check (Akaki), respectively. Based on farmers' and the national variety releasing committee assessments, genotype ICCV-92069, name as Fetenech, was released for Mersa, Kobo and similar agro-ecologies.

Introduction

Chickpea (*Cicer arietinum* L.) is among the major pulses produced in Ethiopia. It ranks second in production next to faba bean (Asfaw *et al.*, 1994). It is used as a human food and animal feed and, in particular, serves as an important protein supplement in the cereal-based diet of most Ethiopians. Senayit (1990) indicated that, it is an excellent source of protein (20-40%), which is approximately three times than that of cereals. The consumption rate increases during the fasting days, when the Orthodox Christians abstain from meat and egg and other animal products. Chickpea also helps in the management of risk aversion where there is crop failure of major cereals due to recurrent drought. It also helps in soil fertility management, particularly in dry land areas, through symbiotic nitrogen fixation.

The major potential constraints and the decline threats of chickpea production in the diverse agro-ecological zones of the country is absence of kabuli chickpea variety that fulfills the required standard for export and do well in drought areas. High priorities were given for the development of varieties resistant to wilt/root rot, drought and bruchid, and improvement of cultural practices (National Crop Research Strategy, 2000). Currently, developing marketable varieties is the primary research agenda. However, due to the existing narrow genetic variability and partly due to less attention given for using hybridization to create variability. the selection is only based on the available stocks. However, it was found possible to identify genotypes from the existing variation that are productive and with good quality attributes acceptable to producer and consumer (Singh and Malhotra, 1984; Van Der Maesen, 1984; Muehlbauer and Singh, 1987). At the early stage of this study, large sample of single seed decent pure lines on both kabuli and desi types were evaluated and selected. Furthermore, it was aimed to select high yielding, bold seeded varieties that fulfill the required standards for export and relatively early maturing genotype that can do well in the moisture stress areas of the region. The current phase of the study was to identify moisture stress tolerant varieties that can escape the terminal drought, with high yielding ability and tolerant to insects and diseases across the major lowland pulse production areas of the region.

Materials and methods

Two independent experiments were conducted using kabuli and desi cheakpea types. The first experiment comprised eight kabuli genotypes, which were compared along two standard varieties (Sasho and Areti) at three sites of the major chickpea growing areas of north Welo, northeastern Ethiopia. Kobo, Sirinka and Chefa represented the lowland altitudes, the intermediate altitudes and the sub-humid lowlands, respectively (Table 1). The second experiment was conducted at Kobo and Mersa sites representing the marginal chickpea growing areas of the Eastern Amhara. Fourteen desi type chickpea genotypes including the standard (Akaki)) and the local checks were evaluated.

Both experiments were carried out in randomized complete block design replicated three times, on a plot size of 2.4 m wide and 4 m long. A row-to-row distance of 40 cm and plant-to-plant distance of 10 cm were maintained. The materials were sown in the first week of September in 2002, 2003 and 2004 cropping seasons. Nine important phenological and yield component characters were recorded i.e., days to flowering, days to maturity, number of pods, number of seeds, plant height (cm), 100 seeds weight (g), biological yield (kg ha^{-1}), seed yield (kg ha^{-1}) and harvest index

Table 1. Geographical, climatic and agro-ecological features of the experimental sites

	Locations			
	Sirinka	Chefa	Kobo	Mersa
Major agro-ecology	M2-5	M1-3	SM1-3	M1-7
Mean range of temp. (^{0}C)	21-32	21-36	25-38	21
Mean annual rainfall (mm)	876	850	660	1102
Altitude (masl)	1850	1450	1500	1600
Latitude	12.11	10.89	12.12	12.11
Soil type	Black soil	Black soil	Sandy loam (Brown)	Dark brown soil

Source: Natural Resource Management and Regulatory Department, MOA, 1998

The observations of characters were recorded on plant basis of 10 randomly selected plants of each plot and on plot basis of four harvestable rows. The promising candidate genotypes were evaluated on station and on farmers' fields with a plot size of 100 m^2 in 2005 cropping season. The analysis of variance was done using GenStat computer software

(Lawes Agricultural Trust, Rothamsted Experimental Station, 2005). Variance components for each location and combined analysis across locations were computed using the formula outlined by Miller *et al.* (1959). Additive main effects and Multiplicative Interaction (AMMI) analysis was used to explore genotype by environment interactions.

Results and discussion

Experiment I: Kabuli Chickpea

The combined analysis of variance across location and year showed that there was a significant difference among the genotype in all traits measured. The mean range for days to 50% flowering, maturity, pod/plant, hundred seeds weight, seed yield and harvest index were 35-76 days, 74-144 days, 2-144, 18-13 g, 300-3800 kg ha^{-1} and 1-59 %, respectively. The two candidate genotypes FLIP-93-22C and ICC-14808 have 37 and 35 g hundred seeds weight, respectively, that fulfilled the require standard for export (Table 2).

Additive main effects and Multiplicative Interaction (AMMI) analysis showed that environments, genotypes, and their interactions were significant ($P<0.05$) for seed yield and accounted for 81 %, 10 % and 9 % of the total variation, respectively. IPCA1 component of the interaction sum of squares explained 64% of the variation (Table 3). The genotypes performed differentially across six environments but the interaction was quantitative i.e., genotypes have non-crossover type interaction.

The IPCA score showed that FLIP-94-119C (G7) and FLIP-93-22C (G1) were more stable across six environments. However, FLIP-94-119C was associated with low yielding ability (Fig 1). Genotypes ICC-14808 (G5), FLIP-93-195C (G2) and FLIP-95-31C (G4) were high yielder at all six environments.

Table 2. Mean seed yield and 100 seed weight across 6 environments

Genotype	100 seeds Weight (g)	Seed yield (kg ha^{-1})
FLIP-93-22C (G1)*	37.2	1471.5
FLIP-93-195C (G2)	34.2	1669.6
ICC-12339 (G3)	20.9	1534.2
FLIP-95-31C (G4)	34.7	1568.8
ICC-14808 (G5)	34.6	1772.3
FLIP-95-39 (G6)	33.5	1012.8
FLIP-94-119C (G7)	32.2	1070.3
FLIP-96805 (G8)	34.4	1048.5
Arerti (G9)	25.2	1389.9
Shaso (G10)	32.5	983.1
Mean	**31.9**	**1352.117**
CV (%)	**8.66**	**19**
LSD (5%)	*	**

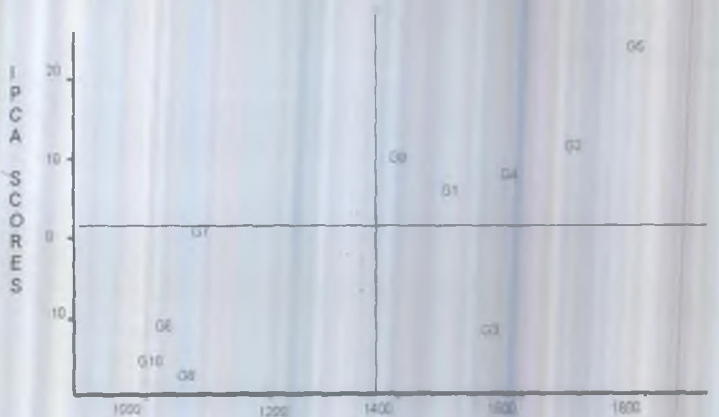
** G-genotype; G number designations given for the biploting purpose*

Table 3. AMMI analysis of variance for seed yield

Source	*df*	Sum of square	Mean square
Total	179	159887630	893227
Treatments	59	151371610	2565621**
Genotypes	9	14330141	1592238**
Environments	5	123145954	24629191**
Block	12	1353604	112800 ^{NS}
Interactions	45	13895515	308789**
IPCA 1	13	8926060	686620**
IPCA 2	11	3045233	276839**
Residuals	21	1924222	91630
Pooled error	108	7162417	66319

**- Significant at the 0.05; **- Significant at the 0.01; NS- non significant*

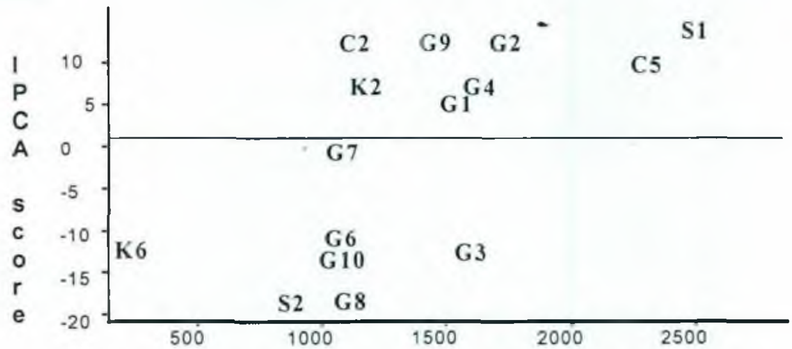
Fig 1. Genotype IPCA 1 scores versus mean seed yield of tested genotypes



AMMI biplot showed that high yield was recorded at Sirinka and Chefa in 2002 and 2003 cropping seasons, respectively (Fig 2). There was significance difference in the mean yield performance among genotypes at Sirinka with varied IPCA scores among seasons. The same trend has happened at Kobo. However, seasonal variations were small at Chefa but the mean performance of the genotype main effects was different. The environments were variable in mean yields and interaction patterns where Sirinka (2002) and Chefa (2003) were the high yielding environments. Kobo was the lowest yielding environment due to the moisture stress that prevailed in the area. Variety ICC-14808 out yielded all genotypes at four environments (Table 4) while ICC-12339 out yielded all genotypes at Sirinka in 2003, but had inconsistent performance across environments.

AMMI Selection per environment revealed that ICC-14808 was the first candidate over four environments, FLIP-93-195C was the first candidate in 2002 cropping season at Kobo and ICC-12339 was the first selection at Sirinka in 2003 cropping season. These best performing genotypes were verified on-station and on-farmer's fields in the 2005 cropping season and were evaluated by variety releasing technical committee and the host farmers. According to farmer's evaluations, ICC-14808 was the first preferred candidate followed by FLIP-93-22C as compared to the standard and the local checks in earliness and yield potential.

Fig 2. Genotype and environments IPCA 1 scores based on their mean seed yield performances



G-genotypes; K, S, and C- environments

Table 4. Performance of candidate varieties (Kabuli) in verification trial combined across three locations

Candidate genotype	DF*	DM	NP	NS	SCH	PH	SW (g)	AY (kg ha^{-1})	Rank
FLIP-93-22C	44	100	48	1.3	902.7	45	37	838	2
ICC-14808	47	101	61	1.8	737.7	40	38	934	1
Arerti	59	119	53	1.3	925.4	41	31	837	3
Shaso	57	116	39	1.3	781.1	43	34	725	4
Grand mean	**52**	**109**	**50**	**1.4**	**836.8**	**42**	**35**	**833**	
CV (%)	**5.3**	**3.5**	**36**	**23.5**	**19.7**	**9.1**	**6.9**	**29**	
LSD (5%)	**3.1**	**4.2**	**NS**	**NS**	**NS**	**NS**	**2.7**	**NS**	

** DF, days to 50% flowering; DM-days to 90% maturity; NP-number of pods per plant; NS-number of seeds per pods; PH-plant height; SW-100 seed weight (g); BI-biomass; AY-seed yield (kg ha^{-1}); HI-harvest index; SCH-stand counts at harvest*

The candidate variety ICC-14808 out yielded the standard check by 22 % in 2005. The same candidates fulfilled the required standard seed size for export where such traits could add value of its marketability and could increase the income for the farmers. As a result, the candidate variety ICC-14808 (named as Yelbe) has been selected and released by the variety release committee for Sirinka, Mersa, Chefa and Kobo and similar agro-ecologies and will be demonstrated and popularized in the recommendation domains.

Experiment II: Desi Chickpea

The AMMI combined analysis of variance across locations showed that there were significant differences among the genotypes in seed yield i.e., 18 % of the variation was explained by the genotype main effect, 46 % by the environment main effect and 37 % by the interaction effects (Table 5; Fig 3 and 4). The first IPCA component explained 58 % of the total interaction variation. The combined analysis of variance across environments showed that there was significant difference among the genotypes in days to 50% flowering, days to 90% maturity, number of pods per plant, number of seeds per pods, 100 seeds weight, plant height, seed yield and harvest index. The mean range for days to 50% flowering was 36 to 61 days. The earlier genotype matured within 74 days and the longest maturity recorded was 117 days. The maximum number of pods per plant was 92 pods and the minimum was 2 pods. The smallest 100 seed weight was 9 g and the largest was 25 g. The lowest (900 kg ha^{-1}) and the highest (2900 kg ha^{-1}) seed yielding varieties across individual environment were the local check and genotype ICCV-92069, respectively. The minimum harvest index was 5% and the maximum was 61%. The lowest CV % was recorded for days to 90% maturity (3.4 %) and the highest was for seed yield in kg ha^{-1} (30.3 %). ICCV-92069, ICCV-91212 and 41213 genotypes matured within 87 days, 83 days and 87 days, respectively (Table 6). These genotypes matured before the onset of the long dry spell i.e., escaped the terminal drought.

Table 5. AMMI analysis of variance of the genotypes for seed yield (kg ha^{-1})

Source	*df*	SS	MS	F	F_prob
Total	251	59221661	235943		
Treatments	83	46600421	561451	8.07	
Genotypes	13	8180000	629231	9.05	*
Environments	5	21404195	4280839	28.99	**
Block	12	1772290	147691	2.12	*
Interactions	65	17016226	261788	3.76	*
IPCA	17	9866254	580368	8.35	*
IPCA	15	3841542	256103	3.68	**
Residuals	33	3308430	100255	1.44	
Error	156	10848950	69545		

Generally, AMMI selections per environment showed that genotype 41210 was the first candidate at three environments while genotype ICCV-92069 was the first selection at two environments (Table 7). Based on the mean yield performance and earliness of the genotypes, ICCV-92069, 41210 and ICCV-91212 were verified on-station and on-farmers' fields. Genotype ICCV-92069 was the second candidate and the highest yielder across all environments in the verification plots (Table 8). Based on the field evaluations by the variety releasing committee, ICCV-92069 (named as Fetenech) was released for the end users.

Table 6. Mean seed yield of the genotype across six environments

Genotypes	Seed yield (kg ha^{-1})	DM
41203 (G1)*	747	87.2
41160 (G2)	758	86.8
208980 (G3)	917	85.9
41110 (G4)	773	86.9
208992 (G5)	670	87.7
41176 (G6)	765	85.8
41210 (G7)	1235	86.5
41207 (G8)	890	91.2
41213 (G9)	1058	86.9
ICCV-91212 (G10)	1010	82.8
ICCV-92069 (G11)	1321	86.5
41004 (G12)	860	84.6
Akaki (G13)	857	90.5
Local (G14)	935	86.1
Mean	**914**	**86.8**
CV (%)	**30.3**	**3.4**
LSD (5%)		*

* *G-genotype; G number designations given for biploting purpose*

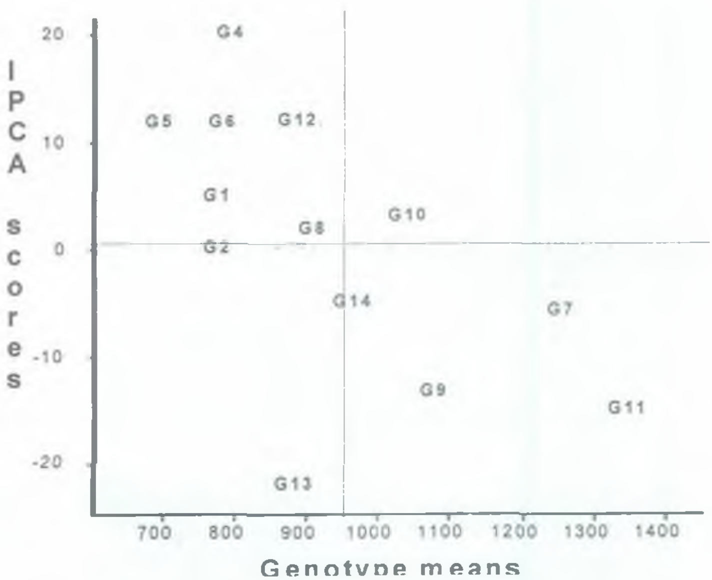
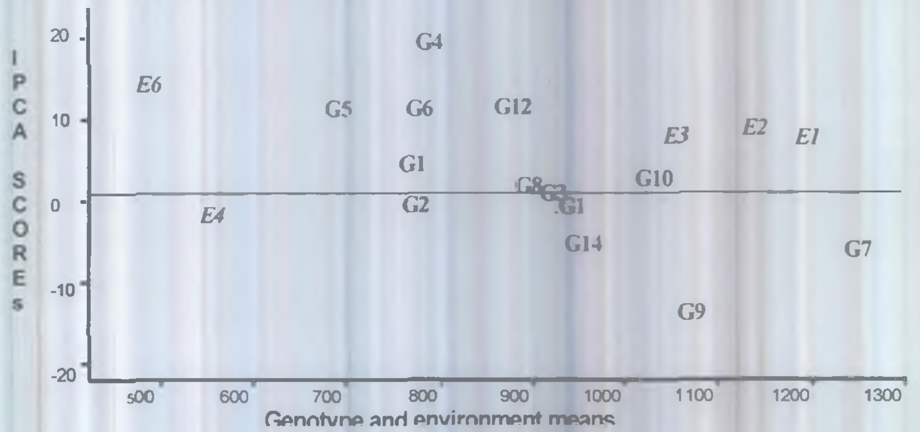


Fig 3. Genotype IPCA 1 scores based on their mean seeds yields



G- Genotypes; E- environments

Fig 4. Genotype and environment IPCA 1 scores based on mean seed yield performances

Table 7. The first four AMMI selections per environment

Environment	Mean	Score	1	2	3	4
E6	473.2	14.32	G10	G11	G6	G1
E2	1123.7	9.02	G7	G11	G12	G8
E3	1039.7	8.03	G7	G11	G8	G12
E1	1182.7	7.76	G7	G8	G14	G11
E4	541.6	-1.73	G11	G10	G9	G7
E5	1125.3	-37.41	G11	G13	G9	G7

Table 8. Mean of measured traits in variety verification trial combined across three locations

Candidate genotype	DF	DM	NP	NS	SCH	PH	SW (g)	AY (kg ha^{-1})	Rank
41210 (G7)	50.0	100.0	44.7	1.2	1152.9	31.5	19.0	1644.8	3
ICCV-91212 (G10)	49.0	97.0	34.9	1.7	1044.4	37.2	21.0	1484.8	4
ICCV-92069 (G11)	50.9	98.4	52.8	1.5	1094.6	30.1	19.9	1924.2	1
Akaki (G13)	52.1	101.3	43.0	1.7	1246.7	32.7	21.5	1150.4	5
Local (G14)	50.0	99.9	44.4	1.8	1134.1	36.2	13.8	1764.3	2
Mean	**50.4**	**99.3**	**44.0**	**1.6**	**1134.5**	**33.5**	**19.1**	**1593.7**	
CV (%)	**4.1**	**4.5**	**29.6**	**11.5**	**14.3**	**14.0**	**8.4**	**35.8**	
LSD (5%)	**2.3**	**NS**	**NS**	**0.2**	**NS**	**5.2**	**1.8**	**NS**	

Conclusion & Recommendation

The primary objective of multi-location trials in breeding programs is to identifying promising genotypes with stable yields. Eight promising kabuli chickpea genotypes, planted in three locations over two years, were used to study the effect of environments on yield and yield components. Seed yield, seed boldness and earliness were taken as an important criteria in selecting the desirable genotypes. The results exhibited significant environment and genotype main effects and high genotype by environment interaction effects. Generally, ICC-14808 was high yielding and had 35 g thousand seeds weight, which fulfilled the required standard for export and was released, named as Yelbe, for Sirinka, Chefa, Kobo and similar agro-ecologies.

Fourteen desi test genotypes, including the standard check (Akaki) and local check, were tested across two locations over three cropping seasons. Significant variations among genotypes were observed in days to 50% flowering, days to 90% maturity, number of pods per plant, number of seeds per pods, 100 seed weight, plant height, seed yield and harvest index. The results showed that variety ICCC-92069 was better yielding across most environments and was early maturing that could escape the long dry spell occurrences in the study areas. Therefore, ICCC-92069, named as Fetenech, was verified and released to be used in the study domains and will be popularized to the users.

References

Asfaw Tilaye, Geletu Bejiga and Alem Berhe. 1994. Role of cool-season food legumes and their production constraints in Ethiopian agriculture. *In:* Asfaw Telaye, Geletu Bejiga, Saxena, M.C. and Soln, M.B. (eds.). Cool-season food legumes of Ethiopia. Proceedings of the first national cool-season food legumes review conference, 16-20 December, 1993, Addis Ababa, Ethiopia. *pp.* 64-84. ICARDA/Institute of Agricultural Research. ICARDA. Aleppo, Syria.

GenStat release 8.1 (PC/Windows XP), 29 June, 2006, 16:06:13. Copyright 2005, Lawes agricultural trust (Rothamsted Experimental Station).

Miller, P.A.; William, J.C. and Robinson, H.F. 1959. Variety by environment interaction in cotton variety tests. *Agronony Journal* 51(3): 132-134

Muehlbauer, F. J. and Singh, K, B. 1987. Genetics of chickpea. *In:* Saxena, M.C and Singh, K.B., (eds.) The chickpea. *pp.*11-18. C.A.B International, Walling Ford, UK.

National Crop Research Priority. 1999. Working document for the national workshop on crop research strategy and priority setting. Ethiopian Agricultural Research Organization, Addis Ababa.

Senayit Yeteneberk. 1990. Uses of chickpea lentil and faba bean in Ethiopia. *In.* Uses of tropical grain legumes, ICRISAT. Andhra Pradish 502324, India. *pp. 85.*

Singh, K.B. and Malhotr, R.S. 1984. Exploitation of chickpea genetic resource. *In:* Witcombe, J. R. and Erskine, W. (eds.). Genetic resource and their explotation: Chickpeas, faba beans and lentils. *pp* 23-125, Kluwer Academic Publisher Group, The Hague, Netherlands.

Van Der Maesen, L. J. G. 1984. Taxonomy, distribution and evolutuion of the chickpea and its wild relatives. *In:* Witcombe, J. R. and Erskine, W. (eds.). Genetic resource and their explotation: Chickpeas, faba beans andlentils. *pp* 140-145, Kluwer Academic Publisher Group, The Hague, Netherlands.

Performance of improved soybean varieties in Eastern Amhara sub region

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This study was carried out to evaluate the adaptability of improved soybean varieties in major lowland pulse producing areas of eastern Amhara sub region. The varieties belong to early and late maturing classes and two independent sets of trials were conducted during 2004 and 2005 cropping seasons. The test locations were Mersa, Chefa and Kobo for both groups. In the early maturing group, three varieties were tested with randomized complete block design (RCBD) with four replication. Where as , four varieties with three replications were used in the case of the late maturing group.

The result of the early varieties indicated that there is variation among the varieties in seed yield and maturity period. The performance of the varieties also varied across the locations. The maturity period ranged between 91 and 97 days for the variety Williams and Crowford, respectively. All varieties performed well at Chefa giving a mean yield 29 qt/ha seed yield. On the contrary, the productivity of all the varieties was too low at Kobo, 7qt/ha seed yeild. Awasa-95 and Crowford have better adaptability and performance than Williams. Therefore Awasa-95 and Crowford were recommended for kobo, Mersa , Chefa and similar agro-ecology.

In the late maturing set, the maturity period ranged between 97 days for the variety Coker 240 and 111 days for the variety Belesa. Combined mean of the varieties revealed that the highest yielding variety was Davis (14 qt/ha). which was similar to the less yielding early variety Williams. As the overall performance of the late maturing varieties was poor non of the materials is recommended for production at the test locations.

Introduction

Legumes are nutritionally important in developing countries. Many legumes have short cropping cycles ranging from 60 to 90 days, which give them considerable production potential. Their overall yield may not be as high as some cereals, but their protein contents are about two to four times higher, making them excellent source of proteins. In addition, Legumes have paramount importance in improving soil fertility, through symbiotic nitrogen fixation.

Soybean is frequently stated to be one of the oldest cultivated crops, whose domestication was long attributed to China. Soybean is basically a warm temperate, short day plant. Soybeans can be grown on a wide range of soil types, but thrive best on sandy or clay loams and alluvial soils of good fertility. It is an herbaceous annual legume with usually erect, bushy and rather leafy growth habit.

Soybeans contain approximately 20% oil and 40% protein. Many developing countries have recognized the potential of soybean as a source for supplementing the traditional cereal staples. It contains all three of the macronutrients required for good nutrition: complete protein, carbohydrate and fat, as well as vitamins and minerals, including calcium, folic acid and iron. Soybeans are the only common plant food that contains complete protein. Soybean protein provides all the essential amino acids in the amounts needed for human health. The amino acid profile of soy protein is nearly equivalent in quality to meat, milk and egg protein. Soybean oil is 61% polyunsaturated fat and 24% monounsaturated fat, which is comparable to the total unsaturated fat content of other vegetable oils (~ 85%). Like other vegetable oils. soybean oil contains no cholesterol.

Soybean is grown in eastern Amahara. There is also a potential to expand area of production and improve productivity. Lack of adaptable and improved varieties has been one of the production constraints that hindered production of soybean. Introduction and selection of soybean varieties with better yield and other desired qualities is important in order to curb these production constraints.

Materials and Methods

Description of the Study Area

Seven improved varieties were used in this study (including three early and four late maturing varieties). The varieties were obtained from Awasa Agricultural Research Center. The trial was conducted during 2004 and 2005 cropping season. The experiment was carried out at Kobo, Mersa Chefa woredas of Eastern Amhara sub region. Detailed geographical and climatic descriptions of the locations are presented in Tables 1.

*Table 1. Geographical, Climatic and Agro- Ecological Features of Experimental Sites.

	Location		
	Kobo	Mersa	Chefa
Major agro-ecology	SM1-3	M1-7	M1-3
Mean range of temp. (°C)	25-38	21	21-36
Mean annual rainfall (mm)	660	1102	850
Altitude (masl)	1450	1600	1500
Soil type	Sandy loam (Brown)	Dark brown	Black soil
Distance from Addis Ababa in km	570	490	355

**Source (Natural Resource Management and Regulatory Department, MOA, 1998)*

The two maturity classes were independently laid out in randomized complete block (RCB) design. For the early maturing varieties the trial was replicated four times, on a plot size of 1.6m wide and 4 m long and spacing of 40 cm X 5 cm. . For late maturing varieties the trial was replicated three times, on a plot size of 2.4m wide and 4 m long. spacing of 60 cm X 5 cm. The data for number of pods per plant, number of seeds per pod and plant height were collected on 5 randomly selected plants from each plot. However, days to 50% flowering, days to 90% maturity, biomass and seed yield were collected on plot basis. Fertilizer was not applied. Well prepared seed beds were used and hand weeding was carried out two times.

Results And Discussion

Early maturing Group

The result showed variability among the varieties in seed yield and days to maturity. The combined mean of the varieties over the six environments indicated that the varieties performed very well at Chefa as compared to the rest two locations. On the other hand, the varieties relatively took shorter time to mature at Chefa. (Tables 2 & 3). The considerable variation observed among the test location on the performance of the varieties can be attributed to difference in temperature, rainfall, and edaphic factors among the locations. Generally, Awasa-95 and Crowford showed better seed yield than Williams. Therefore Awasa-95 and Crowford are recommended for Kobo, Mersa, Chefa and similar agro-ecologies.

