Potato

Proceedings of the 1st Amhara Region Regional Workshop on Potato Research and Development: Achievements and Transfer Experiences and Future Directions.

Workshop Theme: Participatory Potato Technology Development and Transfer: Towards Food Security and improved Livelihoods in the New Millennium.

20 - 21 *December 2007*
Bahir Dar, Ethiopia

Edited by Tesfaye Abebe Desta

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Acknowledgement

We are very grateful to the assisstances received from the Amhara Region Institute of Agricultural Research, Bureau of Agriculture and Rural Developemnt and The Food for the Hungry International/Ethiopia without whom this workshop and this proceeding edition would have been impossible. We are also very much thankful of all the staffs helped us at all stakes for the suceess of this workshop as planned.

The editor.

Welcome Address

Tesfaye Abebe Desta
National Potato Research Project Coordinator

Your Excellency Dr. Alemayehu Asseffa
Deputy Director General, Amhara Region Agricultural Research Institute

Your Excellency Ato Aynalem Gezahegne, Head of Extension Department of the Amhara BoARD, and representative of the Deputy Head of the Amhara BoARD
Dear head of different offices, Colleagues and Fellow Participants of the Workshop

It is a great pleasure and honor for me to welcome you all to this historical and special workshop of potato. I said special because of two very important underlying facts,

One and the most important is that this workshop is the first Regional workshop of potato to the Institute in the dawn of the old and the eve of the new Ethiopian Millennium

The second important reason that makes this workshop special is that the workshop is convened in the eve of the coming 2008 European year, a year which is dedicated to be an International Year of the Potato by the world Food and Agriculture Organization (FAO). And I am quite very sure that every one of you will be very happy of attending this workshop which will not come to pass again in our life time.

As we all know most of us are busy of Regional and institutional work load during the past week. I appreciate the inconveniencies that all of you had to attend this workshop just traveling long distances within few days and also leaving many of your office assignments. I believe you will tolerate all this considering the significance of this deliberation as one of the vital event that will contribute a lot to what the country as well as the Regional government envisioned in the new Millennium that is poverty eradication and ensuring food security at the household level.

Dear participants, within the coming two days a total of 17 papers related to potato technology generation and transfer will be presented. Above all experiences of technology transfer efforts made by different institutions will be thoroughly discussed and recommendations will be passed as to how should we go about scaling up of the previous years pilot works so that the larger community at all stage will benefit from huge public investments made on generating sound and proved technologies. Also the seed system that needs to be established in the Region so as to meet the stipulated Millennium Development Goal will be discussed. We will also finally have an award ceremony in recognition of the efforts of industrious farmers and development agents in Tach Gayint District during the past summer in a community based Potato seed tuber multiplication and technology transfer activity. With this brief introductory remark may I respectfully invite Ato Aynalem Gezahegne, Head of extension Department of the Amhara BoARD. and representative of the Deputy Head of the Amhara BoARD to officially open the workshop?

Opening Address

Ato Ayinalem Gezahegne, Head of the Department of Extension of BoARD and representative of Deputy Head of BOARD

Dr. Alemayehu Asseffa, Deputy Director General of the ARARI
***Participants* of the workshop**

Ladies and Gentlemen

It is an honor and pleasure for me to be present today at the opening of the first Amhara National Regional State (ANRS) Regional Workshop on Potato Research and Development. I want to take this opportunity to express, on hehalf the Amhara Region Bureau of Agriculture and Rural Development, my deep appreciation to the ARARI for all it did to facilitate this very important event of experience exchange among various stakeholders involved in the agricultural development system and information augmentation forum. I also extend my warm welcome to you all gathered in this hall. It is also a great pleasure for me to express my sincere hope that your stay here and deliberations will be pleasant and fruitful one.

As most of you are aware, since the past 1980's an aggressive extension work has been started in the region and the country as a whole. This is also a time during which package formulation for the implementation of the foreseen extension work is launched. Following this urgency and the need for regional agricultural technologies regional agricultural research centers exerted strong effort to develop technologies that best suit to regional priority problems. After years of perceptive efforts today it has been reached to such level at which achievements of various stakeholders will be discussed and augmented into one document to be used as a working guideline.

Today, the Amhara Regional State Government is laying down better environment inline with building good governance, peace and development. The encouraging developments in this respect are being followed by commensurable and all round efforts of the people at all levels. You participants of this workshop are the source of research and development actors to the Regional backbone of the economy, i.e., agricultural sector.

Ladies and Gentlemen

Shortage of appropriate research technologies and transfer system has been the source of current level of agricultural productivity seen in the region as well as the country. This ultimately resulted in the low amount of food reserve and food security problems. Potato as one of the agricultural crop produced in the mid and high altitude areas of the region has multiple constraints that needs closer research attention and technology transfer system so as it could contribute to the access of sufficient food at the household level. Recently, the multifaceted agricultural research outputs and their consequent transfer are letting us see promising results and hope of improving agricultural productivity. To this effect compilation of achievements and exchange of information have far reaching significance. Information that is not properly organized, documented and shared among its users will have greater chance of being not used as they are not accessible.

Ladies and Gentlemen

A workshop of such a kind in which all governmental and non-governmental stakeholders are involved in is expected to identify ways by which existing achievements and experiences will help development actors can support the farming community so that their day to day effort will bring fast and sustainable change in their livelihood. Your concern should include outlining an action plan through which these technologies will address the need to improve the productivity of potato in this region.

In Ethiopia there is a relatively high degree of dissociation among the different stakeholders involved in the technology generation and transfer system. Bridging the gap between these development actors is of great importance for an efficient means of utilizing the scarce resource in a well coordinated and long lasting manner. Such a deliberation lays a milestone to departing from this historical isolated drudgery. It is also an indication that there now exist a possible scenario for the future.

Ladies and Gentlemen

Looking into your programme of the deliberations I feel I could made the following conclusions. Based on the experiences of the various organizations in technology transfer and its possible cross fertilization, the participants of this workshop will be able to design an enabling framework for the scaling up of the pilot try out for improving potato production progressively and sustainably in the Amhara region. In addition, suggestions will be made for the management of the seed system that set serious limitation in transfer of potato technology at the desired rate in the past periods.

Finally I wish you all good progress in the course of your deliberations. It is my great pleasure to declare the first Amhara Region potato research and development workshop is officially open.

Thank you!!

The contribution of potato in addressing food security Agenda of the Millennium Development Goal (MDG): Current and Future Scenario.

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Abstracts

Potato (Solanum tuberosum L.) is the world's fourth important food crop. In Ethiopia this crop production is expanding at a fast rate from being localized around the homestead to distant areas of the farm land in the field. Its productivity per unit area of land and short crop cycle, well recognized facts among the farming community, enabled potato to be a crop of choice addressing food deficit gaps normally experienced in the months of August through September. Additionally, the productive nature of potato has a special place of contribution to address food security issues of the mid and high altitude parts of the region where farm plots are increasingly sizing down due high population pressure. Potato's short crop cycle also adds its value to securing food availability at household level by improving farm productivity through permitting double crop production per annum. Potato is also a trustful crop that can play significant role in those districts of the Region that frequently face serious food shortage due to uneven distribution of rainfall that normally result in crop failure of long cycled crop species. All these underlying facts raised the precious role that potato can play in the farming system in unsubstitutable manner. This can be well understood from the local folklore concerning potato in Amharic language. "Yageren gebere derque wozewozew, Lakas Dinich norwal degifo yeyazew". Besides, potato is an important income generating crop. Because of this fact potato supports about 600 000 rural households in the Amhara National Regional State (ANRS) alone. Moreover, potato did contribute to a reasonable number of households within the cycle of production through consumption. Hence, wholesalers, retailers, cottage level processing individuals, larger fast-food business houses, and different level star hotels do also earn from potato sector. Therefore, potato could play significant role in addressing food security agenda that the world summit stipulated as one of the Millennium Development Goal (MDG). This paper tries to highlight the pro and cons of potato role in line with the objective of the MDG.

Introduction

Potato (***Solanum tuberosum*** **L.**) is one of the world's most important crops, exceeded only by wheat, maize and rice in total production. It is a relatively stable part of the diet of European and North American people. History of household food expenditure survey in these part of the world show that the poorer section of the community obtain a greater proportion of their calories from potato than do richer people. Indeed, the ability of potato to support a large number of people on a small acreage of land is a means of withstanding population pressure. Potato has the advantage over most other crops in that it produces a large amount of dietary energy per unit of land. On a world-wide basis the crop produces more dry matter per hectare surpassed only by Cassava, Sweet potato and yam. Similarly potato produces more protein per hectare than the major cereal crops being exceeded only by Soybean and Cassava. In the past potato has been a significant energy source for industrial communities and have also provided significant quantities of protein. Consequently, in countries where national food self-sufficiency in food is a fashionable thought as the extent of world famine grows more serious most countries that grow potato are self-sufficient. There would therefore seem to be distinct advantages in areas subject to land pressure of substituting more potato in the diet should self-sufficiency become necessary. Research on root crops in low income countries would appear to be an urgent and direct way of contributing to world food supplies in that little yield increasing technology has so far been applied and yet these are the areas of the world where the largest part of the world's increasing population will live. Moreover, due to the low standard of living in such countries, root crops could provide a large part of the population's energy requirement. The biological value of potato protein is reported to be comparable to cow's milk and 70% of whole egg. Besides, eating only 100 grams of boiled potato can meet 10% of child's and 5% adult's daily protein requirement. If the above amount is doubled adult's daily requirement of vitamin C could be met.

Hence, potato is thought to be a balanced diet as it provides quality protein, lycine, which is missing in many cereal crops.

The Ecological Requirement of Potato

Irish potato (***Solanum tuberosum*** L.) is one of the most widely cultivated horticultural crop which can grow from sea level to over 4,000 meters elevation and from the equator to more than 40 degrees South and North. It has a wider range of agroclimatic adaptation, each local environment presenting a specific set of opportunities for and constraints to its production. It requires a temperatures of 18-22^{0}c with a day time temperatures of less than 25^{0}c, night time temperatures of less than 20^{0}c, a rain fall amount of 500-700 mm, soil of deep friable, good water retaining capacity with a P^H in the range of 4.8-6.0 (4).

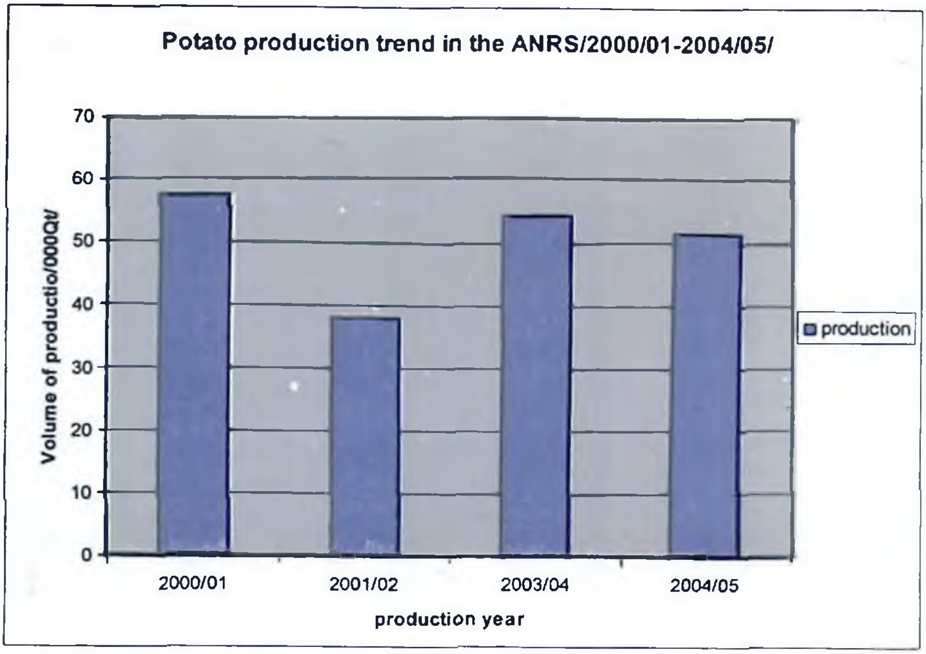
Current status of Potato in the ANRS

The statistics of potato that we have at hand in the Region as well as in the country is so unreliable to exactly indicate the current reality. This shortcoming is normally originated from the low level of emphasis given to recording of potato and other horticultural crops in general. Statistics related to production and the prevailing system is also missing in the annual Central Statistics Agency reports. Nonetheless, potato production data during the summer rainfed production system is observed to oscillate one year after the other. One of the various possible probable reasons for such state of affairs especially during the summer production system is absence of disease tolerant improved potato varieties seed that can help growers manage the inflict caused by this serious and devastating disease. This can be justified by the planting time shift practiced by potato growers where they normally undertake dry planting as an escaping mechanism. Even under such limitation the areas of potato production in the country on average amounts in the 50 000 hectare. The highest figure in potato production is recorded during 2001/2002 cropping season. The area during this period was 164 146 hectare. Contrary to this scenario the total area of land planted by potato during the summer of this period is the lowest record in the data point assessed considered in trend analysis. During this period close to 2,310, 035 households are supported by potato during the stated period (CACC, 2003). This evidently reveals the importance of the crop in the country. This figure does not include those involved post production stages as wholesaling, retailing, from road side cottage processing through fast food restaurants and big hotels.

Future Prospects of Potato in the ANRS

The contribution of potato towards meeting the MDG as specified by the world summit is quite significant. The MDG has stipulated multifaceted development goals to be met within the next few years amongest which Eradication of extreme poverty and hunger or reduce by half or the proportion of people whose income is less than $1 a day between 1990 and 2015, and the proportion of people who suffer from hunger between 1990 and 2015, Reduce child mortality rate of the under-five by two-thirds between 1990 and 2015, Improve maternal health, or reduce the maternal mortality ratio by three-quarters between 1990 and 2015, and Ensure environmental sustainability through integrating the principles of sustainable development into country policies and programs and reversing the loss of environmental resources and achieving by 2020 a significant improvement in the lives of at least 100 million slum dwellers. Ethiopia as one of the least developing countriies in the sub-saharan countries is expected to work agressively to get out of all these aforementioned poverty traps. Cognizant of this underlying fact the Ethiopian governement is working very hard to acieve these objectives through developening stategies and policies that will help attain the MDGs. The nutrient-rich, highly productive and short cycled potato crop has an immense contribution to improved diets thus reducing mortality rates caused by malnutrition as well as improving food security which will inevitably improve the health of target populations, especially women and children. Also potato plays unprecedented role in sustainable intensification of potato-based farming systems as most of the world's farms are less than 2 ha in size and farms are still shrinking and may continue to do so for the next several generations. As farm size shrinks, many farm families are switching from grains and legumes to root and tuber crops to meet subsistence and income goals. Farms with declining area are being managed more and more intensively, leading to soil erosion and ecological imbalances that encourage pest and disease outbreaks. The need to yield-improving and input-saving technologies that will help close the persistent yield and cost gap make potato one of the crop of choice in the list. The prospects of potato in the ANRS, 57% of which is high and mid altitudes (1500-3500 m a s l) with an annual average rain fall of 1200-1500 mm, temperatures of 10-20^{0}c indicating the suitability of the region for the production of quality and quantity potato but alarmingly increasing population leading to shrinking of farm size per household is quite huge in improving availability of nutritious food in sufficient amount from small amount of land within short period of time.

Figure 1: Potato Production Trends over the course of four cropping seasons/years, in 000 ha



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Potato technology transfer experiences and future recommendation for sustainable development of the commodity in parts of Western Amhara Region

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Abstract

Potato is among the leading vegetable crops in Ethiopia and it covered about 0.164 million hectares of land during 2001. More than 940,209 tones were harvested. It directly supported on average more than 2,310,035 house holds. The Amhara National Regional State (ANRS) covers 43.45% of the total potato production area and 36.09% tuber produced in Ethiopia. Although the scale varies, potato is grown in almost all areas of the Region. Yet S. Gonder, Awi, N. Gonder, E. Gojjam and W. Gojjam surpass other zones. However, potato production is constrained by lack of improved crop varieties, post harvest management technology, absence of formal seed multiplying and delivering system As a result the average productivity of the crop is limited to only 4.77 to 5.72 t /ha which is very low compared to world average productivity of 15 t/ha. Almost all farmers in the ANRS cultivate potato using local varieties and traditional management practices. To improve this situation the Research System has made all-around efforts and finally developed high yielding varieties and their associated management practices. Following these findings the Research Extension division of the center demonstrated the improved varieties Tolcha and Zengena in Yilmana Densa, Farta, Lay Gayint, Simada, Chelga, Fageta Lacoma, Ankesha, and Banja Sekudad district from 1997-2003/4 cropping seasons with the objective of creating awareness and demand of the new technologies by farmers, extension agents and other users. Field days were also carried at all districts during exction periods. As a result farmers have got the chance to assess the improved variety and package against their own traditional practices. Finally participant farmers recognized the superiority of the improved varieties over their local variety in their maturity days (90-120), tuber yielding and resistance to the destructive potato late blight disease. Partial budget analysis showed that farmers could get an additional benefit of 102.73-415.09 birr/ha by growing the improved varieties Tolcha and Zengena with its full production package. This paper presents these results.

General objectives

- Creating awareness and demand of the new technology with its recommended production package to farmers /extensionists and other users under actual farm conditions
- To assess farmers, extensionists and others reactions on the performance of the technologies under real farm's situation.
- To accelerate the dissemination of farmers preferred verities through farmer to farmer seed exchange mechanisms.

Materials and method

The demonstration was conducted in three alternative ways: improved technology with improved package of production, farmer's local variety with improved production package and farmer's local variety with their cultural inputs and practices for the check. 70 host farmers were selected for the demonstration in collaboration with moa staff on voluntary bases. Agreement was made between the center and host farmers so that farmers have to perform from land preparation to harvesting as recommended, and have to return the amount of seed and fertilizer given to them in kind from the final produce.

Results and discussion

Field days were made in all the districts during all the activity period. As a result participant farmers have got the chance of assessing/evaluating the improved varieties and their associated packages against their own local variety and traditional practices. Consequently, farmers preferred the improved varieties over their local based on different criterion such as early maturity (90-120) days that allows double cropping to leave the land early in season, higher yielding and resistant to the common and widespread potato problematic disease called late blight of potato.

In Yilmana Densa district, the improved variety Zengena with improved management practices gave average tuber yield advantage of 152.81% over the widely used local variety with farmers' current management practice and 92.31% over local with improved management. The local variety with improved management also gave 31.46 % yield advantage over the local variety with farmers' current management practices.

In Banja Shekudad district, the improved variety Zengena accompanied with improved management gave average grain yield advantage of 148.98% over the local with local management practices and 66.77% over the local with improved management. The local variety with improved management also gave 49.30% over the local variety with farmers' management practice.

In Farta district, the improved this same variety Zengena coupled with improved management gave average grain yield advantage of 180.20% over the local with local management practices and 33.72% over the local with improved management. The local variety with improved management also gave 109.54% over the local variety with farmers' management practice.

The results of partial budget analysis of this technology to newly introduced districts showed that growing of the improved varieties namely Tolcha and Zengena accompanied with its full production package, farmers could get an additional benefit of 102.73 - 415.09. (Table 1, 2 & 3).

Table 1: Mean tuber yield in 6 districts of the demonstrated areas

Year	Variety	Location/ Woreda	No of sites	Mean tuber yield (q/ha)	Yield adv. over the local (q/ha)	(%)	Mrr (%)	Remark
		Addis kidame	3	129.27	-	-	415.09	not compared with the local
1997/98	Uk-80.3	Ankesha	3	179.73	69.11	62.48		
	(Tolcha)	Banja Sekudad	4	221.80	91.87	70.71		
		Farta	6	227.55	120.94	113.44		
		Y/densa	5	236.16	175.43	288.87		
1998/99	Uk-80.3	Lai gayint	4	151.29	35.45	30.60		
			25	1145.8	492.8			

Table 2. Mean tuber yield in 5 districts of the demonstrated areas

Year	Variety	Location/ Woreda	No of sites	a (q/ha)	b (q/ha)	c (q/ha)	Advantagea-b (q/ha & %)	Advantagea-c (q/ha & %)	Advantage b-c (q/ha & %)
2001/02	Zengena	Y/Densa	2	225.00	117.00	89.00	108.00 (92.31)	136 (152.81)	28 (31.46)
2002/03	Zengena	Banjasekudad	3	148.54	89.07	59.66	59.47 (66.77)	88.88 (148.98)	29.41 (49.30)
		Farta	2	104.60	78.22	37.33	26.38 (33.72)	67.27 (180.20)	40.89 (109.54)
		Y/Densa	2	130.67	33.78	-	96.89 (286.83)		
2003/04	Zengena	Banjasekudad	3	132.46	26.07	32.00	106.39 (408.09)	100.46 (313.94)	-5.93 (-22.75)
		Y/Densa	1	162.96	57.52	31.70	105.44 (183.31)	131.26 (414.07)	25.82 (81.45)
				904.23	401.66	249.7			

Note: a=mean tuber yield of improved variety (Zengena) with improved management; b=mean tuber yield of local variety with improved management; c =mean tuber yield of local variety with farmers' traditional management

Table 3. Mean tuber yield of farmers based seed multiplication on the districts

Year	Location / Woreda	Variety	No. of sites	Mean tuber seed yield (t /ha)	Remark Yield range, t/ha
1999/00	Y/densa	Uk-80.3 (Tolcha)	9	16.94	13.33 – 23.33
2000/01	Banja Sekudad	Uk-80.3 (Tolcha)	3	14.70	7.77 – 23.40
	Farta		1	17.20	
2001/02	Chilga	Uk-80.3 (Tolcha)	2	16.97	13.54 – 20.34
	Fagetalakuma		3	14.64	9.82 – 22.40
			18	80.45	
2003/04	Lai gayint	Zengena	8	14.61	6.48 – 18.90
	Simada		6	17.59	9.67 – 22.22

Conclusion and recommendation

Improved varieties gave better tuber yield and benefit on the districts where the demonstration had been carried out. The use of improved potato variety with its full production package, farmers could get an additional benefit of 102.73 - 415.09. Many farmers built their awareness on the qualities of the technology and understood that technology can give reliable yield than the ones that they are previously used if they are used together with the associated improved package of production. Therefore, the wide scale promotion of this variety is recommended.

Promotion of community based participatory potato seed tuber production as an Option of Improving Potato Productivity in Western Amhra Region.

Following the created demand for improved potato technologies from the pilot technology demonstration activities, technology scaling up activity is launched during 2005/06 and 2006/07 cropping seasons with the objective of overcoming food security problems, contribute to the attainment of the five years strategic goal of the Regional Government and consequently ***systematically organize the existing farmer-to-farmer seed exchange scheme and ensure the access of improved varieties' seed at community level.***

Methodology

1) Initially a Regional workshop at the presence of all stakeholders is carried to share experiences of other Center, build consensus on the plan and shared

responsibilities. Similarly, woreda level workshop is carried for the same purposes at the presence of administrators and two committees (Steering and Technical) are formed for the follow up.

2) Then suitable varieties of different purposes, table and processing types, viz, Gera, Jallenie, Marachare for table and Zengena and Wochecha for processing purpose was selected;

3)Then seed of these varieties is provided to organized farmers/private farmers or innovative professionals or investors on a repayment loan basis at least to return it in kind so as to guarantee the 2nd phase redistribution of tubers to another participating groups;

4) This initial seed tuber is agreed to pass at least 2-3 cycles of multiplication before it is intended for table. This will help increase the amount of seed tubers to be distributed to small-scale farmers for further seed or consumer potato production;

5) Both theoretical and practical training sessions of seed production techniques, disease identification and management options and post-harvest handling were carried to improve the knowledge and skill of participants on quality seed production and its management as a result of which 358 farmers (315 male and 43 female) and 90 experts (75 male and 15 females) were given comprehensive trainings;

6) Construction of Diffused Light Store (DLS) by cooperatives or private seed multipliers for appropriate management of multiplied seed until the next cycle of production is carried;

7) Finally to guarantee the sustainability of the system and create market for the produce field days were arranged at the presence of pertinent stakeholders, Zone and Woreda administrators and office heads, Bureau of Agriculture & Rural Development, Seed Enterprise, Cooperative Promotion Agency, Investment Promotion Agency, NGO and farmers. Totally about 550 participants were able to attend the field days at all districts.

Inherent in this activity was the engagement of multipliers in quality potato seed tuber multiplication, handling, marketing and distribution structure. To this effect best practice in potato seed tuber multiplication and management was followed as the guiding principles to the scaling-up of technology multiplication and dissemination.

Results of the activity

Following this scheme very promising results that proved the validity of such community involving system is observed. Among which the following are worthy of mention

1) Before the implementation of this project improved potato varieties seed growers are non existent in this sub Region. However, currently both individual and grouped farmers as well as professional seed growers are flourishing one year after the other

2) The level that some of the professional growers officially registered their private limited share enterprise and got a license and Tax Payer Identification Number. This is one of the greatest successes of the project in which the possibility of becoming

3) Potential seed multiplier and suppliers to requests coming from any corner. Hence, in a Region where very small amount of seed is multiplied by Research centers and other groups now it become a reality to produce improved seeds of different varieties that is close to 5 000 quintals. This can be justified by the following table 4 indicating the trend in the number of growers and seed produced.

Table 4: The trends of number of Potato seed producers and amount of Seed Produced across three consecutive years in Western Amhara.

No.	2005		2006		2007		Zone	Woreda
	Number of Producers	Amount of Seed Produced in tons	Number of Producers	Amount of Seed Produced in tons	Number of Producers	Estimated Amount of Seed Produced in tons		
1	2	1.2	3	4.5	5	15.0-20.0	S. Gonder	Lay Gayint
2	-	-	-	-	23	7.3-10.0	S. Gonder	Lay Gayint
3	6	13.0-13.5	5	60.4-65.4	14	199.0-248.8	West Gojam	Yilmana Densa
4	2	1.0	8	20.0	115	210.0	Awi Zone	Guagsa Banja
Sum	10	152-157	16	84.9-89.9	157	431.3-488.8		

2) Potato seed growers that have get linked with buyers were able to earn from as small as 1 500 through more than 118 000 Ethiopian Birr per season. As a result some of the farmer cleared the loan taken from Amhara Credit and Saving Institute, while others bought ox and others horse and still others constructed residence house and their future seed storage house.

3) On average 160-360 daily laborer job opportunity is also created on monthly basis by the professional seed grower groups which multiply potato seed on an area of close to seven hectare of land. This is a job during both the rainy summer as well as off-season for production under irrigated system. Hence, significant amount of unemployed forces are put under production.

4) The possibility of harvesting 25-30 tons/hectare of potato under on-farm condition is practically demonstrated and farmers' confidence on research out put technologies is raised.

Challenges faced in the process

1. Absence of strong coordination among the partners involved in the system as stipulated in the role and responsibility of each members;

2. The problem of farmers to abide by the agreement signed by the two parties such as failure to timely undertake recommended cultural practices package, construct diffused light store, avail the necessary input such as seed and chemicals and

3. Absence of reliable and assured marketing opportunity at the right time of in need threatens seed producers to keep the product for an extended period without any guarantee which in tern resulted in the destiny of some of the improved seed for household consumption and in the market.

Conclusion and Recommendation

In order to sustain the observed result all stakeholders involved in the agricultural development sector should work in collaboration to overcome the drawbacks of uncoordinated efforts that normally result in fragmentation of the scarce resources.

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Participatory Seed Multiplication and Scaling up of Improved Potato Varieties: Achievement and Experience in North Gondar Zone, Ethiopia

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Abstract

Participatory seed multiplication and scaling up was conducted on improved potato (Solanum tuberosum L.) varieties released by national as well as regional research centers and proved adaptable to Chilga area in north Gondar zone of the Amhara Region. The activity is carried out for two consecutive years, 2006-2007. The study is aimed at facilitating the diffusion and adoption of improved potato varieties and their technologies that can improve potato productivity and provide farmers alternative to their local variety. This was achieved using seed multiplication and scaling up of preferred varieties through full participation of farmers and other stakeholders. In 2005 one Farmers Research and Extension Group (FREG) was organized at Eyahomariam kebele of the study area. Following this training related to quality seed production and its post-harvest management was given to participant FREG members as well as development agents. In 2006 previously evaluated seven varieties were multiplied on the farmers filed. A total of 46 farmers were participated in the scaling up activities and on the same year, four diffused light stores were constructed by the FREG members and 9.82 tons of seed was stored for 2007 cropping season. During 2007 scaling up of the selected varieties was conducted on 4 other new groups of farmers and one new DLS were constructed. The study confirmed that use of group and participatory approach will certainly improve farmers access to preferred varieties and would result in a faster rate of diffusion through farmer to farmer seed exchange and their by enhance adoption.

Introduction

In most rural areas of developing countries like Ethiopia, achieving household food security remains a strategic objective of rural development. Despite the prevailing land degradation caused by high erosion, Ethiopia is endowed with vast land potential for agricultural development. Agricultural production is predominantly rain-fed and depends on long and short rain seasons. It is characterized by fragmented and widely scattered small plots of land that are densely populated per unit square kilometer area. As a result food has remained to be the major problem of this country. The average yield for grain crops has remained at about 11 qt/ha, which is very low (Tesfaye Zegeye, 2004). Besides, most rural poor farmers face food shortage especially during summer season (July-December) where most of the crops are on the field. Therefore, to alleviate such a problem, it is important to focus and get acquainted with early maturing and high yielder root and tuber crops.

Potato (***Solanum tubersum*** L) is an important food and cash crop in Ethiopia. Even if the scale varies; it is also produced in most areas of the Regions in the country. Among the Regions, Amhara National Regional State (ANRS) precedes all the others by its area coverage. This Region accounts for about 43% of the total areas of land put under potato cultivation (CACC, 2003). This figure validates the importance of potato in Region or country as whole.

Among the different districts in the Region, Chilga is the major potato producer area of north Gondar zone of Amhara Region. The crop is a staple food and cash crop that mitigate seasonal food shortage. Moreover, since the area is close to Metema Ethio-Sudan boarder, it has high market opportunity through this boarder trade.

Regardless of this fact, average productivity of the crop in the country as well as in the Region or north Gondar zone remained quite very low (7-9.7 t/ha) as contrasted with the world average yield of 16.45 t/ha (FAO, 2004). Multiple factors have contributed for such very low productivity of the crop. Among them, prevalence of disease especially late blight and the lack of access to seeds of improved varieties precede all. This is due to the absence of any formal seed tuber multiplying and disseminating body. This has severely limited the adoption of most of the improved varieties released. Therefore, this activity is initiated to multiply and scale up improved potato varieties and related technologies through the participation of farmers and other stakeholders.

General Objective

- To facilitate the diffusion and adoption of improved potato varieties and their technologies that will improve potatoes productivity

Specific objectives

- To make aware of improved potato varieties and provide farmers alternative to their local variety
- To multiply potato seed for further dissemination and
- Scale up preferred varieties and their technologies to the farming community in partnership

Methodology

The study was conducted in Chilga woreda, north Gondar zone of the Amhara region in north Ethiopia for about three years. Throughout the overall process, a series of methodologies or steps were utilized;

Participatory seed multiplication

Participatory seed multiplication was conducted over two years (2006 and 2007). At this stage, Farmer Research Extension Group (FREG) members, Developement Agents (DAs), Subject Matter Specialist (SMSs) were involved in all activities of the trial; planning, monitoring and evaluation. This was to give awareness about the varieties for better adoption; and maintain quality seed for further dissemination. In doing so, seeds of nationally or regionally released as well as recommended improved varieties to the area.

Scaling up of selected improved varieties seeds

Before launching the actual activity an inception workshop is undertaken at the presence of FREG members, DAs and extension staff so as to discuss on how to scale up and diffuse the preferred varieties. Researchers' played a catalytic role. Based on the consensus of the group, the seed which is maintained during the evaluation and seed multiplication phase and that obtained from Holeta agricultural research center were distributed to all members of the FREG by dividing the entire group in to four sub groups. The seed tuber was given with an agreement on a repayment loan basis to return it in kind, at harvest, the amount of seed they had received, so that it will be redistribute for other small scale farmers out side the FREG members for further scale up. Each sub group planted the seed on a rented communal land.

DLS construction

While the scaling up is undertaken farmers were encouraged to construct Diffused Light Store (DLS) from locally available material with some industrial material such as corrugated iron sheet and nail support at a repayment loan as a revolving fund. This is to have high quality and disease free seed tuber maintenance at post harvest. Besides, to avoid conflict that will arise from seed management, distribution and DLS establishment, FREG members themselves thoroughly discussed and created their own bylaws together with DAs and SMS of Woreda Agriculture and Rural Development office. All the seed which was produced by the group was placed in each DLSs. Then the seed was distributed equally among the group members to be planted individually on their own plot and the rest was sold to other farmers out side the FREG. Finally, each member of the group selects certain amounts of potato tubers which will be used for next season seed, and placed it on their respective DLS. Quality of seed, which was maintained for next season seed, was monitored by the FREG members, DAs, extension staff and respective researchers.

Result and discussion

The scaling up activity was carried in partnership with woreda agriculture and rural development office. Accordingly, four group of farmers each having 10-11 members and 2 individuals (total of 46 households) were directly participated in the activity over 2 ha of land using the seed tubers of the improved potato varieties provided from the center at a repayment loan base to return the seed in kind. By the second year including the previously participated farmers a total of 62 farmers were participated. To this end 10 tons of seed was maintained using the DLSs which were constructed by the FREG members in group. Four DLSs were constructed by FREG members in group from locally available materials only with support of industrial products which could not be obtained easily like corrugated sheet and nails. The materials were provided by woreda office of agriculture and rural development with agreement to return it back as a revolving fund. This motivated other farmers to build their own DLS and they understand the benefit of the DLS related to secure quality and disease free tuber seed. The total amount of seed produced from the initial seed tubers injected into the system is sufficient enough to plant 7.5 ha of land. Farmer to farmer seed exchange as an established system of seed dissemination has contributed for such high increase of the seed lot and its consequent dissemination.

Lessons learnt

Usefulness of participatory approach to promote diffusion and adoption of technologies

Throughout the whole process of evaluation, seed multiplication and scaling up of the improved varieties, participation of farmers is seen useful to promote the diffusion and adoption of both improved varieties, knowledge and skill of quality seed production, management and post harvest handling using the established lateral farmer-to-farmer seed exchange and information dissemination system.

The usefulness FREGs for efficient resource utilization, knowledge management and monitoring and impact assessment

This study has helped to validate the relevance of organizing farmers in group is a good opportunity to mobilize both social and physical resources as well as to provide of incentives such as improved seed and other materials which could otherwise not be easily obtained in their locality at a repayment loan system. It also helped us to provide training and monitor the diffusion of technologies transferred and ultimately to assess the impact of the technology injected in our intervention area very easily.

Ease of full package and knowledge transfer into the system

Prevalence of disease and pest mainly of late blight and bacterial wilt is common and the most serious problem of the farmers in the study area. Probably such a problem might arise from poor seed production and management, *i.e.*, absence of DLSs as well as introduction of seeds of unknown health standard into an area. This system however has allowed them get seeds of known standards as well as transfer appropriate post harvest seed handling technologies in which farmers were seen encouraged to construct their own DLS in group by pooling locally available materials together with he support of the intervener some industrial materials such as corrugated sheet and nails at a repayment loan base.

Such effort of FREG members and their produce should be linked with the market and credit as a revolving fund so as to facilitate and enable farmers produce quality planting material sustainably. This can easily be discerned from the number of farmers and total areas of seed harvested during the course of the activity.

Table 1. The status of scaling up activities during 2006 cropping season

Varieties	No of farmers participated	Area covered (ha)	Average yield (t/ha)	Seed maintained (tons)
Jaleline	9	0.32	29.7	4.0
Tolcha	8	0.39	19.0	3.0
Guassa	7	0.04	27.2	1.0
Gera	5	0.04	22.0	0.5
Zengena	7	0.04	28.1	1.0
Gudenie	5	0.06	29.9	0.18
Degemegn	5	0.06	23.0	0.14
Total	46	0.95		9.82

Table 2. Number of farmers and area covered in the scaling up activities during 2007 cropping season

Varieties	No of farmers participated	Area covered (ha)	Amount of seed maintained (ton)	No of DLS constructed
Jaleline	4	0.31	9.20	1

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Efforts, Experiences and Future Directions of Potato Technology Transfer in North Shewa Zone of the Amhara Region

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Abstract

Potato production has a short history in most parts of North Shewa, except for the case of Ankober woreda. Considering this, the Debre Birhan Agricultural Research Center (the X-Sheno Agricultural Research Center) has started some adaptation and breeding research activities on potato in 1996. Through this efforts; Tolcha, Wechecha, Menagesha and Shenkola were found to be adaptable, hence recommended to the high land areas of North Shewa zone. Moreover, Gorebella and Gera varieties that are released by the center again recommended for the highland of North Shewa and other similar agro ecological areas. Following this, the research-extension research division of the center tried to disseminate these potato varieties to the target groups using the recommended packages. The introduction of these potato varieties were further accelerated through Farmers-Research-Extension Groups (FREG) using potato seed production scale-up programs. Farmers' opinions on the result of these efforts encourage further dissemination endeavors through critical considerations of these valuable opinions. This will help farmers to produce potato seed in large scale so that they can serve as a potato seed source to their and other woredas of North shewa. The scale up program is implemented in two woredas in partnership with stakeholders of the agricultural system in these respective woredas. This paper presents the experiences of this technology demonstration and scaling up activity in these areas.

Introduction

Recent estimates on poverty levels showed that approximately 41.5% of the total population lives below the poverty line (Mekonen *et al.*, 1998). A more recent and comprehensive analysis by MEDaC (MEDaC, 1999) based on Central Statistic Authority (CSA) rural HH welfare monitoring data indicated that close to 47% of the total rural population live in absolute poverty (CSA, 2000). This, to some extent, portrays that almost half of the Ethiopian population is living under food insecure condition. And the figure for sure increases for North Shewa zone of the Amhara Region. Ameliorating food insecurity for less-developing countries depends, more than any other thing, on maximizing the domestic food production. The attainment of food self-sufficiency depends on a wide range of factors of which ensuring improved varieties seed for farmers is most important (Scowcraf and Polak, 2000). According to these authors, securing supply of seeds (any living organized plant propagule or organ capable of being planted and grown to produce another crop) at the farm level will help combat food-insecurity situations. In other words ensuring the supply of seeds and planting materials of the important food crops is one way to ensure food security.

Agricultural research and extension have key roles to play in increasing agricultural production and productivity through providing improved crop technologies. Potato plays an important role due to its high productivity that is incomparable with other cereals and/or pulses. But there exists no formal organization for the multiplication and provision of seeds of improved potato varieties. A secured seed supply system refers to access by farmers to sufficient, good quality seed of the desired type at the right time and price (Scowcraf and Polak, 2000). In order to fill this gap, the Debre Birhan Agricultural Research Center has been conducting research as well as extension activities on potato in Ankober, Angolelana Tera, Tarma Ber, Menz Gera Midir, Menz Mama Midir, Debre Birhan Zuria, Asagirit, Ephratana Gidim and Merhabete woredas. However, the lion-share of the scheme is delivered to Ankober (the area with higher potential to potato production), Basona Worana, Menz Gera Midir and Menz Lalo Midir woredas. This scheme was implemented using pre-extension demonstration, Farmers' Research Extension Groups (FREGs) and potato scale-up programs. The disseminated potato varieties are Tolacha, Wechecha, Menagesha, Gorebella and Gera varieties. Among these list of varieties Gorebella and Gera are released by Debre Birhan Agricultural Research Center (the X-Sheno Agricultural Research Center).

Though there had been an experience of potato production around Ankober, it is a new crop to almost all the remaining woredas of North Shewa zone of the Amhara Region. In spite of this fact, the adoption level and dissemination rate of potato in these areas is so high and is progressing at an alarming rate. Currently, the research center is undertaking a potato seed production scale-up program in two woredas namely: Basona Worana and Gera Midir woredas on 19 farmers' fields with an average land holding of 500 m^2 per hosting farmer. This program is accompanied with intensive trainings on potato seed production, storage and marketing. The food potato utilization training had been organized during the earlier pre-extension demonstration activities and it is to be delivered in the near future for the participants of the potato seed production scale-up program.

Material and methods

Farmers were selected from different woredas of North Shewa. Each farmer had, at least $200m^2$ for pre-extension demonstrations and $500m^2$ for participatory potato seed production. The center supplied seeds of variety Wochecha, Tolcha, Menagesha, Gorebella and/or Gera. Farmers were given technical support from researchers and extension agents (for the case of scale up programs) on how to plant, fertilize and cultivate and store potato. The farmers were given technical support on how to construct diffused light store. An agreement is made with farmers not to use the harvest for table but to store it in the diffused light stores (DLS) and sale or use as seed tuber. Potato seed diffused light storages (DLSs) were constructed for each farmer participated in potato seed production scale up programs and for some of pre-extension demonstrations participants and FREGs. Field days were arranged to show the farmers, the extension agents, the woreda subject matter specialists (SMSs) and other stakeholders about the production and storage of potato seeds. The treatment for the demonstration, farmers' research and extension group, and the participatory potato seed production scale up program is as follow:

Table 1. The treatment used for the demonstration of potato varieties.

Treatment	Improved method
Varieties	Wochecha, Tolcha, Menagesha, Gorebella and Gera
Spacing	75 cm x 30 cm between rows and between plants for food
Spacing	60 cm x 30 cm between rows and between plants for seed
Planting date	Early June
Fertilizer	110/90 N-P_2O_5
Weeding and hoeing	One hand weeding 5-6th week after emergence and twice hoeing per season

Results and discussion

The potato yields obtained from different locations in different years are put in the following tables. The whole demonstration, farmers' research and extension group as well as the potato seed production scale up programs are conducted with due attention and respect to farmers' seed selection criteria and opinions. This input serves us for revising and adapting our strategies of technology dissemination. Besides, the demonstration activities were conducted using the research recommendation packages treatment alone for potato growing culture is absent and local potato cultivars are unavailable by this time to be included as treatment for comparison purpose. Accordingly, the results are presented in the following tables 2.

Table 2: Result of Potato demonstration activities during 2001 cropping season.

Name	Location	Varity(Menagesha)		Remark
		Average Yield (t/ha)	Adjusted Yield (t/ha)	
F1	Ankober	17.16	15.44	**Meher season**
F2	Ankober	12.54	11.29	
Average	**Ankober**	**14.85**	**13.37**	
F1	Molale	12.38	11.14	
F2	Molale	14.69	13.22	
Average	**Molale**	**13.54**	**12.18**	
F1	Meha Meda	8.45	7.61	
F2	Meha Meda	18.20	16.38	
Average	**Meha Meda**	**13.33**	**11.99**	
		Varity (Tolcha)		**Belg season**
		Average Yield (Qt/ha)	Adjusted Yield (Qt)	
F1	Kotu	5.65	5.09	
Average	**Kotu**	**5.65**	**5.09**	

Table 3: Result Potato variety *Gorebella* demonstration during 2002 meher ropping season.

Location	Tuber Yield, t/ha	10% adjusted yield, t/ha
Ankober	38.55	34.69
Mush	27.28	24.55
Molale	25.75	22.98
Average	**30.53**	**27.41**
Mehal wonz	33.80	33.70
Average	**34.40**	**32.04**

* The Basona Worana yield of this specific season is lower than the others due to the problem of rain fall pattern there.

Table 4: The yield of potato demonstration in 1995/96E.C (2003) meher cropping season.

Location	Yield in t/ha	
	Gorebella	Gera
Ankober	47.70	34.60
Menz Mama	43.60	42.90
Menz Gera and Menz Keya	32.50	31.90
Mean yield	41.27	36.47
Mush (Basona Worana)	14.40	17.10

Table 5: Results of Mer season on-farm Potato technologies demonstration during 2004.

Tuber yield, t/ha			**Districts/Woredas**
	Gorebela	**Gera**	
	32.00	28.33	Gera Keya
	26.67	24.67	Gera Keya
	24.67	28.67	Gera Keya
	20.00	19.33	Gera Keya
	26.67	27.00	Gera Keya
	15.67	20.00	Gera Keya
Mean Yield at Gera Keya	**24.28**	**24.67**	
	21.00	15.93	Ankober
	48.34	46.98	Ankober
Mean Yield at Ankober	***34.67***	***31.46***	
	30.67	20.00	Molale
	13.00	17.00	Molale
	48.48	46.67	Molale
Mean Yield at Molale	**30.72**	**27.89**	
	28.67	24.00	Baso /mush/
	30.67	26.00	Baso /mush/
Mean Yield at Baso/Mush/	**29.67**	**25.00**	
	Total Mean-25.38	**10% adjusted- 23.86**	

The average yield of potato for the year 2005/06 for North Shewa is 286.13 and 233 for Gorebella and Gera, respectively.

Farmers' Opinion on these varieties

Field days are conducted at each of the demonstration sites. Farmers' opinions towards these technologies are also collected and documented as feedback information for future research and extension endeavors. Accordingly, farmers view towards the technologies is summarized as follows.

1. **Tolcha Variety**

- Not suitable for the Belg (short rain season), and
- Very low yielder, so that they asked for another potato varieties.

2. **Menagesha Variety**

- Good yielder,
- Suitable for Meher season production, and
- Relatively adaptable to Ankober, Gera Midir and Mama Midir area

3. **Gorebella Variety**

- High yielder and large sized than the earlier varieties
- Suitable for different areas of North Shewa
- Cookable with small amount of energy
- More suitable for boiling than stew preparation because it disintegrates if it kept a little longer under heat, and
- Relatively resistant to early and late blights.

4. **Gera variety**

- High yielder,

- Very attractive color that fetches higher market price
- Very suitable for stew preparation than boiled potato
- Ffarmers can easily identify it easily from weeds, but
- Relatively susceptible for early blight.

The general comment of farmers in almost all of the demonstration sites is the question of spacing both between plants and between rows. As said, they are facing a problem to getting sufficient soil for covering of the potato while hoeing. This can also be a research agenda for further works.

In a nut shell, farmers of all these locations have appreciated all these three (Menagesha, Gorebella, and Gera) potato varieties for their good yield as compared to the "local" potato varieties. And during the field days farmers express their interest towards these varieties and contributed for closer interaction between the woreda office of agriculture and rural development and the research center. But in the case of Tolcha farmers have refused it due to its low yield potential. Following this, we had prepared a joint action plan with the Woreda Office of Agriculture and Rural Development (WOARD) and other stakeholders of the agricultural system working in these areas for further potato seed multiplication with them.

As far as the potato seed dissemination is concerned, host farmers have disseminated through exchange and selling for other neighboring farmers as well. The tuber yield accrued at each location revealed that potato yield can be increased considerably if properly managed and the soil fertility of the farm improved. Moreover, the total yield of Gorebella and Gera varieties obtained from on-farm demonstrations are by far more than the yield that these varieties gave during their verification trials. This could help as a springboard for further studies too (e.g. in management and site selection aspects).

Considering the increasing demand of these varieties seed by farmers as well as other stakeholders and the absence of formal seed multiplying and disseminating body, the fast transfer of these technologies is quite debatable through the sole efforts of research centers alone. Hence, establishment of organized or private potato seed producer farmers in collaboration with other stakeholders of the agricultural system is found crucial. **In general, linkages and networking are important in enhancing the impact of scaling up/out initiatives.** This underline collaborations among institutions and the interfaces and interactions between and among stakeholders engaged in the generation, transformation, transmission, storage, retrieval, integration, diffusion and utilization of knowledge and information, which potentially work synergistically to improve the goodness of fit between knowledge and environment, and the technology used in agriculture, is important (Kaimowitz, 1990). Scaling up/out is expansion resulting from not only just having more numbers and larger areas but also from evolving roles and responsibilities of institutions and actors that go with improved capacities and diversification of benefits (Hall, *et al.*, 2004). Accordingly, a scale up program of potato seed production is designed in two potential woredas on 19 farmers' fields in addition to the existing pre-extension demonstration and farmers' research and extension groups (FREGs). The whole business was run in close collaboration with the WOARD and other non governmental organizations functioning in each woreda. This program helps at least to cover the respective woreda's and other mid-altitude woredas seed demand of potato in the zone for the coming cropping season. The yield obtained during the 2007 cropping season scale up program is shown in the following table 6.

Table 6. Basona Worana potato seed production under the scale up program

No.	Name of host farmer	Variety	Length of a furrow in meter	obtained yield in Kilogram	obtained potato seed in qt/ha	10% Adjusted yield in t/ha
1	Desta W/ Aregay (F)	Gera	27.0	64.3	39.53	35.5.8
2	Getachew Yshitla	Gorebella	28.0	75.4	44.70	40.23
3	Hailiye Seifu	Gera	12.0	29.8	41.22	37.10
4	Ashenafi Mamo	Gorebella	17.0	24.8	24.22	21.80
5	Kinfe Eshete	Gorebella	31.0	63.9	34.22	30.80
6	W/Birhan W/Tsadik (f)	Gera	25.0	35.6	23.64	21.28
7	Kebede Dubale	Gera	19.0	36.4	33.55	30.20
				Total average	**34.44**	**31.00**
				Average Gorebella	34.38	30.94
				Average Gera	34.49	31.04

Table 7. Yield of Menz Gera Midir's Potato seed production scale up program during year 2007 cropping season.

N0.	Length of a furrow in meters	Obtained yield per furrow in Kg	Yield in t/ha	10% adjusted yield t/ha	Variety name
1	15	44	48.70	43.83	Gorebella
2	18	42	38.73	34.87	Gera
3	9.5	23	42.42	38.18	Gorebella
4	10	30.5	50.63	45.57	Gera
5	15	36	39.84	35.86	Gorebella
6	15.5	30	32.13	28.92	Gera
7	11.5	35	505.2	45.47	Gorebella
8	12	31	42.88	38.60	Gorebella
9	10	23.5	39.01	35.11	Gera
10	22.4	38	28.16	25.34	Gera
11	10.5	27	42.69	38.42	Gera
12	11	15.4	23.24	20.92	Gera
		Total Average	**39.91**	**35.92**	
		Average Gorebella	**44.87**	**40.38**	
		Average Gera	**36.37**	**32.73**	

Diffused Light Stores (DLSs) were constructed for all participant farmers and were linked to potato seed markets through the efforts of woreda OARD, NGOs and the research center. And most farmers sold at leas five quintals of potato seeds for the respective cooperatives and/or for NGOs with a price of 3.50 Eth. Birr per kilogram for Menz Gera and 4.50 Eth. Birr for a kilogram of potato seed at Basona Worana woredas, respectively. They have also kept their own seed in their DLSs for the coming season.