Table. 2. Means of seed (kg/ha) and days to maturity of early set soybean varieties combined over years

Varieties	Seed yield				Days to maturity			
	Kobo	Mersa	Chefa	Mean	Kobo	Mersa	Chefa	Mean
Awasa-95	6.4	11.2	30.1	15.9	95.7	95.8	90.5	94.0
	10.6	8.7	27.8	15.7	93.0	99.7	96.5	96.4
Williams	6.0	9.2	28.3	14.5	92.9	94.8	86.8	91.5
Mean	7.7	9.7	28.7	**15.4**	93.9	96.8	91.3	**94.0**

Table. 3. Means of seed (kg/ha) and days to maturity of early set soybean varieties combined over locations

Varieties	2004		2005	
	Days to Maturity	Seed Yield	Days to Maturity	Seed Yield
Awasa-95	93.2	20.3	94.8	15.9
	98.2	17.1	95.0	19.9
Williams	91.8	15.7	91.2	16.6
Mean	94.4	17.7	93.6	17.5

Late Maturing Group

Despite, longer maturity time that ranged between 97 days for variety *Coker-240* and 111 days for *the variety Belesa*, the over all performance of the late maturing varieties is very low as compared to the early maturing varieties. Alike the result of the early set trial the performance all the varieties was better at chefa than the other two locations. Among the varieties the variety *Davis* gave relatively better over all mean seed yield of 14 qt/ha. And yet this is lower than the least yield obtained from the early set varieties. (Tables 4 & 5)

Table 4. Means of seed (kg/ha) and days to maturity of soybean varieties (Late set) combined over years

Varieties	Seed yield				Days to maturity			
	Kobo	Mersa	Chefa	Mean	Kobo	Mersa	Chefa	Mean
Clarc-63k	6.6	7.9	22.8	12.5	97.4	101.8	94.2	98
Belesa	4.2	6.6	26.5	12.4	115.7	109.9	108.7	111
Davis	8.0	6.0	24.8	13.5	98.5	107.5	97.7	101
Coker-240	6.2	7.3	23.1	12.2	95.4	101.2	94.0	97
Mean	6.2	6.9	24.3	**12.6**	101.8	105.1	98.7	**102**

Table 5..Means, Days to Maturity and Seed Yield (kg/ha) of late set soybean Varieties combined over locations

Varieties	2004		2005	
	Days to Maturity	Seed Yield	Days to Maturity	Seed Yield
Clarc-63k	95.4	12.2	100.1	12.7
Belesa	104.9	11.3	117.9	13.5
Davis	100.3	15.5	102.1	12.4
Coker-240	96.7	13.3	97.0	12.1
Mean	99.3	13.1	104.3	12.7

Conclusion and recommendation

The performance of the early maturing varieties was by far better than the late maturing varieties. This can be attributed to poor adaptability of the varieties to these specific growing areas. Hence, none of these late varieties are recommendable for the test location. Paradoxically, the over all mean seed yield of some of the early maturing varieties could reach as high as 30 qt/ha. The better yield they gave coupled with their earliness makes these early maturing varieties compatible to farming system of the test location. Hence, the best performing early maturing varieties: Awasa-95 and Crowford are recommended for these locations and other similar agro ecologies. In order to improve productivity and expand production of this crops in these areas on farm demonstration and popularization of these varieties is recommended as follow up activities.

Chefa consistently looked best ecology for production of crop. Improving the share this crop in the farming system of such areas may help to improve productivity and there bye income and nutrition of the farming community.

Performance of improved white pea bean (Phaseolus vulgaris L) varieties in eastern Amhara

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Three improved varieties of white pea bean were evaluated in the study with the objective of selecting adaptable and best performing white pea bean variety/ies for the lowland areas of Wollo. The experiment was conducted at Sirinka, Mersa, kobo and Chefa, woredas of the eastern Amhara sub region during 2004 and 2005 cropping seasons. The design was randomized complete block design with four replications. In 2004 the mean grain yield of the location was 6 qt/ha, 12 qt/ha, 3 qt/ha, 21 qt/ha at Sirinka, Mersa, kobo and Chefa, respectively. The highest seed yield was recorded for Awashmelka at Chefa (23 qt/ha). In 2005 the mean grain yield by location was 9 qt/ha, 7 qt/ha, and 9 qt/ha at Sirinka, Mersa and Chefa, respectively. Due to Moisture stress and insect problem the performance of all the varieties was poor at kobo. The over all mean of all locations and years show that Awash-1 and Awashmelka are equivalent in grain yield and maturity period. The two varieties gave better yield than Mexican-142 which was late maturing. Therefore Awash-1 and Awashmelka were recommended for Sirinka, Mersa,Chefa and similar agro-ecology.

Introduction

Common bean (*Phaseolus vulgaris* L) originated in Latin America but is now cultivated worldwide in diverse environments. It is interchangeably called with the name common bean, haricot bean , white pea bean. Currently, it is the second most important source of human dietary protein, and the third most important source of calories for over 100 million people in rural and poor urban communities in Africa.

Beans grow well in most environmental conditions in tropical and temperate zones, but do poorly in very wet tropics where rain causes disease and flower drop. Rain is undesirable when dry seeds are harvested. Frost kills plant. Beans grow best in well-drained, sandy loam; silt loam or clay loam soils rich in organic content.

Common bean has been one of the most important crops grown by small-scale farmers in different parts of Ethiopia. In the central rift valley, the crop is used as one of the cheapest source of protein. It is usually consumed in the form of boiled grain, which is locally known as *nifro* .These days farmers also prepare a local stew known as *shiro wot* from some bean cultivars. In addition to augmenting the nutritional requirement of the farmers, this crop is serving as an important source of cash for the farmers in the area. Although the area has got potential for production of common bean, it is not widely grown in eastern Amhara sub region. Hence, in order to increase production of the crop and improve income and nutrition of the farmers in the area, backing the extension effort with improved varieties and management practices is vital. This activity was undertaken in order to bridge the technological gap that existed in the eastern Amhara sub region

Apart from the aforementioned advantages, inclusion of this crop in to the farming system helps to improve soil fertility through symbiotic nitrogen fixation. Alike many other pulse crops, common bean is short cycled crop. This characteristic of the crop makes it a compatible technology for areas like the eastern Amhara sub region where moisture stress associated with late onset or early cession is common problem.

Materials and Methods

Description of the Study Area

The materials used in this study were three released improved varieties recieved from Melkassa Agricultural Research Center. The trial was conducted in 2004 and 2005 cropping seasons at Sirinka, Mersa, Kobo and Chefa. Randomized complete block (RCB) design with four replications was used . Plot size of 9.6 m^2 was used with spacing of 40 cm X 10 cm. Data on number of pods per plant, number of seeds per pod and plant height were collected on 5 randomly selected plants from each plot. Days to 50% flowering, days to 90% maturity, biomass and seed yield were collected on plot basis. Fertilizer was not applied. Seedbed preparation has been done three times; hand weeding was carried out two times.

Results discussion

In both years variability was observed among the varieties in seed yield. The performance of the varieties varied among the locations too. The highest yield of 23 quintal per hectare was recorded for the variety Awashmelka at Chefa during the year 2004. and the lowest yield 2 quintal per hectare was recorded at Kobo for variety Mexican-142 during the same year. The combined mean of the varieties show that Awash-1 and Awashmelka-142 are better yielders as compared to the third variety, Mexican-142. All the varieties gave low yield at Kobo during the 2004 cropping season. In 2005 , the yield obtained at Kobo for all the varieties was not acceptable and the problem is attributed to insect pest damage and moisture stress. (Table.1). Similarly, variability was observed among the varieties in days to maturity. Relatively the low yielding variety, Mexican-142, took longer time to mature. (Table. 2). There was also variability among the test locations for days to maturity.

Table. 1. Mean of seed yield in qt/ha of the varieties across years and locations

Varieties	2004				2005			mean
	Kobo	Sirinka	Mersa	Chefa	Sirinka	Mersa	Chefa	
Awash-1	2.6	10.4	13.7	20.7	12.7	532.1	945.0	1070
Mexican-142	1.9	3.0	9.4	18.5	6.3	795.0	534.0	748
Awashmelka	4.9	5.4	13.8	23.5	8.6	822.2	1102.2	1078
Mean	3..2	6.3	12.0	21.0	9.2	716.4	860.4	966

Table. 2. Mean of Maturity period of the varieties across years and locations

	2004				2005			mean
	Kobo	Sirinka	Mersa	Chefa	Sirinka	Mersa	Chefa	
Awash-1	88.3	80.3	88.5	82.8	89.0	85.3	79.0	85
Mexican-142	102.4	80.8	87.0	81.8	93.5	89.3	86.0	89
Awashmelka	87.2	78.8	85.3	79.8	82.0	84.5	79.0	82
Mean	92.6	79.9	86.9	81.4	88.2	86.3	81.3	85

Conclusion

The performance of Awash-1 and Awashmelka both in terms seed yield and days to maturity was acceptable. Hence, these two varieties are recommended for production at the test locations and other areas having similar agro ecologies. Seed multiplication, on farm demonstration and popularization of these varieties are suggested as follow up activities in these areas. However, in areas like Kobo, where insect pests are serious problems, such activities have to be complemented with appropriate pest control packages.

Chickpea variety development in Vertisol areas of the Amhara region

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Abstract

Chickpea growers usually grow desi types in the Amhara region and improved cultivars are lacking. A multi-location trial consisting of sixteen desi type varieties was carried out for three years at Enewari, Adet, and Sirinka to identify high yielding, disease and insect pest tolerant, and stable varieties. The combined analysis of variance showed significant ($p<0.01$) variation for days to flower, days to maturity, plant height (cm), pods/plant, seeds/plant, 100 seed weight (g), and seed yield (kg ha^{-1}). Enewari was the top performing location with mean performance of 3010.87 kg ha^{-1} followed by Adet (2844.28 kg ha^{-1}) and Sirinka (2280.50 kg ha^{-1}). Based on overall performance across three locations and years, ICC-V-92006, named as Mastwal, was released for high and mid altitude Veritsol areas of North shewa, South Wolo and western Gojam of the Amhara region and similar environments. Generating basic scientific information on resistance to biotic and abiotic stresses, inheritance of traits should also be studied in the future. The breeding work on quality traits such as seed size, color and protein content aspect is still lacking.

Introduction

Chickpea (*Cicer arietinum* L.) is an important pulse crop next to faba bean in many areas of the Amhara region (CSA 2000). The crop is mainly grown on Vertisols with residual moisture by small-scale farmers under rain-fed condition after the main rainy season (August to January) as well as in the short rainy season (March- June). It serves for crop rotation in the farming systems with Tef and Wheat. Chickpea has been a preferred crop in the low input traditional production system in the region. However, the inherently low yielding potential of the crop and its susceptibility to diseases like aschocyta blight and wilt root rot complex poses a difficulty in its production. Increasing the seed yield, improving disease and insect pest resistance/tolerance and development of adapted cultivars to the chickpea environments are the primary objectives of the highland pulses breeding. It was possible to test and recommend some nationally released improved varieties. Additionally, one variety, ICC-V-92006 (Mastwal), was regionally released for Inewari, Sirinka, Adet and similar Vertisol areas in the Amhara region (Debreberhan ARC progress report, 2005). Therefore, further developing improved and diverse chick pea varieties for high altitude and Vertisol areas is necessary.

Materials and Methods

All acquired desi types of chickpea germplasm passed through sick plots established at Debrzeit Agricultural Research Center to screen for wilt /root rot disease complex. Then, the screening nurseries and advanced trials were conducted at Inewari sub-center. Finally, sixteen promising genotypes were included in the regional variety trial which was carried out during 2001-2003 on residual moisture at *Enewari*, *Adet*, and *Sirinka* with altitude of 2600, 2240, and 1860 m a.s.l, respectively, on black Vertisols. The genotypes were examined in randomized complete block design with three replications together with the standard (*Akaki and Worku)* and respective local checks. The genotypes were planted on beds which had 1.2 width and furrow width of 40 cm. Each plot consisted of 4 rows, 4 m long and 0.3 m spaced apart and 0.1 m spacing between plants. Promising genotypes selected from the regional variety trial were verified in 100 m^2 plots at Enwari, Adet and Sirinka. DAP fertilizer was applied at the rate of 100 kg ha^{-1} for both trials. Seed yield and other agronomic data were recorded. Analysis of variance of the measured traits was computed using Agrobase microcomputer software.

Results and Discussions

The combined analysis revealed significant difference among the testing locations, years and genotypes. However, there was no significant genotype by year, genotype by location and genotype by location by year interactions (Table 1). The presence non-significant interactions showed the consistency of performance of chick pea genotypes across locations and over seasons.

Table 1. Mean square values of seed yield and other agronomic characters for combined analysis of variance over three years and locations

Source	DF	Mean squares						
		Days to flower	Days to maturity	Plant Height(cm)	P/P	S/P	HSW	Seed yield (kg ha^{-1})
Year	2	337.3**	3852.6**	1385.5**	4978.5**	0.8*	79.2**	10915453**
Location	2	2443.6**	20168.5**	3052**	11425.8**	1.5*	414.5**	20993197**
Genotype	14	208.1**	86..5**	181.2*	542**	0.6**	210.4**	837072**
Genotype x year	28	6.5**	19*	21.9**	164.8NS	0.3*	3.8**	162917NS
Genotype x location	28	11.2**	32.1**	13.6NS	133.3NS	0.2NS	5.2**	383984NS
Genotype x year x location	56	9.3**	15 7**	16.2*	164.2*	0.2NS	1.6NS	340346NS
Pooled error	250	2.7	12.4	11.4	120	0.2	2	262295

*NB: The local checks were omitted from the combined analysis and only two standard checks and 13 genotypes were considered. *, ** Indicate Significance at 0.05 and 0.01 probability levels, respectively; Ns: Non-significant*

Mean seed yield over years ranged from 2710-3589, 2179-3236 and 1882-3027 kg ha^{-1} at Enewari, Adet and Sirinka, respectively. The highest seed yield was obtained at Enewari (3010 kg ha^{-1}) followed by Adet (2816 kg ha^{-1}) and Sirinka (2292 kg ha^{-1}) (Table 2 and 3). The coefficient of variation (42%) at Sirinka was high, which could be largely attributed to the lack of moisture uniformity due to varied rainfall distribution in different seasons. Variety ICCV-91014 gave the highest seed yield of 3587 kg ha^{-1} at Enewari, which was greater than ICC-V-92006 (Mastewal) but their difference was non-significant. However, the highest seed yields of 3236 kg ha^{-1} and 3027 kg ha^{-1} were obtained at Adet and sirinka, respectively, by *ICC-V-92006 (Mastewal). ICCV-92006 out yielded the standard checks* (Worku and Akaki) and the respective local checks at all locations. The yield advantage of ICC-V-92006 (Mastewal) over the local and standard checks at all locations was 500-6600 kg ha^{-1}. Likewise, ICC-V-92006 (Mastwal) had the highest hundred seed weight.

There was significant difference for hundred seed weight among genotypes at all locations. Mean hundred seed weight ranged from 7-13 g, 12 -23 g and 14- 23 g at Sirinka, Enewari and Adet, respectively. The highest mean hundred seed weight was obtained at Sirinka (22 g). The standard checks *(Worku and Akaki) and the respective* local checks had lower seed weights than the released genotype (ICCV-92006). There was also significant difference among genotypes (P>0.05) for days to flower, maturity, pods/plant and seeds/pod. Variety ICC-V-92006 (Mastwal) flowered and matureed in 52 and 122 days, respectively. The mean wilt root rot infection ranged from 1.7 to 3 and Mastwal showed moderately resistant reaction and had a score of 2.3 in 1-9 scale.

Table 2. Mean values of seed yield and hundred seed weight for fifteen *desi* type chickpea varieties at three locations over years (2001-2003)

	Seed Yield (kg ha^{-1})			Hundred Seed Weight (g)		
Varieties	Enewari	Adet	Sirinka	Enewar	Adet	Sirinka
ICC-V-91014	3589	3123	2046	20	20	23
ICC-V-89240	2894	2841	2500	17	18	21
ILL-2872	2952	2847	2339	17	18	22
ICC-V-92010	3290	2945	2142	22	23	27
*ICC-V-92006****	3292	3236	2552	23	22	26
ICC-V-92032	3258	2780	2097	23	21	25
ICC-V-89303	3049	2773	2701	15	16	16
ICC-V-93102	2812	2750	2412	19	19	21
ICC-V-91022	2793	2572	2242	14	14	15
ICC-V-90035	2882	2817	2173	20	21	24
ICC-V-89223	3030	2963	2517	20	23	25
ICC-V-92942	2759	2179	1882	21	21	24
ICC-V-91030	2713	2934	2156	19	19	23
Worku*	3023	2819	2339	18	18	22
Akaki*	2967	3053	1889	18	18	20
Local check**	2774	2773	2507	12	11	14
Mean	3010	2816	2292	19	19	22
LSD(0.05)	321.2	406.3	749	0.76	1.1	1.4
CV %	13.5	18.5	41.4	5.1	7.2	8.1

Standard Checks, **Local checks * Released genotype*

Table 3. Mean seed yield, disease score and agronomic characters of 15 Chickpea varieties evaluated in regional variety trial at three locations and years (2001-2003)

Genotype	DTF	DTM	PH	W/RR	P/P	S/P	100SW	SY (kg ha^{-1})
ICC-V-91014	47	120	38	1.7	49	1	21	2919.4
ICC-V-89240	49	123	38	2.5	52	1	19	2745.3
ILL-2872	49	122	45	2.1	54	2	19	2712.6
ICC-V-92010	50	121	42	2.0	43	2	24	2792.6
ICC-V-92006**	52	122	40	2.3	43	1	24	3026.6
ICC-V-92032	46	119	36	2.4	47	1	23	2711.6
ICC-V-89303	49	123	40	1.9	51	2	15.	2840.9
ICC-V-93102	50	122	42	2.0	46	2	19.7	2657.7
ICC-V-91022	54	123	39	2.2	52	1	14	2535.6
ICC-V-90035	48	120	42	3.4	44	1	22	2624.1
ICC-V-89223	52	123	41	2.4	45	2	23	2836.8
ICC-V-92942	44	117	36	2.5	41	1	22.	2273.3
ICC-V-91030	48	121	43	2.7	53	1	20	2600.7
Worku*	48	123	43	3.0	55	2	19	2727.2
Akaki*	52	122	41	1.8	46	2	19	2637.3
Local Check	51	122	41.4	1.9	57	1	12.4	2751.2
Mean	50	121	40	1.9	48	2	21	2709.4
LSD (0.05)	0.7	1.6	1.6		4.9	0.2	0.6	233.3
CV (%)	3.3	2.9	8.3		22.8	28	7.0	19.6

**Standard check, ** Released variety; DTF, days to flower; DTM, days to mature; PH, plant height; P/P, pods/plant; 100SW, 100 seeds weight; SY, seed yield, W/RR, Wilt root rot*

Conclusion and Recommendation

Mastwal (ICCV92006) had better hundred seed weight, better plumpness, uniformity, earliness, wide adaptation (2000m -2600 m.a.s.l) and performed consistently over years and season and could be extended for chickpea growing areas. Generating basic scientific information on resistance to biotic and abiotic stresses, inheritance of traits should also be studied in the future. The breeding work on quality traits such as seed size, color and protein content aspect is still lacking and emphasis should be given.

Faba bean variety development for high altitude and vertisol areas of north Shewa

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Abstract

Faba bean (Vicia faba L.) production on heavy black clay soil (Vertisol) in North Shewa is low largely attributed to the absence of high yielding varieties suitable to waterlogging and frosty conditions. An effort has been made to develop varieties that are resistant/tolerant to waterlogging stress and four cultivars were recommended for the area till 2002 viz., two regional (Dagm and Lalo) and two national (Wayu and Selale). Fourteen genotypes were also tested in regional variety trialed at Enwari. Molale and Mehalmeda during 2004 and 2005 cropping seasons and CS20DK93-sel-1-1 was identified as a candidate variety that gave higher seed yield and hundred seed weight (48 g). The future research should address on resistance to biotic and abiotic stresses, inheritance of selected traits and quality traits (cook ability seed size and shape). As a whole this paper discussed the two completed regional variety trials result conducted from 1998 to 2000 and 2004 to 2005 crop seasons.

Introduction

Faba bean (Vicia faba L.) is cultivated in Ethiopia in the 'Woyna dega' zone (1800-2200 m.a.s.l.) with an average annual rainfall of 740 mm and mean daily temperature of 18-22 0C, and Dega zone (> 2200 m.a.s.l.) with an average annual rainfall of 900 mm and mean daily temperature of 10-18 0C. It is grown from June to December in rotation with cereals (Asfaw et al., 1994). Faba bean is an important source of protein supplement for the majority of the Ethiopian population and is used in various popular dishes such as curry and "injera" and used also as a source of foreign earning. However, its yield is very low in farmers' fields (about 1 ton ha-1). This is mainly because farmers use local cultivars that are either poor yielders or susceptible to different diseases and other biotic and abiotic stresses (Habtu and Derje, 1985; Salt, 1981). Most cultivars of faba bean in use today are farmer's cultivars that resulted from several years of selection and most modern varieties were developed from these landraces without the use of hybridization (Asfaw et al., 1994).

Vertisols cover 10.3% (about 12 .7 million ha) of the Ethiopian land mass and are the fourth most abundant soils after Histosols, Cambisols and Nitosols (Berhanu Debele, 1985). Thus, to increase faba bean production on Vertisols, development of varieties that can tolerate water-logging condition and give better seed yield is essential. Faba bean production on heavy black clay soil (Vertisol) of North Shewa is declining in recent years largely attributed to the absence of high yielding varieties suitable to waterlogging and frost, and lack of resistance/tolerant varieties to black root rot, chocolate spot, ascochyta blight, powdery mildew and aphids. Vertisols has high water holding capacity results and when there is excess moisture after rainfall, the field stay flooded for a few days. Such condition predispose the plant to black root rot disease (Fusarium solani) causing partial/total crop failure on farmers fields and the production depend on the amount of rainfall experienced starting from the seedling stage. Farmers in Enewari-Jihure plane grow highland pulses using traditional hand made broad bed and furrow (BBF) for seed bed preparation to cope the waterlogging problem. Host resistance is also one of the cheapest options for control of black root rot. A limited number of varieties were released and recommended for users until 2002 viz., Wayu, Selale and Dagm and Lalo. Thus, to further increase faba bean production, development of varieties that tolerate waterlogging condition and give better seed yield is essential for high altitude and Vertisol areas.

Materials and Methods

Faba bean improvement program uses germplasm obtained from target collection made on vertisol areas where black root rot infection severely prevails. Besides segregating (F2 -F5) nurseries and materials evaluated on sick plot were received from Holetta and Ambo research center. Thus, among large number faba bean genotypes which passed through screening nurseries at Enewari condition, eleven varieties (with <10 % mortality <10 % and higher seed yield) were promoted to faba bean regional variety trial. These genotypes were tested during 1998 and 2000 crop season at Enwari, Molale and Mehalmeda Vertisol areas with an altitude of 2600, 3000 and 3075 m.a.s.l, respectively, along with susceptible variety Bulga-70 and the local checks of specific locations. The randomized complete block design with three replications was used. The varieties were planted on traditionally hand made broad bed and Furrow (BBF). The furrow was 40 cm wide, 4 m long and 15 cm deep. The plot size had 4 rows with 40 cm spacing and 4 m length. The second experiment consisted of eleven new genotypes, including local and two standard checks (Lalo and Dagm), were grown during 2004 and 2005 growing seasons at the same locations. The results of individual locations were analyzed based on Gomez and Gomez, 1984. The combined analysis of variance was done after Hartley's F-maximum test homogeneity test (Rangaswamy, 1995).

Result and Discussion

Experiment I

There was significant interaction of genotype by location, genotype by year and year by location but genotype by location by year interaction was not significant (ANOVA not presented). Varieties Grarjarso 89-8, Selale kasim 89-4, L82094-13, Selale kasim 91-15 and Selale kasim 91-13-1 gave the highest seed yield of 3.5, 3.6, 3.6, 3.4, and 3.4 (Table1). The yield advantage of the candidate varieties over the local checks at respective locations and the standard check (Bulga-70) ranged from 0.8-1-4 t ha-1 . Therefore, based on better average yield performance and disease reaction in three consecutive years (1998-2000), varieties Grarjarso 89-8, Selale kasim 89-4, and L82094-13, were selected and advanced for verification. Grarjarso 89-8 and Selale kasim 89-4 named as Dagm and Lalo, respectively, were released in 2002 (Sheno progress report, 2001). Both varieties had black root rot resistance. The data were also subjected to stability analysis of Eberhart and Russell (1966) which define a stable variety as one with regression coefficient of unity (b=1.0) and with a minimum deviations from the regression line (S2d) =0. Thus, Dagm and

Lalo had 1.0 and 0.03 regression coefficient and 1.1 and -0.02 deviation from regression, respectively, and accepted as stable varieties.

Table 1. Mean seed yield, disease score and agronomic characters of 13 faba bean varieties evaluated in regional variety trial at three locations (Enwari, Molale and Mehalmeda) and years (1998-2000)

Varieties	DFL	DMT	BRR (1-9)	CS (1-9)	PHT (cm)	P/P	S/P	HSW (g)	SY (t ha-1)	Regression. Coefficient (b)
Grarejarso 89-8 *	68	152	1	2	86	20	3	30	3.5	1.0
Selale kasim 89-4 *	69	154	1	2	88	21	3	33	3.6	1.1
Selale kasim 91-15	65	151	1	3	83	21	3	30	3.4	0.69
Selale kasim 91-13-1	66	153	1	2	82	19	3	33	3.4	0.97
L82094-13	65	153	1	2	85	18	3	34	3.6	1.05
Teltel 89-8 –2	68	152	1	2	82	19	3	28	3.0	0.99
Wayu 83-34	64	151	2	2	80	19	2	30	3.2	1.2
CS20DK 3-2-1	62	151	1	3	77	19	3	31	3.4	1.0
Tumlo 89-34	62	151	2	2	80	19	3	32	3.2	1.1
Bulga 70**	60	154	3	2	73	18	3	40	2.6	0.97
Enewari local	65	150	2	3	76	21	3	30	3.2	0.83
Mehal meda local	60	154	3	3	69	20	3	34	2.4	1.0
Molale local	59	154	3	3	65	21	3	34	2.2	0.98
Mean	64	152	2	2	79	20	3	32	3.1	
LSD (5%)	0.98	1.7	2.7	0.2	3	2	o.2	14.3	0.24	
CV (%)	3.4	2.5	30.6	20.2	8.4	22.8	18.7	9.8	17	

**Standard check; *candidate varieties; DFL = Days to flower DMT = Days to maturity, PHT = plant height P/P = Pods/plant, S/P= seeds/pod, TSW = thousand seeds weight, BY =biomass yield, SY = Seed yield, HI =Harvest index, BRR= black root rot, CS= chocolate spot (Source: Sheno ARC Progress Report, 2000)*

Experiment II

The mean flowering days varied from 56-62 days, maturity from 146-151 days, chocolate spot score from 3-4, black root rot score from 2-4 at Enwari (Table 2). Genotypes flowered and matured early at Enwari than at Mehalmeda and Molale which is helpful to escape frost in late plant growth stage. CS20DK-Sel-93-1-1 gave the highest seed yield (3413.9 kg ha-1) and hundred seed weight (42.7 g) better than standard checks "Lalo" and "Dagm" checks. The variety by year, variety by location interaction was significant for hundred seed weight at (P>0.05) but not significant for plant height (Table 3). Similarly, variety by location by year interaction was not significant for plant height, seed yield and hundred seed weight. The result indicated that varieties had consistence performance for these characters over the environments. Based on overall performance over seasons and locations, CS20DK-sel-93-1-1 was selected as a candidate variety for verification.

Table 2. Mean disease score and agronomic characters of 14 faba bean genotypes tested in regional variety trial at three locations (Enewari, Mehalmeda and Molale) and two years (2004-2005)

No	Genotypes	Enewari			Molale			Mehalmeda	PH* (cm)	HSW*	SY* (kg ha-1)
		DTF	DTM	ChS	BRR	DTF	ChS	DTF			
1	CS 20DK Sel 93-1-1	56	149	3	4	69	2	65	85	42.7	3413.9
2	Coll 96/94-1	59	147	3	2	72	2	70	82	32.8	3052.2
3	Coll 5/94	59	146	4	2	72	2	68	77	30.0	2825.8
4	Wayu 89-26-1E/96	58	148	3	2	71	2	66	87	33.8	3214.4
5	Coll 60/94-1E/96	59	147	3	2	72	2	70	81	29.1	2894.1
6	Selale kasim 91-1-1E/96	62	150	3	2	74	2	73	81	32.1	2960.9
7	CS 20DK-4E/97	59	147	3	2	71	2	69	83	33.9	3157.4
8	Teltele 89-9-1-1E/96	59	147	3	2	72	2	70	85	31.0	3033.2
9	Coll 8/94-1E/96	57	147	3	2	70	2	65	80	30.9	2834.0
10	Teltele 89-8-3-1E/96	58	147	3	2	71	2	69	83	29.0	2983.8
11	PGRC/E Acc.No.25314-1-1E/96-1	61	151	3	2	73	2	72	85	34.8	2719.5
12	Dagem	61	150	3	2	72	2	71	85	30.4	2997.0
13	Lalo	61	148	3	2	71	2	70	84	30.6	3016.0
14	Local check	59	147	3	2	69	3	61	-	-	-
	Mean	59	148	3	2	71	[illegible]	69	83	32.4	3007.9
	LSD (5%)	2	2	0.4	0.6	2.1	0.5	4.2	3.5	1.5	175.7
	CV (%)	3	1	12.6	25.8	2.5	19.0	5.3	7.8	8.2	10.6

*DTF= Days to flower, DTM= Days to maturity, SY = Seed yield, ChS= Chocolate spot, BRR= Black root rot, * Local checks are different across locations and were not included in the combined analysis*

Conclusion and recommendation

Two faba bean varieties were released and two were recommended. Other two are in pipe line for release and one was identified as a promising/candidate variety (Table 4). Hence, the two small seeded varieties Selalekasim 89-4 (Lalo) and Grarjarso 89-8 (Dagm), released for North Shewa and similar environments, had high yield potential, were stable and tolerant to black root rot disease which was severe in waterlogged vertisol areas. Thus, these varieties can be used the growers to increase productivity and production in the future. In addition, the candidate variety CS20DK-Sel-93-1-1 which had better seed yield and hundred seed weight will be verified for release.