Challenges

The major challenges faced during the carrying out of the potato seed production scale-up program are:

1. Weak linkage among the stakeholders of the agricultural system working in both of the woredas,
2. Continuous restructuring of the office of agriculture and rural development is creating a challenge in the stability of contact persons that created a problem in communication and training, and
3. Shortage of human power in the research-extension research division of the Center.

Recommendations

Effective future dissemination endeavors of table and seed potato production packages in all these and other woredas of North Shewa Zone of the Amhara Region requires a strong linkage among actors of the agricultural system. This linkage needs to address the training and marketing aspects of this effort.

Future Plan

The future plan of the center is to pursue the dissemination process using all of the pre-extension, farmers' research and extension groups (FREGs) and the scale up program. Moreover, diffusion in the earlier introduction areas will be conducted.

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Experience on Potato Technology Transfer by the Extension System and Future Direction in the Amhara Regional State

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Introduction

The potato (***Solanum tuberosum*** L.) is regarded as the most important vegetable in the world (Purse glove, 1968), and an important staple to many. Potato ranks fourth as an important source of food, after wheat, rice and maize. Among the root and tuber crops, potato ranks top followed by cassava, sweet potato and yams in their order (Hawikes, 1990). As a crop in the developing world, potato also ranks fifth in money value (Horton, 1987). It has been identified as a cheap source of human diet since it produces more food value per unit time, land and water than any other major food crops.

The tuber supplies carbohydrates, quality protein (Lysine), minerals, nutrient salts and several vitamins from group B and large amount of vitamin C. Due to these merits, potato ranks first in the expansion of production in the developing countries (Horton, 1987).

Apart from being used as food crop, potato has many other uses. Potato starch is an important ingredient for pharmaceutical, paper, petroleum and plastic industries (Geurts, 2001)

Ethiopia has possibly the highest potential for potato production than any country in Africa (Yilma, 1989). An estimated 70% of the countries arable land is potentially suitable for potato production (Yilma, 1989). Similarly, in the Amhara Region most of the area and its climatic condition are suitable for potato production. But, its production trend still shows up and down with area coverage as well as productivity from one year to the other year. Its productivity ranges from 6.85-9.4 tones/ha, which is very low as compared to the world's average production of 16.45 tones/ha (FAO, 2004).

Table 1. Potato area coverage and production in the Amhara Region as compared to National in meher season.

Year	Area in hectare		Coverage	Production in quintal		Coverage	Productivity q/ha	
	Ethiopia	Amhara	in %	Ethiopia	Amhara	In %	Ethiopia	Amhara
2001/02	36,736	11,099	30.2	3,852,281	1,164,294	30.2	104.87	104.9
2003/04	54,603	22,076	40.4	5,097,150	1,753,298	34.4	93.35	79.4
2004/05	51,698	18,362	35.5	5,097,155	1,725,403	33.8	98.6	94
2005/06	61,812	26,512	42.9	4,499,958	1,815,827	40.35	72.8	68.5
2006/07	73,095	23,070	31.6	5,256,568	1,798,255	34.21	83.43	77.9
Average	55,589	20,224.	36.1	4,760,622	1,651,415	34.6	90.6	85

1. Potato production constraints in the Amhara Region

1.1 Lack of improved potato varieties.

Improved potato varieties are not well known in the region. Although different improved potato varieties are registered by research centers, they are not well known by the farmers. In the region 'Cara' or "Key Ater Abeba" which was imported from Europe in 1980's and local varieties are grown by the farmers for a long periods of time. Currently, due to its tolerance to late blight and earliness to mature, the Cara variety is becoming dominant in major potato growing areas of the region (AARC, 2004). But local varieties are reported to be generally low yielding, susceptible to disease and pests, and subject to rapid virus degeneration (Kidane-Mariam 1980; Lemaga, 1983).

1.2 Absence of seed system and storage problem

Potato seed tubers are easily perishable and difficult to transport huge quantity from place to place. In the region and as a whole in Ethiopia, there is no any institution that multiplies and distributes potato seed tubers to the farmers. Thus, farmers are forced to use inferior sized tubers from their own harvest or from other areas where farmers have access of irrigation system of cropping. These practices have contributed either to build up of diseases which causes low yield or rely only on cereals.

Regarding storage both seed and ware potato storage is a serious challenge for most farmers leading to storage losses that can reach up to 50% and sometimes higher (Bergel *et al.* 1980). The storage methods used by potato farmers use floor (wolel), bed (kot/alga) and granary (gotta/kefo) have not significantly changed to diffused light storage (DLS) system. Therefore, it is very important to develop potato seed tuber distribution system and facilitate technology dissemination in the region.

1.3 Market problem

Farmers are still challenged by lack of transportation and timely and accurate market information. Wholesale prices at times of peak supply can drop to as little as 80 birr/quintal. When supplies become excessive, farmers in more remote locations facing high transport costs might be forced to dump their potatoes (Medhin *et.al.* 2001).

1.4 Improper use of agricultural inputs

Seed sizes are not well recognized by the farmers. Mostly, farmers use inferior tuber seeds which weigh under 25 gms to cover more areas with some quintals of seed tuber. As a result, seed is applied at a rate of 8-11 quintals per hectare.

The consumption of commercial fertilizer is also still limited to approximately 25-30 percent of small holder farmers in the region (Desta et. at. 2000). Higher consumption is constrained by untimely supply, limited infrastructure (especially in remote areas), and fertilizer prices in increasing relative to crop prices. Of course, now a days to alleviate this problem farmers start to use animal manure and compost when it is available.

4.1. *Amhara Region Agricultural Research institute (ARARI)*

This institute is responsible to develop new and maintain the existing improved varieties which have high quality and resistance to diseases. The research should also develop packages not only on pre-harvest technologies but also on post harvest technologies. Furthermore, the research system should undertake participatory technology development with all its stakeholders and should provide high quality potato seeds for seed multiplication purpose.

4.2. *Ethiopian Seed Enterprise*

The Ethiopia seed enterprise should give equal attention to potato tuber seed as the other cereal crop seeds. Accordingly, this enterprise should supply basic and certified seeds of recently released potato varieties (Jalene, Guassa, Zengena, etc).

4.3. *Bureau of Agriculture and Rural Development*

This bureau is responsible to give training, supervision and market information, provide technical support and quality control service to the farmers and develop potato seed tuber production and distribution system with in the community.

4.4. *Cooperatives Promotion Agency*

- Market problem is expected to be solved by this agency through service cooperatives and Unions.
- Should establish potato producing farmers' cooperatives.
- Provide agricultural inputs supply and facilitate credit service.

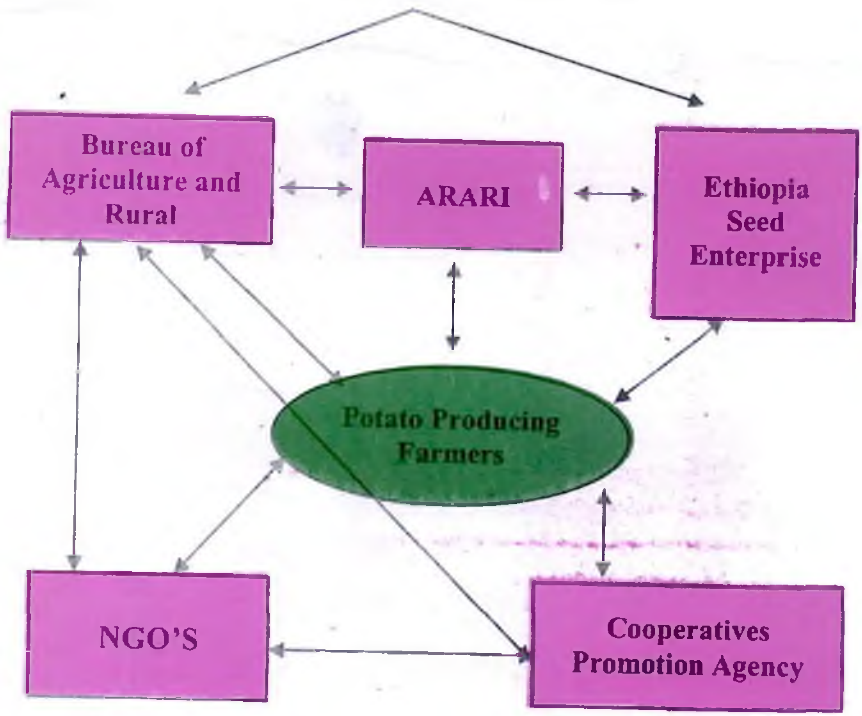
4.6. *NGO'S*

- Facilitate seed tuber multiplication and distribution system among the farmers.
- Give capacity building to the producers.

4.5. *Farmers*

- Implement all potato production technology packages and produce quality potato yields. Farmers should be proud of producing potato.

Stakeholders' linkage diagram



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Introduction

Potato (***Solanum tuberosum*** L.) is one of the widely produced and consumed horticultural crops in the Amhara Regional State. It is a hunger reliever and emergency food crop in the summer during which many of the highlanders of the districts and farmers in the mid altitudes run out of food because of its short crop cycle. It has an immense contribution to contribute to food security problems prevailing in the district. Over 400 hectares of farmland in the Tach Gaynit district are covered annually by this crop (CACC, 2003). Potato can circumvent land problems producing high amount of yield within short periods and allows double cropping leaving the land early in season. Yet potato productivity is only 5 tons/hectare which is far below the world average yield of 16.45 tons/hectare (FAO, 2004). This is mainly caused due to the wide use of late blight susceptible land race potato varieties. This disease causes very high damage of up to 95%. This problem could be alleviated to over five fold if improved varieties and their associated production packages developed by the research system are used. Pilot collaborative technology transfer efforts made earlier has proven this truth. This fact revealed that an augment of technological, institutional and other socio economic constraints have contributed to the low productivity of the crop. Bearing this fact, in the year 2007 the organization has implemented a new strategy to promote improved potato seed tuber multiplication and marketing in collaboration with the agriculture and rural development office and Adet research center. This strategy particularly focused on potato technology transfer activities through linking vulnerable population with potential market opportunities.

Materials and Methods

To undertake this activity the program has passed through the following steps. These are very briefly

1. Training of trainers is carried for the project and ARDO staff in collaboration with Adet agricultural research center and Bureau of agriculture and rural development Bureau technology promotion department.

2. Training is given for front line community workers, development agents, and targeted farmers selected to implement the improved seed multiplication of Irish potato.

3. Three varieties of improved potato tuber (Tolcha, Wochecha and Jalene) are purchased from farmers organized by the Holeta agricultural research center. The amount of seed of these varieties purchased and used for this particular activity were 6 tons of Jalene, 2 tons of Wochecha and 2 tons of Tolcha. 4.72 hectares of land of farmers organized at 11 clusters is planted with the improved varieties using the recommended technology package.

Well-managed fields are the best examples for the impact of the training. The targeted farmers managed their fields according to the seed production technology package.

And finally field day is organized in collaboration with Adet agricultural research center at flowering stage at one of the Kebele to create awareness about the technology among the potato growers in the district and other potential buyers of this technology for further dissemination of the technology.

Invited guests and stakeholders on the field day, PA 03, Kute Mender, Tach Gaynt district.

The participant seed producers have shown a remarkable effort on the construction of diffused light store. Female participants has also constructed Diffused light store.

Productivity of the improved varieties of Irish potato

Results and Discussion

The productivity of the harvested crop is far greater than the land race widely cultivated in the district. The summary of this productivity of the three varieties introduced is indicated in the table 1 shown below.

Table 1. The yield of the three potato varieties across the location planted.

No	*Productivity Range per hectare*	*Potato varieties and Number of farmers involved in producuction*					
		Jallene		*Wochecha*		*Tolcha*	
		No of farmers	*%*	*No of farmers*	*%*	*No of farmers*	*%*
1	*28.55 -31.49 t/ha*	*10*	*19.6*	*0*	*0*	*0*	*0*
2	*23.55-28.55 t/ha*	*16*	*31.38*	*0*	*0*	*0*	*0*
3	*18.54t-23.54 t/ha*	*16*	*31.38*	*2*	*29*	*0*	*0*
4	*13.54 -18.54 t/ha*	*9*	*17.64*	*3*	*42*	*4*	*25*
5	*85.41-13.54 t/ha*	*0*	*0*	*2*	*29*	*12*	*75*
	Total	*51*	*100*	*7*	*100*	*16*	*100*

As it is shown on the table above the variety Jallene is more productive than the other varieties with its yield high of 31.49 tons per hectare and on the average it gave 22.84 tons per hectare. This variety is Wochecha that gave better yield and its productivity of 15.88 t/ha. The variety Tolcha compared to the other two varieties had the lowest average tuber yield of 12.26t/ha.

At the other Kebele where this activity is carried, 12 farmers planted the variety Jalene. Out of the 12 farmers one farmer, Asnake Bahiru, has planted the seed 0.6m X 0.3m spacing (the recommended spacing). However due to seed scarcity, the other 11 farmers development office unity were sound enough and have significantly contributed for the achievements registered in achieving the objectives outlined.

Farmers were told the high productivity and resistance to late blight of potato and the project assured them if any failure occurs. Besides this, the project has shown them a commitment to purchase the product from the end users. This is the first and the foremost issue, which is encouraged.

Limitations

The roads constructed, which connect the seed multiplication sites, are not accessible during the rainy season and is not suitable for trucks even during the drier seasons. Unless this situation is improved the marketability of the tuber to neighboring districts will be under question.

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Assessment of Socio economics status of potato producers in selected areas of North Shewa: A case for potato seed production intervention.

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Abstract

North Shewa is one of the potential zones for potato production in Amhara Regional State. Even though the zone is food insecure and possesses erratic rainfall, farmers in the area struggle and challenges nature with limited and traditional methods and tools to make their livelihood. Effort has been exerted in the areas of both research and development to improve this situation. Therefore, using a survey, there is a need to assess socio-economic and potato production status of these areas and identify the major institutional and management issues which are worthy of further consideration Survey results of the two Weredas (Basonaworena and Menz Gera Midr) considered in this study revealed that most farmers in the study areas (38.9%) started production of potato with local variety but about 27.8% with improved varieties (Gera and Gorebela). The respondents also indicated that potato production in these woredas is started as late as 1985 and its coverage has increased after 2002. Moreover, farmers that have been participated in potato seed scale up activities of the centre disclosed that most of them (72.2 %) have experience of potato production since the past three years and 33.3 %, of them have an access of improved varieties while 22.2 % uses local varieties and 16.7 % both varieties. Therefore, one can safely recommend that much supports and efforts are expected from research and other concerned organizations to enhance the production and productivity of potato in these districts.

Gera Keya Wereda is located at the eastern edge of the Ethiopian highlands in North Shewa zone. Elevations in the Wereda range between 1400 to 3325 masl. The Wereda is divided into four agro-climatic zones in which Kolla, Woinadega, Dega and Wurch with a share of 12%, 27%, 60% and 1% in their order.

The livelihood of the population is dependent on mixed farming and crop production, with about 95% of its population engaged in a risky agriculture. Due to various constraints, the Wereda is one of the critically food insecure woredas of the Amhara National Regional State.

Baso and Werena Wereda, covers 150 249.4 ha of land of which 44.1%, 12.1%, 7.9%, 31.9% and 4.0% of land are allocated for crop production, grazing, forest, unproductive land, and others (building etc.), respectively .

According to the traditional agro-ecological classification, the Wereda has 3 major agro-ecological zones namely Dega (50 %), Woinadega (48%), and Wurch (2%). The rain fall of the area ranges from 900mm to 1200mm and major crops in the area are barley, wheat, faba bean, field pea, and lentil...etc.

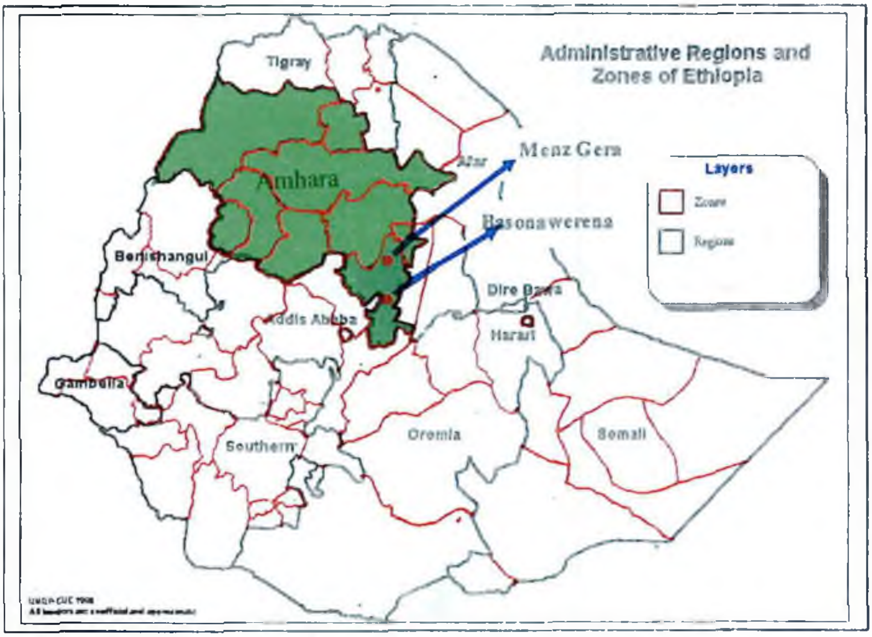

Fig 1. Map of the study area

Data collection and synthesis

Both primary and secondary information were collected. Primary data was collected from those participated farmers in potato seed scale up activity using questionnaire by the research team. Secondary data on production was collected from WOARD. In line with the secondary data collection, repeated discussion was made with key informants. All set of data were subjected to simple descriptive statistics.

Results and Discussion

Agriculture

In the study areas more than 95% of the population of the Wereda and more than 97% of the rural population engaged in agriculture (both in crop production and livestock rearing). The major types of crops grown in the study areas are wheat, barley, and pulses The present level of productivity and yield of these crops is very low. This is due to the limited utilisation of improved and modern agricultural inputs, poor agronomic practices, recurrent drought, pest outbreak and great water-logging problem.

Livestock resource is another source of livelihood for the farmers. The study areas have large livestock resource and particularly it has high number of sheep, which is known for its mutton and skins.

Crops production

In the study areas farmers have attributed the inequitable return of crop farming to a number of constraints. Data from the two WOARD summarized in table 1

Table 1. Productivity of major crops in the selected Weredas, (2006/7) cropping Season.

No.	Major crops types	Basona Werena Wereda	Gera keya Wereda
		Productivity (t/ha)	Productivity (t/ha)
1	Wheat	2.62	1.3
2	Barley	2.29	1.2
3	Field pea	1.59	0.65
4	Faba bean	1.6	1.3
5	Lentil	0.9	0.55
6	Chickpea	1.59	0.7
7	Grass pea	1.59	1.0
8	Tef	1.54	0.65
9	Sorghum	2.75	1.25
10	Maize	3.45	1.1
11	Onion/shallot	8.37	NA
12	Garlic	8.39	NA
13	Potato	13.13	19.3

Source: WOARD data.

Constraints of the crop production

Moisture stress: The crop production sub-system is highly dependent on rainfall. The rainfall pattern is unpredictable and erratic both in amount and distribution. Due to this fact crop failure is common in the area.

Capital: Because of their poor purchasing power, farmers are not usually using agricultural inputs.
Generally there is a problem of soil fertility, pest and diseases, frost, water logging, ball worm, Aphids etc.

Potato production practice in the study areas

Land preparation

In the study areas most farmers plant potato during *meher* season. Planting of potato is usually done before the onset of the rainy season. In the areas for which information is available, most of this work is done by hand or with oxen.

Selection of seed tuber

The importance of early sprouting is not well recognized, and the most common means to break dormancy is achieved by packing with sacks or covering the seed tubers with straw to raise the temperature of the container and thereby facilitate the metabolic activity of the seed tuber. In fact such methods typically isolate the tubers from light, and the resulting sprouts are often weak and pale.

Varieties used

Since names inspired by many circumstances or qualities (such as the place from which a variety was locally introduced or a descriptive quality of the tuber), it is very difficult to know if various names refer to the same or different types. Therefore, those varieties that are introduced to the area long ago, farmers treat them as local varieties. In addition to varieties which have existed for many years in the area more recently few varieties are introduced via research institution. Most farmers in the study areas (38.9%) were started with local variety and about 27.8% with improved varieties (Gera and Gorebela). Potato production this area is started as back as 1985 as indicated by the respondents and its coverage is increased since 2002.

Table 2. Percentage of respondents by the use of variety during the start time.

No.	Variety	Percent
1	Local	38.9
2	Gorebela	16.7
3	Gera	11.1
4	No response	33.3

Source: survey data, N=18

Harvesting

The time of harvesting is determined based on the drying of foliage, the vegetative cycle of the varieties planted, and observations of tubers. Harvesting is usually done manually to avoid tubers damage.

Storage

Storage of both seed and ware potatoes is very problematic for most farmers. Most of them store their produce on the floor or pack it for short time. Very recently Diffused Light Stores (DLS) is introduced to some farmers who are participating in potato seed production.

Marketing and utilization

Farmers who afraid of spoilage, they usually harvest all at once what they have in the field and sale at a near by market at a low price, while others using potato for home consumption harvest any time as need arise. Farmers usually consume potato as boiled or use for stew making. Results of survey made on farmers participated in potato seed scale up activity at the two weredas showed that most of them (72.2 %) have experience of potato production at least in the past three years and used improved (33.3 %), traditional (22.2 %) and both varieties(16.7 %) .

Table 3. Potato cultivation practices in the selected areas in the past three years

Farmers Response	Frequency	%
yes	13	72.2
no	5	27.8

Source: survey data, N=18

Table 4. Potato seed used in the selected areas in the past three years

Farmers Response	Frequency	%
Traditional	4	22.2
Improved	6	33.3
Bboth	3	16.7
Total	13	72.2
No experience before	5	27.8

Source: survey data, N=18

From the survey made at the two selected Weredas on farmers participated in potato seed scale up activity of the centre, they have indicated that potato production is profitable even at the current significantly lower market price of the product.

Table 5. Benefit - cost analysis of major crops produced by those participated farmers in potato seed scale up of the two Weredas, 2006/7 cropping years

Items	Major Crop types				
	Potato	**Wheat**	**Barley**	**Faba bean**	**Lentil**
Average grain production (t/ha)	24.17	0.97	1.13	0.89	0.5
Price (Birr/Qt)	150	235	220	370	395
Value of Grain (Birr/ha)	36255	2279.5	2486	3293	1975
Average straw production (sacks/ha)	0	195	202	110	45
Straw price (Birr/sack)	0	7	8	10	12
Value of straw (Birr/ha)	0	1365	1616	1100	540
Gross return (Birr/ha)	36255	3644.5	4102	4393	2515
All Variable costs (Birr/ha)	18020	1370	1100	1165	1252
Net profit (Birr/ha)	18 235	2274.5	3002	3228	1263

Source: Survey data, (data are average of those participated farmers in potato seed scale up of the two Weredas)

Table 6. Cropping calendar for potato in *meher* season in the study areas

Activities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Meher												
1st Ploughing		XX	X									
2nd Ploughing			XX	X	X							
3rd Ploughing				X	XX	X						
planting						X						
Hoeing/Weeding							X					
harvesting										XX	X	

Source: Survey data, (data are average of participan farmers in potato seed scale up of the two Weredas)

Socio-economic circumstances

This is a category of social, cultural, and economic factors related in one way or another to the livelihoods of the farming community in the study areas.

Demography

The humah population of Gera keya and Basona Werena Weredas is estimated to be 183 027 and 155 237, respectively. The vast majority of the selected Weredas' population lives in rural areas.

Incomes and expenditure

The very nature of agriculture makes a precise estimate of the incomes and expenditures of the rural community difficult, if not impossible. So, only the areas of gains and expenses were dealt with the community.

From the survey income generation, expenditure and amount saved are summarized in table 7. This income is generated from crop, livestock farming and off/ non-farm activities

Table 7. Income generation, different expenditures and saving in a year

	Total income	Expenditure for food	Expenditure for health	Expenditure for education	Expenditure for others	Saving
Mean	4673.42	1891.43	166.67	596.67	964.29	1054.36
% from total income		40.5	3.6	12.6	20.6	22.6
N	12	7	6	6	7	5

Source: Survey data, (data are average of participant farmers in potato seed scale up of the two Weredas)

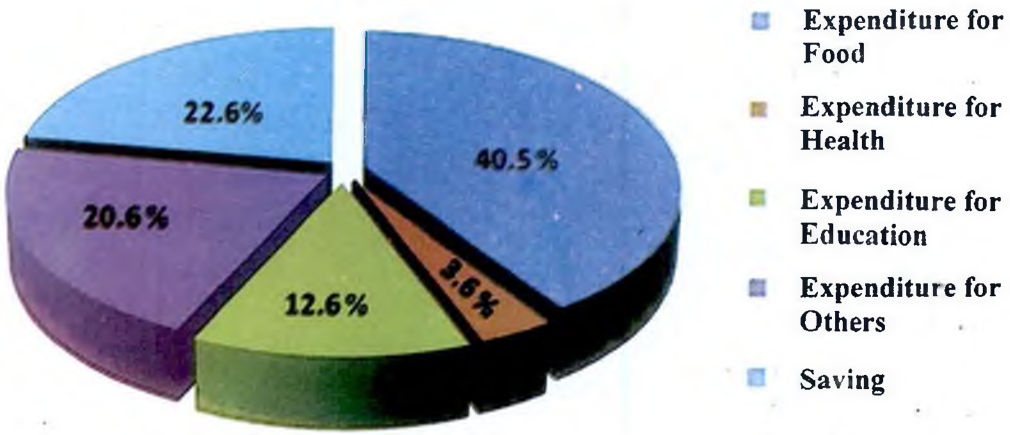

Fig 2. Share of different expenditures of the respondents in the study areas.

The majority of the respondents have living house, kitchen and animals shed made of mud and grass roofed. Housing of the study areas is described in table 8.

Table 8. Percentage of respondents for housing type and construction materials

Construction materials	Living house	kitchen	Animals shed
Mud and grass roof	92	100	100
Mud and grooved iron	7	-	-

Source: survey data, N=18

Socio-economic constraints and possible intervention

Most of the constraints identified are inter linked together often-forming casual chains. The root causes of most of the constraints are erratic rainfall, population pressure, soil fertility, feed shortage, high cost of inputs and social services (health clinic, school etc). Others are derivatives of these constraints. The most important socio-economic constraints in the study areas described below.

Human population pressure

Population density has increased at alarming rate while available scarce resources such as land remained fixed or decline in quality. This led to an increasingly adverse land-man ratio on limited resources. Hence, under the conditions where neither utilisable resources have increased nor technological knowledge has grown such a pressure of human population would indeed be disastrous leading to shortage of cultivable and grazing lands, destruction of vegetation and cultivation of marginal lands and steep slopes. This in turn results to the overall and progressive decline of the economic situation of the population. For this problem the following measures are required:

Family planning measures:- The efficient promotion and implementation of family planning measures for the rural people through Wereda Office of Agriculture and Rural Development (WOARD) is indispensable to create awareness and take measures to control population pressure.

Economics measure:- Attempt should be made to increase intensification of agriculture by the use of improved agricultural technologies. The rural economy should also be diversified through small-scale industries and this may create more employment opportunities especially for the land-less category.

Social measures:- Schooling and improving the social status of women and implementing the policy of the minimum age for marriage are some of the social measures intended to alleviate the problem of population pressure.

Land shortage:- With increasing population of the land-less farmers, agricultural production can not be sustained unless significant changes are made in agricultural intensification. Research results aimed at increasing intensity of land use should thus be of high priority to intensify agricultural production. Therefore using different crops that are adaptable in the area rather than the usual crops should be practice.

High prices of agricultural inputs:-Since the introduction of improved crop production to the study area, farmers have started investing in agricultural inputs, such as fertiliser, improved seeds of crops, herbicides, pesticides, etc. However, it was reported that the prices of these inputs have increased at a faster rate to a level unaffordable by most of the farmers. Hence, agricultural research should give due emphasis in generating low input technologies that are affordable and easily adaptable by the farmers

Cash shortage:- The farmers' main sources of income are mainly from the sale of crops and livestock. However, due to low agricultural productivity, the marketable surplus is inadequate. Consequently, the income gained from on-farm activities is insignificant.

Possible research and development interventions

- Introduction of potential cash crops and emphasis should be given for horticultural technologies under rainfed and irrigation
- Continuous training of the farmers about potato production and storage technologies
- Training to the potato seed producers on most common diseases so that farmers would be able to identify and report on time to the concerned institution whenever a serious incidence occurs.
- Frequent ploughing and solarisation of red ant suspected (home garden) fields
- Improving marketing and post-harvest handling of perishable crops,
- The education of family planning has to be extended extensively,
- Rural financing institutions must take into account the very complex and risky circumstances under which farmers work and live.
- Service cooperatives need to be strengthened to increase the power of the farming community,

Reference

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Review of Crop Improvement Research, Achievements and Future Focus in Parts of Western Amhara Region- The Case of Adet.

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Abstracts

Amhara Region is one of the 14 National Regional States (ANRS) in the country that is located at 9°-14° N Latitude and 36°- 40° E longitude. Altitude within ANRS also ranges from 500-4620 meters. Because of this fact the Region has very diversified agro-ecozones that permits the production of various horticultural and field crops. Potato is among these crops grown at a larger scale in the Region. In fact this Region surpasses the other regions in the total area of potato production coverage. Potato is grown from sea level to over 4 000 meters elevation. This is one of the potato's greatest assets that allowed it to be grown under a wide range of environmental conditions than most crops. Such diversified environments under which potato can be grown do not only present a specific set of opportunities for potato production but lays constraints too. This is vividly reflected in the contrasting figure of production area vis-a-vis total volume of potato produced. To limit the influence of environmental factors various efforts were made by Adet Agricultural Research Center. These efforts are targeted at the development and adaptation of high yielding potato varieties apt for the main rainy season, irrigated system and moisture stressed areas of the region. In these effort four sets of activities, i.e., potato regional variety trial, evaluation of elite and commercial potato varieties under rain-fed and irrigated production system, adaptation of released and elite potato genotypes under moisture stressed and better environmental conditions. These activities were carried for three, two, and one cropping season, respectively. As a result disease tolerant, high yielding and adaptable potato varieties for the different production systems and areas of the Region were developed/recommended. This paper presents the results of these efforts.

Introduction

Potato (***Solanum tuberosum*** L.) is one of the most important food crops grown in the mid- and high-altitude areas of northwest Ethiopia (Gojam and Gonder). Its production ranks in the top four important food crops especially in the high altitude areas (Aleligne *et al.*, 1988). It is grown as sole in the field as well as in the garden and intercropped with different crops such as maize, faba bean, lentil and others. Potato has also both dietary and income-generating importance for small-scale farmers in the cool areas. In some of the northwestern Amhara sub-regions, like Awi zone, potato is produced three times per annum viz., main rainy season, residual moisture, and irrigated systems (Alemu *et al.,* 1998). Yet, the regional average yield is quite very low, i.e., 4.8-5.7 t/ha, compared with the world 15.0 t/ha average tuber yield (CACC, 2003; FAO, 2004). This low productivity generally emanates because of various reasons of which the use of late blight susceptible and low yielding varieties. The production of Potato is highly constrained by this fungal caused disease called late blight of potato (*Phytophthora infestans* (Mont de Barry). Late blight is the most famous and probably the most important diseases of potato world wide. It is caused by the fungus like oemycetes pathogen *phytophthra infestans.* This disease can affect almost all part of the plant like leaves, stems, fruits and tubers. It causes an average yield loss of 56.7 to 95% depending on the environmental condition of an area. To prevent this predicament effort were made to develop potato varieties that can best resist/tolerate this disease. To these effect four sets of trials linked to variety development and adaptation were carried at different times and areas under different production system. As a result promising results that can help solve the aforementioned production problems were obtained. The objective of this paper is therefore to present the review these results.

A. Potato Regional Variety Trial

Materials and Methods

This trial is carried out for three years (1996, 1997 and 1999) across three varying agro-ecolozones of major potato growing areas, Adet, Debre Tabor and Injibara (Table 1). In this trial a total of 10 clones were tested in RCB design with three replications on a gross plot size of $9m^2$. A spacing of 75cm x 30cm between rows and plants, respectively and the recommended fertilizer rate of 81/69 kg/ha N/P_2O_5 were used for the trial. The remaining crop husbandry practices were employed as recommended. Finally data is taken from the central two rows of 16 plants and used for analysis.

Results and Discussion

The trial is harvested just at physiological maturity of the crop. Yield data is generated from the central two rows of 16 plants. The harvested marketable tuber yield of the trial is then analyzed using the MSTATC statistical software. Results of this analysis of variance (ANOVA) discovered the presence of highly significant ($P<0.01$) differences among the tested genotypes. The highest marketable tuber yield (25.48 t/ha) is obtained from the elite genotype CIP-380479.6. In contrast the lowest marketable tuber yield (5.19 t/ha) was harvested from the local check (Table 3). This is mainly attributed to genetic differences in yield ability and tolerance to the disease late blight of potato. The highest yielding genotype gave a yield advantage of 20.13 and 391% over the standard check Tolcha and local check, respectively (Table 2). Mean result of the 10 genotypes over the nine-environment are indicated in table 2 below. Genotypes did also perform differently across locations and seasons (Table 3). This is resulted in both temporal and spatial rank order shift. Such shift in performance rank is common for quantitative character such as yield. The divergent biotic and abiotic factors at each location and during each seasons also contributed for such variation. Under such instances identification of genotypes with slight oscillating behavior or wide adaptation is crucial. To this effect the Eberhart and Russell (1969) cultivars' stability analysis procedure is employed. As a result, the regression coefficient (b) value of the tested genotypes ranged between 0.73 for CIP-384321.18 to 1.43 for the genotype CIP-384321.16 (Table 2). Among the tested genotypes CIP-387028.36 is more stable based on the three stability parameters of regression value, deviation from the regression slope (S^2d) and coefficient of determination (R^2). However, its low mean marketable tuber yield compared to the standard check limited the further recommendations of this genotype.

On the contrary, CIP-384321.16 and CIP-384321.3 had regression coefficient value of 1.40 and 1.30. Hence, they showed specificity to good environments (Table 2). The top yielding genotype CIP-380479.6 however found relatively stable and excelled Tolcha too in its yield (Table 2). The genotype CIP-384321.9 which gave a marketable tuber yield of 22.5t/ha also exceeded the standard check and showed some skewness to better environments. This tendency however is desirable as strongly static variety is not profitable unless it responds to better growing conditions too. The national variety releasing committee has also officially released these two genotypes for use by the potato growers of the sub-region and areas with similar environments. CIP-380479.6, locally named Zengena, is semi-erect, tall, purple flowered, medium maturing (105 days), white skin and flesh colored, oval shaped and late blight tolerant variety with high (32%) dry matter content. This qualifies it for processing purpose. The genotype CIP-

384321.9, named Guasa, is semi-erect variety with medium height, white flower, medium maturity (110-115 days), white but pinked at heel skin and white flesh color, round shaped tuber, late blight tolerant and still high dry matter content (24%). This is also good for crisp preparation purposes.

Table 1. Mean rainfall during the test period, altitude, soil type, pH, agro-ecological and geographical locations of the trial sites of potato regional variety trial.

Location	Soil type	Soil pH	Agro-ecological category	Geographical position *	Altitude (masl)	*Annual rainfall (mm)*
Adet	**Nitosols**	**5.43**	**M2-5**	**$37^0$30'1.8" N $11^0$16'30.3"E**	**2240**	**1091**
Injibara	**Acrisols**	**4.79**	**M3-7**	**~10.85^0N, 36.80^0E**	**2610**	**2019.3**
Debre Tabor	**Luvisol**	**5.37**	**SH2-7**	**~11.89^0N, 38.09^0E**	**2630**	**1344.**

Note: The mean rainfall data shown above is only the average of the crop growing months from May through September during the three-test period.

* IGADD *et al.*, 2000

M2-5 Stands for moist tepid to cool mountains and plateau /plateau only/

M3-7 Stands for moist cold to very cold sub Afro Alpine to Afro Alpine

SH2-7 Stands for sub-humid tepid to cool mid high lands/ cool mountains

Table 2: Mean performance and yield advantage of across nine environments.

Genotypes	Marketable tuber yield, t/ha	Marketable tuber yield *advantage* in % from the st. check	Marketable tuber yield *advantage* in % from the local check	Stability parameters		
				b	S^2d	R^2
CIP-86029.18	15.52^{E}	—	192	0.73	0.28	49
CIP-84321.16	20.68^{BC}	—	298	1.40	0.19	89
CIP-384321.3	22.82^{B}	7.6	340	1.30	0.43	56
CIP-384321.9	22.49^{B}	6	333	1.24	0.24	79
CIP-87028.36	19.15^{CD}	—	269	1.04	0.18	83
CIP-84327.42	17.39^{DE}	—	235	0.99	0.28	64
CIP-380479.6	25.48^{A}	20.13	391	0.84	0.24	64
Tolcha	21.21^{BC}	—	309	0.95	0.19	79
Wochecha	19.65^{CD}	—	279	1.31	0.20	85
Local Check	5.19^{F}	—	—			
Grand mean	18.96					
LSD 5%.	2.64					

Table 3: Mean marketable tuber yield, t/ha, of potato regional variety trial, 1996, 1997, and 1999 at Adet, Debre Tabor and Injibara.

	1996			1997			1999		
Genotypes	A	D	I	A	D	I	A	D	I
CIP-386029.18	15.41	21.45	7.86	22.00	19.17	9.20	12.602	16.35	15.63
CIP-384321.16	32.05	22.82	10.19	28.44	21.59	14.59	21.29	22.22	12.90
CIP-384321.3	29.71	15.91	12.83	36.20	25.90	15.06	31.46	18.41	19.86
CIP-384321.9	**25.44**	**21.67**	**14.29**	**30.69**	**30.41**	**17.41**	**24.69**	**25.79**	**12.05**
CIP-387028.36	22.96	25.60	11.94	20.85	23.59	12.66	21.63	21.33	11.82
CIP-384327.42	28.74	16.00	13.49	20.38	24.47	13.28	16.34	12.72	11.06
CIP-380479.6	28.99	27.46	18.80	27.14	25.45	19.48	34.35	26.81	20.82
Tolcha	29.29	25.10	19.24	23.90	21.50	13.03	23.35	21.18	14.28
Wochecha	29.03	26.93	14.70	23.12	24.34	10.48	19.56	17.94	10.62
Local check	4.65	8.60	5.63	4.90	6.23	3.86	4.39	7.8	0.7
Mean	**24.63**	**21.15**	**12.90**	**23.76**	**22.27**	**12.91**	**20.97**	**19.06**	**12.97**

Note:'A' stands for Adet, 'D' for Debre Tabor and 'I' for Injibara

B. Evaluation of released and elite potato genotypes under rain-fed and irrigated system

Material and Methods

This second trial was carried under rain-fed and irrigated system. The rationale behind this trial was to investigate whether these two dominant potato production systems really demands similar or varying variety development strategies or populations fitting to the environmental conditions prevailing under the two production systems. The trial was conducted at Adet for two consecutive years, 2000 and 2001, under both systems using six commercial varieties, two elite genotypes and a local check of the area. The plot size, spacing, fertilizer rate, type, time and method of application and other cultural practices employed were similar to the earlier trial.

Results and Discussion

Analysis of results of this trial yield data illustrated the presence of highly significant ($P<0.01$) differences between the two seasons in marketable tuber yield. The interactions between year x season, year x variety, season x variety and year x season x variety were also highly significant ($P<0.01$) (Table 4). The year x season interaction is a common phenomenon, as environments do not let themselves repeat across years. However, the remaining interactions imply the inconsistencies of genotypes performance over seasons, years and their combinations, i.e., environments. Under rain-fed condition the regionally released variety Zengena exceeded all with a marketable tuber yield of 33.1 t/ha. CIP-384321.3, an elite genotype, and Guasa followed it with 27.68 and 26.68 t/ha, respectively (Table 5). Conversely, under irrigated production condition CIP-384321.3 surpassed all with a mean marketable tuber yield of 22.19 t/ha. Zengena and Guasa followed with 19.65 and 16.02 t/ha respectively. CIP-384321.3 exceeded these two varieties with a yield advantage of 13% and 39%, respectively. This clearly sparks a light on the need of reconsidering the materials tested under each system. Until then Zengena and Guasa are recommended for production under both seasons.

Table 4: Combined ANOVA of yield and other data of nine genotypes at Adet under four environments, 2000-2001.

Source of variation	Number of main stems/plant	Plant height, cm	Tubers harvested/plot	Marketable tuber yield, t/ha
Year (Y)	*	**	NS	*
Season (S)	*	**	**	**
Y x S	NS	**	**	**
Variety (V)	NS	**	**	**
Y x V	NS	**	**	**
S x V	*	**	**	**
YSV	**	**	**	**

Table 5: Mean tuber yield, t/ha, results of evaluation of released and elite potato genotypes under rain fed and irrigated production system, 2000-2001.

Treatments	Marketable tuber yield, q/ha		Total tuber yield. q/ha	
	Irrigated	Rainy season	Irrigated	Rainy season
Tolcha	**9.66**	**20.90**	15.65	**25.85**
Awash	**12.01**	**14.25**	19.51	**17.20**
Genet	14.56	**24.62**	22.12	**27.27**
Guasa	**16.02**	**26.88**	**24.93**	**32.44**
Wochecha	6.72	**21.80**	12.69	**24.19**
Menagesha	8.25	**17.19**	**13.97**	**20.73**
CIP-384321.3	22.19	**27.68**	27.73	4.10
Zengena	**19.65**	33.10	23.85	35.20
Local	13.62	**1.44**	16.15	1.98
Mean	**13.63**	**20.87**	**19.62**	**25.09**

C. Evaluation of Released and elite genotype adaptability under moisture stressed areas

Material and Methods

The third trial was evaluation of released and elite potato genotypes under moisture stressed areas of South Gonder zone. This trial was carried at Lay Gayint and Simada woreda, 2001/2002 with the main objective of identifying adaptable potato variety for the indicated moisture stressed areas of the south Gonder zone. In this trial a total of five materials, four released varieties and one elite genotype, were tested just for one year at the two districts. The plot size, spacing, number of replications, fertilizer rate and type and other cultural practices were similar to the first trial. Totally nine genotypes under the second and five clones under the third experiment were tested in this set.

Results and Discussion

This third trial ANOVA result of each location indicated significant ($P<0.05$) genotypic differences for stem number/plant and highly significant ($P<.0.01$) differences for stem height only at Lai Gayint. Genotypes did not show statistically detectable differences in marketable and total tuber yield (Table 6). However; highly significant ($P<0.01$) differences were observed among genotypes over stem height, marketable and total tuber yield at Simada (Table 6). The highest number of stems/plant, number of tubers/m^2, and marketable and total tuber yield was recorded from the elite genotype CIP-384321.3 at Lai Gayint (Table 6). At Simada, the highest marketable and total tuber yield, number of tubers/m^2, and stem height is recorded from the released variety Zengena. The elite genotype CIP-384321.3 gave the second highest stem height (54 cm), tuber number/m^2 (6), and marketable (14.84 t/ha) and total (15.19 t/ha) tuber yield (Table 6). Perversely, Zengena gave the lowest marketable (4.37 t/ha) and total (4.39 t/ha) tuber yield at Lai Gayint. At Simada this lowest marketable (7.4 t/ha) and total (8.49 t/ha) tuber yield is harvested from the improved variety Menagesha (Table 6).

Combined ANOVA of this trial revealed statistically detectable genotypic differences in number of tubers/m^2, stem height, marketable and total tuber yield. Genotype x locations interactions was also significant. This is a clear indication of the presence of qualitative or cross-over interactions in which genotypes perform inconsistently from one environment to another. The maximum across locations marketable tuber yield of 13.45 t/ha and total tuber yield of 14.39 t/ha is obtained from the elite genotype CIP-384321.3. The improved variety Zengena followed CIP-384321.3 with a marketable and total tuber yield of 12.10 and 12.51 t/ha, respectively (Table 7). The lowest across location yield performance was obtained from the improved variety Wochecha (Table 7). Since, mean value normally casts shadow over specific adaptability we felt necessary to consider each locations result and consequently recommend Zengena for further promotion at Simada while Menagesha at Lay Gayint. Besides, it is worthy to treat moisture stressed areas differently based on the observed differences in environmental variables, such as elevation, temperature and others. Accordingly, it is very important to fine tune the variety development strategy in such a way that we could be able to capture the potential differences. This statement could be well justified from the results of the above trial in which Menagesha, a variety recommended for higher altitudes, is seen performing better at the higher elevated Laygayint area while Zengena under Simada's elevation condition.

Table 6: Agronomic and yield data ANOVA results of potato variety adaptation trial under moisture stress conditions of Lai Gayint and Simada, 2001/2002.

Treatments	Stem number/plant		Stem height, cm		Number of tubers/m^2		Marketable tuber yield, t/ha		Total tuber yield, t/ha	
	L.G	Sim.	L.G.	Sim.	L.G.	Sim.	L.G.	Sim.	L.G.	Sim.
Tolcha	4^{AB}	4	33^{AB}	39^{BC}	17	18	5.79	10.89^{C}	6.75	13.56^{BC}
Wochecha	3^{AB}	4	20^{B}	34^{C}	14	8	4.86	8.87^{CD}	4.76	10.3^{C}
Menagesha	4^{AB}	3	52^{A}	50^{B}	18	7	9.84	7.40^{D}	12.44	8.49^{D}
Zengena	2^{B}	3	32^{AB}	65^{A}	12	13	4.37	19.83^{A}	4.39	20.63^{A}
CIP-384321.3	5^{A}	2	42^{AB}	54^{AB}	37	12	12.05	14.84^{B}	13.59	15.19^{B}
Mean	4	3	36	48	20	10	7.38	12.37	8.39	13.63
LSD value	2	-	22	13	-	-	-	2.634	-	2.161
C.V.%	29.5	28.2	13.7	13.7	14.8	26.8	19.9	21.5	19.2	16.04
P level	0.05	N.S.	0.01	0.01	N.S.	N.S.	N.S.	0.01	N.S.	0.01

Note: L.G stands for Lay Gayint while Sim. stands for Simada

Table 7: Across location combined ANOVA results of yield and yield components of potato variety adaptation trial for moisture stress areas, Lai Gayint and Simada, 2001/2002.

Treatments	Stem number/plant	Stem height, cm	Number of tubers/m^2	Marketable tuber yield, t/ha	Total tuber yield, t/ha
Tolcha	4	36^{B}	17	8.34	10.16
Wochecha	3	27^{B}	14	6.87	7.53
Menagesha	3	51^{A}	18	8.62	10.47
Zengena	2	48^{A}	12	12.10	12.51
CIP-384321.3	3	42^{A}	37	13.45	14.39
Mean	4	36	20	9.87	11.01
LSD value	NS	11	-	-	-
C.V.%	28.93	15.65	14.8	19.9	19.2
P level	NS	0.01	NS	NS	NS

D. On-farm Potato variety adaptation trial

Materials and Methods

Six released potato varieties (Tolcha, Zengena, Degemegn, Gera, Jalenie and Gudene) were evaluated for their adaptability in Injibara and Lay Gayint areas during 2006 and 2007 cropping seasons. Randomized Complete Block Design (RCBD) with three replications is employed for the trial. The recommendation fertilizer rate of Adet Agricultural Research Center, i.e., 81/69 kg/ha N/P_2O_5 per hectare is used. The whole source of P_2O_5 and one third of N is applied at planting in the form of DAP (150 kg/ha DAP) while the remaining N was side dressed half at 2 weeks after emergence (first earthing up) and the remaining half at 50% flowering (second earthing up) in the form of Urea (117.39 Urea kg/ha). At planting forty well sprouted medium sized tubers of each cultivar were planted in four rows at spacing of 75 cm and 30 cm between rows and plants, respectively on a gross plot size of $9m^2$. All the other cultural practices are carried as needed.

Results and Discussion

Statistically highly significant difference was observed among the tested varieties over the characters considered (Table 8 & 9). Their performance also varied across the two considered locations (Table 8 & 9). A very highly ($P<0.001$) significant differences were observed among the treatments over the stem number/plant, stem height, marketable and total tuber yield/ha. At Injibara the released variety Degemegne surpassed all the other varieties with its 25.87 and 27.02 t/ha marketable and total tuber yield, respectively. This variety is followed by Zengena with 22.78 and 23.80 t/ha marketable and total tuber yield in their order (Table 8).

Table 8: ANOVA results of yield and agronomic data of On-farm Potato Variety adaptation Trial, 2006 at Injibara.

Treatments	Stem no/plant	Stem height, cm	Marketable tuber yield, t/ha	Total tuber yield, t/ha
Gudene	9	55.2	18.38	20.97
Zengena	6	75.5	22.78	23.80
Jalene	9	58.0	21.33	22.91
Tolcha	6	29.2	7.75	8.15
Gera	5	52.5	18.83	18.85
Digemegne	7	58.0	25.87	27.02
Mean	7	54.7	19.16	20.28
C.V%	10.41	9.83	11.83	12.32
P Level	****	****	****	****
S.E.D	4.39	4.4	18.51	20.40

In a similar way these varieties had a very highly significant ($P<0.001$) differences at Lay Gayint too. Accordingly, Digemegne produced 37.79 and 41.62 t/ha marketable and total tuber yield, respectively. Zengena followed it with 33.08 t/ha marketable and 41.34 t/ha total tuber yield (Table 10). The performance the remaining varieties oscillated across the two locations. This result clearly revealed the relevance of testing

Limited potato research activities related to variety evaluation were carried out at Sheno during which Sheno was sub-center of Holetta Agricultural research Center, 1980/81 through 1990/91. Strong potato research was launched since 1996 in north Shewa highlands by Debre Berhan Agricultural Research Center (the then Sheno Agricultural research Center). Remarkable research results were recorded on potato improvement and demonstrated to users in these areas. Potato variety adaptation trials have also been conducted in mid highlands of north Shewa starting from 2002/03 with the main objectives of identifying high yielding potato varieties with good attributes, escape frost (early varieties) and resist disease and tolerate low temperature. This paper presents research results registered so far in north Shewa.