Generally, generating basic scientific information on resistance to biotic and abiotic stresses, inheritance of traits and the breeding work on quality traits (cook ability, seed size and shape) should be the future direction. Frost remains the major production constraint.

There is a need to introduce frost tolerant germplasm and also establish effective and efficient artificial screening methods. The seed multiplication of released varieties and verification of the candidate varieties should continue.

Table 3. Mean square of combined analysis of variance for three characteristics of faba bean genotypes grown at Enewari, Mehalmeda and Molale in 2004-2005

Source	df	Plant Height (cm)	HSW	Seed yield (kg ha-1)
Year	1	64.5 NS	196.6.4**	945257**
Location	2	128**	11392.1**	6214387.7**
Year x Location	2	1310**	150.7**	6235273**
Genotype	12	104.25**	254.4**	646222**
Genotype x year	11	62.3 NS	23.1**	128491.9NS
Genotype x Location	22	46.2 NS	22.1**	2217009.1**
Genotype x year x Location	22	27.3 NS	10.7NS	111266NS
Error	130	40.3	7.1	101213

PHT=. Plant height (cm); HSW = Hundred seed weight; SY = Seed yield
*** , * Significant at 1% and 5% respectively;. NS=non-significant*

Table 4. Faba bean varieties released and recommended for North Shewa (2000-2005)

No	Variety	Year of released	Yield (kg ha-1)	100 seed weight (g)	Altitude (masl)	Institute/Center
1	Dagm (GrarJarso 89-8) RR	2002	3500		2600-3000	ARARI/D.Birhan
2	Lalo (Selelekasim89-4) RR	2002	3600		2600-3000	ARARI/D.Birhan
3	Selele (Selele Kasim 91-13) R	2002	2300		2000-2800	EARO/Holetta
4	Wayu (Wayu 89-5) R	2002	2900		2000-2800	EARO/Holetta
5	CS-20 DK se l 93-1-1 PRL		3400	43	2600-3000	ARARI/D.Birhan
6	EH 94024-OV2 (Large) PL		1200	47.1	2000-2800	EARO/Holetta
7	EH 96049-2 (large) PL		1400	51.5	2000-2800	EARO/Holetta

**Soil type was vertisol at all sites; RR= regionally released, R= Recommended, PRL= Promising line, PL= Pipe line. (Source: Debrebirhan Progress Report, 1994-2005)*

References

Asfaw Telaye, Tesfaye Getachew and Beyene Demtsu. 1994. Genetics and breeding of field pea. In: AsfawTelaye, Geletu Bejiga, S. Mohan and S. Mohmoud (eds.). Cool Season Food Legumes of Ethiopia. Proceedings of the First National Cool-Season Food legumes review Conference, 16-20 December, 1993. Addis Ababa Ethiopia. ICARDA/Institute of Agricultural Research. ICARDA, Aleppo, Syria. pp 285-214.

Berhanu Debele. 1985. The Vertisols of Ethiopia: Their properties, classification and management. In: Fifth meeting of the Eastern African Sub-Committee soil correlation and Land evaluation, Wad, Medani, Sudan, 5-10 December 1983. World Soil Resources Report, No. 56. FAO (Food and Agricultural Organization), Rome. pp. 31-54.

Gomez, K.A. and A.A. Gomez.1984. Statistical Procedures for Agricultural Research. 2nd ed. Johan Wiley and Sons Inc, N.Y.

Habtu Assefa and Derje Gorfu 1985. A Review of Food legume Disease in Ethiopia. In: Tsedeke Abate (ed.). A Review of crop protection research in Ethiopia. 4-7 February, 1985. IAR, Addis Ababa, Ethiopia.

Rangaswamy, R. 1995. A Text Book of Agricultural Statistics. Wiley Eastern Limited. New Delhi, pp 496.

Sheno Agricultural Research Center. 1998-2002. Research progress reports, Sheno, Ethiopia

Environmental challenges to bread wheat research in the highland vertisol areas of north Shewa

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Abstract

Prolonged and severe waterlogging, frost injury, poor soil fertility and terminal moisture stresses are the major yield limiting factors at Gerakeya and Molale. An investigation made over two years revealed that waterlogging has brought about a 16% reduction in grain yield. Frost damage was negatively correlated with days to heading, 1000 seed weight, and grain yield, suggesting that bread wheat varieties that are late to head are not affected by frost damage. Stepwise multiple linear regressions revealed that chlorisis due to waterlogging and frost damages score explained about 33 and 18% of the grain yield variation, respectively. About 75% of the crops' growing period lied between September and December when the ETcrop, exceeded about three times the respective rainfall, which may subjected the crop to terminal moisture stress. The lowest daily temperature range of -4.8 to 4.8 0C has been recorded starting from heading at Gerakeya, which could induce frost injury to the reviving wheat from waterlogging injury. This was supported by the negative correlation (P = 0.1%) between the percent frost damage and days to heading, suggesting that wheat varietal development endeavour should look into late maturing variety that can stay at vegetative stage during the on set of low temperature. Based on the results obtained from this study, it has been possible to identify that waterlogging, frost and terminal moisture stress are the major environmental challenges to wheat production in North Shewa, more specifically at Gerakeya and Molale. Despite theses abiotic challenges, however, it was possible to develop high yielding and stable bread wheat variety for the study areas. The future bread wheat varietal development program should continue to work on targeted introduction and evaluation of bread wheat germplasm under these production constraints if the ever-growing demand of farmers in the study areas for improved wheat varieties has to be met.

Introduction

Wheat is the dominant crop grown in the highland vertisol areas of North Shewa. The variation in crop yield is quite high and the average yield per farm in a bad year is not adequate to meet the household food requirements. This is true especially in Molale and Gerakeya districts of North Shewa) where recurrent droughts have been documented. Sever and prolonged seasonal waterlogging, frost injury, poor soil fertility, terminal drought and lack of adapted varieties (with exception to Inewary area) are some of the factors for low yields. Although the problem of waterlogging is better controlled by planting crops on hand-made broad bed and furrow (BBF) at Ineward, this practice is not well adopted in other vertisol areas of North Shewa where wheat planting is done at the end of the rainy season called *amegne sindie* to escape the adverse effect of waterlogging stress. Early secession of rainfall in September is quite common and terminal moisture stress is a more likely phenomenon especially on shallow soils of Molale and Gerakeya areas. Temperature tends to drop in October and goes through December below the optimum for pollination and grain filling and aggravating the damaging effects of waterlogging and terminal moisture stress. Since 1997, the cereals improvement program of the former Sheno, now Debirebirhan Research Center has started targeted bread wheat germplasm evaluation. In this paper, results are discussed in relation to important soil and weather variables.

Materials and methods

Targeted bread wheat germplasm screening program has been started on 240 bread wheat materials since 1997 at Ineward (2600 meter above sea level), Molale and Gerakeya (3000 meter above sea level). The genotypes were planted on flat and hand-made broad bed furrow (BBF) in an augmented design where national standard checks (ET13, HAR 1709, HAR1685 and the respective local checks) were randomly assigned to each block. Every year best genotypes were advanced for further evaluation. Planting was done in the first week of July. Recommended rate of fertilizers (60-60, kg ha-1, N/P2O5) was used for the experiment. The study areas were described based on soil characteristics, temperature, rainfall and crop evapotranspiration (ETcrop). Stress susceptibility index (S) was calculated as S = (1-YD/YP)/D where YD = yield under waterlogging stress, YP = yield under unstressed condition, and D is the stress intensity (D= 1-XD/XP), where XD and XP are mean yield of all varieties under stressed and unstressed conditions, respectively (Reddy and Kidanie., 1993). Data on waterlogging and frost injury were recorded using a scale (1-10), where 1= 10% chlorisis/frost damage, 2 = 20% chlorisis/frost damage ,9 = 90 % chlorisis/frost damage and 10 = 100%. Chlorisis/frost damage. The latitudinal location of Molale and Gerakeya are 10^0 0' 30" N and 10^0 0'1'' N, respectively. Based on which the tabulated mean daily percentage (p) of the annual daytime hours were read from FAO, 1992) for the determination of ETcrop. Using the average duration of the growth stage of wheat at Gerakeya and Molale to be 150 days, the crop coefficients (KC) value for the four different growth stages (Initial, development, mid season and late season) of wheat were taken from the FAO, 1979). Daily and monthly ETcrop was calculated based on Blaney-Criddle method (FAO, 1992).

Results and discussion

Soil Fertility problem

Ineward: the slop is about 2 % and the soil is pellic vertisol with total clay content of 75-78 %, which classifies the texture to be heavy clay. The pH is slightly acid (6.41), which is a satisfactory soil for most crops but should be monitored. Low organic matter (1.18%), low nitrogen (0.17%) and a narrow C characterize the soil of Ineward: The narrow C: N (6.4) ratio shows a slow rate soil mineralization under the cool climate. Available Phosphorus is low (7.25ppm) and is the limiting factor for crop production. The permeability of the soil is very slow and consequently seasonal waterlogging is its typical feature of the soil.

Molale: the site is plateau with slops of 1.5 %. The soil at the site is pellic vertisol with a clay content of 65-73%. The pH is slightly acid (6.11), and with very low organic matter (1.73%) and low phosphorous 8.93 PPM. The total nitrogen status of the soil is low (0.16%) with a narrow C: N ratio (6.41). the nutritional status of the soil at the site is not adequate to meet the wheat requirements for mineral nutrients. The soil is typical clay, and hence waterlogging injury to wheat is inevitable.

Gerakeya: the physiography of the surrounding area is moderately plateau, the soils are cambisols, lithosols, and stones are abundant. The subsoil is imbedded with impermeable layer of stone. The well known farmers' proverb describes this as a "Tincha" soil'' or "Bechereka Yemiderk" or ''Yeset lib Keyatie." The clay content is 57-65 %, suggesting that the soil texture is clay. The pH is slightly acid (6.28) with relatively low organic matter (2.3%) and better phosphorous supply (49.81 PPM). The total nitrogen status of the soil is low (0.17%) with narrow C: N ratio (8.08). The soil is typical clay, and hence waterlogging injury to wheat is inevitable.

Waterlogging problem

The inherent physical properties of the soil in the study areas along with heavy rainfall between July and August have been imposing serious damage to crops. About, 82.5% at Gerakeya and 92.3 % of the rainfall at Molale concentrated in July and August when the crop water requirement of wheat is very low. During these two months, the soil is waterlogged or very wet beyond the moisture demand of the crops, which consequently brought bout an odd injury to wheat. Waterlogging injury is manifested by progressive leaf yellowing or chlorisis starting from the older leaves, which therefore has known to cause a reduction of stomatal conductance and rate of photosynthesis. Nutrient deficiency caused either by inhibition of ion up take and transport in the roots or decreased concentration of some nutrient (notably) nitrate and some basic cations due to leaching were described as the major injury attributed to waterlogging (Alemayehu, 1995). In our bread wheat regional variety yield trial carried out at Molale and Gerakeya, waterlogging brought about on average a 20% grain yield reduction, which is in agreement with the result of (Gales et al., 1984), who was able to observe a 30% yield reduction in barley. Alemayehu (1995) reported a significant reduction of number of spiklets per plant, grain yield per plant, daily dry matter accumulation per plant and leaf area per plant due to a 12 day waterlogging on barley in pot experiment. Negative and significant ($P < 1\%$) correlation coefficient between Chlorisis due to waterlogging with plant height, 1000 seed weight and grain yield were noticed in bread wheat Table 3. The negative correlation between grain yield and thousand-grain weight with chlorisis may be attributed to the unfriendly effect of waterlogging on the leaf stomatal conductance and rate of photosynthesis. Abuhay and McDavid (1995) reported an increase of 82.9-96.4% stomatal resistance, but a decrease of 55.6% net photosynthesis over the control plant because of four cycle and six days waterlogging and giving relief for four days. The positive correlation between days to heading and chlorisis due to waterlogging may be the adverse effect of waterlogging on growth rate or daily dry matter accumulation and dalliance of seed emergence as reported in (Alemayehu, 1995).

Improved surface drainage can alleviate waterlogging effects, but cannot fully avoid for it depends on the slope of the farmland used for cropping and the soil characteristics. In our wheat trial, the use of hand-made broad bed furrow significantly (P = 1%) reduced chlorisis on the average by 19%, and enabled the crops to establish well and fair utilization of the transition period from one developmental stage to the next and head earlier than by seven days. Because of three to six days of waterlogging, (Alemayehu, 1995) reported about 9 to 23% seedling establishment reduction and 5 to 8 days dalliance of germination. Wheat varieties respond waterlogging differently. For instance, out of the 18 bread wheat genotypes included in regional yield trial, about 13 genotypes have had Susceptibility index to waterlogging (S<1) Table 4. Variety HAR1568 has had very low value of "S" = 0.04 in comparison to well widely adapted nationally released variety, ET-13 and HAR604 with corresponding " S" value of 0.06 and 1.02 respectively. Low values of" S"< 1 indicates that resistance of a given variety for a given stress, in this case waterlogging (Reddy and Kidanie., 1993).

Terminal moisture stress

Enhanced wheat vegetative growth and full ground cover are attained in September, during which the ETcrop is exceeded the rainfall at Gerakeya (Table 2). Gerakeya received about 26.2-42.4mm rainfall, which is by far lower than the corresponding ETcrop 77.4-102.5mm in September. Much of the reproductive stages of bread wheat varieties fall in October when the ETcrop 73.5-100 7 mm/month is beyond a doubt greater than the respective rainfall 11.4 -19.8mm/month Table 3. About 70 % of the growing periods of wheat are characterized by 62.54 mm ETcrop as opposed to 18.4 mm rainfall at Gerakeya while Molale is symbolized by 53.56mm ETcrop and 23.43mm rainfall, implying that most of the reproductive and grain filling period of wheat may suffer from moisture stress. It is expected that the mid season and late season stage wheat liable to moisture stress. It is obvious, that wheat grown on shallow soils face rapid soil moisture loss especially when it is accompanied by dry desiccating wind, low relative humidity and frost, both of which are characteristics of the study areas. Hence, there is likelihood of experiencing a sudden moisture deficit during the reproductive and grain filling stage of the crop. Drought resistance increases during germination and until tillering stage and decrease remarkably when shooting in cereals (Pandey and Sinha, 1995).

Table 1. The effect of land preparation methods on some agronomic traits of bread wheat varieties combined over two locations (Molale and Gerakeya) in 1999 and 2000 main seasons

Year	*Seedbed*	*Chlorisis* (1-10)*	*Frost damage (%)*	*Days to heading*	*Plant height*	*Seed weight (g plot^{-1})*	*(kg ha^{-1})*
1999	BBF	2.86	17.7	89	76	37.3	1382
	Flat	3.78	14.7	94	63	36.5	1028
2000	BBF	2.81	12.6	93	73	38.2	1493
	Flat	3.25	3.06	99	69	38.2	1377
Mean	BBF	2.835	15.15	91	75	37.75	1437.5
	Flat	3.515	8.88	97	66	37.35	12.02.5
CV (%)		17.14	50.56	4.23	7.73	11.32	28.94

** Chlorisis due to waterlogging*

Table 2. Mean and ranges of temperature, rainfall and daily crop evapotranspiration (ETcrop) at two sites during the crop season (July-November) in 1996-2000

	July		August		September		October		November	
Gerakeya (1996 -1998)	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Maximum mean temp. in °c	16.6	16.5-16.8	17	16.4-17.5	17.6	17.2-18.1	16.8	17.6-17.2	17.1	16.9-17.5
Minimum mean temp. in °c	8.1	7.8-8.3	7.9	7.4-8.6	8.0	7.7-8.5	6.4	4.7-7.3	5.6	4.7-6.8
Lowest daily temp. in °c	5.5	4.8-5.8	5.0	3.0-6.2	6.5	5.6-7.2	6.5	-4.8-4.8	4.85	3.9-5.8
Rain fall in mm/month	338.8	248.5-458.5	248.1	203.7-315.8	35.4	26.2-42.4	19.8	0-48.4	13.3	0-21.2
Et crop in mm/month	29.47	26.14-34.68	29.08	25.5-34.02	87.67	77.4-102.5	85.16	73.5-100.7	14.79	6.3-21.88
Rain fall in mm/day	11.29		8.27		1.18		0.66		0.44	
Et crop in mm/day	0.98		0.97		2.92		2.84		0.49	
Molale in 1996										
Maximum mean temp. in °c	12.4		11.8		14.8		14.6		14.6	
Minimum mean temp. in °c	7.8		7.4		7.9		6.6		7.1	
Lowest daily temp. in °c										
Rain fall in mm/month	335.9		393.7		40.9		11.4		18.0	
Et crop in mm/month	23.9		22.76		22.7		69.67		68.61	
Rain fall in mm/day	11.19		13.12		1.36		0.38		0.60	
Et crop in mm/day	0.79		0.76		0.76		2.32		2.28	

Frost injury

Temperature tends to drop in October and goes through December below the optimum (15-20^{0}c) for grain filling, and inflicting serious damage on the reviving plants from waterlogging (Fig. 4). The lowest daily temperature range of -4.8 to 4.8^{0}c has been recorded at Gerakeya that could induce frost injury to wheat (Table 2). This temperature range was lower than wheat basal temperature 5^{0}c. Drainage may reduce the amount of water to be held by the soil that consequently crops on BBF may get more frost injury than their counterpart on flat seedbed. This may happen because of the fact that crops may fail to replace the dehydrated protoplasmic water by the coalescing and growing intercellular ice crystals. Varieties took to head less than or equal to 95 days had a 35% more frost injury than those took more than 100 days. It was observed that varieties planted on hand-made broad bed furrow (BBF) headed earlier and tends to be more vulnerable to frost injury than on flat seedbed. This is so because drainage may reduce the amount of water to be held by the soil that consequently crops on BBF may get more frost injury than their counterpart on flat seedbed. This may happen because of the fact that crops may fail to replace the dehydrated protoplasmic water by the coalescing and growing intercellular ice crystals. Freezing to death usually occurs in association with insufficient soil moisture (Poehlman and Sleper, 1995). This was confirmed by the negative and significant ($P<1\%$), correlation between frost injury and percent chlorisis due to waterlogging (Table 3). Therefore, as low-temperature injury was more pronounced on early heading varieties than on late, the wheat breeding efforts should emphasize on selecting late heading varieties that can stay vegetative during the onset of low temperature while giving due consideration for the potential harm of terminal moisture stress.

Bread wheat germplasm evaluation

The relative performance of 240 bread wheat genotypes along with the respective local and national standard checks have been assessed for their yield potential under north Shewa conditions on flat (with out draining excess water) and on hand-made broad bed furrow (BBF) since 1997. Promising genotypes were advanced for the subsequent yield trial. Accordingly, multi-environment bread wheat regional variety trial comprised of 16 genotypes along with the standard check HAR1899 and the respective local check of Inewary, Molale and Gerakeya was carried out in 2001-2004/2005 main seasons. The objective of this research was to identify stable and high yielding bread wheat variety under North Shewa conditions. The experiment was arranged in RCBD replicated three times within an experiment. AMMI-1 analysis of grain yield data from 12 environments highlighted that variety HAR3008 ranked first in 10 out of 12 environments. In addition, HAR2941, HAR3076 and HAR2975 were the most stable varieties across ten environments, reflecting their potential use for wide adaptation at Inewary, Molale and Gerakeya areas. These varieties are characterized by high grain yield, resistant to yellow rust and relatively more stable than the standard check HAR1899. In an other multi-environments yield trial, varieties HAR2909, HAR2896 and HAR2489 were identified to be superior for grain yield, and out of which variety HAR2896 was released in 2005 for North Shewa wheat growing areas. All varieties selected from the two multi-environments yield trial are proved suitable for bread making as confirmed by the Kaliti food processing industry.

Table 3: Correlation coefficient between some agronomic traits

	1	2	3	4	5	6
Days to heading	1.0	-0.48***	0.24***	-0.35***	-0.22***	0.47***
Plant height		1.0	0.35***	0.47***	-0.02^{ns}	-0.63***
1000 seed weight			1.0	0.50***	-0.12*	-0.45***
Grain yield kg/ha				1.0	-0.38***	-0.58***
Frost damage %					1.0	-0.09**
Chlorisis due to waterlogging						1.0

**** Significant at P < 0.1%, ** significant at P <1%, * significant at P <5%, ns- not significant*

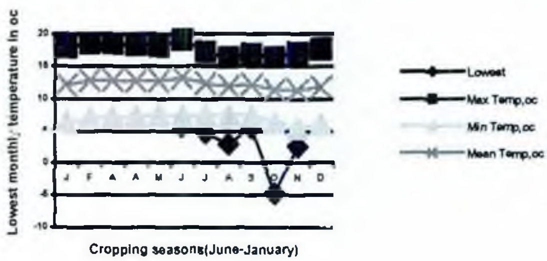

Fig 4. The lowest daily mean, minimum and maximum temperature during the cropping season (June-January) in 1998 at Mehal Meda

Table 4. Mean grain yield , days to heading and susceptibility index (S) of varieties tested across two locations (Molale, and Gerakeya) and over two years (1999-2000) using different seed bed preparations (flat and BBF)

Varieties	Seed bed preparation methods				Susceptibility index (S) for grain yield (kg ha^{-1})
	BBF		Flat		
	Days to heading	Grain yield (kg ha^{-1})	Days to heading	Grain yield (kg ha^{-1})	
ET 13 A2	101	1497	103	1482	0.06
HAR 1568	93	1440	96	1430	0.04
HAR 1899	93	1798	99	1674	0.42
HAR 1884	94	1089	97	1113	0.13
HAR 1008	78	1417	85	1272	0.62
HAR 1852	91	1303	94	1137	0.78
HAR 1920	90	1524	96	1017	2.03
HAR 1868	88	1783	92	1387	1.35
HAR 2103	93	1185	97	1133	0.27
HAR 1780	95	1344	99	1189	0.70
HAR 1847	91	1517	95	1110	1.63
HAR 1881	86	1835	92	1335	1.66
HAR 1889	83	1197	89	934	1.34
HAR 1909	92	1435	97	1179	1.09
HAR 1913	88	1426	94	1128	1.27
HAR 1924	88	1597	95	1137	1.85
HAR 2023	90	1382	95	985	1.75
HAR 2049	95	1068	103	849	1.25
HAR 1904	104	1763	107	1541	0.77
HAR604	94	1540	98	1283	1.02
Local check	92	1050	95	919	0.76
Mean	**91**	**1437**	**96**	**1201**	**0.99**
LSD (5%)	**1.61**	**176.1**	**2.18**	**197.4**	
CV (%)	**3.57**	**24.94**	**4.59**	**33.3**	

Reference

Abuhay T. and C.R. McDavid. 1995. Physiological and Anatomical Responses of Cowpea (*Vigna anguiculata* (L.) Walp) to Short Durations of Waterlogging. In: Proceedings of the 7th Annual Conference of the Crop Science Society of Ethiopia. 27-28 April, 1995. Addis Ababa, Ethiopia.

Alemayehu, A.G. 1995. Effect of Waterlogging on Growth and Nitrogen Content in the Shoot of Barley (*Hordeum vulgare* L.) at Different Stages. In: Proceedings of the 7th Annual Conference of the Crop Science Society of Ethiopia. 27-28 April, 1995. Addis Ababa, Ethiopia.

FAO. 1979. FAO Irrigation and Drainage Paper No. 24. P. 3, 1977.

FAO. 1992. FAO Irrigation and Drainage Paper No. 33. P. 3, 1977

Gales, K., Sarah, M.A., and Cannel, R.Q. 1984. Effects of Waterlogging and drought on Winter wheat and Winter barley Grown on a Clay and Sandy loam soil. II. Soil and plant Water Relationships. Plant and Soil, 80, 67-78.

Pandey S.N. and B.K. Sinha. 1995. Plant Physiology. 3rd edition. Vikas Publishing House Pvt.Ltd. New Delhi, India.

Poehlman, A.M and D.A. Sleper. 1995. Breeding Field Crops (4th. ed.). IOWA State University Press, IOWA,

USA.

Reddy, M.S. and Kidane Georgis. 1993. Dry Land Farming Research In Ethiopia: Review of the past and thrust in the nineties. Institute of Agricultural Research, Addis Ababa, Ethiopia *In:* Pandey, S.N and B.K., Sinha. 1995. Plant Physiology (3rd ed). Vikas Publishing house, Pvt. Ltd. New Delhi, India.

Improving sorghum production using striga resistant and early maturing varieties in north eastern Ethiopia

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Abstract

Sorghum is the most important food crop in Wollo both in area coverage and production. It is a multipurpose crop used for food, animal feeds and as source of cash. However, it faces production constraints such as drought (low moisture stress), striga competition and stalk borers attack. Therefore, developing high yielding, drought tolerant and striga resistant varieties is an indispensable solution. Sirinka agricultural research enter, as one of the mandatory research centers of sorghum research, has released four striga (Striga hermonthica) resistant varieties (Abshire, Gobye, Birhan and Hormat) and three early maturing varieties (Yeju, Teshale and Abuare) for low moisture stress areas. These varieties have better yielding ability, good grain traits and are accessible technologies for the poor farmers in the striga prone and low moisture stress sorghum growing environments.

Introduction

Sorghum (*Sorghum bicolor* L.[Moench]) is the fifth important crop among the cereals in the world (Dogget, 1988; Rohman *et al.*,2004). It is one of the most important indigenous cereal food and feed crops in Ethiopia. It grows in 13 of the 18 major agro-ecological zones (AEZs) and in 41 of the 49 sub-AEZs in the country. Sorghum is the second most important crop next to teff in eastern Amhara region (CSA, 2000a). Factors limiting sorghum production are poor soil fertility, erratic and unreliable rainfall, weeds and other biotic factors (Asfaw *et al.*, 2005). Uneven distribution of rainfall with short rainy season is the frequent phenomena in sorghum growing regions of north eastern Ethiopia. Witchweeds (*Striga spp.*) are weeds of economically important parasites of sorghum, millets and other cereals in addition to moisture stress in tropical Africa and Asia. Yield losses of sorghum are very high due to striga infection coupled with low moisture stress and lack of production inputs. *Striga hermonthica* causes considerable losses of yield to many crops that can reach up to 70 % in sorghum (Dogget, 1988). Eradication of striga has been difficult to the unique adaptation of striga to its environment and the complexity of the host parasite relationship. Suggested control measures including mechanical or chemical weeding, soil fumigation and nitrogen fertilization have been costly and beyond the means of poor subsistence farmers. Host plant resistance (physiological mechanism) is probably the most feasible and potentially durable method for the control of striga (Oliver *et al.*, 1991; Ejeta, 2003). One of the means by which sorghum plants could avoid parasitism is through a low production of stimulants for the germination of striga seeds, which germinate only in response to specific compounds exuded by host roots (Saunders, 1933; Kumar, 1940; Williams, 1959).

Therefore, the objective of this study was to resolve some sorghum production constraints (striga and low moisture stress) with sustainable and cost effective technologies for subsistence sorghum growing farmers in north eastern Ethiopia.

Materials and methods

Field experiments were conducted at Sirinka, Kobo, Gobye, Cheffa and Hara (representative sites for sorghum growing areas of Wollo) since 1997 by Sirinka Agricultural Research Center (SARC). The genotypes were planted in randomized complete block design with three replications. Each plot had 5 rows at spacing of 15 cm and 75 cm between plants and rows, respectively. Fertilizer was applied at the rate of 50 kg ha^{-1} Urea and 100 kg ha^{-1} DAP at all locations. Planting was done from end of June to beginning of July at the onset of the main rainy season. Other cultural practices were done as required. The released materials were studied in two groups based on their maturity and striga resistance, and were evaluated for their heading and maturity days, plant height, 1000 seeds weight, weight and number of heads per plot, striga count per plot and economical yield. Combined and specific analysis of data over years and locations were computed using MSTAT-C computer program.