Materials and Method

Procedures

We have used two procedures for potato variety improvement. These are

1. Introduction and adaptation studies of improved varieties released else where in the country

2. Introduction and selection of varieties for our research mandate area (starting from observation plots/or preliminary variety trial to verification)

Methods

Plot size for all experiments: 9 m^2

Fertilizer rate: 195 kg Dap (at planting) and 165 urea kg /ha (split application)

For observation trial the genotypes were not replicated

Other practices are used as recommended.

Data related to marketable and total tuber yield, average tuber weight/gm and number of tubers /hill, disease score, wind tolerance, flowering and maturity were recorded and analyzed to identify varieties with suitable attributes outlined in the objectives.

Results and Discussion

Potato Variety Development Research Achievements in cool highlands

In 1997, about 21 potato genotypes brought from Holetta were tested against the local variety in potato variety observation trial at Molale and Mehal meda. These sites represent cool highlands of north Shewa (more than 3000 m.asl). From this observation trial about 12 varieties which gave high tuber yield were selected and evaluated again in replicated design at Molale and Ankober during 1998/1999 cropping season. Menagesha was the only released variety which gave reasonable yield. At this stage five varieties which gave better marketable tuber yield and exceeded the standard check (Menagesha) were selected. At the same time, in the same year, 16 varieties including the local check and Tolcha (released variety) were tested in Pre-national Potato Variety trial at Ankober. From this experiment KP-90134.2 variety was selected for its high

Table 2. Mean tuber yields and other tuber yield characters of varieties tested at four locations of cool highlands of north Shewa during 2002/03- 2003/04.

Varieties	*Average tuber weight (g)*	*No. of tubers/m²*	*Marketable tuber yield (t/ha)*	*Total Tuber yield (t/ha)*
CIP-385021.26	46.17	53.92	16.33	24.58
KP-90138.12	54.79	50.00	16.37	26.49
CIP-389701.1	32.96	78.42	18.86	25.60
KP-90108.5	44.08	58.96	14.21	25.73
Local	18.21	118.58	14.30	21.33
KP-90134.5	65.75	48.04	22.51	30.32
Gorebella	57.13	59.92	21.43	34.27
CIP-386389.1	30.42	89.46	19.96	27.46
CIP-387744.1	36.67	67.29	16.89	23.54
Mean	42.907	69.398	17.87	26.59
LSd (5 %)	6.157	8.4559	3.91	40.04
CV (%)	30.09	25.55	45.91	31.57

Performance of Potato varieties in moisture stress and cool highlands of north Shewa

Potato variety adaptation trial was conducted at Gumer (2800 m.a.s.l.) and Dargegn (3200 m.a.s.l.) of Gera Keya woreda in north Shewa during 2001 and 2002 cropping season. . Seven varieties were tested at Gumer and five varieties at Dargegn. These two locations represent moisture stress and cool highland areas of north Shewa.

At Dargegn, Gera and Gorebella varieties gave significantly high marketable and total tuber yields. At Gumer, these two varieties were the leading in total tuber yield while in respect of marketable tuber yield Gera was the leading followed by Gorebella. Significantly high average tuber weight was recorded on Gorebella and Gera varieties (Table 3). This indicated that these two varieties were best adapted for these areas. Based on the two years data the variety Gera and Gorebella are recommended for the moisture stress highland areas of Gumer, Dargegn and Similar Agro ecological areas of Gera Keya and Lalo Mama Woredas (Semagn Asredie *et al.*, 2007).

Table 3. 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(t/ha)*		*Total Tuber yield*		*Average tuber weight (g)*		*Number of tubers /m²*	
	Gumer	Dargegn	Gumer	Dargegn	Gumer	Dargegn	Gumer	Dargegn
Zengena	7.99	13.37	11.31	15.90	20.18	21.36	54.17	76.64
Gorebela	10.14	17.81	15.63	22.90	31.87	45.49	48.68	52.53
Gera	12.95	18.86	16.40	22.90	28.80	44.45	58.21	60.07
Menagesha	4.37	9.34	6.92	10.86	37.88	38.72	18.61	27.69
Tolcha	8.99	-	11.55	-	28.46	-	41.71	-
Wechecha	5.68	8.02	7.44	9.78	23.43	25.67	34.53	40.27
Genet	6.54	-	9.14	-	21.66	-	41.80	-
Mean	8.09	13.48	11.20	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

Note: The mark – stands the variety was not tested at the respective location

Performance of potato varieties in mid highlands of north Shewa

Potato variety adaptation comprising five released varieties were tested at two locations, Lay Saramba and Mehal Wonz of Efratana Gidim Woreda of north Shewa to examine their adaptability during 2002/03–2003/04 cropping seasons. These two kebeles represent mid highlands of Efratana Gidim and other areas with similar agroecology.

The Analysis over locations and years indicated that the varieties differed significantly in terms of marketable and total tuber yields and other tuber yield parameters. 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 areas with similar agroecology (Semagn Asredie *et al.*, 2007).

Two experiments such as Potato variety trial comprising nine varieties and Potato variety adaptation trial comprising eight improved varieties were conducted at Alem Ketema (2300 m.a.sl) during 2002/03 and 2003/04 and 2004/05-2005/06 cropping seasons, respectively to identify the best adapted variety or varieties in mid highlands of Merhabete, north Shewa. Gorebella was the standard check for the first experiment. In both experiments the varieties differed significantly in both marketable and tuber yields and tuber yield parameters. KP-90134.5 (later called Shenkola) gave high and consistent marketable and total tuber yields in both experiments. From the tested varieties in the adaptation trial, Gera, Jalene and KP-90134.5 gave significantly (P≤ 0.05) higher marketable and total tuber yields. Based on their yield potential and farmers' observation, Gera, Kp-90134.5 and Jalene varieties are recommended for mid highlands of Merhabete and other areas with similar agro ecology (Semagn Asredie *et al.*, 2007)..

Potato variety screening activities and Research achievements under rain-fed and irrigation in off-season

Screening activities and achievements under rain fed for belg season production in cool highlands of north Shewa

Twenty materials including the local check and improved varieties such as Awash, Tolcha, Menagesha, Wechecha, Al-624 and Genet were tested in single observation plots at Ankober during belg season in 1997 for the objectives of identifying high yielding, early maturing and frost tolerant potato varieties for belg season production. There was no moisture stress except a period of dry weeks immediate after planting and at the mid of the growing season. Most of the materials showed good performance. Eleven varieties were selected based on their tuber yield, frost tolerance and relative earliness. These varieties were tested against the local check at Ankober during belg season of 1998. The experiment was laid out in RCB design with three replications in a plot size of 9 m^2. Potato diseases such as potato late blight and Potato leaf roll virus (PLRV) were recorded in the growing season. Late blight especially was very severe at Ankober on Local cultivar (up to 5 CIP scale). PLRV was also observed in some varieties such as Genet, CIP-381169.16 and CIP-387028.1 9Table 4).

Significant marketable and total tuber yield difference was observed at 5 % level between varieties at Ankober (Table 4). All of the varieties out yielded the local check on total tuber yield. Variety CIP-387341.2, 387351.1, 382146.27, 382173.12382173.12, and 387315.2 gave significantly (P <5 %) the highest total tuber yield in the experiment.

In Conclusion, for belg dependent areas like Ankober some varieties were promising and early to bulk. From these varieties 382173.12 gave high total tuber yield, early to bulk and resistant to late blight. Three years after, this variety was released for production for rain fed condition. More over, varieties selected for meher season production is proved successful for belg season under rain fed. Therefore, varieties released for meher production can be used for belg season production under rain fed for the same agroecology.

Table 4. Tuber yield and other agronomic characteristics of varieties included in the preliminary potato variety trial for belg season, 1998, Ankober.

Variety	No. of tubers/m^2	Av. tuber wt/g	Total tuber yield (t/ha)	Late blight (1-9 CIP scale)	PLRV (no. of plts /plot)
387028.1	40.3	93.9	36.67	-	7.67
384321.9	74.3	55.5	41.28	-	-
382173.12	48.0	106.1	51.04a	-	-
Genet	45.7	73.9	33.65	-	2.0
387315.2	91.7	53.1	48.80a	-	-
382146.27	67.3	77.9	52.27a	-	-
387341.2	78.7	75.6	58.70a	-	-
387351.1	56.3	95.1	52.59a	-	-
Local	134.7	228	30.60	4.67	-
386029.18	40.7	90.7	37.08	1.00	-
381169.16	71.0	60.9	43.24	-	2.67
387317.7	75.3	60.1	43.89	-	-
LSD 5 %	-	-	11.63		
CV %	-		16.38		

Screening activities and achievements under under irrigation condition in lowland areas of north Shewa

Potato variety adaptation trial comprising eight improved varieties were conducted at Ataye and Shewa Robit, representing lowlands of north Shewa during 2006 cropping season under irrigation condition. The experiment was laid out in RCB design with three replications.

Analysis of variance of the experiment indicated that the varieties differed significantly ($P< 0.01$) in marketable and total tuber yields and other tuber yield parameters at Ataye and Shewa Robit. In all of the tested parameters the performance of varieties at Ataye is better than that of Shewa Robit. However, the performance of the varieties at Ataye is lower than the same varieties grown in the high altitude areas of north Shewa. Despite of location difference, Shonkola and Gera gave consistently and significantly ($P< 0.05$) high marketable and total tuber yields (Table 5). These varieties gave desirable tuber size in both locations. Moreover, according to the farmers assessment based on color, tuber size and tuber yield, Shonkola and Gera are selected 1st and 2nd, respectively. Therefore, Shonkola and Gera are recommended for low lands of north Shewa under irrigation in off season. Jalene is also the 3rd alternative variety for Efratnana Gidim and similar areas of north Shewa lowland areas with irrigation in off season. The study also showed that year round potato production would be possible in lowland areas of north Shewa with the above varieties. However, for greater potato production, the potato should be planted in coolest months of the year. Comparative advantage of growing potato with other high value crops in these areas is another research area which should be addressed in the future.

Table 5. Tuber yields and tuber yield parameters of varieties tested in Potato Varieties Adaptation under irrigation condition, Ataye and Shewa Robit, 2006

Varieties	Marketable tuber yield, t/ha	Total tuber yield, q/ha	Tuber weight/g	Tuber number /hill	Stand count at Harvest	% deformed tubers
Gera	21.07	24.98	52.61	10.568	15.83	0.58
Gorebela	18.70	24.60	57.603	10.335	15.67	3.17
Wechecha	8.31	13.51	57.288	6.12	13.00	21.67
Digemegn	12.65	19.18	37.702	12.332	14.00	3.72
Shonkola	22.95	26.815	70.748	8.943	15.50	0.94
Menagesha	12.79	16.22	64.435	6.308	14.50	0.53
Zengena	8.44	12.73	39.852	8.935	14.17	4.05
Jalene	18.08	23.95	40.877	14.212	14	3.417
Mean	15.37	20.25	52.639	9.719	14.583	4.759
CV (%)	22.65	19.06	15.76	23.17	9.04	62.30
LSD 5%	41.19	45.63	9.814	2.663		

Potato variety screening for frost

Frost is a major constraint of potato production both in meher and belg season production in cool highlands of north Shewa. It is prevalent from October to January for meher season production and caused for potato yield reduction. Variety trial experiments under irrigation also revealed that frost is a major production constraint occurred in April or May.

Pot experiment was carried out at Sheno, in 1996 to screen nine potato lines against frost during the months of October to January. These lines were developed for their tolerance for low temperature at CIP, Peru. Six frost days in October and four frost days in November were recorded. The minimum temperature on 28 October 1996 (-2.5 °c) and on 8 and 10 November 1996 (-2 °c and -3.5 °c, respectively) caused for the injury of the lines. On October 28 1996 some lines showed some degree of tolerance. CIP-377744.1 which showed only 30 % damage was the only line which some how tolerated the injury. After 8 and 10 November most lines were greatly damaged. Even CIP-377744.1 went up to 80 % damage (Table 6).

Thus, the yield of the lines was poor. Relatively the highest tuber yield/plot was obtained from CIP-720064. The highest tuber no./plot was also obtained from CIP-377744.2 and CIP-720064. Due to the poor condition of planting materials, emergence percent and growth of most of the varieties were poor.

In 1997, Frost was not recorded in the growing season so that it was hardly possible to evaluate the materials of their frost tolerance level. However, the materials were evaluated in yield bases. CIP-384867.1 and CIP-720064 gave high number of tubers per plant, which is 36 and 34, respectively. CIP-720064 gave the highest tuber weight per plant (297.79 gram per plant)

Potato variety observation was conducted under irrigation at Chacha during 1997 for the objective of identifying high yielding, early maturing and frost tolerant varieties. About 20 varieties including the local variety and improved potato varieties were included. During this condition, high frost injury was recorded. From this injury some clones such as CIP-384321.9, CIP-387341.2 and CIP-386029.18 showed very good recovery. (Table 7). Due to the adverse conditions, the growing period extended to the main rain season. As a result flooding and water logging affected the varieties. Despite of these challenges, some varieties such as CIP-384321.9 and CIP-387341.2 gave relatively better tuber yield. These varieties also showed good recovery after frost damage.

Table-6. Frost injury level (%) of the lines included in the potato germplasm screening for frost tolerance, Sheno, 1996.

Genotypes	Min.temperature occurred	Frost injury level in % on 28/10/96	No. of plants killed	Min.temp. injury occurred	Frost injury level in % on 13/11/96
CIP-376181.5	-2.5 °c	75	1	-2 °c &-3 °c	100
CIP-380389.1	"	60	-	"	95
CIP-377924.1	"	50	-	"	100
CIP-381263.2	"	75	-	"	95
CIP-384867.1	"	50	1	"	80
CIP -377744.1	"	30	-	"	80
CIP-720072	"	65	-	"	95
CIP-377744.2	"	50	-	"	90
CIP-720064	"	50	-	"	100

Table 7. Frost tolerant levels(%) of the materials included in the potato variety/or clone observation under belg condition, Chacha, 1997.

Genotypes	Frost damage score (%) 13/5/97	Recovery stage 13/6/97	Recovery stage 11/7/97
CIP-387315.2	40	R	SR
CIP-382146.27	40	GR	GR
Awash	80	D	D
CIP-381169.16	50	R	R
CIP-384321.9	40	GR	VGR
AL-624	40	SR	PR
Genet	30	SR	D
CIP-383032.15	60	SR	SR
CIP-382173.12	50	SR	SR
Wechecha	40	PR	D
CIP-386031.4	40	MR	PR
Tolcha	50	PR	SR
CIP-387341.2	25	VGR	VGR
CIP-381403.40	40	MR	SR
Local	40	MR	GR
387028.1	30	MD	D
386029.18	20	-	VGR
387351.1	40	GR	GR
387317.7	40	GR	GR
Menagesha	40	SR	R

Remark:- MD: most damaged, SR: some recovered, PR: poor recovery, D: damaged, R: recovered, MR: most recovered, GR: good recovery, VGR: very good recovery

Sheno Agricultural Research Center. Progress Report for the period 1996/97

Sheno Agricultural Research Center. Progress Report for the period 1997/1998

Sheno Agricultural Research Center. Progress Report for the period 1998/1999

Sheno Agricultural Research Center. Progress Report for the period 1999/2000

Sheno Agricultural Research Center. Progress Report for the period 2000/2001

Sheno Agricultural Research Center. Progress Report for the period 2003/2004

Participatory on farm evaluation and demonstration of improved potato varieties in the highlands of North Gondar Zone

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Abstract

A field experiment was conducted to evaluate the adaptability of released potato varieties along with the local check from 2004 to 2006 main cropping season in Chilga Woreda of North Gondar Zone (Northwestern Ethiopia). The experiment was laid out in RCB design with three replications on a gross plot size 9m2 planted at a spacing of 75 cm x 30 cm between rows and plants, respectively. Statistical analysis of agronomic and yield results were run using MSTATC statistical software right after harvesting. As a result the cultivar Guassa gave the highest marketable tuber yield of 27.41 ton ha^{-1} followed by Zengena (27.31 ton ha^{-1}) and Gorebela (22.31 ton ha^{-1}) in 2004 cropping season. Among the genotypes tested during this same cropping season the highest Area under Disease Progressive Curve (AUDPC) for late blight of potato fungal disease was recorded from the local cultivar indicating that the local variety is susceptible to late blight. In 2006 one Farmers Research and Extension Group (FREG) with 30 members were organized at Eyahomariam kebele of the study area and training was delivered related to quality seed production and its post harvest management. This group of farmers was also participated in the evaluation of the improved varieties under their own field condition. As a result they have ranked the varieties based on their own selection criterion. *Through pair wise and matrix ranking and farmer's selection criteria Jalenie, Zengena and Guassa were preferred as 1^{st}, 2^{nd} and 3^{rd} varieties respectively. Resistance to the disease late blight of potato, tuber yield and size were identified as the most sensitive criteria of farmers. This paper presents the results of these research activities during the aforementioned period.*

In 2005, seeds of the tested varieties and two newly released improved varieties were multiplied (Jalenie and Gudenie).

In 2006 the varieties (Tolcha, Guassa, Degemegn, Gera, Zengena, Jalenie Gudenie and local) were evaluated in a plot size of 8m * 5m over two farmers' field. Both male and female FREG members, DAs, extension staff and multidisciplinary team of researchers were jointly evaluate the performance of the varieties in field at different stage of the crop like; vegetative growth, maturity and storage time. At the same time farmers variety selection criteria were identified and documented.

Organizing Farmers Research and Extension Groups (FREG)

Multidisciplinary team of researchers, in collaboration with woreda office of agriculture and rural development, organized one FREG in Eyahomariam kebele, Chilga woreda. The group has 30 members and 30% of it is women. Development agents in the Kebele are members of the group. Chair person and secretary of the group were elected by the consensus of the group members. Similarly, date and place of regular meting were also decided in order to meet and discuss about the activities performed and problems encounter due course of time.

Training

With the intention of improving the knowledge and skill of participants (FREG members, DAs and extension personnel) in quality seed production and its management training sessions was organized in collaboration with Holeta Agricultural Research Center. The training was focused on both theoretical and practical seed production techniques, disease management options and post-harvest handling of the produce (DLS construction and management). Accordingly, 25 FREG members (19 male and 6 female farmers), 1 DA, 1 SMS and 4 researchers were participated on the training. Finally, farmers were advised to construct their own DLS individually or in group base from locally available material.

Results and Discussion

Yield and yield related traits

Statistically highly significant difference was observed among the cultivars based on the agronomic and yield parameters recorded. Cultivar Gorebela produced the highest plant height of 47.7cm followed by Zengena (46.9cm). The local check produced the maximum stem number per hill of 6. The variety Gorebela produced the highest average tuber yield per hill of 0.66 kg followed by Zengena (0.64 Kg) and Guassa (0.64 Kg). Cultivar Guassa gave the highest marketable tuber yield of 27.41 ton ha^{-1} followed by Zengena (27.31 ton ha^{-1}) and Gorebela (22.31 ton ha^{-1}) (Table 1). The lowest marketable tuber yield was recorded in variety Tolcha (9.16 ton ha^{-1}) and the local check (9.35 ton ha^{-1}). Guassa gave the highest total tuber yield of 28.33 ton ha^{-1} followed by Zengena (27.92 ton ha^{-1}) and Gorebela (24.91 ton ha^{-1}). Cultivar Gorebela had the highest unmarketable tuber yield of 2.59 ton ha^{-1} of which most of them had cracking problem. On the other hand the local check had produced 2.04 ton ha^{-1} small sized unmarketable tuber. There was an average yield advantage of 11.65 ton ha^{-1} and 10.55 ton ha^{-1} marketable and total tuber yield over the local check, respectively.

The lowest Area under Disease Progressive Curve (AUDPC) was recorded from the cultivar Gera (158) and the highest is from local check (2608), which indicated that cultivar Gera, had better tolerance to late blight infestation to the others while the local cultivar was susceptible than the rest cultivars.

Accordingly, FREG members and other farmers outside the group were evaluated the varieties and ranked them in the order of Jalenie, Zengena, Guassa, Gudenie, Tolcha, Digmegn, local and Gera (table 4). The farmers suggested that the first three varieties need to be scaled out/up since the varieties full fill all the selection criteria and have high yield potential; 23.04, 21.24, 20.44 and 21.19 t/ha of yield respectively (table 5).

Potato variety selection criteria

The FREG members identified 6 selection criteria. These selection criterion are ranked through pair wise ranking matrix based on farmers' own recommendation. Resistance to disease late blight and tuber yield were identified as the most sensitive criteria of farmers (table 2).

Rationale for setting the criteria

Resistance to disease: In the study area, potato late blight and bacterial wilt is the most serious problem that causes a considerable yield loss on farmers plot. Hence, farmers seek to have potato varieties which are resistance to these problems.

Taste of tuber: Potato is used for household consumption as "wot" or by simply boiling it bare. Therefore, it has to have an acceptable taste.

Tuber size: When there is surplus production or there are other compelling reasons, potato is sold in the market but the market prefers large sized potato tuber.

Seed color: Since potato is food and cash crop, its tuber color is important in food preparation and for its high marketability. As to farmers' explanation, tuber with white color is highly demanded for either house hold consumption or market purpose.

Cooking time requirement: Due to the shortage of fuel wood and need to save cooking time, varieties with short cooking time are highly preferred by the farmers or consumers.

Table 1. The yield and agronomic performance of potatoes varieties grown under Chilga agro climatic condition in 2004

Varieties	Plant Height (cm)	Stem N°/hill	Average Yield (Kg/hill)	Marketable tuber yield (t/ha)	Unmarketable tuber yield (t/ha)	Total tuber yield (t/ha)	AUDPC* value for late blight
Gera	41ab	4.00bc	0.53 ab	22.04ab	0.93b	22.96ab	158
Gorebela	47.7a	3.67c	0.66 a	22.31ab	2.59a	24.91a	193
Tolcha	25.7d	3.67c	0.39 bc	9.16c	0.28b	9.44c	366
Zengena	46.9ab	4.33abc	0.64 a	27.31ab	0.60b	27.92a	178
Guassa	38.4bc	5.33ab	0.64 a	27.41a	0.93b	28.33a	245
Degemegn	30.3cd	4.33abc	0.42 bc	17.87b	0.23b	18.10b	315
Local	25.4d	5.67a	0.28 c	9.35c	2.04a	11.39c	2608
CV (%)	12.92	17.42	15.54	17.19	49.83	15.85	
P value	0.0002	0.0442	0.0003	< 0.0001	0.0011	< 0.001	

Means within a column followed by the same letter(s) are not significantly different at the specified probability (p) level. Means were separated using Duncan's Multiple Range Test. *AUDPC- Area under Disease Progressive Curve

Table 2. Matrix ranking of farmers' potato varieties selection criteria and their relative importance under Chilga condition in 2006

	Selection criteria	Score	Rank	Gender emphasis on criteria	Ranked criteria
1	Tuber yield	8	2	men	Reaction to Late light
2.	Reaction late blight	10	1	Men/women	Tuber yield
3.	Taste of tuber	4	4	Men/women	Tuber size
4.	Tuber size	7	3	Men/women	Taste of tuber
5.	Seed color	2	5	Women	Seed color
6	Cooking time	0	6	women	Cooking time

Table 3. FREG evaluation of the varieties against the criteria set by farmers

Criteria	Jalenie	Zengena	Digmegn	Guassa	Gudenie	Gera	Tolcha	Local
Tuber yield	2	1	4	3	6	5	7	8
Reaction to Late blight	2	3	6	4	1*	7	5	8
Taste of tuber	2	3	8	5	4	7	6	1
Tuber size	1	2	4	3	7	6	5	8
Seed color	1	4	7	6	5	8	2	3
Cooking time	2	1	5	3	4	7	8	6
Score	10	14	34	24	27	40	33	34+1
Rank/preference	1	2	6	3	4	8	5	7

* 1= highly preferred and 7= less preferred

Table 4. Mean tuber yield and yield advantage of varieties evaluated under Chilga condition in 2006.

Variety	Marketable Yield (t/ha)	Unmarketable Yield (t/ha)	Total tuber yield (t/ha)	Yield advantage (t/ha)	Yield increase (%)	Rank by farmers selection criteria
Jalenie	20.42	2.63	23.04	12.86	55.82	1
Zengena	18.82	2.43	21.24	11.06	52.07	2
Gudenie	19.02	2.18	21.19	11.01	51.96	4
Gera	13.18	2.45	15.63	5.45	34.87	8
Guassa	17.23	3.21	20.44	10.26	50.20	3
Tolcha	11.55	1.15	12.70	2.52	19.84	5
Digmegn	15.49	2.28	17.76	7.58	42.68	6
local	8.00	2.18	10.18	-	-	7

Crop Management Research and Achievement on Potato in Amhara Region with especial reference to western Amhara parts.

Tesfaye Abebe[1], Yigzaw Desalegne, and Errmiase Abate

Abstracts

Potato growers in the northwestern part of the country traditionally undertake suboptimal agronomic practices that have resulted in the very low regional average yield. These practices include fertilizer rate, type and amount, stem density (spacing), seed tuber size, ridging frequency, time of planting and planting pattern and ratio in an intercrop. To optimize the productivity of this crop in the sub-region, agronomic studies related to fertilization, plant density, seed tuber size, ridging frequency, planting time and ratio and pattern of intercropping potato with maize have been undertaken by Adet Agricultural Research Center with an objective of developing area specific recommendations. This paper presents the review of these research undertakings in this part of the country.