Result and discussions

Early maturing sorghum varieties

Early maturing sorghum genotypes screening has been done for the last 20 years at Sirinka and Kobo. Variety 76 T_1 # 23 (Wediaker) is the oldest variety released for low land Wollo areas and is performing well in Kobo areas. MeKo-1 variety was also nationally released for Meiso and Kobo areas. Teshale and Yeju varieties were released in 2002 by Sirinka Agricultural Research Center for low land and intermediate areas. These varieties have good plant height, white bold seed and higher yield i.e., are sorghum growers' selection criteria. The performance of these varieties in the study environments revealed that they showed up to 31 % and 94 % yield advantage over the local check (Jigurty) and the standard check (76 T1 # 23), respectively (Table 1).

Table 1. Average yield and agronomic performance of Yeju and Teshale, On-station, 1997-1999

						% yield advantage over the	
Variety	DH*	PH (cm)	DM	GY (kg ha^{-1})	100 SW (g)	Local check	Standard check
ICSV 111 inc. (Yeju)	68	172	108	5095.8	3.4	21	79
3443-2-OP (Teshale)	73	215	117	5546.8	3.2	31	94
76 T_1 # 23(Standard check)	67	143	107	2852.8	2.4	-	-
Jigurty (Local check)	78	284	126	4228.8	3.5	-	-
Mean	**73**	**190**	**114**	**4588.6**	**3.0**		
CV (%)	**7.9**	**17.4**	**5.4**	**14.8**	**1.8**		

** DH-days to heading; PH- plant height; DM-days to maturity; GY-grain yield; SW-seed weight*

Abuare variety, recently released as early maturing, has an additional advantage of earliness, white bold seed and stay-green traits. Stay-green genetic background is one of the post-flowering mechanisms of drought resistance by delaying senescence then proceeds at a normal rate (Thomas and Howard, 2000). During post-anthesis drought, genotypes possessing the stay-green trait maintain more photosynthetically active leaves than genotypes not possessing similar trait (Rosenow *et al.*, 1983). Therefore, the stay-green trait of abuare variety is similar to the above findings. The across locations statistical analysis in 2000 and 2001 cropping seasons revealed that there was significant difference among the tested genotypes for all evaluated traits (Table 2). Abuare showed significantly higher grain yield than other tested varieties with short growing periods and also had 5.9 % and 4.9 % yield advantage over the local and the standard checks, respectively. The released varieties are better than the checks in maturity, grain yield, seed quality and adapted to lower altitudes of sorghum growing environments.

Table 2. Performance of early maturing sorghum genotypes over locations and years (2000-2001)

Variety	DH	PH (cm)	DM	GY (kg ha^{-1})	100 SW (g)
90MW5250	71	202	123	4040.4	2.9
90MW5353 (Abuare)	73	148	120	3824.2	2.7
ICSV-1112 BF	69	167	116	3950.7	3.0
97MW6038	72	152	119	4210.0	2.8
97MW6072	69	145	119	3834.8	2.7
[IS 6744 X 23209-96]-9-1	68	137	112	3684.3	2.5
97MW6050	75	139	124	3335.7	2.7
97MW6105	68	147	112	3555.1	2.6
MEKO-1 (standard check)	72	174	121	3645.8	2.9
JIGURTI (local check)	76	260	126	3612.3	3.0
MEAN	**71**	**167**	**119**	**3769.3**	**2.8**
CV (%)	**3.61**	**14.01**	**8.15**	**15.61**	**12.85**
A	**	**	**	**	**
YL	**	**	**	*	**
LA	**	**	**	NS	*
LYA	NS	**	**	NS	NS

** Significant at 5 % probability level; ** Significant at 1 % probability level;*
NS-nonsignificant; LY-Location by year, LA-Location by variety; YA-Year by variety;
LYA-Location by year by variety interactions

Striga resistant sorghum varieties

Striga resistant sorghum varieties were released for striga prone sorghum growing environments. According to Ejeta (2003), the new genotypes which showed lower striga infestation number per plot with better grain yield than resistant released variety are considered as resistant genotypes. Therefore, the released striga resistant varieties (Abshire, Gobye and Birhan) hosted very small amount of striga number than the susceptible and resistant checks with good grain yielding ability (Table 3). Birhan had 50.5 % and 26.1 % grain yield advantage over the local (Jigurty) and standard (Gobye) checks, respectively.

Table 3. Mean grain yield and agronomic data of Birhan compared with the checks

Variety	DH	PH (cm)	DM	GM (kg ha⁻¹)	Actual striga counted	Striga Count (SQRT)	100 SW (g)
KEY # 8566 (Birhan)	63	133	101	4187.8	86	7	3.3
P-9401 (Gobye)(Standard check)	62	127	100	3320.5	113	7	3.0
Jigurty (Local check)	71	234	114	2782.1	965	23	3.4
Mean *	**62**	**139**	**102**	**3405.2**	**189**	**9**	**3.2**
CV (%)	**5.3**	**8.1**	**6.11**	**13.4**	**46.4**	**18.3**	**2.3**

** Mean of 13 entries over 6 environments (location by years)*

Abshire and Gobye had good resistant to striga with better grain yielding ability in moisture stress environments but had thresh-ability problem. Birhan has red seed color which is not preferred in the market but hosted small number of striga per plot and had better yield advantage than Gobye. To alleviate such limitations of existing striga resistant varieties, variety Hormat was released in 2005 cropping season. It has an additional advantage of good plant height, white bold seed, with less number of striga infestations, better grain yielding ability and good thresh-ability. It also had 32.7 % yield advantage over the checks (Table 4).

Table 4. Mean grain yield and other agronomic data of test genotypes across locations and years

Variety	DH	DM	PH (cm)	1000 SW (g)	Striga Count	GY (Kg ha⁻¹)
99MW 4002	79	123	130.6	24.5	40	2168.5
99MW 4003	72	121	133.8	31.5	55	2731.2
ICSV 1005 HV	68	120	161.2	27.4	70	2075.5
ICSV 1112 BF(Hormat)	71	121	164.1	30.5	38	2326.2
P- 9403	70	121	128.5	29.0	42	2212.4
Ayfere-Asfachew	79	127	197.1	29.1	298	1918.5
P-9401	71	121	116.7	25.1	36	1757.7
KEY # 8574 (Susceptible check)	89	130	134.0	20.8	689	737.9
Jigurti (Local check)	81	130	226.6	31.9	325	1752.7
Mean	**75.8**	**123.9**	**154.8**	**27.8**	**177.2**	**1964.5**
CV (%)	**6.74**	**1.7**	**9.9**	**8.9**	**88.9**	**13.8**
LY	**	**	**	**	**	**
LA	**	NS	NS	NS	**	NS
LYA	**	**	**	**	**	**

** Significant at 5% probability level. ** Significant at 1% probability level; NS-Non significant;*
LY-Location by year, LA-Location by variety, YA-Year by variety; LYA-Location by year by variety interactions

Hormat showed better performance at Hara, Gobye and Kobo than at Sirinka (the intermediate area). It had also fewer striga numbers in lower areas than intermediate areas. The susceptible check hosted more number of striga producing lower grain yield at both low and intermediate environments. Therefore, Hormat was better than Birhan and Gobye in plant height, thresh-ability, grain yield and seed quality. It had also better adaptation in low moisture stress and striga prone sorghum growing environments.

References

Asfaw Adugna, Tesfaye Tesso and Abera Deresa. 2005. Production Guideline: Production and Research Experiences, EARO, Ethiopia.

CSA (Central Statistical Authority). 2000a. Agricultural Sample Survey, 1999/2000, Volume I: Report on area and production for major crops (Meher season). Statistical Bulletin No. 244. Addis Ababa, Ethiopia.

Dogget, H. 1988. Sorghum. Tropical Agriculture Series, 2nd ed., Longman Scientific and Technical –IDRC, New York.

Ejeta, G. 2003. Striga Biotechnology Development and Technology Transfer: *Proc*: Sustainable Plant protection Systems. Dept. of Agronomy, Purdue University, West Lafayette, USA.

Kumar, L.S.S. 1940. Striga Research in Bombay. *Indian Farming* 1: 609.

Oliver, A, K.V. Ramaiah and G.D. Leroux.1991. Assessment of Sorghum Resistance to Striga *hermonthica*. Pp 114-121. *In*: Ransom J.K., L.J. Musselman, A.D. Warsham, and C. Parker (eds). Proceedings of the 5th International Symposium of parasitic weeds. Nairobi: CIMMYT.

Rohman, M. M., M.A. Hakim, N.A., Sultana, M.E. Kabir, M. Hasanuzzan and M. Ali. 2004. Genetic diversity analysis in sorghum. *Asian journal of plant sciences* 3(2): 211-214.

Rosenow, D.T., J.E. Quisenberry, C.W. Wendt, and L.E. Clark. 1983. Drought tolerant sorghum and cotton germplasm. *Agriculture Water Management* 7: 207-222.

Saunders, A.R. 1933. Studies in Phanerogamic parasitism with particular reference to striga lutea Lour. Science Bulletin-Department of Agriculture (South Africa) 128:1-56

Thomas H. and Howard CJ. 2000. Five ways to stay green. *Journal of Experimental Botany* **51**, 329-337.

Williams, C.N. 1959. Resistance of sorghum to Witchweed. *Nature* 84: 1511-1512.

Wheat variety development efforts in Wollo, Ethiopia

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Abstract

Wheat is one of the major cereal crops grown in Ethiopian highlands. It is an emerging crop grown by farmers for food, animal feeds and cash source in northeastern Ethiopia. Low moisture stress, poor soil fertility and diseases are the main production constraints for wheat production in northeastern Ethiopia. To solve these production constraints of wheat in the region, Sirinka Agricultural Research Center was involved in wheat improvement since 1997. The center has recommended some high yielding and drought resistant wheat varieties for the area. These released and recommended wheat varieties were popularized and distributed to farmers and other stakeholders in the region to enhance wheat production and productivity.

Introduction

The cultivated wheat (*Triticum aestivum* L. and *Triticum durum* Desf) is largely grown in North America, Canada, Mexico, Central America and South America, Western Europe, Eastern Europe, Former Soviet Union, Asia, North Africa, East and Southern Africa and Oceania (CIMMYT, 1996). Ethiopia is the largest wheat producer in sub-Saharan Africa with about 0.75 million hectares of land allotted to wheat per year (Hailu *et al.*, 1991). It is one of the major cereals crops grown in the Ethiopian highlands. Its importance is increasing because of its higher productivity than other crops. Farmers grow wheat for food, animal feed and cash source in northeastern Ethiopia. The production of wheat in eastern Amhara sub-region is increasing and currently covers 13 % of the arable land and 33.3 % of the crop area coverage annually (CSA, 1997/98). Low moisture stress, poor soil fertility and diseases are the major wheat production constraints in northeastern Ethiopia and the amount and the distribution of rainfall are the prime concern in the region. Because of these constraints the production and productivity per unit area is far below the potential. The objective of this study was to solve wheat production constraints by developing appropriate technologies (high yielding, early maturing and disease resistant varieties) that are suitable in the region.

Materials and methods

Two sets of field experiments, i.e., bread wheat and durum wheat, were conducted at Geregera, Kone and Jamma testing sites starting in 1997. The genotypes were planted in a randomized complete block design with three replications. The plot size used was 1.2 m with 2.5 m width and length, respectively. Fertilizer rate was 50 kg ha^{-1} urea and 100 kg ha^{-1} DAP in all locations and years. Planting was done at the onset of the main rain season, i.e., from the end of June to the beginning of July. Cultural practices were done as required.

The genotypes were evaluated based on days to heading and maturity, plant height, 1000 seed weight and grain yield. Combined analysis over years and locations and specific analysis of data were computed using MSTAT-C computer program.

Result and discussions

Adaptation trials

The bread wheat varieties HAR 1685 (Qubsa) and HAR 604 (Galama) showed good performance in 1998 and 1999 at Kone and Geregera. They had good harvest index and grain yield than all varieties. These two varieties were recommended for the tested environments and similar areas (Kebede and Hailemichael, 2004). The adaptation trial of durum wheat in 1998 and 1999 revealed that Bichena and Boohai showed better performance than the local check at Kone and Geregera. They also gave high biomass yield (feed) compared with other varieties. These varieties matured earlier than the local check (Hailemichael and Kebede, 2006).

Variety development

Statistical analysis of bread wheat variety trial across years and locations revealed that there was significant difference ($p<0.05$) among the tested genotypes in all evaluated traits except biomass per plot (Table 1).

Table 1. Mean grain yield and agronomic data of bread wheat genotypes tested over locations (Geregera, Kone and Jamma) and over years (2002-2004)

Variety	Days to Heading	Days to maturity	Plant height (cm)	Biomass (g plot^{-1})	Grain yield (kg ha^{-1})	1000 seed weight (g)
HAR 3802	79	138	75.6	1376.3	2712.7	34.6
HAR 3863	74	135	75.1	1491.5	2800.4	38.1
HAR 3947	83	141	76.9	1614.8	2603.1	35.4
F6-99, 8-3	77	138	94.7	1508.5	2562.9	40.8
F6-99, 19-2	80	141	85.8	1520.4	2750.4	34.8
HAR 3821	78	137	77.9	1415.6	2834.8	37.6
HAR 3819	81	137	76.7	1350.7	2491.0	31.0
HAR 3807	77	135	78.2	1383.3	2777.1	38.5
HAR 3820 a	77	136	82.2	1502.9	2933.7	37.8
F6-99, 15-14	79	137	79.56	1537.0	2927.4	41.3
Standard check	76	135	74.8	1485.6	2799.4	41.6
Local Check	76	132	82.0	1277.0	2245.8	37.7
Mean	**78**	**137**	**80.0**	**1455.3**	**2703.2**	**37.4**
LSD (5%)	**2.2**	**2.0**	**2.8**	*NS*	**261.3**	**185.2**
CV (%)	**5.3**	**2.7**	**6.5**	**23.7**	**18.0**	**7.2**
V	**	**	**	*	**	**
LV	*NS*	**	**	*NS*	*NS*	**
LY	**	**	**	**	**	*NS*
LYV	*	**	**	*NS*	**	*

**Significant at 5% probability level, **Significant at 1% probability level, NS=Non significant V=Variety, LY=Location by year, LV=Location by variety, & LYV=Location by year by variety interactions; [a] released variety.*

The released bread wheat variety, Warkaye (HAR 3820), has 23.5% and 4.6% yield advantage over the local and standard checks, respectively. It also had good resistance to yellow rust compared to other candidate varieties and checks. The score for HAR 3227, HAR 3661, HAR 3820 (Warkaye), HAR 3123 (Tossa) and the local check were 20 MR, 20 MR, 10 MR, 20 MR and 30 MR, respectively.

The combined analysis over years and locations of durum wheat trial revealed that there was significant difference among the tested genotypes for all plant characters (Table 2). *Malefia* (variety no. 10; table 2) showed better yield than other genotypes. It showed 19% and 10.4% yield advantage over the local and standard checks, respectively. The variety also showed better disease resistance than other genotypes. In general, the durum wheat genotypes as well as the released variety-Melefia showed better performance in red and brown soils of North Wolo than the Jamma vertisols. The same result was obtained in durum wheat variety adaptation trial (Hailemichael and Kebede, 2006). Kality Food Share Company has approved the quality standard of these durum wheat varieties.

The released and recommended durum and bread wheat varieties were popularized, distributed and require further scaling out operations in the region.

Table 2. Mean grain yield and agronomic data of durum wheat genotypes tested over locations at Geregera, Kone and Jamma and over years (2001-2003)

No	Variety	Days to heading	Days to maturity	Plant Height (cm)	Grain yield (kg ha⁻¹)	1000 seed Weight (g)
1	Acc#212651	78.0	136.7	99.2	2522.2	37.7
2	Acc#213131	80.4	138.0	99.4	2509.1	40.8
3	/ARUD/NIGRIS3//GANCD97383-15Y-040M-040YRC-3M-OY	82.5	142.5	73.0	2087.0	43.1
4	AL TAR 84//AL TAR 84SERI/3/6#ALTAR84CIGM91-349-6B-OY-OB	74.0	140.3	76.1	2322.5	40.1
5	DIPPER/RISSALLAL TAT84/AOSCD91Y253-C-2Y-040M-030Y-1M-OY	74.3	139.1	75.0	2591.8	40.2
6	ICD92-0150-CAB1-11AP-OAP-8AP-OTR-4AP-OAP-Gdfl/G01	72.8	136.4	78.1	2480.0	45.4
8	CID91-0980-AR-5AB-OAP-2AP-OAP-Mrb3/Mna-1	73.3	141.8	76.9	2533.3	51.9
9	CID91-0760-AR-9AP-OAP-6AP-OAO-Rcr/3/chi//Gta/Stk/4/Bcr/1/1K54	69.6	138.0	81.5	2419.6	41.4
10	CDI91-0109-M-OAP-3AP-OAP-2APTR-3AP-OAP-Mrb3/Mgr-4	72.3	136.5	71.0	2383.5	38.4
11	CDI91-0746-AR-3AP-OAP-2AP-OAP-AL TAR84/Stn//Lahn	72.7	139.2	80.4	2711.9	41.5
12	F4/B/R 1996#21002(98 OSN Patho)	77.2	138.6	74.5	2443.9	36.5
13	DZ2514- - - F8N#1898 OSN	70.3	141.7	108.9	2322.9	43.3
14	Acc#7503	71.1	142.5	97.8	2423.0	43.3
15	Acc#8185	74.6	142.5	99.8	2486.4	47.0
16	Standard Check (Laste)	74.8	140.3	94.1	2456.3	43.2
17	Local Check	75.1	133.9	86.8	2285.1	39.2
	Mean	**74.61**	139.30	85.83	**2436.2**	**42.11**
	YA	NS	NS	**	**	*
	LV	**	**	**	NS	**
	LYA	**	**	**	**	**
	CV (%)	**5.32**	3.37	**15.87**	**17.44**	**8.84**

**Significant at 5% probability level, **Significant at 1% probability level, NS=Non significant; LY=Location by year, YA=Year by variety, & LYA=Location by year by variety interactions*

References

CIMMYT. 1996. CIMMYT 1995-96 world wheat facts and trends: understanding global trends in the use of wheat diversity and international flows of wheat genetic resources. Mexico, DF.

CSA (Central Statistics Authority). 1997/98. Addis Ababa, Ethiopia.

Hailemichael Shewayirga and Kebede Teshome. 2006 . Adaptability of released durum wheat varieties in moisture stress areas of northeastern Ethiopia. *Journal of Crop Science Society of Ethiopia*, Addis Ababa, Ethiopia (*in Press*).

Hailu Gebre-Mariam, Tanner, D.G. and Mengistu Hulluka. 1991. Wheat research in Ethiopia: A historical perspective . Addis Ababa: IAR/CIMMYT.

Kebede Teshome and Hailemicheal Shewayirga. 2004. Performance of bread wheat varieties in moisture stress areas of Wolo, northeastern Ethiopia. Crop Science Society of Ethiopia. Sebil. Vol.10. Proceeding of the tenth conference, June19-21, 2001. Addis Ababa.

Performance of tef varieties in moisture stress areas of Wolo, northeast Ethiopia

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Abstract

Two separate field experiments were carried out at Sirinka, Kobo, Mersa and Chefa to evaluate the adaptability of ten nationally released tef varieties, and to select early maturing varieties. The trials were laid out in RCB design with three replications. The results of experiment I indicated that the varieties showed better performance at Sirinka and Kobo. The mean days to maturity at Sirinka, Kobo and Mersa were 84, 74 and 68, respectively, indicating that the varieties tend to mature late at Sirinka, but early at Mersa. The performance of varieties DZ-01-974 and DZ-Cr-37 was consistent across locations and years which had a yield advantage of 26.5% and 24.2% over the local check, respectively. DZ-01-974 was also preferred in areas where there is acute feed shortage such as in Kobo and Chefa due its' highest biomass of of 8867.7 kg ha^{-1}. Based on the consistent performance and relatively higher yield, these two varieties could be recommended for production in the test locations. The results of experiment II showed that the highest mean grain yield was recorded by the genotype DZ-01-146 (2167.9 kg ha^{-1}) followed by DZ-01-1821 (2074.6 kg ha^{-1}) and Ho-Cr-139 (1947.2 kg ha^{-1}). Genotype DZ-01-146 had a grain yield advantage of 19.1% and 11.8% over the local and standard checks, respectively. Similarly, DZ-01-1821 had a yield advantage of 12.3% and 6.5% over the local and standard checks, respectively. Based on the grain yield, biomass yield and seed color, farmers ranked DZ-01-1821, DZ-01-146 and DZ-01-2054 as first, second and third, respectively. The two genotypes i.e., DZ-01-1821 and DZ-01-146 were officially released in 2005 named as Zobel and Genete, respectively.

Introduction

Tef, *Eragrostis tef* (Zucc. Trotter) the versatile small seeded cereal, has originated and diversified in Ethiopia (Vavilov, 1951), and it is not known much as a cereal crop outside of Ethiopia. It's tolerance to a reasonable level of drought and waterlogging, wide adaptation and the ability to grow on a range of soil types (Assefa *et al.*, 1999), and its suitability to be grown in various crop production systems (multiple and mixed, and stand by), makes tef a reliable cereal for unreliable climates, especially those with dry seasons of unpredictable occurrences and length. The plant's palatability, premium prices, and its ability to withstand attacks of diseases and insect pests, make tef more attractive to farmers in Ethiopia (Ebba, 1969; Ketema, 1993; National Research Council, 1996). Its grain is mainly used for making *Injera*, traditional bread prepared from fermented dough, and porridge. The straw is used for thatched roofing, and binds mud to construct household materials and walls of houses. As fodder, tef plant is cheap to raise and quick to produce. Its soft and fast drying straw is both nutritious and extremely palatable to livestock (National Research Council, 1996).

In the lowlands of Wollo, the crop is planted as a staple or as stand by whenever crops like sorghum failed to grow. It is not uncommon to see the crop grown under irrigation in places like Sanka, Mersa, Woino and Kobo. Despite all these merits, the yield of this unique and indigenous crop is remained to be low (the national average is 900 kg ha^{-1}) due to lodging, moisture stress and low yielding capacity of the farmers' varieties.

Until 1995, the National Tef Improvement Project released ten improved varieties of tef. Yet no variety was released and/or recommended for Northeast Ethiopia, Wollo during those years. It is, therefore, imperative to study the adaptability of those nationally released varieties and select best performing varieties for immediate use by farmers. Two separate field experiments were carried out with the objectives of evaluating the released tef varieties and recommend adaptable varieties for moisture stressed areas (Experiment I), and developing early maturing tef varieties for northeastern Ethiopia (Experiment II).

Materials and methods

Experiment I

The adaptation trial was carried out at Sirinka, Kobo and Mersa during the 1998/99 and 1999/2000 main cropping seasons consisting of 10 cultivars released by the National Tef Research Project, Debre Zeit Agricultural Research Center. Farmer's variety (local check) was also included for comparison. The trial was laid out in randomized complete block design with three replications. The space between plots and blocks were 1 m and 1.5 m, respectively. Fertilizer was applied at the rate of 100 kg ha^{-1} DAP and 50 kg ha^{-1} urea and the seed rate was 25 kg ha^{-1}. The varieties were grown on a plot of 9 m^2. Weeding and other agronomic activities were done as required.

Experiment II

Locations, design, spacings, seed rates and agronomic activities were the same as Experiment I.

The trial was executed for five years (2000-2004). Ten genotypes along with two checks (standard and local) were tested on 4 m^2 plots from 2000-2002. Data were not collected due to severe terminal moisture stress in 2003. Three candidate varieties, together with local and standard checks, were verified on station and under farmers' conditions on 100 m^2 plots in 2004.

Results and discussion

Experiment I

In 1998, DZ-Cr-37 out yielded all other varieties followed by DZ-01-974. In 1999, DZ-01-974 was the highest yielding variety followed by DZ-Cr-255. Variety DZ-01-974 gave the highest yield (2301.9 kg ha^{-1}) at Sirinka. The lowest yield (789.3 kg ha^{-1}) was obtained at Mersa by the variety DZ-01-354. DZ-01-974 was the highest yielding at Sirinka and Mersa followed by DZ-Cr-37 at Mersa, and DZ-Cr-82 at Sirinka. DZ-Cr-37 and DZ-01-974 were the first and the second high yielding varieties, respectively, at Kobo. The comparative higher yield of DZ-Cr-37 at Kobo (2290.3 kg ha^{-1}) showed its' importance at moisture stressed areas. The means days to maturity at Sirinka, Kobo and Mersa were 84, 74 and 68, respectively, which indicated that the varieties tended to mature late at Sirinka, but early at Mersa. Generally, the varieties had better performance at Sirinka and Kobo while the performance of the varieties was poor at Mersa.

The combined analyses of variance over years and across locations showed significant ($p<0.01$) differences among varieties for days to maturity, plant height, panicle length, biomass yield and grain yield (ANOVA not shown). The genotype by year interaction was significant ($p<0.01$) for days to maturity, panicle length and grain yield and genotype by location interaction was significant ($p<0.01$) for days to maturity and grain yield showing differential responses of varieties at different locations and years. However, the performance of DZ-01-974 and DZ-Cr-37 was consistent across locations and over years. All tested varieties were relatively higher yielding than the local check except DZ-01-787 and DZ-01-354 indicating these varieties couldn't adapt moisture stressed areas with short growing periods (Table 1). DZ-01-974 and DZ-Cr-37 had a yield advantage of 26.5% and 24.2% over the local check, respectively. Besides the highest biomass of DZ-01-974 (8867.7 kg ha^{-1}) make it preferable in areas where there is acute feed shortage such as Kobo and Chefa. Therefore, based on their relatively higher grain and biomass yield, and consistent performance, DZ-01-974 and DZ-Cr-37 could be recommended for production in the test locations and other similar moisture stressed areas.

Table 1. Grain yield and other agronomic data of tef varieties combined across locations (Sirinka, Kobo and Mersa) and over years (1998 and 1999)

Varieties	Day to maturity	Plant height (cm)	Panicle length (cm)	Biomass yield (kg ha^{-1})	Grain yield (kg ha^{-1})
DZ-01-196	76 a	107.9 a	37.2 ab	8210.9 f	1516.8 g
DZ-01-787	76 b	102.5 e	40.0 d	8306.5 a	1386.3 f
DZ-Cr-44	74 a	108.1 d	39.8 c	8602.5 cde	1624.0 cd
DZ-01-974	77 a	111.7 ab	43.2 a	8867.7 e	1786.4 cd
DZ-Cr-255	76 a	100.7 cd	41.4 ab	7458.6 e	1608.8 de
DZ-Cr-37	72 b	98.7 e	35.1 d	7526.4 de	1754.7 c
DZ-01-354	78 a	104.0 bc	39.8 a	8041.3 bc	1281.6 e
Local check	76 a	103.6 cd	39.9 c	7474.0 ab	1412.4 b
DZ-01-99	71 b	95.9 e	37.3 d	8220.2 ab	1552.0 de
DZ-Cr-358	75 a	99.8 d	38.3 ab	8349.7 cd	1505.0 c
DZ-Cr-82	76 a	100.3 d	38.1 b	7893.3 bc	1539.7 a
Mean	**75**	**103.0**	**39.10**	**8086.5**	**1542.5**
CV (%)	**4.13**	**8.1**	**11.10**	**16.3**	**13.6**
LSD	**2.05**	**5.5**	**2.9**	**867.7**	**138.1**
SE (±)	**0.73**	**2.0**	**1.0**	**309.9**	**49.3**

Experiment II

The results revealed that DZ-01-1821 and DZ-01-146 took 78-85 days while Ho-Cr-139 took 70-74 days to mature. The standard (DZ-Cr-37) and the local checks, however, matured in 74 and 80 days, respectively. The highest grain yield (3011.1 kg ha^{-1}) was recorded from DZ-01-146 in 2002. Yields were generally higher in 2002 than in 2000 and 2001.