Introduction

Potato (*Solanum tuberosum* L.) is one of the most important vegetable crops grown intercropped with maize (*Zea mays* L.) in almost all maize growing farmers' fields of Yilmana Densa covering about 11.07% of the arable land (Aleligne, 1987). Besides, it is the third major food crop in the high land nitosols of Debre Tabor awraja where it is grown by about 72% of the farmers. It occupies close to 12% of the area under crop production at this district (Aleligne *et al*., 1992). However, potato growers in the Western Amhara sub-region of the country traditionally undertake suboptimal agronomic practices that have resulted in the very low regional average yield. These includes use of insufficient amount of fertilizer levels, inappropriate planting time, seed size, plant population, ridging frequency, and planting patterns and ration in their intercropping practices. This can be easily discerned from the amount fertilizer used for potato production during 2001 cropping season at the national level. During the aforementioned period the total amount of fertilizer used to cultivate 31 004 hectare potato land was only 23 892 quintal of DAP. Computation of fertilizer rate usage at the national level during this period was 57 kg DAP per hectare (CACC, 2003). To optimize potato production the use of appropriate cultural practices is very crucial. As a result two sets of fertilizer and plant population studies, seed size and ridging frequency, planting time and intercropping pattern and ratio experiments were undertaken to develop area specific recommendation that can help maximize potato production in this part of the country.

A. Fertilizer rate studies

Material and Methods

Potato is naturally a heavy feeder crop. Economical feasible fertilizer rate vary with the soil type, fertility status, moisture amount, other climatic variables, variety, crop rotation and crop management practices (Smith, 1977). To date there are no specific recommendation made for the northwestern areas. To fill this gap two sets of trials were conducted at different time in different areas. The first set was conducted for two years, in 1992 and 1993, at Adet and Injibara while; the second set was carried out in 1999 and 2000 in south Gonder zone. Both sets were conducted on-farm and laid out in RCBD with 4 X 4 factorial arrangements. The N/P levels used were 0, 27, 54, 81 and 0, 69, 138 and 207 kg/ha for the first set and 0, 54, 81, 108 and 0, 69, 138 and 207 kg/ha for the second set, respectively. The phosphorus source was triple supper phosphate (TSP) and the whole rate was applied at planting near but below the seed tuber since phosphorus is immobile. The nitrogen source was Urea and each nitrogen level was equally splitted in to three and applied at planting, 2-3 weeks after emergence and at flowering. A plot size was $9m^2$ (3m x 3m) with four rows per plot spaced at 75cm x 30cm between rows and plants respectively was used. The varieties used were *Sisay* and *Tolcha* for the first and second set, respectively. In the first set fungicide was sprayed three times for late blight control. All other cultural practices were applied as recommended and the crop was harvested at its physiological maturity.

A.1. Results of Adet and Injibara areas Trials

Result of the trial at Adet and Injibara showed significant ($P< 0.01$) response to the applied levels of N and P_20_5 on marketable tuber yield, tuber number/hill and average tuber weight (Table 1, 2 & 3). Although N and P_20_5 had significant effect on number and weight of tuber, their effect level was variable. Accordingly the effect of N is greater on average weight while P_20_5 This result is in agreement with earlier works of similar kind in other corners of the world. Significant difference was also observed among the two locations in their productive potential. This could be attributed to their difference in soil fertility status, available soil moisture and other environmental factors, which ultimately influence the availability and uptake of nutrients. The growing plants have also showed easily observable deficiency symptoms of both N and P_2O_5. Location x phosphorus and location x nitrogen interaction was also significant. However, the interaction effect of N x P_2O_5 was not-significant for all of the characters considered (Table 1).

The mean marketable tuber yields, result of partial budget, dominance and marginal rate of return (MRR) analysis is given in table 4. The partial budget analysis showed application of 81 kg/ha N with 138 kg/ha P_2O_5 had the maximum net benefit (10685.99 birr/ha). However, MRR analysis is carried to draw an attractive net benefit rate to farmers. As a result 81/0 and 81/69 kg/ha N/P_2O_5 levels are seen economically feasible rates with a MRR of 1418% and 1316%, respectively (Table 4). The fertilizer rate with the highest net benefit had a MRR of 268%. This is far lower than the above treatments. The minimum acceptable MRR to farmers is between 50 and 100% (CIMMYT, 1988).

Therefore, the selected treatments will have higher probability of acceptance by farmers. These levels had 51.2% and 73.3% yield increase, respectively over the control (0/0). Considering the deficiency symptoms seen on P_2O_5 untreated plots and significant response to it at both locations application of P_2O_5 is crucial for normal growth and maximum yield of the crop. Consequently, application of 81kg/ha N and 69kg/ha P_2O_5 is found economically and agronomically feasible. Hence, this rate is recommended for potato production in Adet and Injibara areas.

A.2. Results of South Gonder zone Trial

Similarly result of the second set showed significantly ($P<0.01$) different marketable and total tuber yields, number of tubers/hill and average weight of a tuber over the different levels of N and P_2O_5 levels tested (Table 5). Moreover, the effect of N x P_2O_5 interaction on marketable and total tuber yields and on number of tubers harvested per hill was statistically significant. Also locations responded differently to the applied fertilizer levels. This could be ascribed to their inherent soil physical and chemical properties and the prevailing climate difference among the locations. Consequently the interaction effect between location and nitrogen and location and phosphorus appeared to be significantly different for most of the parameters considered (Table 5). This clearly indicates the response of the crop to N and P_2O_5 fertilization.

The mean marketable tuber yields, partial budget, dominance and marginal rate of return (MRR) analyses were also made and indicated in table 6. Results these analyses pointed out that 108/69 and 81/69 kg/ha ranked as first and second economically optimum rates of N/P_2O_5 for potato production in south Gonder zone. The MRR and net benefit after sensitivity analysis for these rates were 274.6 and 342.5% for MRR and 5149.7 and 4777.3 birr/ha for net benefit (Table 6). The MRR of both treatments was above the minimum acceptable rate of return (50–100%). However, as indicated above application of 108kg/ha N with 69kg/ha P_2O_5 gave higher marketable and total tuber yields. Therefore, 108/69 kg/ha N/P_2O_5 is recommended as an economically feasible and agronomically optimum rate for potato production in south Gonder zone.

Table 1: Results of combined analysis of variance for total and marketable tuber yield, number of tubers harvested per hill and average weight of a tuber.

Source of variation	Total tuber yield	Marketable tuber yield	Number of tubers harvested /hill	Average weight of a tuber
Location (L)	**P<0.01**	**P<0.01**	**P<0.01**	**P<0.05**
Nitrogen (N)	**P< 0.01**	**P<0.01**	**P<0.01**	**P<0.01**
L X N	**Ns**	**P<0.05**	**P<0.01**	**Ns**
Phosphorus (P)	**P< 0.01**	**P<0.01**	**P<0.01**	**Ns**
L x P	**P< 0.01**	**P<0.01**	**P<0.01**	**Ns**
N x P	**Ns**	**Ns**	**Ns**	**Ns**
L x N x P	**P<0.05**	**Ns**	**P<0.05**	**Ns**
CV %	**12.3**	**14.5**	**12.1**	**24.8**
Maximum value	33t/ha	29.4 t/ha		0.065 kg

Table 2: Results of fertilizer trial on marketable tuber yield (t/ha) at Adet, 1992-1993.

N levels, kg/ha	Effect on number of tubers					Effect on average weight of a tuber, kg				
	P_2O_5 Levels					P_2O_5 Levels				
	0	69	138	207	Mean N	0	69	138	207	Mean N
0	10.08	11.17	12.08	12.42	11.44^{C}	0.040	0.040	0.041	0.037	0.040^{D}
27	10.50	17.17	14.00	13.75	12.85^{B}	0.049	0.045	0.041	0.041	0.044^{C}
54	10.75	14.25	14.00	15.00	13.50^{B}	0.050	0.047	0.048	0.047	0.048^{B}
81	12.08	13.75	15.50	16.08	14.35^{A}	0.054	0.053	0.053	0.047	0.052^{A}
Mean P_2O_5	10.85^{C}	13.08^{B}	13.90^{AB}	14.31^{A}		0.048^{A}	0.046^{B}	0.046^{B}	0.043^{C}	
C.V%					12.00					12.84

Table 3: Results of fertilizer trial on number of tubers and average weight of a tuber (kg) at Adet, 1992-1993.

N levels,	P_2O_5 Levels				
kg/ha	0	69	138	207	Mean N
0	15.79	16.99	18.04	16.59	16.85^{D}
27	19.13	20.16	21.52	20.08	20.22^{C}
54	20.92	24.53	25.43	26.09	24.24^{B}
81	23.87	27.36	29.39	25.31	26.48^{A}
Mean P_2O_5	19.93^{B}	22.26^{A}	23.59^{A}	22.02^{B}	
C.V%					14.33

Table 4: Partial budget, dominance and marginal rate of return analysis for fertilizer rate trial conducted at Adet and Injibara.

Treatments (N/P levels) in kg/ha	Marketable tuber yield, t/ha	Gross benefit (birr/ ha)	Total variable cost	Net benefit (birr/ha)	Marginal rate of return (%)
(0,0)	15.79	6314.4	-	**6314.4**	-
(0,69)	**16.99**	**6796.8**	**351.6**	**6445.2**	37
(27,0)	19.13	**7651.2**	**427.6**	**7178.56**	**606**
(54,0)	**20.92**	**8366.8**	**550.53**	**7816.27**	**819**
(0,138)	**18.04**	**7216.8**	**571.6**	**6645.2**	**D**
(81,0)	**23.87**	**9548.8**	**682.4**	**8920.4**	**1418**
(27,69)	**20.16**	**8064.4**	**692.65**	**7371.75**	**D**
(54,69)	**24.52**	**9806.4**	**770.54**	**9035.86**	**81**
(0,207)	16.60	6638.8	**791.61**	**5847.19**	**D**
(81,69)	27.36	**10944.4**	**848.41**	**10095.99**	**1361**
(27,138)	21.52	**8608.8**	**912.65**	**7696.15**	**D**
(54,138)	**25.43**	**10171.2**	**990.54**	**9180.66**	**D**
(81,138)	**29.39**	**11754.4**	**1068.41**	**10685.99**	**268**
(27,207)	**20.08**	**8031.2**	**1132.66**	**6898.54**	**D**
(54,207)	**26.09**	**10436.8**	**1210.55**	**9226.25**	**D**
(81,207)	**25.31**	**10123.2**	**1288.42**	**8834.78**	**D**

40 birr/q of potato — 2.75 birr/man day wage rate

132.68 birr/q of urea — 0.115hr/m2 man-days calculated for fertilizer application.

146.65 birr/q of TSP — D: ***stands for dominated treatments***

Table 5: Results of combined analysis of variance for total and marketable tuber yield, number of tubers harvested per hill and average weight of a tuber in South Gonder.

Source of variation	Total tuber yield	Marketable tuber yield	Number of tubers per hill	Average weight of a tuber
Location (L)	**P<0.01**	**P<0.01**	**P<0.01**	**P<0.01**
Nitrogen (N)	**P<0.01**	**P<0.01**	**P<0.01**	**P<0.01**
L X N	**P<0.01**	**P<0.01**	**P<0.01**	**P<0.01**
Phosphorus (P)	**P<0.01**	**P<0.01**	**P<0.01**	**P<0.01**
L X P	**P<0.05**	**P<0.05**	**Ns**	**P<0.01**
N X P	**P<0.01**	**P<0.01**	**P<0.05**	**Ns**
L X N X P	**ns**	**Ns**	**Ns**	**Ns**
CV %	**20.6**	**21.9**	**19.7**	**17.5**
Maximum value	**18.43**	**17.77**	**41.9**	**50.6**

Table 6: Partial budget, dominance and marginal rate of return analysis for fertilizer rate trial conducted in south Gonder zone.

Treatments (N/P_2O_5 levels) in kg/ha	Adjusted market. tuber yield (t/ha)	Gross benefit (Birr/ha)	Total variable cost	Net benefit (Birr/ha)	Marginal rate of return (%)
(0,0)	6.57	2694	-	2694.0	-
(54,0)	9.48	3887	271.2	3615.8	340
(81,0)	10.42	4272	406.8	3865.2	183.9
(0,69)	6.10	2501	478.5	2022.5	D
(108,0)	11.64	4772	542.4	4229.6	268.7
(54,69)	12.01	4924	614.1	4312.9	116.2
(81,69)	13.48	5527	749.7	4777.3	342.5
(108, 69)	14.72	6035	885.3	5149.7	274.6
(0,138)	6.86	2813	957	1856.0	D
(54, 138)	12.92	5297	957	4340.0	D
(81,138)	14.29	5859	1092.6	4766.4	D
(108,138)	15.99	6556	1228.2	5327.8	51.9
(0, 207)	7.13	2923	1435.5	1487.5	D
(54,207)	12.99	5326	1435.5	3890.5	D
(81,207)	15.90	6519	1435.5	5083.5	D
(108,207)	14.87	6097	1571.1	4525.9	D

- D: stands for dominated treatments
- Yield adjustment coefficient of 10% was taken appropriate
- The marginal rate of return and net benefits are calculated by adding 10% increase from the current fertilizer price.
- Field price of DAP: 2.90 birr/Kg
- Field price of Urea: 2.1 birr/Kg
- Field price of potato: 0.41 birr/Kg

B. Seed tuber size, inter-row spacing and ridging frequency study

Material and Methods

Here two sets of trials are conducted at different times and area. The first set a study of the effect of seed tuber size, inter row spacing and ridging frequency on the yield and yield components of potato (1993 and 1994) at Adet (2240 masl). The second set was a study on the effect of inter and intra-row spacing on semi-prostrate growth habit potato genotype, Zengena. The first experiment was laid out in partially confounded design of 3^3. Treatments were three levels of seed tuber size i.e. 25-35mm, 35-45mm and 45-55mm diameter. Three levels of inter-row spacing, i.e., 45cm, 60cm and 75cm and three levels of ridging frequency, i.e., ridging one time at the third week, riding twice at the third and sixth weeks and ridging trice at the third, sixth and ninth weeks from the time of crop emergence. Plot size was $27m^2$ (9m x 3m) and spacing between plants was 30cm. Other agronomic practices were applied as recommended. The variety used was *Sisay* and harvested at its physiological maturity. The second set trial consisted of seven treatments made up of three levels of intra-row spacing (30, 40 & 50 cm) factorially combined with two levels of inter-row spacing (80 and 90 cm) and the commonly used spacing combination of 75cm x 30cm between rows and plants, respectively. This study is carried during 2003 and 2006 at Adet (2240 masl) and Injibara (2650 masl). The plot size, fertilizer rate and other agronomic practices used were similar to the first set.

Results and Discussion

The result of the first set investigation indicated that seed tuber size significantly affected total and marketable tuber yields, tuber size grades of >50mm diameter and stem number/m^2 (Table 11). The maximum total and marketable tuber yields and number of stems/m^2 were obtained from seed tubers with 45-55mm diameter. Similar kind of result was reported by Burton (1989) in which he found that increased seed tuber sizes increased tuber yield. However, larger seed tubers were advantageous only under conditions where soil and weather conditions at planting were unfavorable (Beukema and Van der Zaag, 1990). Therefore, use of large sized seed tubers could be taken as a strategy to maximize the productivity of potato in marginal areas.

Inter-row spacing significantly influenced tuber size grades of >50mm, 40-50mm and 30-40mm and number of stems/m^2 (Table 7). The maximum number of stems/m^2 and 40-50mm sized tubers were obtained from 45cm inter-row spacing. However, more number of tubers of size grades of 30-40mm and >50mm were produced from 60cm and 75cm inter-row spacings, respectively (Table 8). This implies that wider inter-row spacing creates favorable growing environment for production of large sized tubers through reducing inter-stem competition for growth factors. The significant changes observed between the spacings for the characters considered can largely attributed to the differences observed for the number of stems/m^2 as this caused shading, strong competition which ultimately affected other characters. In a related study, Burton (1989), Beukema and Van der Zaag (1990) and Mwansa and Mwala (2000) reported similar result. Therefore, use of 75cm inter-row spacing is found suitable for ware potato production with tuber size >50mm diameter. However, use of 60cm inter-row spacing is found ideal for seed potato production.

Ridging frequency had no significant effect on any of the parameters considered (Table 7). In Cuba, Hernandez *et al.* (1986) similarly reported that ridging did not affect tuber yield but planting at 15cm depth gave the highest yield (26.03- 46t/ha) with fewest green tubers. This could be attributed to the nature of the soil and level of land preparation during planting. Highly significant (P<0.01) interaction effect was seen between seed tuber size and inter-row spacing. Consequently, the maximum stem number/m^2 was recorded by using 45-55mm diameter seed tuber in a 45cm inter-row spacing.

Therefore, considering the amount of seed tuber required, type of out put and synergism with other cultural practices, seed tuber size of 35-45 diameter, 60cm inter-row spacing (28 q/ha seed rate) and ridging once at 3-4 weeks of crop emergence is recommended for seed potato production. However, 35-45mm diameter seed tuber, 75cm (22q/ha seed rate) inter-row spacing and ridging once at 3-4 weeks from crop emergence is found optimum and recommended for ware potato production.

Table 7: ANOVA of total and marketable tuber yield, stem number/m^2 and different tuber size grades.

Source of variation	Total tuber yield	Marketable tuber yield	20-30 mm size grade	31-40 mm size grade	41-50 mm size grade	>50mm size grade	Stem no. /m2
Year	**P<0.01**	**Ns**	**Ns**	**P<0.01**	**P<0.01**	**Ns**	**P<0.01**
Seed tuber size (SS)	**P<0.01**	**P<0.01**	**Ns**	**Ns**	**Ns**	**P<0.01**	**P<0.01**
Inter-row spacing (IS)	**Ns**	**Ns**	**Ns**	**P<0.05**	**P<0.01**	**P<0.05**	**P<0.01**
Ridging frequency (RF)	**Ns**	**Ns**	**Ns**	**Ns**	**Ns**	**Ns**	**Ns**
SS X IS	**Ns**	**Ns**	**Ns**	**Ns**	**Ns**	**Ns**	**P<0.01**
IS X RF	**Ns**	**Ns**	**Ns**	**Ns**	**Ns**	**Ns**	**Ns**
CV %	12	17					

Table 8: Effect of seed tuber size, inter-row spacing and ridging frequency on the number of different size grades and average weight of a tuber in gm.

Seed tuber size	***Tuber size (mm)***			
	20-30mm	***30-40mm***	***40-50mm***	***>50mm***
25-35mm(25gm)	110 (11.5)	39 (25.6)	20 (50)	13 (80)
35-45mm(50gm)	82 (13.7)	41 (25)	23 (45)	12 (86)
45-55mm(90gm)	94 (14.6)	40 (25)	23 (45)	[illegible] (87)
Iner-row spacing (cm)				
45cm	85 (12)	39 (26)	22 (46)	10 (100)
60cm	93 (14.8)	43 (24)	21 (48)	11 (91)
75cm	107 (11.8)	38 (27)	21 (48)	11 (91)
Ridging frequency				
Once at 3rd week	85 (12)	40 (25)	21 (48)	9 (112)
Twice at 3rd & 6th	89 (12)	39 (25.6)	21 (48)	11 (91)
Trice at 3rd, 6th & 9th	111 (10)	41 (25)	21 (48)	11 (91)

Table 9: Results of combined ANOVA of spacing trial on the agronomic and morphological data of potato variety Zengena at Adet and Injibara, 2003 & 2006.

Treatments	21-30mm diameter		31-40mm diameter		41-50mm diameter		>50mm diameter		Stem no./m²	Stem ht., cm	MTY, t/ha	TTY, t/ha
	No.	Wt. kg	No.	Wt. kg	No.	Wt. kg	No.	Wt. kg				
75cm x 30cm	35	0.38	75	2.23	39	2.14	59	5.98	13[A]	68.28	22.86[AB]	23.68[AB]
80cm x 30cm	39	0.43	70	1.68	50	2.36	72	7.09	13[A]	67.17	23.98[A]	25.00[A]
80cm x 40cm	28	0.31	63	1.82	29	1.46	40	3.83	9[BC]	67.05	16.45[CD]	17.38[CD]
80cm x 50cm	30	0.33	54	1.59	25	1.39	42	4.22	7[C]	69.23	15.67[D]	16.90[D]
90cm x 30cm	36	0.42	88	2.47	39	2.24	58	5.76	11[AB]	68.86	20.39[BC]	21.01[BC]
90cm x 40cm	28	0.33	58	2.08	40	1.91	50	5.61	7[C]	66.02	17.32[CD]	18.65[CD]
90cm x 50cm	23	0.27	48	1.22	31	1.72	44	4.49	6[C]	68.62	14.75[D]	15.84[D]
Mean	31	0.35	65	1.87	35	1.89	52	5.28	9	67.89	18.78	19.78
P level	**	**	**	**	*	NS	NS	NS	***	NS	***	***

variety Al-624 gave the highest tuber yield almost in all planting dates than the local cultivar. Generally, regardless of type of varieties, yield was declined as planting date was delayed. Yield reduction due to delayed planting was relatively higher on the local cultivar compared to Al-624. This could be attributed mainly to their genetic difference for late blight resistance/tolerance. Therefore, from May first to mid May and from May first to June first are recommended as optimum planting dates for late blight susceptible and moderately tolerant/resistant potato cultivars production in Adet, respectively.

Table 10: Tuber yields (t/ha) of two potato varieties as influenced by planting dates

			1988			
Cultivar	May 1	May15	June 1	June 15	July 1	Mean
Al- 624	**17.61**	**15.02**	**15.61**	**7.6**	**4.7**	**12.11**
Local	**2.97**	**4.90**	**3.67**	**1.39**	**0.18**	**2.62**
Mean	**10.29**	**9.96**	**9.64**	**4.49**	**2.44**	
LSD at 1% for planting dates =2.11						
LSD at 1% for varieties = 1.13						
			1989			
Al-624	**10.48**	**9.09**	**8.28**	**6.72**	**4.30**	**7.77**
Local	**8.46**	**7.31**	**2.06**	**1.58**	**1.29**	**4.14**
Mean	**9.47**	**8.2**	**5.17**	**4.15**	**2.80**	
LSD at 1 % for planting dates = 3.25						
LSD at 1 % for varieties = 0.93						

Intercropping of potato with maize

A potato with maize intercropping trial was carried out at Adet for two consecutive years to identify economically feasible intercropping pattern. The maize variety used was BH660. It is tall, late maturing, high yielding, resistant to major leaf diseases of maize and adaptable from mid to high altitude areas of Ethiopia. Tolcha was the potato variety used for this investigation. It is late blight tolerant, high yielding and adaptable to mid altitude areas. Both crops were planted by hand at a spacing of 50cm between rows and 30cm between plants for intercrops and 75cm between rows and 30cm between plants for sole crops. Recommended fertilizer rate, 81/69kg/ha and 80/40kg/ha of N/P_2O_5 were applied for potato and maize respectively. Other management practices for each crop were applied as recommended. Randomized complete block design with four replications was used each year. Plot size was 6m x 6m ($18m^2$). In addition to the two sole cropping treatments, the trial had four intercropping treatments (one row of maize after every one row of potato, one row of maize after every two rows of potato, one row of potato after every two rows of maize and farmers intercropping practice).

The result of this investigation was statistically analyzed using total monetary value (TMV) of the system and economic yield of each component crop. Moreover, the land equivalent ratio (LER) of each intercropping system is calculated. In 1997 cropping season, intercropping of potato with maize using 1:1, 2:1 and 1:2 row spatial arrangements gave significantly higher total monetary value compared to the farmers' intercropping practice and both of the sole crops. However, in 1998 cropping season, intercropping of potato with maize with 2:1 row spatial arrangement gave significantly higher total monetary value compared to all other treatments. Intercropping of potato with maize with 1:1 row spatial arrangement also gave the next significantly higher total monetary value. However, the remaining treatments were not significantly different from each other. Similarly, their across years mean performance indicated that intercropping of potato with maize with 2:1 row spatial arrangement gave significantly higher total monetary value compared to all other treatments. In addition intercropping of potato with maize in 1:1 row ratio gave significantly superior total monetary value compared to both sole crops, intercropping of potato with maize in 1:2 row arrangement and farmers intercropping practice. The traditional potato/maize intercropping practice was significantly least in total monetary value compared to all other treatments including the sole crops (Table 12).

The advantage of intercropping of potato with maize was also assessed using land equivalent ratio (LER). The result of this assessment indicated that, intercropping of potato with maize with 1:1, 2:1 and 1:2 row arrangements had 1.51, 1.71 and 1.16 LER (Table 12). This indicates that intercropping of potato with maize with the above spatial arrangements is more beneficial than sole cropping. However, the LER of the traditional intercropping practice was found less than unity. This implies that sole cropping is better than the farmers' practice of maize with potato intercropping. This could be attributed to the effect of the high maize population. It reduced light interception of potato and encouraged to competition for soil moisture and nutrients.

The effect of intercropping on the yield of component crops is given in table 12. The result indicated that, all intercropping treatments significantly influenced the tuber yield of potato. The sole crop of potato gave significantly higher tuber yields compared to the tuber yield obtained with intercropping. However, the grain yield of sole maize was not significantly different from the grain yield obtained by intercropping it with potato in 2:1 (potato: maize) row arrangement. Hence, farmers could get additional potato yield without reducing the grain yield of maize using 2:1 spatial row arrangement. Moreover, this spatial arrangement gave the maximum tuber yield of potato compared to all other intercropping treatments and resulted in only 13.2 % yield loss from the sole crop. However, increasing maize of population in the system will radically reduce potato tuber yield. This is due to the shading effect of maize on potato and interference with light interception for photosynthesis. Therefore, intercropping of potato with maize in 2:1 and 1:1 (potato: maize) row spatial arrangement are found superior in their order and recommended for potato production at Adet.

Table 11: Total monetary value and land equivalent ratio (LER) of maize/potato intercropping at Adet in 1997 and 1998.

Treatment	Total monetary value (birr/plot)	LER
(1:1) One row potato one row maize alternating	25.69	1.51
(2:1) Two row potato one row maize alternating	30.05	1.71
(1:2) One row potato two row maize alternating	20.19	1.16
Farmers intercropping practice	14.03	0.83
Sole maize	16.61	1.00
Sole potato	18.47	1.00
LSD	2.58	

Note: Average market prices of the commodity Maize: 1.12 birr/Kg Potato: 0.41 birr/ Kg

Table 12: The effect of maize/potato intercropping on the yield of both potato and maize at Adet, 1997/98.

Treatment	Yield (kg/ plot)	
	Maize	Potato
One row potato one row maize alternating (1:1)	**11.43**	**31.16**
Two row potato one row maize alternating (2:1)	**12.48**	**39.0**
One row potato two row maize alternating (1:2)	**11.97**	**16.4**
Farmers intercropping practice	**7.7**	**14.03**
Sole maize	**14.9**	**-**
Sole potato	**-**	**44.94**
LSD	**2.43**	**3.73**

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Research achievements in potato agronomy at Debre Birhan Agricultural Research Center

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Abstract

Two separate agronomic trials of planting date and fertilizer rate were conducted in north Shewa zone by Debre Birhan Agricultural Research Center with the main objectives of determining the appropriate planting time of potato and fertilizer sources and rate. This paper presents the results of these two separate experiments' conducted under rain-fed (Meher season). The first experiment was conducted at Ankober (3200 m.a.s.l.) to study the effect of planting dates and fertilizer on the yield of potato for three consecutive years. The second experiment is conducted to determine optimum N and P_2O_5 requirement of potato in two soil types at two locations: Faji (2800 m.a.s.l.) representing light vertisol, and Keyit (3000 m.a.s.l.) representing nitosol. The results of the first experiment indicated that last week of May to Mid June planting is better as it gave the highest marketable and total tuber yields. Results of the fertilizer combinations study also revealed that application of 6 ton of well decomposed farmyard manure (FYM) together with 100 kg DAP/hectare gave a yield advantage of 108 percent over unfertilized control in 1997 (year of well distributed rainfall). In the rest of the seasons, characterized by late onset and early cessions of rainfall, however, result of FYM application is seen unsuccessful. Highest common scab damage was also recorded from plots treated with FYM. The results of the second experiment also revealed that increasing the amount of nitrogen up to 110 kg N per hectare significantly ($P<0.05$) increased both marketable and total tuber yield. Contrarily, significant response to phosphorus is recorded only from the lowest level of phosphorus (70.5 kg P_2O_5 per hectare) applied for some parameters considered.

Introduction

Potato (***Solanum tuberosum*** L.) is grown at a smaller scale in most parts of North Shewa administrative zone of the Amhara Regional State (ANRS). This clearly indicates that the experiences of potato growers in this crop production is to shallow. As a result most of the potato production practices followed by these growers are so traditional. Research results are also almost inexistent to even advised by the extension services. This in turn has resulted in the use suboptimal agronomic practices as well as low yielding cultivars that contributed for the low average tuber yield present in the zone. The X Sheno and the now Debre Birhan Agricultural Research Center has launched a multifaceted research undertaking with an objective of developing appropriate technologies for this areas. Among these endeavors determination of optimum planting time and fertilizer type and sources prominent activities undertake. This paper presents the results of these activities and recommendations drawn for the area.

A. Effect of planting dates and fertilizers on the tuber yield of potato

Materials and Methods

The effect of planting date and fertilizer on potato was studied for three consecutive years (1997-1999) at Ankober. The experiment was laid out in split plot design with three replications with sub-plot size of 11.7 m^2. The treatments studied were four planting dates (mid May, early June, mid June and early July) and three fertilizer levels (195/165 Kg DAP/Urea, 6 ton farm yard manure + 100 Kg DAP and the control or no fertilizer). The planting dates treatments were assigned to the subplots while the fertilizer treatments were arranged on the main plots. Farm yard manure (FYM) was applied at planting regardless of onset of rain whereas DAP and Urea were applied on moist soil. The recommended spacing of 75cm x 30cm between rows and plants respectively was used. The remaining cultural practices were also followed as recommended.

Results and Discussion

Results of this study indicated the presence of statistically detectable significant yield differences among fertilizer levels (main plots), Planting dates (sub-plots) and their interaction at 5% and 1% level of significance during 1997/98 cropping season (Table 1). Of the four planting dates level tested in this experiment the first planting date (May 26) had the highest mean tuber yield of 17.33 t/ha followed by the second planting date (June 11) which gave a mean tuber yield of 13.06 t/ha. Among the fertilizer levels tested the treatment 6 ton farmyard manure and 100 Kg DAP gave significantly ($P < 0.050$) high mean tuber yield than the recommended fertilizer types and the control (without fertilizer). Significant interaction ($P<0.05$) of planting date by fertilizer was also observed. Accordingly, statistically significant ($P < 0.050$) tuber yield is harvested from the first planting date and farmyard manure followed by the second planting date and farmyard manure.

Late blight infection was very high on fertilizer 195/165 Kg DAP/Urea and the control whereas plots fertilized with 6 ton FYM plus 100 Kg DAP somehow showed relative tolerance. The first and second planting dates bulked early in the season before the onset of both late blight and frost giving better tuber yield. The yield of the third and the fourth planting dates was extremely low due to low stand, high late blight infection and frost (Table 1).

The tuber yield and tuber quality obtained during the second year, i.e., 1998/99, was very poor over both the planting dates and fertilizer types studied due to several reasons. The reasons were the occurrence of heavy rain that caused erosion of the plots. Hail damage has also contributed for severe damage of leaves of the variety. Hence, this result is discarded from statistical analysis of the experiment.

Table 1. Main effect of fertilizer types and planting dates on potato yield at Ankober (1997/98)

Factor A	Marketable tuber tield, t/ha	Total tuber yield, t/ha
6 ton FYM+100 kg DAP	118.566	123.514
195/165 DAP/Urea	70.435	76.528
Control	57.101	61.512
LSD (5%)		13.89
Factor B		
26 May	165.83	174.183
11 June	123.34	130.994
2 July	29.066	31.580
16 July	9.896	11.982
LSD (5%)		16.04
CV		18.91

During 1999/2000, significant marketable and total tuber yield difference ($P < 0.01$) was observed between planting dates (Table 3). Potato planted on the first two planting dates (25 May and 11 June 1999 planting) gave better marketable tuber yields. Furthermore, significant ($P < 0.05$) marketable and total tuber yield difference was observed between fertilizer types. The recommended fertilizer level (195/165 kg DAP and Urea) gave significantly better marketable and total tuber yields (Table 3). Rain started late so that the tubers planted in dry condition on the first and second planting dates. The marketable yield obtained by Farm yard manure was very low due to the prevalence of common scab damage on tubers. A tuber yield damage of up to 55.64 percent on weight basis was recorded on tubers quality harvested from third planting date (June 25/1999 planting).

Table 3. Main effect of fertilizer types and planting dates on potato yield at Ankober (1999/2000)

Factor A	Marketable tuber yield, t/ha	Total tuber yield, t/ha
6 ton FYM+100 kg DAP	46.061	98.765
195/165 DAP/Urea	110.019	152.168
Control	50.667	86.339
LSD (5%)	35.52	44.64
Factor B		
25 May	96.849	145.271
11 June	90.890	146.477
25 June	70.582	117.898
8 July	17.341	40.051
LSD (5%)	21.37	31.07
CV %	31.33	27.91

Consequently, based on the two years data last week of May to Mid June planting is recommended to be appropriate for optimum potato production for the highlands of Ankober and other areas with similar agroecology. The fertilizer study also revealed that application of 6 tons of well decomposed farmyard manure (FYM) plus 100 Kg DAP/hectare gave a yield advantage of 108 percent over unfertilized control in 1997 (well distributed rainfall year). However, in the rest of the seasons, during which rainfall started late and ceased early, the result of farm yard manure application was not successful. Common scab was a major threat on plots treated with the FYM. Highest common scab damage was recorded on plots fertilized with FYM. Hence, direct use of incompletely decomposed farmyard manure is not advisable for potato production in these areas where the availability of the disease is suspected. It is very important to investigate further the relationship between common scab diseases with farm yard manure.

B. Determination of N P for potato in vertisol and nitosol of highland of North Shewa

Materials and Methods

This experiment was conducted in two seasons at Faji (Debre Berhan) (2000/2001 and 2002/03) representing light vertisol, and Keyit (2000/01 and 2001/02) representing Nitosol. The treatments included factorial combinations of four N (0, 69, 110, 151 Kg/hectare) and four P_2O_5 (0, 70.5, 90.7, 110.8 Kg/hectare) levels. The treatments were laid out in RCBD with three replications. The potato variety used in this treatments study was Menagesha. The fertilizer sources used were Urea as source of N, and TSP as a source of P_2O_5. Nitrogen was split applied half at planting and the other half at 45 days after planting whereas the whole phosphorus source was applied at planting time. Tuber yield data was taken at maturity from the net plot of the central rows. Then this data was analyzed using SAS statistical software's GLM procedure considering year and location as random factors.

Results and discussions

Mean squares of the measured crop parameters revealed that all N by P_2O_5 interactions were not statistically significant at $P<0.05$ probability level. Hence, only main effects are considered in this paper.

On vertisol at Faji significant ($P<0.05$) difference over marketable and total tuber yield was observed among nitrogen levels during the first year alone. Nevertheless, increasing nitrogen application beyond 110 Kg per hectare did not result in significant increment of the other two the parameters considered, i.e., wt. and number of tubers/m^2 (Table 1). A statistically in-significant but wider yield difference was also observed only between the control and the minimum P_2O_5 level (70.5 kg/ha).

Table 1. Main effect of N and P on av. tuber weight, no. of tubers, marketable and total tuber yields at Faji (2000/01)

Treatments	Average tuber weight (g)	No. Of tubers/m^2	Marketable tuber yield (t/ha)	Total tuber yield (t/ha)
N levels (kg/ha)				
0	43.00 a *	19.17 b	5.71 c	6.33 c
69	34.50 a	27.42 a	8.29 b	9.04 b
110	37.92 a	32.50 a	10.29 ab	11.64 a
151	41.42 a	31.17 a	12.25 a	12.98 a
P_2O_5 levels (kg/ha)				
0	34.08 a	21.83 a	6.52 b	6.87 b
70.5	42.67 a	28.00 a	9.65 a	10.74 a
90.7	38.92 a	29.08 a	9.80 a	10.71 a
110.8	41.17 a	31.33 a	10.57 a	11.68 a
CV	28.86	34.38	29.75	28.83

*Means in the same column followed by the same letter are not significantly different at alpha=0.05 according to DMRT

The combined analysis of results of the trial at Faji indicated the significant contribution of increasing nitrogen application on marketable and total tuber yields as nitrogen application moves from 0 to 110 kg/ha only while non significant effect of phosphorus on all the parameters considered (Table 2).

Table 2. Main effect of N and P on av. Tuber weight, no. of tubers, marketable and total tuber yields at Faji combined over years.

Treatments	Average tuber weight (g)	No. Of tubers/ m^2	Marketable tuber yield (t/ha)	Total tuber yield (t/ha)
N levels (kg/ha)				
0	45.17 a	17.96 b	5.73 c	8.19 c
69	46.71 a	27.17 a	8.58 b	12.08 b
110	49.37 a	30.00 a	10.66 a	14.34 ab
151	55.5 a	30.42 a	12.34 a	16.18 a
P_2O_5 levels (kg/ha)				
0	46.04 a	22.54 a	8.44 a	11.55 a
70.5	50.87 a	27.50 a	9.71 a	12.93 a
90.7	49.04 a	27.62 a	9.77 a	13.49 a
110.8	50.79 a	27.87 a	9.40 a	12.81 a
CV	23.55	29.9	36.22	33.55

*Means in the same column followed by the same letter are not significantly different at alpha=0.05 according to DMRT

As shown in Table 3, analyzing over years at Keyit (nitosol) also revealed significant (P<0.05) yield increment in number of tuber per square meter, marketable and total tuber yields as N increases from 0 to 110 kg/ha. Phosphorus did not result in significant response in any of the parameters.

Table 3. Main effect of N and P on av. Tuber weight, no. of tubers, marketable and total tuber yields at Keyit combined over years.

Treatments	Av. tuber weight (g)	No. Of tubers/ m^2	Market. tuber yield (t/ha)	Total tuber yield (t/ha)
N levels (kg/ha)				
0	25.65 c	17.34 c	3.74 c	4.37 c
69	49.43 ab	21.77 b	8.90 b	10.64 b
110	44.98 b	27.26 a	9.85 ab	11.82 ab
151	50.39 a	25.39 ab	10.19 a	12.85 a
P_2O_5 levels (kg/ha)				
0	41.77 a	19.72 a	6.91 a	8.12 a
70.5	41.09 a	23.58 a	8.18 a	9.83 a
90.7	42.61 a	24.18 a	8.41 a	10.35 a
110.8	44.98 a	24.28 a	9.17 a	11.35 a
CV	20.91	31.80	23.89	28.37

*Means in the same column followed by the same letter are not significantly different at alpha=0.05 according to DMRT

Results of combined analysis of variance over locations and years again revealed that increasing N up to 110 kg/ha significantly ($P<0.05$) and consistently increased all the parameters considered except average tuber weight where its effect is inconsistent (Table 4). As expected phosphorus fertilizer levels studied did not influence significantly all the parameters considered except the number of tubers per square meter. This result was also recorded from the minimum phosphorus treatment levels (70.5 kg P_2O_5/ha) at which significant response is observed.

Table 4. Main effect of N and P on av. Tuber weight, no. of tubers per square meter, marketable and total tuber yields combined over locations and years

Treatments	Average tuber weight (g)	No. Of tubers/ m^2	Marketable tuber yield t/ha)	Total tuber yield (t/ha)
N levels (kg/ha)				
0	35.41 a	17.65 c	4.73 c	6.28 c
69	48.07 a	24.47 b	8.74 b	11.36 b
110	47.18 a	28.63 a	10.26 a	13.08 a
151	52.95 a	27.90 a	11.27 a	14.51 a
P_2O_5 levels (kg/ha)				
0	43.91 a	21.13 b	7.67 a	9.84 a
70.5	45.98 a	25.54 a	8.95 a	11.38 a
90.7	45.82 a	26.03 a	9.09 a	11.93 a
110.8	47.89 a	25.95 a	9.28 a	12.08 a
CV	23.41	30.15	34.63	33.66

*Means in the same column followed by the same letter are not significantly different at alpha=0.05 according to DMRT

Conclusion

The crop responded consistently and significantly ($P<0.05$) to nitrogen application at both locations (soil types) over years with the optimum yield being recorded at 110 kg N per hectare. However, increasing the level of phosphorus did not result in significant yield response at both locations over years except for minimum phosphorus level (70.5 kg P_2O_5/ha).

Recommendation

110 kg per hectare nitrogen applied half at planting and half 45 days after planting at ridging, and 70.5 kg P_2O_5 per hectare applied at planting are recommended for optimum potato tuber yield in nitosol and light vertisol of the highland of North Shewa.

Soil K Status and K Requirement of Potato Growing on Different Soils of Western Amhara

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Abstract

An experiment was conducted in 2005/06 and 2006/07 cropping seasons on Nitosols, Acrisols and Luvisols of Western Amhara to investigate the inherent soil K status and K requirement of potato growing on these soils. The field experiments were conducted in Yilmana Densa (West Gojjam Zone), Farta (South Gondar Zone) and Banja (Awi Zone) woredas. Soil samples were collected from experimental sites before planting of potato and analyzed for exchangeable K status. The treatments included in the study were 6 levels of potassium fertilizer (0, 30, 60, 90,150 and 210 kg K_2O ha^{-1}) that were arranged in randomized complete block design with three replications. All of the K fertilizer for each trèatment was band-applied at planting along and in one side of the rows at a distance of 5 cm below and 5 cm aside the seeds. Muriate of potash (KCl) was used as a source of K. Moreover, 81kg N and 69kg P_2O_5 (recommended rates for western Amhara) were added to all plots. This was done by applying 150kg DAP and 58.5kg Urea at 2 weeks after emergence and side dressing 58.5kg Urea at flowering stage. Results of the experiment indicated that there was no significant increase in potato tuber number, plant height, number of main stems per plant, potato dry matter yield due to increase in K fertilizer rate on Nitosols, Acrisols and Luvisols. However, increase in K fertilizer rate significantly increased mean tuber weight and tuber yield of potato on Acrisols of Banja Woreda and improved shelving life of potato collected from all soil types.

Introduction

Of all the essential elements, potassium is the third most likely crop yield limiting nutrient after nitrogen and phosphorus. It plays a critical role in lowering cellular osmotic water potentials, thereby reducing the loss of water from leaf stomata and increasing the ability of root cells to take up water from the soil. Potassium is also essential for photosynthesis, protein synthesis, nitrogen fixation in legumes and for starch formation and increasing tuber yield (Brady and Weil, 2002). It is also especially important in helping plants adapt to environmental stresses like drought and frost. Nevertheless, this nutrient has received little attention in Ethiopian agriculture. This is mainly because K has been regarded as adequately available nutrient in Ethiopian Soils. Murphy (1963) in his work, which is recognized as the first systematic approach in characterizing the nutrient status of Ethiopian soils, reported that Ethiopian soils have adequate potassium. However, his work lacked adequate data on crop yield response to fertilizers (Taye, 1998). Moreover, more recent information of Mesfin (1998) indicated that Ethiopian Alfisols, as all moderately to intensively weathered soils, have limited amounts of basic rocks that usually contain more easily weatherable potassium, which affects the potassium content of these soils. This situation could be even worse on more weathered and leached Ultisols of Injibara area where potato is widely cultivated.

It is also apparent that intensive cropping in the absence of K replenishment would not only lead to "hidden hunger" but also can precipitate diminished productivity. Therefore, preliminary study on potassium status of Nitosols, Acrisols and Luvisols would help to devise strategies for proper soil fertility management. Moreover, studying the K requirement of potato, a crop which is believed to be highly responsive to K application, may play a significant role in improving land productivity and assist the food security endeavors of the region. Therefore, the objective of this study was to assess the potassium status of Nitosols, Acrisols and Luvisols and investigate the K requirement of potato growing on these three soils of western Amhara.

Materials and Methods

Determination of Soil K Status

Representative soil samples were collected from Nitosols, Acrisols and Luvisols of western Amhara where potato is intensively cultivated. Exchangeable potassium was determined by extracting potassium with 1*N* NH_4OA and analyzing the K status as outlined in Sahlemedihin and Taye (2000).

Treatments experimental design and field lay out

The field experiment was conducted in Yilmana Densa, Farta and Banja woredas representing three soils of western Amhara. The treatments included in the experiment were 6 levels of potassium fertilizer; i.e., 0, 30, 60, 90, 150 and 210 kg K_2O ha^{-1}. These treatments were arranged in randomized complete block design with three replications. The gross plot size used was 3.0m x 3.0m (9.0m^2) and the net plot size was 1.5m x 2.4m (3.6m^2). Spacing between rows was 75cm and between plants was 30cm. The distance between plots in a block was 0.5m while between blocks was 1.0m

The two years results indicated that, based on Beemeart (1990), K status is high and very high in Nitosols of Yilmana Densa, medium in Luvisols of Farta and low in Acrisols of Banja.

Potato tuber number

Potassium fertilizer rate did not have a significant effect on potato tuber number at four of the five locations in 2005/2006. A significant difference in potato tuber number per plant due to K fertilizer application was achieved only on Acrisols of Wonjella in Banja Woreda (Table 3). However, the significant increase was achieved up to application of 30kg ha^{-1} K_2O. Increasing the rate beyond this rate did not bring a significant effect on the parameter considered.

Table 3. The Effect of K Fertilizer Rates on Potato Tuber number in 2005/06 cropping season.

Treatments	Location				
	Mossobo Nitosol	Adet Hanna Nitosol	Wonjella Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	166.7a	135.0a	33.7b	126.0a	94.7a
30 kg ha^{-1}	141.0a	130.0a	57.0a	133.3a	122.0a
60 kg ha^{-1}	195.0a	101.7a	55.3a	94.7a	94.7a
90 kg ha^{-1}	171.7a	124.3a	34.0b	112.3a	103.0a
150 kg ha^{-1}	187.3a	112.7a	39.3b	109.7a	146.0a
210 kg ha^{-1}	149.0a	115.0a	32.7b	107.7a	136.7a
CV (%)	17.6	20.3	15.9	28.3	31.4
P(0.05)	ns	ns	*	ns	Ns

*** = significant; ns= not significant**

However, results of the experiment conducted in 2006/07 cropping season indicated that application of K fertilizer also did not give a significant effect on number of tubers produced per plant across all locations (Table 4). It is worthy enough to note that locations incorporated in the experiment in this year in each Woreda had relatively higher exchangeable K levels as compared to sites included in each Woreda in the previous year which generally diminished the effect of K fertilizer on this parameter.

Table 4. The Effect of K Fertilizer Rate on tuber number in 2006/07 cropping season

	Location					
Treatments	Mossobo Nitosol	Debre Mewi Nitosol	Biden Jebella Acrisol	Injibara Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	76.3 a	76.3 a	89.0 a	94.0 a	104.0 a	71.7a
30 kg ha^{-1}	79.3 a	76.3 a	85.0 a	117.0 a	93.7 a	71.0 a
60 kg ha^{-1}	57.0 a	62.0 a	76.7 a	108.7 a	116.3 a	89.0 a
90 kg ha^{-1}	78.3 a	59.0 a	90.7 a	113.7 a	112.3 a	93.3 a
150 kg ha^{-1}	64.0 a	75.3 a	99.7 a	105.3 a	86.3 a	101.0 a
210 kg ha^{-1}	57.3 a	55.7 a	88.3 a	115.0 a	93.0 a	79.7 a
CV (%)	21.2	30.2	14.0	11.9	31.0	23.4
P(0.05)	ns	ns	ns	ns	ns	ns

ns= not significant

This suggests that this yield component did not play a significant role in determining the tuber yield of potato.

Plant height

Except at one location (Mossobo Nitosols), K fertilizer rate did not have a significant effect on plant height of potato (Table 5). It is also necessary to note that the data on plant height obtained from this specific location did not have defined trend to make firm conclusion.

Table 5. The Effect of K Fertilizer Rates on plant height of potato plant in 2005/06 cropping season (cm)

Treatments	Location				
	Mossobo Nitosol	Adet Hanna Nitosol	Wonjella Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	38.0b	37.2a	28.3a	33.7a	28.7a
30 kg ha^{-1}	40.3ab	32.4a	27.7a	36.6a	30.6a
60 kg ha^{-1}	39.7ab	36.5a	28.3a	34.6a	32.6a
90 kg ha^{-1}	42.1a	36.7a	30.0a	34.7a	33.0a
150 kg ha^{-1}	41.6a	35.6a	28.4a	35.1a	32.8a
210 kg ha^{-1}	40.5ab	32.5	30.1a	36.3a	31.3a
CV(%)	4.4	8.1	5.3	6.7	15.2a
P(0.05)	*	ns	ns	ns	ns

*** = significant; ns= not significant**

The result obtained in 2006/07 cropping season also indicated that potassium fertilizer did not give a significant effect on plant height of potato plants on four of the five testing sites included in the experiment (Table 6).

Table 6. The Effect of K Fertilizer Rate on plant height (cm) of potato in 2006/07 cropping season.

Treatments	Location					
	Mossobo Nitosol	Debre Mewi Nitosol	Biden Jebella Acrisol	Injibara Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	49.2 a	46.6 a	46.6 a	20.3 b	49.6 a	49.1 a
30 kg ha^{-1}	51.2 a	47.2 a	44.3 a	23.0 ab	52.2 a	48.6 a
60 kg ha^{-1}	49.3 a	44.5 a	44.9 a	24.1 ab	54.3 a	52.8 a
90 kg ha^{-1}	51.8 a	43.8 a	45.7 a	25.9 ab	56.1 a	53.2 a
150 kg ha^{-1}	45.6 a	43.3 a	44.9 a	25.5 ab	52.6 a	52.3 a
210 kg ha^{-1}	50.0 a	44.7 a	46.9 a	26.9 a	55.8 a	49.7 a
CV (%)	8.9	5.4	11.8	12.1	6.4	7.6
P(0.05)	ns	ns	ns	*	ns	ns

*** = significant; ns= not significant**

It is, therefore, possible to suggest that potassium nutrient may not have a significant contribution in increasing the height of potato plants.