The combined ANOVA showed that the highest mean yield was recorded by DZ-01-146 (2167.9 kg ha^{-1}) followed by DZ-01-1821 (2074.6 kg ha^{-1}) and Ho-Cr-139 (1947.2 kg ha^{-1}). The local check gave the lowest yield of 1819.9 kg ha^{-1} (Table 2). Based on their overall performance, DZ-01-146, DZ-01-1821 and Ho-Cr-139 were proposed for verification and release. DZ-01-146 gave a grain yield advantage of 19.1% and 11.8% over the local and standard checks, respectively (Table 3). Similarly, DZ-01-1821 had a yield advantage of 12.3% and 6.5% over the local and standard checks, respectively.

Table 2. Mean grain yield and agronomic data of early maturing tef genotypes combined over years (2000, 2001 and 2002) and across locations (Sirinka, Kobo, Mersa and Chefa)

Variety	Days to heading	Days to maturity	Plant height (cm)	Panicle Length (cm)	Grain yield (kg ha^{-1})
DZ-Cr-37[#]	41	74	81.8	32.5	1939.7
DZ-01-1821	45	82	90.1	34.7	2074.6
DZ-01-146	43	82	85.6	35.7	2167.9
Ho-Cr-139	40	72	77.0	30.6	1947.2
Local check	44	80	87.9	34.2	1819.9
Mean*	**43**	**77**	**83.8**	**32.9**	**1829.2**
CV (%)	**3.5**	**3.67**	**7.47**	**10.29**	**17.18**
LSD (5%)	**0.7**	**1.3**	**2.9**	**1.6**	**150.9**

**= mean of 12 genotypes, [#] = Standard check*

Table 3. Grain yield of the candidate varieties as percent of the standard and local checks

Variety	Grain yield (kg ha^{-1})	Yield advantage (%) over the standard check	Yield advantage (%) over the standard check
DZ-01-146	2167.9	19.1	11.7
DZ-01-1821	2074.6	12.3	6.5
Ho-Cr-139	1947.2	7.0	0.4
DZ-Cr-37[#]	1939.7	-	-
Local check	1819.9	-	-

[#] = Standard check

During the verification trial for release in 2004, varieties DZ-01-146 and DZ-01-1821 gave grain yields of 1545.7 kg ha^{-1} and 1502.7 kg ha^{-1}, respectively. The highest biomass yield was also recorded by DZ-01-146 (6124.38 kg ha^{-1}) followed by DZ-01-1821 (5884.64 kg ha^{-1}) (Table 4). Based on grain yield, biomass yield and seed color, Farmers ranked DZ-01-1821, DZ-01-146 and DZ-01-2054 as first, second and third, respectively. Ho-Cr-139 was the least preferred by farmers. The two high yielding genotypes, DZ-01-1821 and DZ-01-146 named as *Zobel* and *Genete*, respectively, were officially released in 2005 for moisture stress areas of Northeast Ethiopia.

Table 4. Mean grain yield and agronomic data of early maturing tef genotypes combined over locations (Sirinka, Kobo, Mersa and Chefa) in variety verification trial (On-farm and on-station), 2004

Entry	Days to heading	Days to maturity	Plant height (cm)	Panicle length (cm)	Grain yield (kg ha^{-1})	Biomass yield (kg ha^{-1})
Local check	47	86	80.6	31.9	1364.8	5340.0
Ho-Cr-139	41	72	72.7	30.1	1230.7	4014.4
DZ-01-146	48	88	83.3	34.1	1545.7	6124.4
DZ-01-1821	48	86	86.9	33.4	1502.7	5884.6
DZ-01-2054[a]	47	87	84.4	35.7	1490.8	5342.5
Mean	46	84	81.6	33.1	1426.9	5341.2
CV	4.6	5.1	8.2	9.0	13.5	16.5
LSD (5%)	1.5	3.1	4.8	2.1	136.8	639.2

[a] = *Latest standard check*

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References

Assefa, K.; Seifu Ketema, H. Tefera, H.T. Nguyen, A. Blum, M. Ayele, G. Bai, B. Simane and T. Kefyalew. 1999. Diversity among germplasm lines of the Ethiopian cereal tef [*Eragrostis tef* (Zucc.) Trotter]. *Euphytica* 106: 78-97.

Ebba, T. 1969. Tef (*Eragrostis tef*). The Cultivation, usage and some of its known diseases and insect pests. Part I. Expt. Stat. Bull. No. 60, HSIU, College of Agriculture, Dire Dawa, Ethiopia.

Seifu, K. 1993. Tef (*Eragrostis tef*): Breeding, genetic resources, agronomy, utilization and role in Ethiopian agriculture. Institute of Agricultural Research, Addis Ababa, Ethiopia.

National Research Council. 1996. Lost crops of Africa. Volume I: Grains. National academy press, Washington, D.C., pp. 215-235.

Vavilov, N.I. 1951. The Origin, Variation Immunity and Breeding of Cultivated Plants. Translated from the Russian by K. Srarrchester, Roland Press, New York, pp. 37-38.

Research achievements of vegetable seed production in north Shewa

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Abstract

The cool highland of North Shewa, which covers thirty seven percent of the administrative zone, is suitable for seed production of a variety of vegetable crops such as potato, garlic, carrot, beet root, cabbage, Swiss chard and other cool season vegetables. The low and mid altitudes are suitable for production of onion seed by identifying appropriate planting dates. At present there are neither government organizations nor private investors responsible to multiply these vegetables seeds. Hence, seed is a major constraint for production of these crops in the country. Though attempts were made to produce potato and garlic seeds by some farmers in the area, the quality appeared to be poor. Other cool season vegetables and onion seeds are being imported from abroad which is very costly. In view of the above constraints, seed production experiments were conducted for these crops by the Horticulture Research Division of Debre Berhan Research Center to investigate their seed production potentials, seed storage life and the potential of locally produced seeds for vegetable and seed production. Results revealed that seeds of potato could successfully be produced without significant yield loss by diseases and insect pests. The tuber seeds can be stored in diffused light store for 9 months for optimum tuber seed and ware potato production. In case of garlic, earlier variety trials in different locations of the highland of north Shewa showed that high seed bulb could be produced and garlic bulb seed can be stored up to 9 months in ventilated stores for next season garlic production. Swiss chard, head cabbage, beetroot and carrot can successfully produce seeds at Ankober (3100 m. asl). Further the results indicated that Mid July, early March, and mid May and mid July are appropriate planting dates for high seed production of Swiss chard and head cabbage, carrot and beetroot, respectively. Comparison of locally produced seeds with the imported seeds of these vegetables in terms of uniformity of vegetable production and seed setting potential revealed that except beet root, the identity and uniformity and amount of locally produced seed is similar to the imported seeds in all of the tested vegetables.

Introduction

The production of sufficient quantity and good quality seed is crucial to improve production and productivity of any crop, especially vegetables. Seed greatly influences the next season crop yield and quality. It is estimated that the seed has about 50 % influence on potato yield (HaileMichael, 2003). Vegetable crops seed production is generally influenced by environmental factors such as light, temperature, rainfall, wind, soil and varietal differences. For seed production of most vegetables low temperature is necessary for flowering and seed set. Potato and garlic also need cool temperature condition for high seed tuber and seed bulb production. Cool temperature also enables to store seed for a long time.

Lack of quality seed is a major constraint for production of most cool season vegetable crops in Ethiopia. At present there are neither government organizations nor private investors responsible to multiply these vegetables seeds. Hence, they are imported at exorbitant cost. Most of the seeds available in the market are also poor in germination and uniformity (Lemma, 1998). However, research results show that for almost all types of vegetable crops produced in the country, seeds can be produced domestically including those requiring vernalization (Dawit et.al., 2004). Production of vegetable seeds locally can play great role in import substitution, domestic price reduction, and income generation for seed growers (Dawit et.al., 2004). Besides, it can significantly contribute to increasing the production and productivity of these crops.

The cool climate and varied soil conditions of North Shewa administrative zone of Amhara region is potential for seed production of several vegetable crops. It is estimated to cover an area of 2081400 hectare of which 795700 hectare is arable. The altitude varies between 1200 and 3525 m.asl.. According to the traditional agro-ecolgical classification 37.4 % of North Shewa is Dega (above 2300 m.a.s.l), 30.1 % Woina Dega (1500- 2300 m.a.s.l) and 32.5 % Kolla (below 1500 ma.s.l). Temperature varies between 5.7 to 31 ^{O}C and average annual total rainfall ranges between 892.28 to 1883.00 mm. The average annual rainfall of the highland part ranges from 892.28 to 1883.00 mm and the average minimum and maximum temperatures range from 5.7 - 9 ^{O}C and 17 ^{O}C to 21 ^{O}C, respectively (Table 5). The soils of North Shewa are predominantly categorized as Lithosols, Eutric Cambisols, Cambic Arenosols, Vertic Cambisols, Pellic Vertisols, Eutric Nitosols, Chromic Cambisols and Eutric Regosols. Among these vertisols, Acrisols and Cambisols are widely used for agricultural production.

The North Shewa zone has a large potential of irrigation water which is not adequately exploited so far. The major rivers that flow to Abay and Awash catchments are Jemma, Jewha, Sewar, Gunagunit, Wonchit, Moferoha, Chacha and Kesem, which are enough to cover the demand of for irrigation. There are also many springs and water harvesting ditches in the area. In addition to the irrigation potential, at least four *Woredas* have dependable *belg*(short rain) season rain. The *belg* rain is enough for potato production. However, cool season vegetables seed production needs supplemental irrigation since they need more than one year to complete their life cycle. Besides, the proximity of the area to the country's capital city, Addis Ababa, gives seed growers a competitive advantage of easy market access at relatively low transportation cost..

Cognizant of the constraints associated with the vegetable seed sector and the potential of North Shewa zone for cool season seed production, research has been conducted with the objectives of assessing seed production potentials of various vegetable crop varieties, their seed storage life and the potential of locally produced seeds for vegetable and seed production. As a result, some promising results have been recorded. This paper summarizes the achievements recorded so far.

Achievements

Potato seed tuber production

Potato research has been conducted in the highlands of North Shewa since 1996. So far two potato varieties (Gorebela and Gera) are released and several other varieties are recommended for the area. The result of the experiments also indicated that potato could give very high and quality seed tuber in *belg* (short rain) and *meher* (main rain) seasons. Yield of improved varieties was better in *belg* season than in *meher* season. And yet despite availability of production constraints such as frost, seed tuber yields of as high as 519 quintals per hectare were obtained in *meher* season using Gorebella and Gera varieties.

Severe potato diseases were not recorded except where the crop is stressed by frost in areas like Faji *Kebele* of Baso-Werana Wereda (ShARC progress report, 1997, 1998, 1999). However, common scab is a serious seed tuber quality deteriorating factor at Ankober where farm yard manure, which is considered as source of food for scab agent, is a sole fertilizer source. Potato tuber moth is not a problem in highlands of North Shewa though it is known to cause up to 100 % loss elsewhere (CIP, 1997).

Potato seed tuber storage:

Successful potato production in the tropics is dependent on the storage conditions of the mother tubers and on temperatures after planting. Entire crop may fail if seed tubers that are not at proper stage of physiological development are planted. Since tuber seed is a living entity it should be stored in ventilated and cool environments for good sprout development. Sprouting involves spreading the tuber seed in a layer no more than two or three tubers deep in diffuse light. This encourages the development of short, green and healthy sprouts. Complete darkness must be avoided because this causes the development of long, white, thin sprouts which are easily broken before or during planting. When subjected to light, buds take several weeks (depending on the variety and the temperature of storage) to produce sprouts of about 1.3 cm long; the seed can be stored in this form for a further two or three months during which the sprouts grow little, if at all, provided that they are not kept in darkness. The main advantage of sprouting is that, stem growth commences immediately after the seed is planted making maximum use of the available rainfall and causing rapid and even emergence.

The average minimum and maximum temperature range of highland part of North Shewa is 5.7 - 9 ^{0}C and 17 ^{0}C to 21 ^{0}C, respectively (Table 5). This condition with the help of appropriate storage structures provides favourable condition for potato seed tuber storage. Observations were made at Sheno and Ankober to see the storability and conditions for good tuber sprouting. At Ankober, a diffused light store (DLS) made with locally available material with grass cover, and at Sheno both a well ventilated standard diffused light store and local diffused light store were used for tuber seed storage. In both cases, due to cool temperature of the area, seed tubers took several weeks to break dormancy and reach the right sprout development stage for planting. Storage of tuber seeds in local DLS, gave relatively long dormancy period. It was observed that seed tubers could be stored for about 9 months in modern DLS and more than a year in local DLS at both locations. The sprouts after emergence took several days. At Sheno and Ankober condition. dormancy break of potato tuber seed started between 2 and 3 months after storage depending on the variety. After 10 months of storage, Gorebella variety sprouts reached a length of 2.5 to 3 cm in diffuse light store at Sheno. Ideally, seed potatoes should be stored at 4 ^{O}C immediately after harvest, pre-germinated in diffuse light at 13 ^{O}C until the sprouts are 3 cm long (Burton, 1989). Hence, still after 10 months of storage of potato in these areas, the potato seed tubers are in good condition for planting.

It was also found out that the sprouts on a tuber appeared in almost similar time indicating the absence of apical dominance. This is in agreement with Burton (1989) who stated that the establishment of apical dominance occurs only if the tubers are stored under conditions that favor growth. He also added that at fairly low temperatures (7-8 ^{O}C) which are permissive of growth, the growth of apical bud may not be sufficiently rapid to achieve this and dominance may not be established.

Garlic bulb production

Garlic is grown in cooler and sub-humid locations and does not tolerate lowland humidity. It is best situated to dry hill stations above 1000 m and to higher altitude areas with a distinct dry season. The plant does best in rich friable loam soil, it does not thrive in clay soils (Tindall, 1992). In the tropics, the best season for growing garlic is similar to that of onion, although garlic is less able to withstand high temperatures. These climatic conditions are found at latitudes higher than 20-25^{O} N and S, or nearer to the equator at higher altitudes. The growth cycle varies from 100-160 days, depending on the variety. The cooler the temperature and the longer the growth cycle the larger the size of bulbs will be at harvest. (Messiaen, 1992).

Cool highlands of north Shewa are suitable for garlic bulb seed production. Garlic research was conducted in the highland of north Shewa in 1997 by Debre Berhan Agricultural Research Center. So far, one cultivar (MM-98) collected from Menz area is recommended for the highland part of north Shewa. The results of the experiments also indicated that garlic could give very high and quality bulb seed using this cultivar, even though the soil type of all the sites , except Ankober, is vertisol. Bulb yield of as high as 88 quintal per hectare was harvested by using the recommended cultivar (Table 1). On the average, a bulb weight of up to 41 gm was recorded at Sheno using MM-98 cultivar. This bulb size can meet the world garlic export standard.

Garlic bulb should be stored in dry, cool and ventilated store for better garlic production. Observation at Sheno indicated that garlic bulb stored in diffused light store thinly spread in layers on the shelf stored for about 8 months.

Other cool season vegetables seed production

Seed production of cool season vegetables, except for lettuce and some Chinese cabbages, is impossible for tropical countries and new seeds need to be acquired from temperate countries. Cool season vegetables seed production require cool growing season and it can only be produced at high elevations in the tropics (Messian, 1992). Their seeds are not readily produced in many parts of Ethiopia. Seed production of these

Table 1. Bulb yield (Q/ha) of Garlic cultivars in Regional Variety trial over two years, (2000/01, 2001/02) in North Shewa, Amhara Region

Cultivars	Location Mean				Across
	Ankober	Sheno	Molale	Mehal Meda	Locations mean
PB-206	22.83	26.52	40.10	42.13	27.93
G-420	38.12	19.10	37.88	36.74	27.89
W-17	30.99	10.33	29.81	35.47	21.83
P-302	31.88	27.27	37.38	42.59	30.64
PB-203	36.37	20.01	42.23	46.01	30.10
Sheno local	42.66	47.77	47.32	53.63	42.85
PB-207	32.24	20.90	34.15	38.87	27.16
W-13	29.26	17.23	35.92	37.45	25.06
MM-98	65.22	62.53	60.80	51.72	60.07
Mean	36.62	27.97	40.62	42.73	
LSD (5%)	16.60	6.10	9.21	10.19	4.405
CV (%)	38.54	18.55	19.20	20.28	26.87

crops is possible only in distinct high elevations areas (IAR, 1986). In north Shewa, 37 % of the zone is highland (*Dega*) and is suitable for seed production of these vegetable.

A study conducted at Ankober (3100 m. asl) starting from 2000 using open-pollinated varieties of carrot (Nantes), Swiss chard (Fordhook giant), head cabbage (Copenhagen market) and beetroot (Detroit darkred) indicated that there is a great potential to produce seeds of these crops. The appropriate sowing dates for optimum seed production of these crops have also been identified. According to the study 16.78 q/ha of Swiss chard seed and 5.80 quintal/ha of cabbage seeds could be harvested from mid July planting. Also, 5.86 quintal/ha of carrot seed and 18.78 quintal/ha of beet root seed was harvested from first week of March and mid May, planting treatments , respectively.

Locally produced and imported seeds of these vegetables were also compared in terms of uniformity of vegetable yield and seed setting potential. Plants raised from locally produced seeds appeared to be vigorous in Swiss chard, cabbage and carrot. There was no significant variation in terms of vegetable yield except in beet root, and Swiss chard and cabbage in marketable heads. In case of beet root, due to early bolting the vegetable yield of locally produced seeds is lower than that of imported seeds. The marketable vegetable yield of cabbage plants raised from locally produced seeds was relatively lower than that of the imported seeds. Locally produced seeds gave 58.5 % firm head plants while imported cabbage seeds gave 71.1 % firm heads. Plants raised from locally produced seeds of these vegetables did not show exaggerated number of off- types (Table 2).

Similarly, except beet root, plants of all the vegetables raised from locally produced seed gave better seed yield than that of imported seeds. Beet root plants raised from imported seeds gave better seed yield (Table 3). Since, plants raised from locally produced seeds started flowering and maturity before end of January, frost affected the seeds and the yield and quality of produced seeds were low. However, the same locally produced seed lots gave similar vegetative and seed yield in Tera farm (Debre-Birhan) and Lai Gaint (South Gondar) areas.

The difference in vegetable- and seed yields produced between the locally produced and imported seeds might be due to the difference in seed storage condition and period of storage as the locally produced seeds were stored in very cold DLS for a long time. George (1985) stated that storage of vegetable seeds in low temperature condition favored early bolting. No distinct variation in vegetative parts was observed except very few off-type plants in those plants produced from locally produced seeds. Hence, the result is indicative that seeds produced locally (the first generation) can equally be used for production of these vegetables for both vegetable use as well as seed production. For vegetable production purpose, use of beet root and cabbage seeds in relatively warm condition and for seed production in cool condition is advisable.

Table 2. Comparison of locally produced and imported seeds of cool season vegetables for vegetable yield per m^2 in North Shewa, Amhara Region (2004/2005)

No.	*Parameter*	*Source of seed*		t-test at p=0.05
		Locally produced	Imported	
1	Beet root (Detroit dark red)			
	Root yield (kg)	3.3 ± 0.03	4.43 ± 1.03	ns
	Root length (cm)	5.23 ± 0.54	5.57 ± 0.55	ns
	Root diameter (cm)	4.83 ± 0.29	5.43 ± 0.49	ns
	Number of off-types	1.33 ± 0.33	0.00 ± 0.00	
2	Carrot (Nantes)			
	Root yield (kg)	8.4 ± 2.00	7.4 ±1.3	ns
	Root length (cm)	13.07 ± 0.79	12.27 ± 0.67	ns
	Root diameter (cm)	3.67 ± 0.18	3.40 ± 0.29	ns
	Number of off-types	3.0 ± 1.00	0.00 ± 0.00	
3.	Head cabbage (Copenhagen Market)			
	Total yield (kg)	23.0 ± 0.58	23.03 ± 1.13	ns
	Marketable yield (kg)	8.51 ± 1.80	10.55 ± 2.37	ns
	Head length (cm)	16.33 ± 0.58	15.27 ± 0.24	ns
	Head diameter (cm)	7.91 ± 1.42	9.43 ± 0.72	ns
	Average head weight (g)	681.33 ± 93.53	744.0 ± 98.01	ns
4.	Swiss Chard (Fordhook Giant)			
	Total yield (kg)	19.01 ± 3.30	16.12 ± 1.60	ns
	Marketable yield (kg)	10.67 ± 2.26	6.88 ± 1.06.	ns
	Average leaf weight (g)	10 ± 1.33	7.03 ± 1.20	ns

Table 3. Comparison of locally produced and imported seeds of cool season vegetables for seed yield (g/m^2) in North Shewa, Amhara Region (2004/2005)

No.	*Parameter*	*Source of seed*		t-test at p=0.05
		Locally produced	Imported	
1	Beetroot	44.45 ± 12.96	67.94 ± 16.39	ns
2	Carrot	8.04 ± 1.68	2.91 ± 1.32	ns
3	Head cabbage	16.16 ± 1.99	7.49 ± 2.19	*
4	Swiss chard	64.79 ± 24.19	49.08± 6.80	ns

Onion seed production

Onion is a recently introduced crop that rapidly becoming a popular cash crop among the growers in lowland irrigated areas of north Shewa. To cultivate this crop, however, farmers have to buy costly imported seeds every time. Storage condition and optimum planting time for onion seed production were earlier identified at Melkassa and Melka Werer condition by Melkassa Agricultural research Center and onion seed production is now possible under farmers' condition in the Rift valley areas. To verify the available technologies in onion seed production under Shewa Robit condition, observation plots were established in Shewa Robit in 2005/06 cropping season under irrigation condition. The results indicated that Red Bombay variety produces 7.4 quintal onion seed with a germination percent of 92.5 to 97.5 (Table 4).

Harvesting of seeds was started 126 days after sowing and took one month to the last harvest. Compared with the previous research results in other areas, the result of this observation is promising. Hence, local onion seed production need to be scaled-up under farmers condition.

Table 4. Result of onion seed production activity at Shewa Robit , North Shewa, Amhara Region (2006)

No.	*Parameters*	Results
1	Marketable seed yield (kg/ha)	740
2	Germination (%)	97.5
3	1000 seed weight (g)	3.9
4	Days to seed harvest	126-156

Conclusion

The cool highlands of North Shewa are suitable for seed production of a variety of vegetable crops such as potato, garlic, carrot, beet root, cabbage, Swiss chard and other cool season vegetables. Furthermore, the cool environment also enables potato seed tuber and garlic bulbs to be stored for several months. Also, the low and mid highland areas are suitable for production of onion seed by adjusting planting dates to match cooler easons of the year for flower stalk development and seed set. Generally, high quality seeds of most of the currently produced vegetable crops can successfully be produced in the area. Besides, the proximity of the area to the country's capital city, Addis Ababa, gives seed growers a competitive advantage of easy market access at relatively low transportation cost. Hence, the necessary technical assistance has to be provided to farmers to let them better now the production techniques and there bye help them change the potential of the area to improvement of their income and lively hood.

Table 5. Climatic data of experimental sites

Site	Altitude (m.a.s.l.)	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean/ Total
Debre Birhan	2765	Max Temp C°	19.5	20.3	20.6	20.6	21.5	21.9	18.6	18.1	18.7	18.5	18.7	19.0	19.7
		Min Temp C°	4.4	5.7	7.6	7.6	7.1	7.1	8.7	8.7	7.1	3.7	1.8	3.2	6.1
		Rainfall (mm)	9.8	22.2	52.4	48.5	38.9	45.8	289.0	290.4	84.4	19.7	5.4	3.7	911.2
Ankober	3152	Rainfall (mm)	49.8	46.3	143	175	100	83.9	317.3	495.4	251	48.1	39.5	59.4	1793.1
Mehal Meda	3058	Max Temp C°	18.0	18.6	18.6	18.3	18.2	[illegible]	17.3	16.4	17.0	16.5	17.2	17.7	17.7
		Min Temp	6.2	7.0	7.2	7.4	7.6	7.4	7.5	7.5	7.5	6.5	5.5	6.1	6.9
		Rainfall (mm)	17.3	29.8	73.5	52.0	40.6	37.4	297.4	264.5	69.8	29.6	5.0	6.3	900.6
Molale	3036	Min Temp C°	6.1	6.8	8.2	8.6	9.1	8.0	8.3	8.4	8.3	7.2	5.7	5.7	7.5
		Rainfall (mm)	11.2	8.4	41.0	33.5	28.2	[illegible]	368.7	318.4	78.6	22.3	4.6	1.9	945.1
Sheno	2800	Max Temp C°	18.7	20.7	19.5	19.8	20.4	21.4	30.3	29.1	21.4	18.7	17.4	17.3	21.2
		Min Temp C°	3.9	4.9	6.2	7.3	7.3	6.0	8.2	8.7	7.1	5.5	2.9	2.8	5.9
		Rainfall (mm)	8.2	18.2	47.8	48.8	50.8	72.5	285.8	274.7	88.4	18.0	3.6	3.2	921.1

References

Acland, J.D. 1971. East African Crops. Longman Inc, London.

Burton, W.G. 1989. The Potato. Longman Inc, London.

Dawit A., Abera D., Lemma D., and Chimdo A. 2004. Domestic vegetable seed production and marketing. Research Report No57. Ethiopian Agricultural research Organization. Addis Ababa, Ethiopia.

George, Raymond, AT. 1985. Vegetable seed production. Longman Inc, New York.

Haile Mickael K/Mariam. 2003. Consultation Report on the Improvement of Potato Seed Production In Amhara Regional State. AMAREW Project. 70 p.

IAR (Institute of Agricultural research). Department of Horticulture Roots and tubers team. 1986. Progress Report of 1978/79. Addis Ababa, Ethiopia.

International potato Center (CIP) Circular. 1997. Vol. 22(3)/23(1) Lima, Peru.

Lemma Dessalegn. 1998. Seed production guidelines for Tomatoes, Onion and Hot pepper. Institute of Agricultural Research, Addis Ababa, Ethiopia.

Messian, C.M. 1992. The Tropical Vegetable Garden. The Macmillan Press LTD. London

Sheno Agricultural Research Center. 1998. Progress Report for the period 1998/98

Sheno Agricultural Research Center. 1999. Progress Report for the period 1999/2000

Smith, D.L. and C. Hamel. 1999. Crop yield: Physiology and Processes. Springer-Verlag, Berlin Heidelberg. P: 333-354

Tindall, H.D.1992. Vegetables in Tropics. Published by MACMILLAN PRESS LTD. London.

Review of Potato and Sweet potato Research Achievements in North Shewa

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Abstract

Production of potato and sweet potato has not been popular among the farming communities of north Shewa zone. Unavailability of improved potato varieties adapted to these areas and lack of knowledge of their cultivation practice are among the likely constraints that contributed to low level of production. In order to curb these problems , multifaceted research activities were launched on these crops. Relatively, research on potato improvement was started in 1996. Sweet potato, however, is a recent addition to the to the research agenda of the center.

As a result of series of research activities conducted on varietal and management aspects of these crops, several remarkable achievements have been registered. In case of potato, two high yielding and diseases resistant varieties called Gorebella, and Gera were released by the center for cool high land parts of the zone. More over, variety called Shonkolla (Kp-90134.5) released by Awassa agricultural research center is also recommended for production in the area owing to its better yield performance and other desired qualities. Suitability of the two varieties (Gorebella, and Gera) to areas that have moisture and frost stress is also proved by the center. Adaptation trial of potato varieties released by the regional and national research system in mid altitude areas of north Shewa zone also indicated the superiority of the aforementioned varieties and another released variety called Jalene in marketable and total tuber yields. Similarly, the result of adaptation trial of released sweet potato varieties conducted at Saramba (1500 m. asl) of Efrata Gidim Woreda and Alem Ketema of Merhabete Woreda (2200 m. asl) also showed appropriateness of the varieties called Kudadie and Guntutie to the areas. Selection of this varieties is augmented with farmers participatory evaluation.

Regarding crop management trials, Fertilizer rate and planting date trials were conducted on potato for three consecutive years (1997 – 1999). As out come of these studies, potato planting between last week of May and Mid June, depending on availability of adequate moisture, is recommended to get higher marketable and total tuber yield. Application of 6 tons of well decomposed farmyard manure (FYM) combined with 100 kg /hectare DAP is also recommended for the test location. Combined application of these two rates gave a yield advantage of 108 % over unfertilized control. However, highest common scab damage was recorded on plots fertilized with Farm yard manure. Hence, care should be taken not to use farmyard manure that is not well decomposed.

Introduction

Potatoes are crops of choice for densely populated areas where land holding per house hold is small. In such areas, the higher yield per unit area they give as compared to other grain crops, helps to sustain the population. Inherently, these crops have high calorific value when compared with other important food crops. In addition, Potatoes and sweet potatoes can , relatively, grow well in drought prone areas of high and low altitude areas , respectively.

As a food crop, potato has a high potential to supply a cheap and quality food within a relatively short period. It produces approximately twice as many calories per unit area as that of rice or wheat. Even in terms of dry matter production per unit area, potatoes are among the most productive crops cultivated in the developing countries (Poehlman and Sleper, 1995). Potato provide essential amino acids, vitamins, minerals and trace elements in the diet (Horton and Sawyer, 1985).

Alike potato, sweet potato is also a widely produced and consumed food crop. In addition to the roots that are rich in carbohydrate the young shoots are popular food for many Africans and Asians (Danhniya, 1981). The shoots are rich in protein and are good complements to the root. In Ethiopia, roots are eaten after boiling and vines are either given to livestock or left decomposed in the field as crop residue.

Potatoes and sweet potatoes can be important complements of other food crops in north Shewa, where the population experiences malnutrition due to heavy dependence on cereal crops. The high and mid altitude areas of the zone are suitable for potato production. On the other hand, the lowlands and warmer mid altitude areas can meet agro ecological requirements of sweet potato. These crops can be compatible to the diversity of the production systems such as the rainy meher and belg seasons and the dry season irrigated production systems.

Despite availability of favorable agro ecological conditions and other socio economic opportunities, area coverage and production of is very limited in the zone. The farming system in the zone is dominated by production of cereals and pulses. Among factors that contributed for low production of these crops in the area; un availability of improved varieties and planting materials, lack of awareness on production techniques and poor agronomic practices adopted by growers of these crops are that worth mentioned.

In order to overcome such constraints and improve contribution of these crops in the farming system of the zone, the center has been undertaking several research activities on these crops. This paper reviews results of these research activities to assist utilization of the out puts and document the findings.

Review of potato research

Potato research was started at the center in 1980s by the then Sheno research sub center when the center was operating under IAR with the supervision of the main research center of that time, Holetta agricultural research center. The research activities were limited to variety evaluation as one test location of the national program. A planting date trial was also conducted by the time.

Relatively, stronger potato research was launched in north Shewa highlands by Debre Berhan Agricultural Research Center (the then Sheno Agricultural research Center) in 1996. This review of potato research focuses on results obtained since 1996 in areas of variety development , potato agronomy and fertility.

Potato Variety Development

Potatoes variety evaluation in cool high lands of North Shewa: Variety trial comprising of eight potato genotypes including local check and standard check (Menagesha) was conducted at five locations (Ankober, Debre Berhan, Mehal Meda, Molale and Mush) in 1999 and 2000 main rain season in order to identify varieties for high marketable and total tuber yield under cool high lands of north Shewa where environmental stress frost and desiccating wind are prevalent. The altitude of Debre Berhan is 2765 m. a.s.l., where as the rest of the locations exceeds 2900 m. a.s.l. The soil of Mehal Meda, Molale and Faji is pellic vertisol; where as the soils of Ankober and Mush are cambisol and nithosol, respectively. The experiment was laid out in RCB design with three replications in a plot size of 9 m^2. The tubers were planted with a spacing of 75 cm between rows and 30 cm between plants. Seed tubers were planted in dry condition. Fertilizer was applied in the form of Urea and DAP, 165 and 195 kg/ha, respectively. Urea was split in to two applications, half during planting and the rest half during first ridging. Weeding and ridging were done two times in the growing season.

Observations made on the experiments indicated that environmental stresses such as frost and desiccating wind were limiting factors for potato production in cool highlands of north Shewa. They occurred simultaneously and their effect was very severe in all of the varieties. Theses stresses made favorable condition for Late blight and early blight infection.

ANOVA result of the experiment indicated the superiority of the advanced clone CIP-382173.12 (now called Gorebella). The variety showed good yield stability across all the test locations and seasons. It gave a mean marketable tuber yield advantage of 78.3 % and 201.5 % over the standard check Menagesha and the local check, respectively. Furthermore, the variety has got preferable horticultural characteristics such as , shallow eye depth, good tuber size, desirable shape, high dry matter content and acceptable taste. The variety also showed better resistance to late blight and has good tolerance to lodging caused by high pressure of desiccating wind. Following Gorebella, KP-90134.2 (now called Gera) is selected for its high marketable and total tuber yield, earliness and high number of tubers per m^2. It gave a mean marketable tuber yield advantage of 56.0 % and 163.9 % over the standard check Menagesha and the local check (Table 1). It is also found to be resistant to late blight. Shortcomings of this variety are its susceptibility to early blight, poor tolerance to lodging. However, since early blight and wind and frost injuries that cause lodging happen late in the growing season i.e. in September, the variety can escape these problems when there is early on set of rain during planting time to allow early planting. Dry planting of such a variety allows early emergence of the plant as soon as the rain commences. This is in agreement with Acland (1971) who stated that potatoes should be planted at the beginning of the rainy season . The aforementioned result justified the release of Gorebella 2001/02 and Gera in 2002/03 for production in the test locations and other similar agro ecologies.

A separate set of variety adaptation trial was conducted at Gumer, Dargegn of Gera keya woreda during 2001 and 2002 cropping season. These two locations represent moisture stress and cool highland areas of north Shewa. The altitude of Gumer is about 2800 m. asl. where as that of Dargegn is 3200 m a.s.l. The trial comprised seven and five released potato varieties at Gumer and Dargegne respectively. Combined analysis of the variance over two years indicated that the varieties differed significantly ($P < 0.05$) in both marketable and total tuber yields in both locations. At Dargegn. Gera and Gorebella varieties gave significantly high marketable and total tuber yields per hectare. Similarly, at Gumer these two varieties gave higher total tuber yield. However, with respect to marketable tuber yield Gera was the leading followed by Gorebella (Table 2). Significantly high number of tubers per square meter was recorded for the varieties Gera and Zengena at Gumer and Dargegn, respectively. Significantly high average tuber weight was recorded on Gorebella and Gera varieties (Table 2). Hence, based on the two years data the variety Gera and Gorebella are recommended for the moisture stress highland areas of Gumer, Dargegn and other similar agro ecologies of Gera Keya and Lalo Mama Woredas.

During 2002/03 and 2003/04 cropping season another potato variety trial comprising nine varieties including standard check (Gorebella) and the local check was executed at four locations of cool highlands of north Shewa (Debre Berhan, Ankober, Mush and Molale). Analysis of the result revealed that there is statistically significant ($P < 0.05$) difference among the tested clones in both marketable and total tuber yields and other yield parameters. KP-90134.5, Gorebella, CIP-386389.1 and CIP-389701.1 gave significantly ($P < 0.05$) high marketable tuber yield, where as, Kp-90134.5 and Gorebella gave significantly ($P < 0.05$) high total tuber yield. Highest average tuber weight and tuber number per meter square were recorded by KP-90134.5 and the local check, respectively (Table 3). In addition to its high marketable and total tuber yields Kp-90134.5 has better tuber size, white colored skin and smooth eye depth. The variety Kp-90134.5 was released by Awassa Agricultural research center by the name *Shonkolla* by the time this experiment was completed. Hence variety Kp-90134.5 is recommended for cool highlands of north Shewa as an alternative variety for potato growers.

Table 1. Mean tuber yields and other tuber yield parameters of varieties tested in five locations over two years (1999- 2000)

Varieties	*Average tuber weight (g)*	*No. of tubers/m²*	*Marketable tuber yield (q/ha)*	*Total Tuber yield (q/ha)*
CIP-382146.27	53.11	45.64	178.92	251.78
Local	14.25	116.85	70.95	177.05
CIP-382173.12	60.38	61.94	214.09	301.21
Menagesha	54.61	31.22	120.05	174.61
CIP-387351.1	61	29.41	103.5	180.13
KP-90134.2	43.07	60.73	187.43	259.29
CIP-386031.4	46.97	52.53	182.48	250.48
CIP-381169.16	38.87	59.69	168.5	243.22
Mean	46.53	57.25	153.24	229.72
LSD (5 %)	4.053	12.251	15.4197	18.7196
CV (%)	20.37	53.04	23.54	19.06

Table 2. Marketable and total tuber yields and other yield parameters of varieties in Potato variety adaptation trial, Gumer and Dargegn, 2001/02 -2002/03

Variety	*Marketable Tuber Yield(Q/ha)*		*Total Tuber yield*		*Average tuber weight (g)*		*Number of tubers /m²*	
	Gumer	Dargegn	Gumer	Dargegn	Gumer	Dargegn	Gumer	Dargegn
Zengena	79.87	133.68	113.05	159.00	20.18	21.36	54.17	76.64
Gorebela	101.39	178.13	156.25	229.00	31.87	45.49	48.68	52.53
Gera	129.52	188.55	163.95	229.03	28.80	44.45	58.21	60.07
Menagesha	43.68	93.41	69.165	108.61	37.88	38.72	18.61	27.69
Tolcha	89.94	-	115.45	-	28.46	-	41.71	-
Wechecha	56.81	80.21	74.44	97.78	23.43	25.67	34.53	40.27
Genet	65.42	-	91.35	-	21.66	-	41.80	-
Mean	80.95	134.80	111.95	164.68	27.47	35.14	42.53	51.44
CV (%)	25.65	32.39	21.98	21.01	17.11	17.40	17.42	21.14
Lsd (5 %)	21.10	44.96	24.98	35.70	4.77	6.30	7.48	11.20

Table 3. Mean tuber yields and other tuber yield parameters of varieties tested in four locations of cool highlands of north Shewa over two years (2002/03- 2003/04)

Varieties	*Average tuber weight (g)*	*No. of tubers/m²*	*Marketable tuber yield (q/ha)*	*Total Tuber yield (q/ha)*
CIP-385021.26	46.17	53.92	163.29	245.75
KP-90138.12	54.79	50.00	163.71	264.88
CIP-389701.1	32.96	78.42	188.63	255.96
KP-90108.5	44.08	58.96	142.13	257.29
Local	18.21	118.58	143.04	213.33
KP-90134.5	65.75	48.04	225.13	303.21
Gorebella	57.13	59.92	214.25	342.71
CIP-386389.1	30.42	89.46	199.63	274.58
CIP-387744.1	36.67	67.29	168.88	235.42
Mean	42.907	69.398	178.741	265.905
LSd (5 %)	6.157	8.4559	39.14	40.04
CV (%)	30.09	25.55	45.91	31.57

Potatoes variety evaluation in mid highlands of North Shewa: Potato variety adaptation trail comprising five released varieties was conducted at two locations, Lay Saramba and Mehal Wonz of Efratana Gidim Woreda of north Shewa during 2002/03 – 2003/04 cropping seasons with the objective of selecting adaptable variety/ies to the area. These two kebeles represent mid highlands of Efratana Gidim and other areas with similar agroecology. The combined analysis over locations and years indicated that the varieties differed significantly in terms of marketable and total tuber yields and other tuber yield parameters (Table 4). Gorebella gave significantly ($P<0.05$) the highest marketable and total tuber yield. Hence Gorebella is recommended for the two areas of Efratana Gidim Woreda and other similar agro ecologies.

In 2002/03 and 2003/04 cropping seasons, potato variety trail that comprised nine varieties was conducted at Alem Ketema to identify the best adapted variety or varieties in mid highlands of Merhabete, north Shewa. In 2002/03, Kp-90134.5 and Kp-90108.5 gave significantly ($P < 0.05$) high marketable tuber yield. In case of total tuber yield, Kp-90134.5 (which was latter named as *Shonkolla* by Awassa Agricultural Research center) , Kp-90108.5 and Gorebella gave significantly ($P< 0.05$) high tuber yield. In 2003/04 Kp-90134.5 gave significantly ($P<0.05$) high marketable and total tuber yields (Table 5). Kp-90134.5 *(Shonkolla)* consistently gave high marketable and total tuber yields in both years. Hence this variety is recommended for mid highlands of Merhabete and other similar agro ecologies .

In 2004/05-2005/06 cropping seasons, Potato variety adaptation trial comprising eight released varieties was conducted at Alem Ketema (2300 m.a.sl). The combined analysis over years indicated that the varieties differed significantly ($p < 0.05$) on both marketable and total tuber yields. From the tested varieties Gera, Jalene and *Shonkolla* gave significantly (P < 0.05) higher marketable and total tuber yields (Table 6). The Farmers evaluated the varieties based on tuber yield and taste and selected Gera, *Shonkolla* and Jalene. Hence, based on performance of the varieties and farmers preference, the three are recommended for mid highlands of Merhabete and other similar agro ecologies.

Table 4. Marketable and total tuber yields (q/ha) of varieties tested in Alem Ketema, during 2002/03 and 2003/04

Variety	*Marketable tuber yield (q/ha)*			*Total tuber yield (q/ha)*		
	2002/03	*2003/04*	*Mean*	*2002/03*	*2003/04*	*Mean*
CIP-385021.26	150.37	95.74	123.17	208.70	167.78	188.17
KP-90138.12	178.89	107.6	143.50	246.48	179.63	213.00
CIP-389701.1	225.74	114.26	170.00	290.00	170.00	230.00
KP-90108.5	295.93	108.33	202.17	360.56	188.33	274.50
Local	71.85	28.15	50.00	157.22	72.41	114.83
KP-90134.5	308.15	184.07	246.17	344.08	257.41	300.83
Gorebella	210.74	126.85	168.67	313.71	217.96	266.00
CIP-386389.1	143.89	75.18	109.50	195.00	133.15	163.83
CIP-387744.1	107.22	59.45	83.50	182.41	110.37	146.33
Mean	188.09	99.96	144.03	255.35	166.34	210.83
LSD(5 %)	91.91	49.50	67.894	87.33	49.34	69.335
CV (%)	28.23	28.61	48.55	19.76	17.14	33.88

Table 5. Marketable and total tuber yield and other tuber yield parameters of varieties tested in Potato variety adaptation trial , Mehal Wonz and Lay Saramba of Efratana Gidim Woreda, 2002/3 and 2003/4

Variety	*Marketable tuber yield (Q/ha)*	*Total tuber yield (Q/ha)*	*Average tuber (gm)*	*Number of tubers/m^2*
Wechecha	149.65	182.09	55.41	32.24
Tolcha	110.14	145.95	55.06	25.49
Zengena	146.42	189.9	29.74	64.11
Gorebella	195.18	263.27	41.32	63.7
Guasa	133.89	189.1	30.45	62.78
Mean	147.05	194.06	42.40	49.66
LSD 5 %	25.39	24.67	4.89	7.63
CV (%)	24.29	17.88	16.24	21.61

Table 6. Mean marketable and total tuber yield in q/ha of potato varieties tested at Alemketma

Variety	*Marketable tuber yield*			*Total tuber yield*		
	2004	2005	Mean	2004	2005	Mean
Gera	266.67	309.44	288.05	334.72	315.43	325.08
Wechecha	158.24	125.58	141.91	191.85	128.92	160.39
Zengena	237.50	152.20	194.85	335.19	155.81	245.50
Menagesha	214.81	192.13	203.47	283.87	194.01	238.94
Gorebella	210.83	137.73	174.28	332.22	141.02	236.62
Kp-90134.5	270.83	233.80	252.32	349.08	237.45	293.27
Digemegn	81.48	246.24	163.86	101.39	251.77	176.58
Jalene	255.18	261.57	258.38	329.72	266.89	298.30
Mean	211.94	207.34	209.64	282.25	211.41	246.83
CV%	19.48	28.25	24.13	11.25	27.66	18.63
LSD 5 %	59.37	84.2342	49 5642	45.6693	84.1058	45.0542

Potato Agronomy Research

Potato planting date trial was conducted at Sheno (2800 m.asl) by Holetta Agricultural Research Center to determine optimum planting dates for higher tuber yield during 1985 and 1986 cropping seasons. According to the result, early June planting based on availability of adequate soil moisture, is recommended as appropriate planting time for better potato yield at Sheno and other similar agro ecologies. (Semagn Asredie *et al.*, 1998).

During 1997 – 1999 cropping seasons, planting date and fertilizer type and rate trial was conducted for three consecutive years at Ankober. Four planting dates (mid May, early June, mid June and early July) and two fertilizer types (195/165 kg DAP/Urea and 6 ton + 100 k.g DAP) and a control with no fertilizer application were studied using the released variety, Wechecha. Farm yard manure was applied irrespective of soil moisture during planting time; where as the recommended fertilizer was applied when the soil was moist. The experiment was laid out in split plot design with three replications. The fertilizer treatments were assigned to main plots and the planting dates were arranged in sub plots with a sub-plot size of 11.7 m^2 and.

During 1997/8, significant yield difference among fertilizer types , Planting dates and their interaction was observed at 5% and 1% level of significance. In this location the first planting date (May 26/97) followed by the second planting date (June 11/97) gave high mean tuber yield, 173.29 and 130.55 q/ha, respectively. Regarding the fertilizer treatments , combination of 6 ton farmyard manure with 100 k.g DAP gave significantly ($P < 0.05$) higher mean tuber yield than both the recommended in organic fertilizers combination (195/165 kg DAP/Urea) and the control (No application) . The interaction of the combined treatment of farmyard manure and DAP, with first planting and second planting gave significantly ($P < 0.050$) high tuber yield (Table 7).

Late blight infection was very high on in organic fertilizer combinations, 195/165 k g DAP/Urea, and the control. Relatively, plots fertilized with 6 ton FYM and 100 k.g DAP showed relative tolerance (Table 8). The first and second planting date treatments escaped late light and frost damage. The yield of the third and the fourth planting dates was extremely low due to low stand, high late blight infection and high frost damage.

During 1998/99, tuber yield and tuber quality was very poor in both planting dates and fertilizer treatments because of several reasons. Occurrence of heavy rain which caused the plots to be eroded and hail damage were among the factors. . Hence, this result is avoided from statistical analysis of the experiment.

During 1999/2000, since the rain started late, planting of the first and second planting dates treatments was accomplished under dry condition. significant marketable and total tuber yield difference ($P < 0.01$) was observed between planting dates. Potato planted on the first two planting dates (25 May and 11 June) gave better marketable tuber yield. Furthermore, significant ($P < 0.05$) marketable and total tuber yield difference was observed between fertilizer types. Recommended fertilizer (195/165 kg DAP and Urea) gave significantly better marketable and total tuber yield (Table 9). The marketable yield obtained from the combined FYM and DAP was very low due to prevalence of common scab damage on tubers. On weight basis, up to 55.64 percent damage was caused on tuber quality of tubers harvested from third planting date (June 25/1999 planting) (Table 10).

Hence, based on the two years data Last week of May to Mid June planting is recommended for optimum potato production in highlands of Ankober and other areas with similar agro ecology. The fertilizer study also revealed that application of 6 ton well decomposed farmyard manure (FYM) and 100 kg DAP/hectare gave a yield advantage of 108 Percent over unfertilized control in 1997 (well distributed rainfall year). However, Since, distribution of rain fall was not even because of early onset and early cession during the rest seasons, the result of farm yard manure application was not complete. As common scab is observed to be a problem associated with plots fertilized with FYM, direct use of incompletely decomposed farmyard manure is not advisable for potato production in these areas. And yet, it is very important to make further investigation on association between FYM application and incidence of common scab.

Table 7. Total tuber yields of potato in q/ha grown in different fertilizer types and planting dates at Ankober, 1997/8

Planting date	Fertilizer types			Planting date mean
	Control (without ferti.)	195/165 k.g Dap/Urea	6 ton FYM + 100 k.g Dap	
May 26/97	108	152	260	173
June 11/97	92	110	189	130
July 2/97	33	31	31	31.5
July 16/97	8	13	15	12
mean	60	76.5	124	

	Fertilizer	Planting date	Interaction (F x PL)
C.V	18.91	18.91	-
LSD 5%	13.89	16.04	27.78
LSD 1%	18.88	21.80	37.76

Table 8. Late blight infection rate (1-9) of potato grown in different planting dates and fertilizer types

Planting dates	Fertilizer types			planting date mean
	Without fertilizer	195/165 k.g Dap/Urea	6 ton FYM + 100 k.g Dap	
May 26/97	5.5	6.1	4.1	5.2
June 11/97	4.5	5.9	2.9	4.4
July 2/97	5.6	6.6	4.6	5.6
July 16/97	6.0	5.7	4.1	5.3
Mean	5.4	6.0	3.9	

Table 9. Marketable and total tuber yields of potato in q/ha grown in different fertilizer types and planting dates at Ankober, 1999.

Planting date	Fertilizer types						planting date mean	
	Control (without ferti.)		195/165 k.g Dap/Urea		6 ton FYM + 100 k.g Dap			
	Marketable TY	Total TY	Marketable TY	Total TY	Marketable TY	Total TY	Marketable TY	Total TY
May 25/99	70.1	118.0	145.6	187.8	74.9	130.1	96.8	145.3
June 11/99	62.0	119.1	152.0	202.6	58.6	117.8	90.9	146.5
June 25/98	66.8	92.8	107.5	151.7	37.4	109.3	70.6	117.9
July 8/99	3.7	15.6	35.0	66.7	13.3	38.0	17.3	40.1
fertilizer types mean	50.7	86.3	110.0	152.2	46.1	98.8		
	Block		Fertilizer		Planting date		Interaction (F x PL)	
	Marketable TY	Total TY	Marketable TY	Total TY	Marketable TY	Total TY	Marketable TY	Total TY
C.V	-	-	31.33	27.91	31.33	27.91	31.33	27.91
LSD 5%	NS	NS	35.52	44.64	21.37	31.07	NS	NS
LSD 1%	NS	NS	58.78	73.87	29.31	42.6	NS	NS

Table 10. Common scab damage on tuber quality on weight basis (%) of potato grown in different planting dates and fertilizer types at Ankober, 1999

Planting dates	*Fertilizer types*			*planting date mean*
	Without fertilizer	195/165 k.g Dap/Urea	6 ton FYM + 100 Kg Dap	
May 25/99	1.06	0.97	22.22	8.09
June 11/99	0	1.01	7.92	2.98
June 25/98	2.99	0.85	55.64	19.83
July 8/99	2.38	1.39	25.00	9.59
Mean	1.61	1.06	27.69	

Review of Sweet potato research

Sweet potato Variety Development

Three sets of sweet potato variety adaptation trial was conducted at Ataye (1500 m. asl) in Efratana Gidim woreda and at Alem Ketema (2300 m.asl) in Merhabete Woreda of north Shewa during 2004/05 and 2005/06 cropping season. The varieties belonged to three maturity classes : early, medium and late maturing. At Ataye five and seven and late maturing sweet potato varieties were tested against the local checks with four and three replications, respectively. Plot size of 7.2 m^2 was use in both situations. At Alem Ketema 10 sweet potato varieties (early and medium maturing sets) were tested for two consecutive years The varieties were laid out in Randomized complete block design with three replications in a plot size of 5.76 m^2. The varieties were planted in a spacing of 60 cm between rows and 30 cm between plants. Fertilizer was not applied in all of the trials.

In all the areas and seasons the stand count of local check was too low. Hence, it is excluded from data analysis and interpretation. During the first year (2004/05), at Ataye, the varieties establishment was poor and because of that the CVs of the varieties were high and the root yield between varieties were not significantly different at 5 % alpha level in both sets. In this season the stand of the varieties at Alem Ketema were better than that of Ataye and the varieties were significantly different in both parameters ($p < 0.05$) (Table 11). From the tested varieties Belela and Guntutie gave significantly highest root yield. Beletech and Belela gave significantly highest marketable root yield.

In 2005/06 , no root yield was harvested at Alem Ketema from two poorly established varieties called Belela and Feleha. In general, the yield obtained from the tested varieties was very low. From the tested varieties Guntutie, Kudade and Temesgen gave significantly the highest root yield. In case of marketable root yield, Kudade followed by Temesgen gave higher yield. Due to insect attack Guntutie gave no marketable root yield (Table 12). Guntutie, Kudade and Bereda gave the highest average root weight in gram. Table 13 and 14 show the performance of early and medium set varieties at Ataye during the second year. From the early varieties Kudade and Dubo gave the highest marketable and total root yield/ha. These two varieties also gave the highest average root weight in gram. The variety Temesgen gave highest root length and the farmers preferred it because of its attractive color. However, it is late in maturity. From the medium and late maturing varieties Guntutie, Damota, Awassa-83 and Bereda gave significantly the highest total root yield (Table 14). In case of marketable root yield Guntutie, Damota and Awassa-83 gave significantly the highest yield. However, statistically significant root weight was obtained from Awassa-83 and Guntutie. Beletech and Koka-12 gave the lowest root yield. Beletech however, gave the highest biomass yield.

As conclusion, the yield obtained from Alem Ketema was not satisfactory mainly be cause of the elevation of the site which is about 2200 m.asl. The varieties took long days to mature and the size of tubers was very small. Therefore, it is advised that this site can be used for vine production instead of root production. If root yield is needed, use of Guntutie, Kudade and Belela can be used for the area. The result of the experiment and farmers observation at Ataye indicated that the varieties Kudade and Dubo from the early set and

Guntutie from the medium are suitable for production. Hence, these varieties are recommended. Despite low dry matter yield, the variety Guntutie has high root yield and vitamin A content. Kudade has relatively higher dry matter content.

This experiment also showed that establishment of the cuttings should be given great care in order to get productive field. Planting of the cutting materials in the middle of the ridges in stead of the top the ridges is advisable. Rainfall should be reliable during planting and after planting for several days for good establishment.

Table 11. Root yield and other parameters of sweet potato varieties in Sweet potato varieties adaptation trial at Alem Ketema, during 2004/05 cropping season

Variety	Root No./Hill	Root weight/g	Marketable root yield (q/ha)	Total root yield (q/ha)	Green top yield (q/ha)
Belela	12.136	53.477	101.08	226.852	101.843
Dubo	6.079	49.385	59.028	147.763	60.18
Feleha	4.035	67.784	37.808	101.852	37.903
Kudadie	5.65	35.469	23.148	104.166	117.473
Temesgen	13.772	21.151	9.259	142.747	69.187
Damota	4.976	37.933	30.864	81.404	65.39
Bereda	7.225	49.489	71.759	163.195	96.06
Guntutie	7.273	54.15	60.962	199.46	75.227
Koka-6	9.644	30.941	26.235	150.463	78.7
Beletech	6.445	62.567	113.812	180.941	204.277
Mean	7.724	46.235	53.396	149.884	90.624
CV (%)	34.76	26.34	41.35	20.18	20.4
LSD (5%)	3.801	17.2448	31.2637	42.8198	26.1768

Table 12. Root yield and other parameters of Sweet potato varieties at Alem Ketema, during 2005/06 cropping season

Variety	*Root No./Hill*	*Root weight/g*	*Marketable root yield (q/ha)*	*Total root yield (q/ha)*
Beletech	1.449	32.878	0*	26.07
Dubo	3.848	52.038	49.303	91.484
Koka-6	3.133	51.566	45.833	75.926
kudadie	3.509	96.807	114.469	135.153
Temesgen	4.778	69.098	70.217	104.823
Damota	3.042	44.857	7.202	54.398
Bereda	1.317	92.857	23.148	37.5
Guntutie	4.889	104.286	0	138.889
Mean	3.246	68.048	38.771	83.03
CV(%)	34.42	36.47	51.16	31.74
LSD (5%)	1.606	35.693	28.5245	37.8967

* Due to insect attack marketable root yield was not harvested

Table 13. Root yield and other parameters of varieties in sweet potato adaptation, early maturing set, at Ataye, 2005

Variety	*Root No./Hill*	*Root Weight/g*	*Marketable root yield (q/ha)*	*Total Root yield (q/ha)*
Dubo	9.28	144.09	358.94	376.74
Feleha	16.39	82.62	182.29	322.92
Kudadie	8.14	139.70	404.51	465.71
Temesgen	11.73	53.15	171.87	217.88
Mean	11.39	104.89	279.40	345.81
CV (%)	24.91	23.64	27.56	30.38
LSD (5%)	3.6768	32.14	99.8086	136.1949

Table 14. Root yield and other parameters of Varieties in sweet potato varieties adaptation, mid and late set,
Ataye, 2005

Varieties	*Root No./Hill*	*Root Weight/g*	*Marketable root yield (q/ha)*	*Total Root yield (q/ha)*	*Green TY*
Damota	10.026	52.488	255.545	330.498	101.852
Bereda	4.793	50.515	176.725	260.278	52.084
Guntutie	10.658	70.617	284.265	333.171	71.296
Koka-12	7.327	51.056	146.412	199.074	111.111
Koka-6	7.357	46.623	171.586	223.958	76.389
Beletech	7.633	41.51	114.746	143.842	123.842
Awassa-83	6.43	83.487	249.746	295.787	62.5
Mean	7.747	56.614	199.861	255.23	85.582
CV (%)	25.46	20.14	28.4	23.5	47.07
Lsd (5 %)	2.8705	16.5926	82.5948	87.4931	NS

Referenc

Acland, J. D. 1971. East African crops. Longman. London.

Alemayehu Assefa and Wondafrash Mulugeta. 1997. Crop Improvement Research in North Shewa. pp. 97- 109. *In*: Beyene Seboka and Abera Deressa (eds.). Agricultural Research and Technology Transfer Attempts and Achievements in Northern Ethiopia. Proceedings of the Fourth Technology Generation, transfer and Gap Analysis Workshop. 18- 21 March 1997, Bahir Dar, Ethiopa.

Central Agricultural Census Commission. 2003. Statistical Report on Area and Production of crops. Part II A. Ethiopian agricultural Sample Enumeration. Addis Ababa, Ethiopia.

Dahniya, M.T. 1981. Effect of leaf harvest and detopping on the yields and roots of cassava and sweet potato. pp 137- 142. *In*: ER.Terry,., K.A Duro, and F. Cauness, (eds.). Tropical root crops Research strategies for the 1980s. Proceedings of the first perennial root crops symposium of the international society for tropical root crops, Africa branch, IITA, Ibadan.

Horton, D. and R.L Sawyer. 1985. The potato as a World Crop, with Special Reference to Developing Areas. *In*: Potato Physiology (Paul ed.). Academic Press, Inc., London. 1-32 pp.

Poehlman, J.E. and D.A. Sleper. 1995. *Breeding Field Crops*. 4th ed. Iowa State University Press, Ames, USA. 419-433 pp.

Semagn Asredie, Bereke-Tsehai Tuku and Gebre Medhin W. Giorgis. 1997. Potato Research in North Shewa and Future Research Directions. Pp. 110- 117. ***In***: Beyene Seboka and Abera Deressa (eds.). Agricultural Research and Technology Transfer Attempts and Achievements in Northern Ethiopia. Proceedings of the fourth Technology Generation, transfer and Gap Analysis Workshop. 18- 21 March 1997, Bahir Dar, Ethiopa.

Field biology of sorghum chafer, *Pachnoda interrupta* (Coleoptera: Scarabaeidae) in northeastern Ethiopia

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Abstract

The biology of sorghum chafer (*Pachnoda interrupta)* was studied under field conditions for two consecutive years, i.e., 2002 to 2003. A total of 156 and 236 samples were investigated from nine habitats (under trees in the forest, under trees in crop field, in crop fields, boarder of crop field, grazing land, riverside, manure heaps, termite mound and cattle dung in homesteads) to identify breeding and hibernating areas of the beetles. On average, oviposition rate by a single female was 1.3 eggs per day which lasted for 11 days. Observation disturbance affected the duration of developmental stages. Less disturbed treatments had extended developmental period. In general, eggs hatched within 4 to 22 days with a mean of 15.7 days, larval and pupal stages lasted a mean of 59.8 and 18.3 days, respectively. The highest rate of oviposition was recorded during the first four days after mating and none after the 11[th] day. Fertile humus and moist light soil under shades of various tree species in the forest and riverside were found to be the potential breeding and hibernating area of the beetles. During the June 2001 outbreak, a total of 1770 beetles with equal sex proportion were caught within 15 days from 36 passive metal boards and the beetles infestation were first recorded near the Afar border. Monitoring of flight direction at time of outbreak using metal board traps showed no significant difference in beetle catches among different directions (north, south, east and west).

Introduction

Pachnoda interrupta (Coleoptera: Scarabaeidae: Cetoniinae) is a polyphagous pest commonly found in Africa except a few species which were recorded in Arabia and Madagascar (Grunshaw, 1992). In Ethiopia, surveys conducted about 20 years ago revealed the presence of nine species of *Pachnoda*, one represented by two subspecies (Clark and Crowe, 1977). Except the two species, i.e., *P. stehelini* Sch. and *P. abyssinica* Blan., which were often observed above 2000 m a.s.l, the remaining species were mainly found in the *Acacia* woodlands distributed between 800-1800 m a.s.l (Clark and Crowe, 1977).

Among the nine species, the sorghum chafer, *Pachnoda interrupta*, has become a well-established regular pest since the last eight years attacking a wide range of crops (over 35 types), sorghum being the major one (Hiwot *et al.*, 1999; Hiwot, 2000). According to the local farmers, although *P. interrupta* was recognized three decades ago it caused a minor and sporadic damage on sorghum plants. However, between 1993 and 2005, increasing *P. interrupta* beetle density and area coverage of attack was evident. The area infested has increased from 1,375 ha in 1993 to a staggering 112,000 ha in 2001 (Hiwot, 2001).

Successful management of *P. interrupta* requires a detailed knowledge of its biology and ecology. Seneshaw and Mulugeta (2002) described its biology under laboratory conditions. Clark and Crowe (1977) reported some aspects of the life cycle of *P. interrupta*. In Mali, Grunshaw (1992) also briefly described some aspects of the life history and feeding habits of *P. interrupta* and estimated the yield loss using caged plants in pearl millet fields. The present study was conducted in the field to elucidate developmental durations of the immature stages, adult emergence, and to identify the breeding and hiding areas and the source of infestation of the adult beetles in northeastern Ethiopia.

Materials and methods

Oviposition

Sexually mature and mated female *P. interrupta* were collected from Sefiberet (09° 5474" N, 040° 0309" E) in June 2003 and 2004 and placed in plastic cages. Pots were half filled (10 cm deep) with moist soil rich in compost and maintained in the field to simulate the beetles' breeding ecology. This was done at two sites in Shewarobit and Sefiberet using three pots at each location. Five female beetles were kept in each experimental pot and all eggs were collected and removed daily by brushing gently on a tray until the beetles stopped egg lying. The mean number of eggs laid per female per day and the number of days the beetles continued laying eggs were recorded.

Duration of developmental stages (life cycle)

To study the duration of the different developmental stages of sorghum chafer under field conditions, pots were filled with soil, which was brought from the actual breeding area of the beetles and 10 newly laid eggs were placed on each pot and buried in the soil under trees at Shewarobit and Sefiberet. Each of the pots was covered with mesh cloth. Data on duration of each developmental stage was recorded by disturbing the pot every day, every three days and every six days to see the effect of disturbance. A total of nine pots three for each sampling method were used.

Identification of breeding and hibernating areas

To determine breeding and hibernating areas of *Pachnoda inturrapta*, 236 and 156 samples were investigated, respectively, from nine suspected habitats during February 2002 and August 2003 in areas bordering Afar, Amhara and Oromia regions (Fig. 1). Each soil sample was investigated for the presence of the different growth stages of the insect. Data on number of larvae per meter square, quiescent adult (F: M) ratio on plots of 0.25 m^2 were taken at a depth of 50 cm. Moreover, soil and atmospheric temperature, altitude and surrounding tree species were recorded.

Flight direction

Flight direction was monitored using 36 passive and reflecting metal boards (60 cm × 50 cm) traps which were installed to face four directions with 3 m height and 100 m apart from each other at one site. It was done in three districts (Kewet, Bati and Habru). At each district three sites were selected starting at the nearest accessible area bordering Afar region and at five kilometers interval to the west. Data on the number of beetles caught at each trap (metal board) were collected daily starting from the first day of infestation during the adult flight period in early June and continuously for about15 days and the data were subjected to statistical analysis using general linear model of SPSS software.

Results and discussion

Oviposition

A total of 283 eggs obtained from about 45 female beetles were used to determine the oviposition rate. Under field conditions new beetles emerged in September and became sexually mature in June. After mating, females laid their eggs singly in the soil. On average, the oviposition rate per female was 1.3 eggs per day continuously for 11 days (Fig. 2). Higher or lower rates of oviposition were reported in earlier laboratory studies conducted in Ethiopia. Thus the average number of eggs per female per day varied from 0.6 (for 25 days) (Gebeyehu, 2002) and 1.8 (for two months) (Seneshaw and and Mulugeta, 2002). In Mali, the rate 24 eggs per female per day (Grunshaw, 1992). Differences in feed, soil type, moisture level and egg collection techniques might have contributed to such great differences in the rate of oviposition. Laboratory and field studies could also vary. Diet of the beetles and constant disturbance of egg lying adult has been suggested to determine egg development and rate of oviposition (Donaldson, 1992). Methodologies were not uniform across the board. Seneshaw and Mulugeta (2002) fed the beetles with banana and freshly cut acacia flowers and they collected eggs every five days. Gebeyehu (2002) fed them with banana alone and collected eggs every two days. In the present experiment, the beetles were fed with different naturally preferred feeds and eggs were collected daily. .

Life cycle

Pachnoda interrupta is univoltine insect having only one generation per year. In this study the duration of developmental stages was found to be affected by disturbance made for observation. Life cycle was short in more disturbed treatments. Eggs hatched within 14.1, 17 and 16 days and egg to adult developmental stages took 88.6, 99.5 and 93.5 days when they were observed every day, 3-day and 6-day intervals, respectively, and life cycle took 110 days on undisturbed treatments (Table 1). The overall hatching period for eggs was from 4 to 22 days interval with a mean of 15.7 days. Larval stage lasted between 53 and 67 days with a mean of 59.8 days, and pupal stage took 13 to 25 days, the average being 18.3 days. The duration of adult emergence varied from 70 to 114 days and a mean of 93.8 days (Table 1). Under field condition adults died soon after egg laying and this was supported by Clark and Crowe (1977). In contrast, Seneshaw and Mulegeta (2002) reported that adults survived for six months after egg laying and this might be due to continuous feed supply.

Fig. 1. Surveyed areas for identification of the beetles breeding and hibernating habitats.

Table 1. Period of time elapsed (in days) in different developmental stages of sorghum chafer as disturbed everyday, three days and six days for data collection.

Stages	Disturbed daily		Disturbed every three days		Disturbed every six days		Overall	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Egg	8-20	14.1	5-21	17	4-22	16	4-22	15.68
Larvae	55-67	61	59-66	62.5	53-59	56	53-67	59.83
Pupa	13-14	13.5	17-23	20	18-25	21.5	13-25	18.33
Egg-Adult*	76-101	88.6	81-110	99.5	75-106	93.5	70-114	93.8

** On undisturbed soil, egg to adult stage took 110 days.*

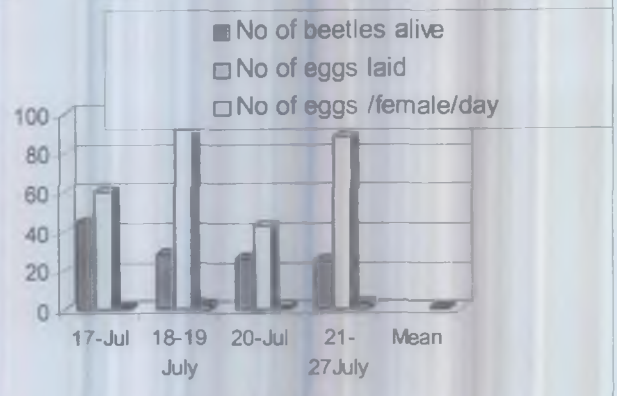

Fig 2. Oviposition rate of sorghum chafer under field condition at Shewarobit

The beetles' hibernating habitat

Adult beetles which emerge in September fly and actively feed on various hosts up to December. Then they disappear and remain quiescent for about six months up to the first rains in June or July to escape the dry season feed shortage. Results of field surveys conducted in Afar and Amhara region revealed that preferred habitats for hibernating beetles were fertile and moist soils in the forest and river sides shaded by dense branch of different species of trees and shrubs and soil depth ranging from 5 to 43 cm depending on moisture status and vegetation cover (Table 2). The higher the soil moisture, the shallower the beetles dig in. In all the surveyed areas, the beetles were not found in dry and sun exposed soils. In most cases, the quiescent beetles were found in altitudes ranging from 700 to 1660 meters above sea level and at soil temperatures varying from 22 to 25°C (Table 3).

The dominant tree species in which the beetles were hibernating were different Acacia species, *Ximentia americana* (Enkoy), *Zizyphus spinacristy* (Qurqura), *Capparis tomentosa* (Gumero), *Berchemia discolor* (Jejeba), *Carissa edulis* (Agam), *Euclea schimperi* (Dedeho) and others. Previously, farmers perceived that beetles emerged in September disappeared to the Afar region after heavily damaging the crop. However, the beetles could hibernate in all invaded areas or regions as far as the favorable hibernating habitats exist (Table 3).

The beetles' breeding habitat

Once male and female beetles sexually matured, the quiescent beetles emerged from their hibernating habitats starting from the first rain shower in June, then mating, oviposition and other developmental stages to the second generation continued. Some 236 samples from one meter square area were taken from all the suspected breeding habitats. Eggs and larvae of sorghum chaffer beetles were obtained only from 70 of the 116 samples in soils and litters under trees in the forest and 5 of the 13 soil samples taken from under trees in river sides (Table 2). Beetles preferred moist and light soils in forest and river sides under shade of acacia and other tree species for reproduction (Table 2). Clark and Crowe (1977) suggested that goat and sheep dung piles were the potential breeding habitats of the pest. In Afar region, heaps of goat and sheep dung were considered as breeding places of sorghum chaffer and control strategies focused on spreading and burning dung piles. The current study, however, did not support the theory that claimed the positive role of habitats such as under trees in crop fields, in the crop field, boarder of crop field, pastureland, sheep and got manure heaps, termite mound and cattle dung in the homestead for the reproduction of the sorghum chafer beetles.

Larvae were found from breeding habitats in Amhara, Afar and Oromia regions at a depth of 2-3 cm and soil and atmospheric temperature of 22.5-31.5°c and 25.5-34°c, respectively (Table 4). The beetle larvae were found in altitudes ranging from 519 to 1475 meters above sea level. Although larvae were found in surveyed areas in Afar, Amhara and Oromia regions, the maximum and minimum larval density per meter square of 322 and 3 were recorded from Amibara district of Afar region and Fentale woreda of East Oromia, respectively (Table 4).

Table 2. Total number of samples, number of samples with larvae and adult in suspected breeding and hibernating areas.

Suspected breeding and hibernating habitats	Hibernating area: Total # of samples	Hibernating area: # of samples with quiescent adult beetles	Soil depth (cm)	Breeding area: Total number of samples	Breeding area: Samples with larvae of sorghum chafer
Under trees in the forest	45	38	5-20	116	70
Under tree in crop field	13	0		12	0
Crop field	30	0		15	0
Boarder of crop field	18	0		20	0
Pastureland	11	0		27	0
River side covered by trees	16	12	20-43	13	5
Sheep and got manure heaps	9	0		12	0
Termite mound	6	0		15	0
Cattle dung in homestead	8	0		6	0

Table 3. Quiescent adult beetles of *Pachnoda interrupta* in 0.25 m^2, soil and atmospheric temperature and altitude range of sampled areas.

District	Number of beetles//0.25 m^2			Temperature (°c)		Altitude range (m.a.s.l)
	Female	Male	Total	Soil	Atmospheric	
			Amhara			
Harbu	4	5	9	22	28	1150-1400
Bati	2	2	4	24	28	1300-1360
Kewet	5	5	10	24	29	1320-1460
Minjar	7	8	15	22	31	1200-1660
			Afar			
Semurobe Gelealo	25	22	47	25	33	800-1190
Dulecha	5	7	12	24	34	700-990
Argoba Liyu	8	6	14	22	29	1050-1260

Flight direction during outbreaks

From all 36 metal boards, a total of 1770 beetles (852 males & 918 females) were caught within 15 days. The ratio of male and female beetles during this period was one to one. Monitoring of sorghum chaffer flight direction using metal board during time of infestation showed that there was no significant difference in number of beetles caught per trap per day between the four directions (Table 5). Meta traps did not show source and direction of infestation. This might be due to the mixed and swarming flight behavior of the beetles after emergence from the soil in search of feed and mating. In most cases the beetle infestation was first recorded in areas near the Afar border (Table 6). This might be because of the low altitude and high temperature in the area that enhanced the insect development and infestation.

Conclusion and recommendations

The adult beetles that emerged during the day time in September and October were extremely abundant and often caused considerable damage to sorghum, maize and several other cereals until the end of November or to some extent to the beginning of December. At the end of November, the beetles began to hide in the hibernating habitat and remained quiescent until they emerged again in June as sexually matured adult beetles.

Table 4. Larval density per m^2, soil and atmospheric temperature, soil depth and altitudes of adjacent areas in

District	No. larvae/ m^2	Temperature (°c)		Soil depth	Altitude range (m.a.s.l)
		Soil	Atmospheric		
		Amhara			
Harbu	22	24.5	25.5	2	1180-1475
Bati	12	25.0	34.0	2	1300-1400
Kewet	26	22.5	31.0	2	1360-1441
		Afar			
Mile	51	29.0	33.5	3	519-900
Gewane	34	31.5	31.0	3	630-690
Amibara	322	26.0	31.0	3	735-750
Awash	10	25.0	28.5	3	975-1020
		Oromia			
Fentale	3	27	32	3	1000-1030

Table 5. Mean number of beetles caught/ day/ trap in north, south, west and east directions during June, 2001 outbreak in Kewet, Bati and Harbu districts of the Amhara region.

Direction	Kewet	Bati	Harbu	Mean	Total
North	40.3	48.7	79.7	56.2	224.8
South	50.3	56.0	33.0	46.4	185.7
East	51.3	21.7	17.0	30.0	120.0
West	47.7	12.7	31.7	30.7	122.7
LSD	NS	NS	NS		
CV	18.4	53.2	68.3		

Table 6. First date of beetle catches using metal boards at different directions and locations in June-July 2001 outbreak.

District	Site	Date of first catch			
		North	South	East	West
Kewet	I	June 25	June 29	June 27	June 29
	II	July 6	July 6	July 7	July 6
	III	July 8	July 8	July 8	July 8
Bati	I	June 27	June 27	June 27	June 27
	II	July 4	June 27	July 4	-
	III	July 4	June 27	July 5	July 4
Harbu	I	July 1	July 1	July 8	July 2
	II	July 2	July 2	July 2	July 2
	III	July 8	July 8	July 10	July 10

Total adult beetles: 1770 (male=852, female=918)

Moist and composted light soils in the forest and the river side densely shaded by different tree species were the suitable habitats for hibernation and breeding of the beetles. Under field conditions, new beetles that emerged in September became sexually mature in June. After mating, each female beetle laid about 1.3 eggs per day for eleven days in the soil and then died. Egg to adult development stages of sorghum chafer under field conditions took an average of 93.8 days.

Based on this, we can suggest the stage of the insect and the particular time of the year when control measures should be taken. Controlling sexually matured quiescent beetles that emerge in June, which are parents of the devastating September beetles, should be the first control target. Moreover, control of the newly emerged beetles during September to October should continue. The larvae could also be targeted for control through mechanical destruction, but its practical application is limited because its breeding areas are inaccessible, i.e., mostly the acacia wood land.

Reference

Clark, R.O.S. and Crowe, T.J. 1977. *The Genus Pachnoda in Ethiopia. Identification, Pest Status and Control of the Species*. IAR, Addis Ababa.

Donaldson, J.M.I. 1992. Biology and rearing techniques for twenty-two species of Cetoniinae (Coleoptera:

Scarabaeidae). *Technical Communication Department of South Africa* **237**: 1-22.

Gebeyehu Feleke. 2002. Study on the effect of physical factors and soil types on the development and food

preference of sorghum chafer, *Pachnoda interrupta* (Oliver) (Coleoptera: Scarabaeidae). MSc thesis, Addis Ababa University.

Grunshaw, J.P. 1992. Field studies on the biology and economic importance of *Pachnoda interrupta* (Coleoptera: Scarabaeidae) in Mali, West Africa. *Bulletin of Entomological Research* **82**: 19- 27.

Hiwot Lemma, Adane Kassa, Yeraswork Yilma, Legesse Zewde, Tsegaye Ejigu, Mohamed Seid and Ararsa Workineh. 1999. The significance, distribution and control of sorghum chafer, *Pachnoda interrupta* (Oliver) (Coleoptera: Scarabaeidae) in Amhara and Afar regions. MOA and EARO, Addis Ababa.

Hiwot Lemma. 2000. Historical background on the pest status and control of sorghum chafer, *Pachnoda interrupta* (Coleoptera: Scarabaeidae) in Ethiopia. In: *proceedings of the workshop on the development of monitoring and control strategy against sorghum chafer, Pachnoda interrupta (Coleoptera: Scarabaeidae) in Ethiopia*. MOA. 28th Feb- 2nd March, 2000. Addis Ababa, Ethiopia.

Hiwot Lemma. 2001. Distribution of sorghum chafer in Ethiopia, control approaches and their limitations.

Proceeding of the workshop on sorghum chafer, *Pachnoda interrupta* (Oliver) (in Amharic). 12-14

February 2001. Dessie. pp28.

Seneshaw Aysheshim and Mulegeta Negeri. 2002. Study on the biology of sorghum chafer, *Pachnoda interrupta* (Coleoptera: Scarabaeidae) under laboratory condition. *Pest Management Journal of Ethiopia* **6**: 31-36.

Management of sorghum stemborers using *Azadirachta indica* L. and *Melia azedarach* L. in northeastern Ethiopia

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Abstract

Plant seed extracts of two plant species, *Azadirachta indica* and *Melia azedarach* were evaluated for the management of stemborers on sorghum at Sirinka and Chefa in 2002-2004. The experiment was arranged in Complete Randomized Block Design with three replications. Sorghum varieties 'Gambella1107' and local 'Jigurty' were used at Chefa and Sirinka, respectively. The treatments were water extracts of neem seeds, powder form of neem seeds and powder form of the seeds of Persian lilac. Synthetic chemicals, cypermethrin 1% G and karate 5% EC and an untreated control were compared. On-farm demonstration on farmers' fields was conducted at Lenche-Dima and Chefa in 2005. The seed powder of each botanical and untreated control was demonstrated. The botanical treatments did not significantly vary in leaf infestation and chaffy heads. Significantly lower percent leaf infestation was detected in neem and Persian lilac treated plots than on the control in both locations and years. Both the water extract and the neem seeds powder did not vary in percent infestation. In almost all locations and years, higher grain yields of sorghum were recorded in neem and Persian lilac treated plots than untreated control plots. A grain yield advantages of 8-58% and 15-43% over untreated control were obtained in neem and Persian lilac treated plots, respectively. The results obtained during on farm demonstration were similar to the result obtained on station experimentation. Leaf infestation was reduced from 36% to 11% and from 36 to 26% at Lenche-Dima using neem and Persian lilac seed powder, respectively. Moreover, percent infestation was reduced from 80% to 2.1% and 80 to 35% in neem and Persian lilac treated plots, respectively. Higher grain yield and lower percent infestation were recorded in neem and Persian lilac treated plots than the untreated plots.

Introduction

Sorghum production faces a number of constraints. Annual yields are often low and are subjected to extreme fluctuation. Grain yields on peasant farmers in Africa are low, which range from 500 to 800 kg ha^{-1} (Alghali, 1986). In Eastern Africa, FAO (1991) reported that 3.9% of the world's acreage is planted to maize and 11.5% to sorghum. Yields in this region range between 700 to 1800 kg ha^{-1} for maize and from 455 to 1471 kg ha^{-1} for sorghum. In the USA, maize and sorghum give average yields of 7437 kg ha^{-1} and 3951 kg ha^{-1}, respectively. In Ethiopia, despite the tremendous genetic diversity of sorghum, the current average yield is very low, i.e., 1187 kg/ha (CSA, 2000).

Factors contributing to such low yields are drought, low soil fertility, soil erosion, poor crop management practices, insect pests and diseases. Among insect pests, lepideptrous stemborers contribute a great share, which are the most serious and prevalent insect pests in Eastern Africa (Seshu Reddy, 1981). Two lepidopterous stemborers, *Busseola fusca*

(Fuller) (Lepidoptera, Noctuidae) and *Chilo partellus* (Swin.) (Lepidoptera, Pyralidae) are economically important pests of sorghum and maize in Ethiopia and they cause up to 100% yield loss on these crops (Kassahun, 1993). Assefa (1985) reported that *B. fusca* is the dominant stemborer species at high altitude and in cooler areas, whereas *C. partellus* is the predominate species at lower altitudes and in warm areas of the country.

In an effort to control these insect pests, crop management practices like time of planting, crop rotation, tillage, plant spacing, intercropping and field sanitation, as well as the use of synthetic insecticides, resistant varieties, botanical pesticides and biological control have been used. Synthetic insecticides are effective and convenient, but they are harmful. They are toxic to non-target organisms, cause health hazard, develop pest biotypes resistant to specific pesticidal chemicals and aggravate pest problems in some situations due to the effect of chemicals on natural enemies of pests (Harris, 1963; Schmutterer, 1998). These facts encouraged researchers to look for alternative pest control strategies especially those that are effective, low cost and environmentally friendly. The use of plant extracts to control pests is not new. Rotenone (*Derris* spp.), nicotine and pyrethrins have been used for a long time in small-scale subsistence and also in commercial agriculture (Stoll, 2000). The use of pesticides derived from plants is increasing from time to time. They are easily and locally available, require low technical input to prepare, less phytotoxic, easy to grow and they pose no hazard to non-target organisms, wild life, humans or the environment.

Neem plant protects itself from the multitude pests with a multitude of pesticidal ingredients. Its main chemical broadside is a mixture of three or four related compounds, and it backs these up with 20 or others that are minor but nonetheless active in one way or another. These compounds mainly belong to a general class of natural products called "triterpenes", more specifically "limonoids". Although bioactive compounds are found throughout the tree, those in the seed kernel are the most concentrated and accessible (NAP, 1992). They are obtained by making various extracts of the kernels and, to a lesser extent, of the press cake. Although the active ingredients are only slightly soluble in water, they are freely soluble in organic solvents such as hydrocarbons, alcohols, ketones, or ethers. The processing can be done using either simple village-level technology, high-technology methods at industrial scale. The most common extract procedures are water, alcohol, hexane and pentane extracts. Neem and Persian lilac extracts can be applied in various ways like sprays and powders. Therefore, the objective of these studies were to evaluate the efficacy of neem and Persian lilac seeds in water extract and as powder form for the management of stemborers.

Materials and Methods

Study sites

On station experiments were conducted at Sirinka and Chefa where *B. fusca* and *C. partellus* were important, respectively. Sirinka and Chefa are situated at altitudes of 1850 and 1450 m.a.s.l., respectively. Both are major sorghum growing areas of the region. The trial was conducted in 2002 and 2003 cropping seasons. Sorghum varieties, "*Gambella 1107*' (improved variety) and local

'Jigurty' were used at Chefa and Sirinka, respectively. Both varieties are susceptible to stemborers. In 2005, as a follow up study, the powder form of the neem and Persian lilac was demonstrated on farm at Chefa and Lenche-Dima each on 10 farmers' fields.

Treatments

The treatments consisted of neem in the form of water extract and powder, and Persian lilac in powder form for on-station trials. Two insecticides, cypermethrin 1% G, karate 5% EC (300 ml/ha) and untreated check were included as checks. During on farm demonstration neem and Persian lilac powder form were used and comparison was made between the two botanicals and the untreated control.

Preparation and application of neem seed powder and water extracts

The neem seeds, yellow in color, were collected from Kobo. Coat of the freshly collected seed was removed using local mortal and pistol. After removing the seed coats, the remainder of the seed part was washed and dried under shade. To avoid fungal contamination, hand gloves were used during spreading on canvas. The dried parts were ground until fine powder was obtained. Water extract of neem seed was prepared by mixing 13 kg powder with 333 liters of water, which was enough for one hectare. Little alcohol and liquid soap were added in the admixture to facilitate the release of the active ingredient, as the active ingredient is highly soluble with alcohol, and to enhance adherence of the spray on to the crop, respectively. Finally the admixture was allowed to pass through a cloth with very fine sieve so as to make the residues remained on the cloth and the filtrate easily passed through the nozzle of the knapsack sprayer. To reduce the degradation of the active ingredient through high temperature, the extract was applied on sorghum leaf funnels in the afternoon when daily temperature drops.

The powder form of the neem seed was placed in the young leaf funnels of the sorghum plants to make the powder reach where borer larvae fed. Approximately one hand pinch, which is equivalent to one teaspoon or 0.65 g, was applied per plant. One-teaspoon dust of endosulfan was applied per sorghum shoot.

Persian lilac leaf powder

Seeds of Persian lilac were collected from Sirinka Agricultural Research Center, Woldia, Wolo. The collected seeds were dried under shade and ground using pistol and mortar. The powder was applied into the funnel or leaf whorl using hand pinch. Both chemicals and botanicals were applied four times starting at 2 weeks after crop emergence (WAE) or every week after the first dead heart plant was observed.

Collected data

Data on leaf infestation, chaffy heads and grain yield were recorded. Percent leaf infestation and chaffy heads were calculated based on total plants and total harvested heads, respectively. Data on percent infestation and grain yield were collected during on farm demonstration. A field day was arranged in which 25 men and 5 women farmers participated. The evaluation criteria were discussed with farmers and development agents. The criteria were leaf infestation, head chaffyness, lodged head, plant height and plant population. Based on these criteria farmers ranked the plots as 1= very good, 2= good and 3= bad or heavily infested plots.

Statistical analysis

The experiment was laid out in a randomized complete block design with four replications. Plot sizes of 3.75 m × 5 m with spacing 0.20 m between plants and 0.75 m between rows were used. ANOVA was done using GenStat. Mean separation was done using DMRT tests. Grain yield advantage was calculated as follows: Yi = (Y/X)*100-100. Where, Yi=yield increase; Y= yield of treated plots; X= yield of untreated plots.

Results

In 2002, botanical treatments did not significantly vary in percent leaf infestation and chaffy heads at both locations. Percent leaf infestation was significantly lower in neem and Persian lilac the treated than on the untreated (control) plots in both locations and years. Both water extract and powder of neem seeds had similar effect on percent infestation and chaffy heads (Table 1). However, there was no significant difference between the chemical insecticide and botanicals in percent infestation at Chefa in both years and locations (Tables 1 & 2). Percent leaf infestation and chaffy heads were reduced from 35% (untreated control) to 10-18% and from 54% (untreated control) to 4-17% at Sirinka, respectively, and from 47% to 2-12% and from 24% to 2-10% at Chefa, respectively. Generally, synthetic chemicals and botanical pesticides reduced the infestation and damage levels by stemborers. Numbers of dead hearts were not significantly different between treatments in each location and year.

In 2002, the botanicals and the untreated control did not significantly vary in grain yield at Sirinka. Although, yield difference between botanicals and untreated control was not significant, higher grain yield was recorded in neem and Persian lilac treated plots than the untreated control plots. Significantly higher yield was recorded in neem and Persian lilac treated plots than untreated control at Sirinka in 2003. Grain yield advantages of 8-58% and 15-43% over untreated control were recorded using neem and Persian lilac, respectively at Sirinka in both years (Table 3). Similarly, grain yield was not significantly different among treatments at Chefa in 2002 but it was significantly higher in plots treated with neem seed powder as compared to untreated control plots in 2003. At Chefa, grain yield advantages over untreated control of 9-31% and 17-21% were recorded on plots treated with neem and Persian lilac, respectively in both years. Generally, higher yields were recorded in neem and Persian lilac as well as in chemical insecticide treated plots than untreated control plots in all locations and years. Almost in all locations and years, higher grain yield of sorghum and less percent leaf infestation and chaffy heads were recorded in neem powder treated plots than neem seed water extract treated plots.

Table 1. The effect of neem and Persian lilac on percent leaf infestation and percent chaffy heads due to stemborers on sorghum in 2002 at Sirinka and Chefa

Treatments	Sirinka			Chefa		
	Leaf infestation (%)	Chaffy heads (%)	No. of dead heart plants at 6WAE^{NS}	Leaf infestation (%)	Chaffy heads (%)	No. of dead heart plants at 6WAE^{NS}
NSWE	17.5b	16.8b	1.6	12.0b	2.5b	1.7
Neem seed powder	16.5b	15.5b	1.3	6.8bc	1.8b	2.0
PLSPE	14.8b	13.8b	0.8	9.2bc	2.8b	0.7
Cypermethrin 1G	0.5c	1.0c	1.3	1.0c	1.0bc	1.8
Karate 5% E.C.	1.0c	7.3c	1.4	5.5c	2.0b	1.7
Untreated control	35.0a	26.8a	2.3	47.0a	12.3a	2.2
CV (%)	34.23	25.6	32.0	31.23	36.23	23.62

Values in each column followed by the same letter(s) are not significantly different (P<0.05) using DMRT; NSWE and PLSPE stand for neem seed water extract and Persian lilac seed powder extract; Ns=No significant difference (P>0.05) between treatments; WAE= Weeks after emergence

Table 2.The effect of neem and Persian lilac on percent leaf infestation and percent chaffy heads due to stemborers on sorghum in 2003 at Sirinka and Chefa.

Treatments	Sirinka			Chefa		
	Leaf infestation (%)	Chaffy heads (%)	No. of dead heart plants at 6WAE^{NS}	Leaf Infestation (%)	Chaffy heads (%)	No. of dead heart plants at 6AE^{NS}
NSWE	10.7b	5.3b	1.4	2.3b	9.8b	1.7
NSPE	10.0b	4.3b	1.6	2.3b	7.8b	2.0
PLSPE	11.6b	5.8b	1.6	2.3b	7.8b	0.9
Cypermethrin 1G	6.4bc	3.8b	1.8	1.8bc	0.7c	1.8
Karate 5% E.C.	7.3bc	3.8b	1.8	2.0bc	1.0c	1.7
Untreated control	34.5a	54.a	1.7	30.0a	24.6a	2.2
CV (%)	21.41a	30.45	22.33	40.36	32.60	24.5

Values in each column followed by the same letter(s) are not significantly different (P<0.05) using DMRT; NSWE, NSPE and PLSPE stand for neem seed water extract, neem seed powder extract and Persian lilac seed powder extract; Ns=No significant difference (P>0.05) between treatments; WAE= Weeks after emergence.

Table 3. Grain yield and grain yield loss on sorghum due to stemborers at Sirinka and Chefa in 2002/03 and 2003/04.

Treatments	Sirinka				Chefa			
	2002		2003		2002		2003	
	Yield (q/ha)	Grain yield advantage (%)	Yield (q/ha)	Grain yield advantage (%)	Yield (q/ha)	Grain yield advantage (%)	Yield (q/ha)	Grain yield advantage (%)
NSWE	18.4bc	21.9	30.0b	18.6	34.6b	8.5	36.5bc	18.5
NSPE	16.3c	8.0	40.0ab	58.1	39.3ab	23.2	40.4b	31.2
PLSPE	17.3c	14.6	36.2ab	43.0	37.3ab	16.9	37.4bc	21.4
Cypermethrin 1G	22.2a	47.0	46.4a	83.1	42.9ab	34.5	51.4a	66.9
Karate 5% E.C.	20.7ab	37.1	42.7ab	68.8	40.5ab	27.0	40.8b	32.5
Untreated control	15.1c	0	25.3c	0	31.9b	0	30.8c	0
CV (%)	11.1	----	13.0	----	9.4	----	14.2	----

Values in each column followed by the same letter(s) are not significantly different (P<0.05); NSWE, NSPE, PLSPE stand for neem seed water extract, neem seed powder extract and Persian lilac seed powder extract, respectively.

The result obtained during on-farm demonstration was similar to the result obtained on station experimentation. Percent infestation was lower in neem and Persian lilac treated plots than the untreated plots. Leaf infestation was reduced from 36% to 11% and from 36 to 26% at Lenche-Dima using neem and Persian seed powder, respectively. Percent infestation was reduced from 80% to 2.1% and 80 to 35% in neem and Persian lilac treated plots, respectively (Fig. 1). The highest percent infestation, 80% and 36 was higher in untreated plots at Chefa and Lenche-Dima, respectively. Grain yield was higher in neem and Persian lilac treated plots than untreated plots (Fig.2). During the field day, participant farmers ranked neem seed powder plots as first and Persian lilac seed powder plots as 2nd most preferred plots (Table 4).

Table 4. Farmers' ranking evaluation (%) during the field day in 2005.

Treatments	No. of farmers	Rank (%)		
		1st	2nd	3rd
Neem seed powder	30	100	-----	----
Persian lilac seed powder	30	----	100	----
Untreated control	30	----	----	100

The figure 100% indicates all the farmers agree as 1st =very good, 2nd =good and 3rd =heavily damaged plots.

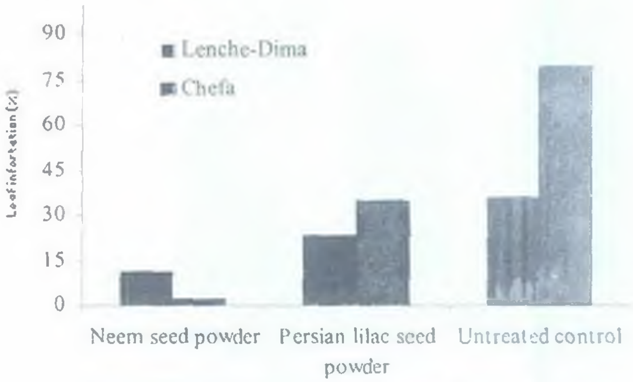

Fig. 1. The effect of neem and persian lilac on percent leaf infestation at differnt localities on farm demonstration in 2005.

Discussion

Assefa and Ferdu (1999) reported that Persian lilac caused stemborer larval mortality comparable with the recommended insecticide. Schmutterer (1998) and NAP (1992) reported that home-made water extracts of neem seeds or neem kernel are effective providing that the raw material used was of good quality, which means, iner-alia, free of fungal infestation. In doing so, approximately one teaspoon full of neem powder is needed to treat the funnel of one plant and control the stemborers very well. Stoll (2000) reported that timely application of neem and Persian lilac seeds and leaves reduced infestation and damage levels of stemborers and boosted sorghum and maize yields.

The reason for better efficacy of neem seed water extract on stemborer's infestation could be due to the addition of little soap that stick the extract to the leaf. Mensah (1998) reported at alcohol extracts were the best method for obtaining liminoids in the extract.

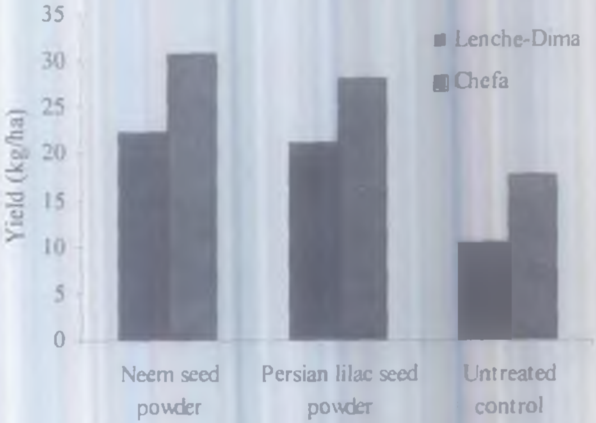

Fig. 2. The effect of neem and persian lilac on sorghum grain at different localities on-farm demonstration in 2005

The liminoid content in such extract are 50 times more concentrated than for water extracts. The alcohol extracts contain between 300 and 100,000 ppm of azadirachtin. Although alcohol extracts of neem seeds control more effectively than water extracts, water extract of neem in this experiment also provided more yield than untreated plots. Therefore, it is advisable to use alcohol extract for better efficacy. The efficacy of powder form of botanical pesticides could increase provided that there was sufficient water or rainfall that moist the powder and reach at the site of action where size larvae feed on. It is important to note that sufficient powder or spray enters the leaf sheath where the early instar larvae were located. The timing of application is also crucial for the effectiveness of these botanical pesticides. The young larvae rest on the leaves and in the sheath before they bore in to the stalk. Therefore, it is essential to apply during this time, when they are most vulnerable. It is also a need to study application frequency of these botanical pesticides because several generations of the stemborers over a long period of crop development is expected. The same recommendations were also suggested earlier (Mugoya,, 1995; Assefa and Ferdu, 1999).

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References

Alghali, A.M.1986. Effects of cultivar, time and amount of *Chilo partellus* (Swin.) infestation on sorghum yield components in Kenya. *Tropical Pest Management* 32: 126-129.

Assefa, G. 1985. Survey of Lepidopterous stalks borers attacking maize and sorghum in Ethiopia.
Ethiopian Journal of Agricultural Science 7(1) : 15-26.

Assefa, G. and Ferdu, A. 1999. Insecticidal activity of chinaberry, endod and pepper tree against the maize stemborers (Lepidoptera: Noctuidae) in Southern Ethiopia. *International Journal of Pest Management* 45(1): 9-13.

CSA (Central Statistical Authority). 2000. Area and production for major crops. Statistical Bulletin No. 227. Addis Ababa, Ethiopia.

FAO 1991. FAO production year book 44 1990. FAO statistics series No. 99, Rome. 283 pp.

Harris, K.M. 1963. Annual variation of day season populations of larvae of *Busseola fusca* (Fuller) in North Nigeria. *Bulletin of Entomological Research* 54: 643-647.

Kassahun, Y. 1993. Phenology and management of the maize stemborers, *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) as a sorghum pest in Eastern Ethiopia. A thesis submitted to the school of graduate studies, Alemaya University of Agriculture, Alemaya Ethiopia. 87 pp.

Mensah, I.A. 1998. The use of neem (*Azadirachta indica*) in Ghana and their relationships to chemical constituents and biological activities. *In*: proceedings of a seminar held in Dodowan, October 1998, the potential of the neem tree in Ghana, Gschborn, Germany. 11-26 pp.

Mugoya, C..F. 1995. Effect of *Tephrosia Vogelii* water extracts on the oviposition behavior of *Chilo partellus* and evaluation of an effective field dose in the management of stemborers in maize. Swedish University of Agricultural Sciences, Development of Plant Protection Sciences, report No. 4, Alnarp 1995.

NAP (National Academic Press). 1992. Neem: A tree for solving global problems. Board on Science and Technology for International Development, National Research Council, Washington D.C., USA. 152 pp

Seshu Reddy, K.V. 1981. Pest Management in sorghum II. pp237-246. In sorghum in the eighties, 2-7 November 1981. Patancheru, India: ICRISAT.

Schmutterer, H. 1998. Target pests for application of home-made and commercial neem products. In: proceedings of a seminar held in Dodowan, October 1998, the potential of the neem tree in Ghana Gschborn, Germany. 42-45 pp

Stoll, G. 2000. Natural crop protection in the tropics Margraf Verlag. 376 pp.

Efficacy of natural insecticides for the management of Wolo bush cricket, *Decticoides brevipennis* Ragge, (Orthoptera, Tettigonidae) in northeastern Ethiopia

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Abstract

A cage experiment was carried out at Sekota and Meket districts in 2000-2005 cropping seasons using five botanicals and animal urine. Carbaryl 85% WP and untreated check were included for comparison. Completely randomised block design with four replications was used. *Agave sisalana (*Agavaceae*)*, *Drucaenena steuaer*, *Carissa schimperi* (Apocynaceae) and animal urine caused 48-92%, 63-86%, 70-81% and 67-95% cricket mortality, respectively. The efficacy of sisal diluted by urine was nearly similar to their individual killing efficacy. Sisal diluted by urine caused 98% mortality whereas sisal and urine diluted by water caused 83% and 95% cricket mortality, respectively at Meket. Water extracts of *Melia azedarach* L. seed, *Azadirachta indica* A. Juss seed and *A. indica* leaf caused 88%, 84% and 49% cricket mortality, respectively. For maximum efficacy, botanicals and animal urine should be applied against the early instars (2-4th) of the cricket. Moreover, they should be applied in the afternoon.

Introduction

Wolo Bush Cricket (WBC) is a flightless long-horned grasshopper. It was first reported as an important pest in 1968 when an outbreak occurred in Wolo at Wadla Delanta district. WBC is an important pest in North Shewa, Gojam, Gonder, Tigrai and Wolo (Jaggo, 1977; Stretch *et al*., 1979; Bayeh and Tsedeke, 1995). The local name "Deggeza" was given after the name of a locality called 'Deggeza Amba', where the insect was first discovered feeding and reproducing.

The insect is known to have seven nymphal instars. The first three are completely black, the later are light brown and the adults are brown. It feeds mainly on the grass family and the most preferred hosts are tef, barley and wheat. In a survey carried out by Bayeh and Tsedeke (1995), yield losses of 15-35% on tef and 15-20% on wheat were reported. WBC is the most challenging insect pest for the production of barley, wheat and tef in Wag-himra and in some districts of South and North Wolo (Adane *et al*., 1997). Some 25 to 50% incidence was recorded in the field on these crops.

To date to replace toxic synthetic pesticides, there is a pressing need to develop environmentally safer alternative crop protectants such as botanical insecticides and antifeedants. Leaves and fruits of *Azadirachta indica* A. Juss were found effective for the control of insect pests and mites (Wawrzyniak and Wrzesinsak, 2000). Plants synthesize secondary plant compounds, which can partly be considered as weapons to defend plants against insect pests that have competed with since time immemorial (Schmutterer, 1995). Methanolic extracts of chinaberry fruits possess insecticidal potency that are comparable or equivalent to that of *Azadirachta indica* seed extracts (Chung Huang *et al.*, 1996).

Indigenous control techniques in the region include field clearing, frequent ploughing, growing chickpea border to the main host crops, digging trenches around the crop border, using chicken as biological control, killing the insect using branches, dusting ash on the insect in the morning, spraying of botanicals and animal urine (Adane *et al.*, 1997; Girma *et al.*, 2000).

In Wolo, resource poor farmers have good experience in the use of plant extracts for the control of pests, such human parasites (lice and bed bugs), domestic animals (leeches and ticks) and insect pests of crops (Wolo bush cricket, aphids, storage insect pests). However, the use of botanicals is not standardized. This is due to differences in individual know-how of the insect, botanicals and preparation procedures. It is very fundamental to examine indigenous farmers knowledge on how to develop pest management strategies. Therefore, the objective of this study was to assess the efficacy of different natural substances for the management of Wolo bush cricket.

Materials and Methods

Preparation of experimental cages

The experiment was conducted in cages (to prevent escape of the insect) at Sekota and Meket districts in 2000-2005. A cage made of mesh wire with an area of 4 mx4 m was used. A natural grass (alternative host) was enclosed in the cage to simulate the field condition. In each cage, 30 nymphs with similar instars, a mixture of approximately 2-4 instars (black in colour) were released in to each cage.

Treatments

The botanicals *Agave sisalana*, *Clematis hirsuta*, *Carissa schimperi*, *Azadirachta indica and Melia azedarach* and animal urine were used. The insecticide Carbaryl 85% WP and untreated check were included for comparison purpose.

Preparation of natural substances

Agave sisalana, Clematis hirsuta and Carissa schimperi. Fresh parts of *Agave sisalana*, *Clematis hirsuta* and *Carissa schimperi* were collected from middle the part of the twig. Leaves were collected from the middle of the twig because very young and very old leaves might have low insecticidal content. Each freshly collected leaf was chopped with local pistol and mortar and squeezed to obtain juice. One litre-extracted juice of each botanical was diluted by one litre water, which is enough for 4 m×4 m cage areas replicated four times. To enhance adhesion of the juice on to the grass, little liquid soap was added.

Neem and chinaberry

Neem leaves and seeds and chinaberry seeds were collected and dried under room temperature and ground with local mortar and pestle. Preparation procedures were the same as the above botanicals. The juice was allowed to pass through a fine sieve (with fine cloth) that eases its passage through the nozzle of knapsack sprayer. Two litres of juice (1:1 ratio of botanicals to water) was obtained.

Animal urine

Animal urine was collected in buckets from cow and allowed to stay in sun for 15 days. After 15 days of fermentation, 0.5 liter urine was diluted by one litre water. Finally, the diluted urine was applied in the cages.

Sisal diluted by urine

Following farmers' practice, sisal diluted by urine was evaluated to investigate the synergetic effect. Procedures and design were the same except that the extracted juice of the sisal was diluted by urine in a proportion of sisal to urine (1:2) i.e., 0.5 litre sisal diluted with 1 litre urine.

Data collected

After spraying, live and dead crickets were counted and recorded.

Statistical analysis

The experiments were laid out in completely randomised block design. Each treatment was replicated four times. Differences between treatments in the number of dead nymphs per plot was analysed using ANOVA model and MSTAT-C statistical software. DMRT was used for mean separation.

Results

Plots treated with neem and chinaberry seeds, sisal and fermented animal urine resulted in significantly higher percent mortality of crickets than neem leaf and untreated check. Except neem leaf all treatments had comparative efficacy as carbaryl. Chinaberry seeds, neem seeds, sisal and fermented animal urine caused 88%, 84%, 68% and 67% cricket mortality, respectively (Table 1). Significantly high percent mortality of crickets was recorded in cages treated with animal urine diluted with water and sisal diluted with animal urine. However, similar trend of percent mortality was recorded in sisal diluted with urine and water, and urine diluted with water. Sisal diluted by urine caused 98% cricket mortality whereas sisal and urine diluted by water caused 83% and 95% cricket mortality, respectively (Table 1).

Table 1. The effect of different natural substances in percent mortality of WBC in Meket and Sekota, 2000/2001

Treatments	Local names	Mortality (%)
	Meket	
Chinaberry seed	----	87.8a
Neem seed	Kinin	84.4ab
Neem leaf	Kinin	48.9c
Animal urine	Shint	66.7ab
Agave sisalana	Kacha	68ab
Carbaryl 85% WP	-	100.a
Untreated check	-	0d
CV (%)	-	8.9
	Sekota	
Animal urine	Shint	95a
Animal urine + Sisal	Shint + Kacha	98a
Sisal	Kacha	83b
Carbaryl 85% WP	-	100a
Untreated check	-	0c
CV (%)	-	5.35

Values in each column followed by the same letter(s) are not significantly different ($P<0.05$) using DMRT

In 2002/03, cricket mortality was higher in cages treated with *Carissa schimperi,* animal urine and *Clematis hirsuta.* Most treatments killed the insect four hours after spray. Mortality of crickets was significantly higher in cages treated with botanicals and animal urine than the untreated check. *Carissa schimperi,* animal urine and *Clematis hirsuta* had comparable efficacy as Carbaryl (Table 2). In 2003/04, high cricket mortality was recorded 4 hrs after spray. Four hrs after spray, significantly higher cricket mortalities was recorded on cages treated with sisal, *Clematis hirsuta* and animal urine. Except *Carissa schimperi* most botanicals and animal urine were effective at 4 hrs after spray. However, more crickets died at 24 hrs after spray using *Carissa schimperi.* Percent mortality of crickets was significantly higher in cages treated with natural substances than the untreated check. Although, there was no significant difference between natural substances in percent mortality, *Agave sisalana* and *Clematis hirsuta* were as effective as Carbaryl (Table 2). In 2004/05, in contrast to the other years, relatively high cricket mortality was recorded at 24 hrs after treatment. However, there was no significant difference among natural substances. *Carissa schimperi* had the same efficacy as Carbaryl (Table 2).

Discussion

Resource poor farmers practice numerous cultural control methods of different insect pests in general and Wolo bush cricket in particular. Previously governmental and non-governmental organizations introduced synthetic insecticides to tackle such epidemic insect pests. Huge amounts of chemicals were used in Wagi-himra and North Wolo zones. Chemical supply was not sustainable. Instead, farmers are adviced to improve their indigenous knowledge. Among the numerous cultural control options, botanicals are becoming the most important component for Wolo bush cricket management. Some of the natural substances used for the management of this and other insect pests are *Agave* *sisalana, Clematis hirsuta, Melia azedarach, Carissa schimperi* and animal urine. Through the effort of Save the Children UK, in IPM FFS (integrated pest management farmers field school) project, resource poor farmers are able to identify and use these natural substances.

Most natural substances effectively killed the cricket 4 hrs after spray in all areas and years. Cricket mortality was particularly higher 24 hrs after spray than the other times. The reason could be that the latter cricket instars (larger than the 4^{th} instar), which were not quickly knocked down by natural substances, and died later. Moreover, some natural substances were not consistent across years. For instance, the highest and lowest percent mortality of crickets using sisal were 92% and 48% in 2002/03 and 2003/04, respectively. Similarly, the highest and lowest percent mortality of crickets using *Clematis hirsuta* were 63% and 86% in 2002/01 and 2003/04, respectively.

Table 2. The effect of different natural substances in the mortality of WBC in 2002/03 at Sekota district

Treatments	Local names	No. of dead crickets at 4 hrs	8hrs	24hrs	Mortality (%)
		2002/03			
Agave sisalana	Kacha	7.3bc	4.3a	2.7ab	47.8b
Animal urine	Shint	14.0b	2.7ab	4.3a	70.0ab
Clematis hirsuta	Azohareg	10.0bc	3.3a	5.7a	63.3ab
mperi	Merez	18.0b	2.0ab	2.7ab	75.6ab
Carbaryl 85% WP		30.0a	0.0b	0.0b	100.0a
Untreated check		0.0c	0.0b	0.0b	0.0c
SE (±)		3.28	0.91	1.06	12.11
		2003/04			
Agave sisalana	Kacha	25.0a	0.3b	2.3bc	92.2a
Animal urine	Shint	14.7ab	1.0b	4.3b	66.7bc
Clematis hirsuta	Azohareg	22.3ab	1.3b	2.0bc	85.6ab
Carissa schimperi	Merez	5.7c	4.3b	11.0a	70.0bc
Carbaryl 85% WP		30.0a	0.0b	0.0c	100.0a
Untreated check		0.0c	0.0b	0.0c	0.00d
SE (±)		1.26	0.55	0.93	5.73
		2004/05			
Agave sisalana	Kacha	2.0cd	5.3ab	10.7a	60.0b
Animal urine	Shint	8.7bc	6.7a	6.0ab	71.1b
Clematis hirsuta	Azohareg	6.0bcd	4.0ab	12.7a	75.6b
Carissa schimperi	Merez	10.0b	4.7ab	9.3ab	81.1ab
Carbaryl 85% WP		29.3a	0.0b	0.0b	97.8a
Untreated check		0.0d	0.0b	0.0b	0.0c
SE (±)		2.16	1.72	2.37	6.59

Values in each column followed by the same letter(s) are not significantly different (P<0.05) using DMRT.

The reason for this lack of consistency across years might be due to the use of lat nymphal instars (above 4th instars) during experimentation. Therefore, identification skill of the early instars is important in WBC management. Under cage conditions, all the tested natural substances were as effective as the synthetic chemical. Generally, *Agave sisalana*, *Clematis hirsuta, Carissa schimperi*, and animal urine caused mortality ranging from 48-92%, 63-86%, 70-81% and 67-95%, respectively across locations and years. Neem leaf, neem seed and chinaberry seed water extract caused 49%, 84% and 88% cricket mortality, respectively. The synthetic chemical (carbaryl) caused 98-100% cricket mortality. To incorporate these natural substances as integrated pest management components, the methods of preparation should be as simple as possible; the active ingredient should be identified, other very easy formulation for users should be investigated. Training of farmers on botanical conservation, methods of preparation, biology of the insect and studies on the economics of natural substances over synthetic insecticides should be conducted.

References

Adane Tesfaye, Eshetu Belete and Getaw Tadesse. 1997. Participatory analysis of Wolo bush cricket (*Decticoides brevipennis* Ragge) (Orthoptera, Tettigonidae) problems in Wag-Himra zone. *Pest Management Journal of Ethiopia* 5: 81-84.

Bayeh Mulatu and Tsedeke Abate. 1995. Survey results of the Wollo-bush cricket (*Decticoides brevipennis* Ragge) (Orthoptera, Tettigonidae). Pp 37-44. *In*: The proceedings of the 3rd annual conference of the Crop Protection Society of Ethiopia held in 18-19 May 1995. Addis Ababa, Ethiopia.

Chung Huang, R., Tadera, K., Yagi, F., Minami, Y., and Nakatani, Y. 1996. Limonoides from *Melia azedarach*. *Phytochemistry* 43(3): 581-583.

Girma Tesfahun., Wondimu Bayu and Adane Tesfaye. 2000. Indigenous crop pest management techniques in Wolo. *Pest Management Journal of Ethiopia* 4: 98-103

Jaggo, N.O. 1977. *Degeza* survey and control studies in the Abay Gorge. London. 41p.

Schmutterer, H. 1995. The neem tree. New York: VCH Publishers. 345p.

Stretch, C., Tekleab, K., Edward, S.B. 1979. The biology and control of the Wollo bush cricket, *Decticoides brevipennis* Ragge (Orthoptera, Tettigonidae), a pest of cereals in Ethiopia. *SINET: Ethiopian Journal of Science* 3(2): 21-36.

Wawrzyniak, M. and Wrzesinsak, D. 2000. Activity of Azadirachtin relating to *Pieris brassicae* and *Apanteles glomeratus, Journal of Plant Protection Research* 25: 119-127.

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