Number of main stems per plant

Application of different rates of K fertilizer did not affect the number of main stems per plant of potato at all of the locations included in 2005/06 cropping season (Table 7).

Table 7. The Effect of K Fertilizer Rates on number of main stems per plant of potato in 2005/06 cropping season.

Treatments	Location				
	Mossobo Nitosol	Adet Hanna Nitosol	Wonjella Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	5.0a	4.7a	3.0a	4.0a	6.3a
30 kg ha^{-1}	3.7a	4.7a	3.7a	3.7a	5.7a
60 kg ha^{-1}	5.0a	5.0a	3.0a	4.3a	5.7a
90 kg ha^{-1}	4.3a	5.3a	3.3a	3.7a	5.3a
150 kg ha^{-1}	4.7a	5.3a	3.0a	4.3a	6.0a
210 kg ha^{-1}	4.3a	5.0a	3.0a	3.7a	6.3a
CV (%)	28.7	19.7	14.1	12.8	12.7
P(0.05)	ns	ns	ns	ns	ns

ns= not significant

Similar trend was observed in 2006/07 cropping season as that of the previous year. Significant effect was observed only at Acrisol of Injibara on-station. On the rest of the locations, K fertilizer application did not significantly affect the number of stems per plant (Table 8). The two years results suggest that this yield component did not significantly contribute to the difference obtained in potato tuber yield.

Table 8. The Effect of K Fertilizer Rate on number of stems per plant in 2006/07 cropping season..

Treatments	Location					
	Mossobo Nitosols	Debre Mewi Nitosols	Biden Jebella Acrisol	Injibara Acrisol	Debre Tabor Luvisol	Tsegur Luvisols
0 kg ha^{-1}	5.7 a	5.7 a	3.3 a	2.7 b	4.3 a	4.3 a
30 kg ha^{-1}	6.7 a	6.0 a	3.3 a	3.3 ab	6.0 a	4.0 a
60 kg ha^{-1}	5.7 a	5.7 a	3.0 a	3.3 ab	5.0 a	4.3 a
90 kg ha^{-1}	6.0 a	6.0 a	3.3 a	3.7 ab	5.3a	4.7 a
150 kg ha^{-1}	4.7 a	5.7 a	3.3a	3.7 ab	5.3 a	5.3 a
210 kg ha^{-1}	6.0 a	6.3 a	2.7 a	4.0 a	5.7a	3.7 a
CV (%)	18.3	10.6	17.3	14.7	17.5	22.3
P(0.05)	ns	ns	ns	*	ns	ns

*** = significant; ns= not significant**

Mean tuber weight

Application of K fertilizer gave a significant effect on mean tuber weight of potato at 3 locations (Adet Hanna Nitosol, Wonjella Acrisol and Tsegur Luvisol) out of the five locations incorporated in the experiment in 2005/06 cropping season (Table 9).

Table 9. The Effect of K Fertilizer Rate on mean tuber weight of potato in 2005/06 cropping season (gm/tuber)

Treatments	Location				
	Mossobo Nitosol	Adet Hanna Nitosol	Wonjella Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	59.1 a	70.5 ab	19.3 b	35.4 a	63.2 ab
30 kg ha^{-1}	61.5 a	61.1 b	24.1 ab	35.6 a	53.6 ab
60 kg ha^{-1}	50.4 a	82.5 a	24.8 ab	44.0 a	75.3 a
90 kg ha^{-1}	56.3 a	65.6 ab	30.1 ab	45.4 a	68.2 ab
150 kg ha^{-1}	47.4 a	70.3 ab	24.3 ab	46.1 a	52.3 b
210 kg ha^{-1}	60.5 a	68.8 b	33.1 a	46.9 a	55.0 b
CV (%)	12.9	13.5	22.0	18.9	17.1
P(0.05)	ns	*	*	ns	*

*** = significant; ns= not significant**

However, in 2006/07 cropping season only two locations in Banja woreda which have Acrisol soil type gave significant difference in mean potato tuber weight (Table 10). From the results of the experiments of the two years it is possible to conclude that this yield component affected tuber yield of potato on Acrisol of Banja Woreda. Therefore, in both years, significant effect on mean tuber yield was obtained on Acrisols of Banja Woreda.

Table 10. The Effect of K Fertilizer Rate on mean tuber weight of potato in 2006/07 cropping season (gm/tuber)

Treatments	Location					
	Mossobo Nitosol	Debre Mewi Nitosol	Biden Jebella Acrisol	Injibara Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	88.7 a	63.3 a	29.5 b	29.6 c	61.1 a	53.9 a
30 kg ha^{-1}	87.3 a	61.7 a	45.9 a	32.4 cb	76.3 a	47.7 a
60 kg ha^{-1}	95.5 a	70.7 a	43.6 ab	36.1 ab	59.0 a	58.2 a
90 kg ha^{-1}	97.5 a	69.4 a	45.1 a	41.0 a	59.3 a	55.5 a
150 kg ha^{-1}	83.4 a	65.5 a	48.2 a	40.3 a	71.2 a	50.1 a
210 kg ha^{-1}	93.7 a	65.9 a	46.5 a	42.0 a	68.3 a	54.8 a
CV (%)	8.4	10.3	19.4	9.1	23.9	22.6
P(0.05)	ns	ns	*	*	ns	ns

* = significant; ns= not significant

Percent tuber dry matter yield

Application of different rates of K fertilizer did not affect the % tuber dry matter yield at four of the five locations. At Adet Hanna Nitosol, where significant difference was achieved, the data seem inconsistent and lack clear trend to make a conclusion (Table 11). Therefore, it is possible to suggest that K nutrient does not contribute a lot in determining potato dry matter yield.

Beyond this rate significant yield increase was not observed. It is important to note that the yield from Wonjella location was very low as compared to other locations which indicated overall deficiency of major nutrients and deteriorated soil physical condition. In such cases, increasing K rate alone cannot bring yield increase unless the demand for other yield limiting nutrients is met.

Table 13. The effect of K fertilizer rate on tuber yield of potato in 2005/06 cropping season (t ha^{-1})

Treatments	Location				
	Mossobo Nitosol	Adet Hanna Nitosol	Wonjella Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	21.26a	19.41a	1.81b	11.02 a	16.29a
30 kg ha^{-1}	19.26a	17.18a	3.10a	12.68 a	17.85a
60 kg ha^{-1}	21.704a	18.22a	3.80a	11.48a	18.17a
90 kg ha^{-1}	21.04a	18.00a	2.85ab	13.88a	18.71a
150 kg ha^{-1}	19.63a	17.48a	2.73ab	13.98a	20.94a
210 kg ha^{-1}	20.00a	17.63a	2.62ab	13.98a	20.21a
CV (%)	9.2	17.9	29.9	13.9	22.4
P(0.05)	ns	ns	*	ns	ns

*** = significant; ns= not significant**

Results of the experiment conducted in 2006/07 cropping season also indicated that potato planted on Acrisols of Banja Woreda responded for K application. Similar to the previous year, potato planted on Nitosols of Yilmana Densa and Luvisols of Farta (one location) did not respond to K application (Table 14).

Table 14. The Effect of K Fertilizer Rate on Tuber Yield of Potato in 2006/07 cropping season (t ha^{-1})

Treatments	Location					
	Mossobo Nitosol	Debre Mewi Nitosol	Biden Jebella Nitosol	Injibara Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	18.52 a	13.33 a	7.30 c	7.75 b	17.64 a	8.70 b
30 kg ha^{-1}	19.07 a	13.15 a	8.21 bc	10.48 ab	18.01 a	11.06 ab
60 kg ha^{-1}	15.18 a	11.94 a	9.31 b	10.93 ab	18.29 a	14.35 a
90 kg ha^{-1}	21.30 a	11.67 a	11.29 a	12.89 a	18.29 a	14.21 a
150 kg ha^{-1}	18.67 a	13.43 a	12.25 a	11.82 a	16.06 a	14.12 a
210 kg ha^{-1}	14.82 a	10.00 a	12.06 a	13.22 a	17.59 a	12.13 ab
CV (%)	20.2	28.7	9.1	14.3	21.3	18.8
P(0.05)	ns	ns	*	*	ns	*

*** = significant; ns= not significant**

Relationships between soil K and potato tuber yield

From the experiment, it was also clearly seen that there was curvilinear and positive relationships between soil exchangeable K levels and potato tuber yield (Figure 1). Those sites that had lower exchangeable K levels gave lower tuber yield and vise versa.

However, the intensity of the response diminishes as the soil K level increases and significant difference in potato tuber yield among treatments was not achieved on locations with relatively higher K status and vise versa. Therefore, it is also possible to suggest that those sites that had relatively higher K status also can have higher levels of other macro and micro nutrients and vice versa.

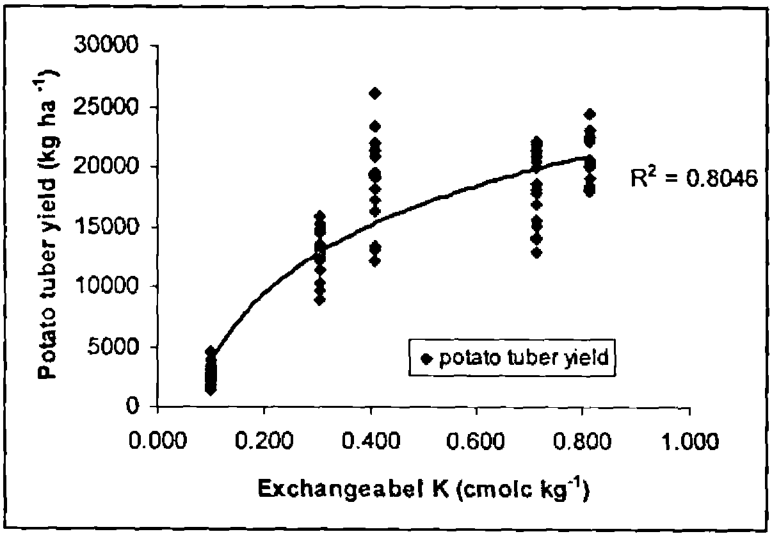

Figure 1. The relationships between soils exchangeable K status and potato tuber yield in 2005/06 cropping season

Conclusions and recommendations

From the results of the experiment, it is possible to draw the following conclusions:

1) Increasing K fertilizer rate did not significantly increase potato tuber number, plant height, number of main stems per plant and potato dry matter yield on Nitosols, Acrisols and Luvisols;

2) Increase in K fertilizer rate significantly increased mean tuber weight, and tuber yield of potato on Acrisols;

3) Increase in K fertilizer rate significantly improved shelving life of potato.

4) Potato tuber yield had linear and positive relationship with soil exchangeable K status. However, potato tuber yield response level to K fertilizer application had negative relationship with soil K status.

From the results of the experiment, it is possible to recommend that application of 30kg ha^{-1} on Acriosls of Banja Woreda could be taken as blanket fertilizer recommendation. For those soils with exchangeable K values of greater than 0.3 $cmol_c\ kg^{-1}$, it is less likely that response for K fertilizer may be obtained. Therefore, it is advisable to make soil analysis prior to determine whether to apply K fertilizer or not. But still, further investigation is required to reach to firm recommendation.

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Demonstration of integrated potato late blight (Phytophthra infestans) management options through Farmers Field School (FFS) Approach: The case of Adet

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Abstract

Potato (***Solanum tuberosum*** L.) is one of the widely grown tuber crops in the mid and high-altitude areas of western Amhara sub-region. This crop has both dietary and income generating role to its producers. However, the tuber yield obtained by the growers in this region is very low. One of the several reasons for such low yield level is the disease late blight of potato. Late blight, caused by the fungus pathogen *phytophthra infestans*, is the most prominent and probably the most important diseases of potato world wide. It causes an average yield loss of 56.7 to 95% depending on the environmental condition of an area. Use of appropriate planting time, biologically tolerant varieties and chemicals spray are among the various successful options of managing this disease. Use of integrated disease management measures is found more effective for a successful suppression of the diseases. To this effect demonstration of these integrated management options is carried using Farmers Field School (FFS) approach with the main objectives of enhancing farmers' awareness on various late blight management options, determination of the effect of group work in identifying solution for a common problem and finally identify and determine area based management options at farmers' condition. This activity is carried at three hot spot locations (Adet, Sekela and Lay Gayint) for one year (2006/07) using three potato varieties of varying level of disease tolerance and two levels of metalaxyl fungicide treatment (treated and untreated). Statistically detectable differences were observed among the tested genotypes and fungicide spray levels. However, integrated management of potato late blight is found to be the best and effective method of controlling the disease compared to the solitary disease controlling strategy. Besides, economic analysis of the different integrated potato late blight management options was conducted to see the economic feasibility of the chemical treatment for the users of this recommendation. Following CIMMYT economic analysis this result has shown that only Guassa variety treated and untreated remained reasonable alternatives to the farmers' condition. This paper presents the results of this activity in the light of the field observation.

Introduction

Late blight is the most famous and probably the most important diseases of potato world wide (R. Burrous, F.L. Pfleger, 2001). It is caused by the fungus like oemycetes pathogen *phytophthra infestans.* This disease can affect almost all part of the plant like leaves, stems, fruits and tubers of potato. This fungus affect several plant species and has a potential to cause devastative damage every where potatoes are grown. It causes an average yield loss of 56.7 through 95 percent depending on the environmental condition of an area (Bekele and Hiskias, 1992).

To control this disease several efforts are made in many countries. Development of resistant varieties, sanitations, chemical spray prior right at the time the first disease symptom is seen on the growing crop and adjustment of planting date are among these tactics developed and applied during production management. However, there is no single and effective measure developed in the management of this disease. Rather use of integrated management practices should be adopted for successful suppression of the diseases (William F. E., 1982). This is because of the fact that the diversity in agro ecosystem affects the relative importance of specific strategy to be employed (William, 1982). Besides, ways of disseminating technology itself is not an easy task especially at the subsistence farming level for it is highly dependent on the availability, effectiveness and cost, ease of application, user and environmental friendliness despite the availability of specific technology for potato diseases management.

There are various means of disseminating pest management methods. Among these various means of diffusing and disseminating appropriate pest management options in the farming community, farmers field school is a promising approach as it is seen from in- country and foreign countries experience (Bekele and G/medihin, 2002). This approach was established in Indonesia in 1988 following the impact of devastating insect induced out breaks of brown plant hopper that destroyed rice (Fantahun and Admassu, 2003). It was also introduced to Ethiopia in 1999 through an EU funded project (Fantahun and Admassu, 2003) and in Amhara Region to control Wollo bush cricket. The core activity in farmers' field school involves curriculum development and offering farmers opportunities to learn through hands-on experience and through being involved in simple experimentation and innovation in discussion and joint decision-making about appropriate crop protection and production interventions. The activity will be supervised by trained agricultural extension agents who play only facilitation role, while researchers provide the technical inputs. Through this system a strong Farmer-Extension-Researcher partnership is created to support and promote cost effective, environmentally sound and sustainable agricultural production. Hence, this activity is carried to meet the following objectives:

Objectives

1. To enhance farmers awareness on various late blight management options;

2. To determine the effect of group work in identifying solution for a common problem and

3. To identify and determine area based management options at farmers' condition

Materials and Methods

Procedure:-

In the execution of this activity the procedures followed included formation of a group of farmers with 25 members. These members are formed from farmers in the same area and have at least an interest of working together under the umbrella of FFS. They did also work together under the facilitation of extension agents and technical support of the researcher. Following this group formation two IPM -FFS treatments, i.e., the IPM and conventional practice, were adopted and evaluated at the FFS experiment site at three locations (Adet, Sekela and Lay Gayint). In general IPM-FFS establishment procedures included planning; implementation, evaluation and follow processes. Farmer selection is done at first meeting by all interested groups from a village or peasant association in the presence of local leaders. The criterion used for the selection of participant farmers were:-

- Willingness to work together
- Active interest in learning new things
- Able to attend FFS over an entire growing season
- Willingness to disseminate what they learn to other farmer

Woman participants are more encouraged to participate in this activity.

Planning

- At the planning phase training was given to the selected FFS group participants on the different aspects of potato production such as the cause, source and management of late blight of potato, seed quality, varietal resistance, cultural practices and post harvest management practices. The learning approach followed was of participatory and farmer's practices were utilized in quantifying and addressing potato production constraints. In general, farmers fully participated on experimentation, diagnosis and

▪ Symptom identification, varietal evaluation, fungicide application and its safe use. This group work continued until the end of the project so as to evaluate the progress and the out come of the program. During the training discussion is made with the farmers exhaustively to seek their indigenous knowledge on potato late blight diseases management. Awareness creation for other important potato diseases management such as bacterial wilt and viruses were included. Frequent follow up sessions and discussion were also held at weekly interval.

The treatments:-

1) Host resistant (Guassa) + untreated
2) Host resistance (Guassa) + metalaxyl 3kg/ha
3) Host resistant (Tolcha + untreated
4) Host resistance (Tolcha) + metalaxyl 3kg/ha
5) Susceptible host (Local)+ untreated
6) Susceptible host (Local) + metalaxyl 3kg/ha

The treatments were arranged in factorial randomized complete block design of three replications. Then the treatments were applied on a plot size of was 4.5m x 4m that is planted with seed tuber at a spacing of 75cm x 30cm between rows and plants, respectively. A fertilizer rate of 150 kg/ha DAP and 117 kg/ha Urea is used as recommended. All the other cultural practices are applied as per the recommendation by the research system.

Implementation

Selection of common site and the alternatives to conventional control methods were implemented. Accessible site to the members of FFS was selected.

Evaluation

- Evaluation of the IPM components is undertaken at each stage of the crop optionally at each week interval depending on the sign, characteristic, damaging level of the diseases, the part of the plant affected, convenience of detecting the efficacy of alternatives, determination of crop loss in-terms of quality and quantity and the best time for the identification of best management options against their indigenous knowledge

Follow up procedure:

The DAs and the supervisors who attended the TOT course monitored the application of all the alternative options as set in the beginning of the experiment just to insure its adoption and continued use. Finally data related to planting and infestation date, diseases incidence (%), severity (%) and tuber yield (marketable, unmarketable and total).

Results and Discussion

Mean results of the trial showed that there is a detectable difference among the tested genotypes as well as the fungicide treated and untreated plots (Table 2). This result showed that all the selected locations (Adet, Sekela and Gaint) are hot spot areas for late blight of potato although the severity of the disease was significantly different for the different management options and locations (Table 1 & 3). In terms of disease severity Lay Gayint had the largest score (Table 1). Accordingly, of all the varieties tested in the trial the regionally released Guasa variety had the of disease severity (Table 1 & 3). This is followed by the moderately late blight resistant potato variety Tolcha. The local potato variety generally had the largest percentage score of disease as severity (Table 1 & 3). This result normally emanates from the inherent genetic background of the genotypes. The variety Guasa, Tolcha and Local cultivars had a natural make up of high tolerance, medium tolerance and susceptible characteristic to this devastating disease as put in order. Due to this inherent difference, their response to fungicide treatment was also significantly different. Fig.1. also shows the relationship between variety yields and fungicide level tested. In this case there are only two environments represented, fungicide sprayed environment and unsprayed environment. Accordingly the figure clearly shows the variation in the response of the resistant variety, moderately resistant variety and the susceptible local variety to the different levels of fungicide spray.

The local cultivar responded significantly to fungicide treatment as observed in the percentage score of disease severity of the fungicide treated and untreated plots. Generally, the local cultivar suffers very high from the attack of late blight of potato if not timely sprayed by fungicide (Table 1 & 3). This differential effect between treated and untreated plots is vividly reflected on the tuber yield differences of the treated and untreated plots of each variety. As a result the marketable tuber yield harvested from the local cultivar was very low, 6.45 t/ha, as contrasted with the treated plots of the same variety in which a marketable tuber yield of 21.85 t/ha is harvested (Table 2 & 4). Similar kind of differences is observed for the other two varieties in the trial. The genotypic performance rank of Guasa takes the lead across all locations followed by Tolcha and Local cultivar for both treated and untreated plots (Table 2 & 4). This result generally agrees with earlier works of similar kind elsewhere in the country as well as other countries as indicated in the introductory part of this paper.

Participant farmers in the FFS at all locations have also recognized the possible options of this disease management. They have realized the inherent differences among genotypes. They did also come to know that there are chemical management options for controlling of this serious disease of their major crops. As a result farmers to whom this activity is demonstrated collected sufficient amount of money and urged the researcher in charge to purchase and provide them with this chemical. This is one of the interesting events worthy of mention encountered during the final field assessment stage of harvesting. They have realized that they could even improve the yield of their susceptible local cultivar if they have got access to this chemical. Moreover, their confidence on research output is also developed from what they have practically observed on their field. Their request for the improved potato variety such as Guasa, Jalenie, Zengena and others to which they were aware became also very high to the level that they sent their delegate to purchase seed tubers of these varieties from potato seed tuber producers around Adet.

An economic analysis is carried to draw economically feasible recommendation for users. As the result shows Guassa variety, when treated, offers the highest average net benefit. In addition the marginal analysis shows that only Guassa variety treated and untreated remain as reasonable alternatives (Table 5). The smallest alternative available to the farmer is to spend birr 6000/ha for the Guassa variety. In exchange for this he can expect to receive a net return of birr 5759(the first year),for a rate of return of 95.99%.This is an adequate rate to warrant farmers' investment, and moreover, the farmer can expect to receive *additional benefits in the future* without the necessity of again investing in seed. The actual rate of return is then underestimated by this figure. The alternative of investing an additional birr 1000/ha to apply fungicide to Guassa variety, the expected increase in net benefit is birr 2800/ha, for a rate of 40.06%.This rate is acceptable (if the risks are not unusually great), and the size of the increase in net *returns is quite significant.*

Table 1: The effect of different late blight management options on severity of the disease at Adet, Sekela and Lay Gayint, 2006/7.

Variety	Severity %								
	Chemical treatment								
	Treated			Untreated			Mean		
	Adet	Sekela	Lay Gayint	Adet	Sekela	Lay Gayint	Adet	Sekela	Lay Gayint
Guassa	2^{C}	1^{D}	2^{C}	17.3^{BC}	12^{C}	7.7^{C}	10^{B}	6.5^{C}	5^{C}
Tolcha	9^{BC}	3.7^{CD}	6^{C}	21^{B}	27^{B}	29^{B}	15^{B}	15.3^{B}	17.5^{B}
Local	9^{BC}	7^{CD}	2.7^{C}	48.3^{A}	49^{A}	52^{A}	28^{A}	28^{A}	27^{A}
Mean	6.4	3.9	3.6	28.8	29.33	29.6			
C V %	45.34	30.63	23.39						
LSD (5%)	V 10.27	V 6.55	V 4.98	C 14.6	C 9	C 7	V*C 14.53	V*C 9.24	V*C 7.04

Table 2: The effect of different late blight management options on marketable and total tuber yield of potato at Adet, Sekela and Lay Gayint, 2006/7.

Variety	Marketable yield (t/ha)									Total yield (t/ha)								
	Chemical treatment									Chemical treatment								
	Treated			Untreated			Mean			Treated			Untreated			Mean		
	Ad	Sek.	LG	Ad	Sek.	LG	Ad	Sek.	LG	Ad	Sek.	LG	Ad	Sek.	LG	Ad	Sek.	LGay
Guassa	49.26	63.5^{A}	39.8^{A}	37.78	34.8^{B}	29^{B}	43.5^{A}	49.2^{A}	34.4^{A}	50.6^{A}	64.6^{A}	41.9^{A}	39.4^{B}	34.8^{B}	31.4^{BC}	45.0^{A}	49.7^{A}	36.6^{A}
Tolcha	31.3	38.4^{B}	35^{AB}	20.4	17.8^{C}	21.5^{C}	25.8^{B}	24.1^{B}	28.4^{B}	32.6^{B}	38.4^{B}	36.8^{AB}	23.0^{C}	17.8^{C}	23.3^{D}	27.8^{B}	24.1^{B}	30.1^{B}
Local	27.4	17.6^{C}	30.8^{C}	11.7	7.2^{D}	5^{D}	19.5^{B}	12.4^{C}	10.5^{C}	29.3^{C}	17.5^{C}	26.7^{CD}	14.1^{C}	7.2^{D}	3.8^{E}	21.7^{B}	12.4^{C}	15.25^{C}
Mean	30.9	37.2	31.8	23.3	19.9	17.1				37.5	37.5	35.1	25.5	19.9	19.5			
CV%	16.56	14.38	15.58							14.58	13.87	12.02						
LSD (5%)	V 64.65	V 55.01	V 30.25	C 51.7	C 78	C 71	V*C 51.43	V*C 77.8	V*C 71.06	V 65.49	V 51.27	V 42.23	C 53	C 42	C 90	V*C 92.61	V*C 72.51	V*C 59.72

Table 3: The effect of different late blight management options on diseases severity at Adet, Sekela and Lay Gayint, 2006/7.

Variety	Severity %		
	Chemical treatment		
	Treated	Untreated	Mean
Guassa	2^d	12^c	7^C
Tolcha	6^d	26^b	16^B
Local	6^d	50^a	28^A
Mean	4.6	29	
C V %	34.89		
LSD (5%)	V	C	V*C
	4.02	10	5.7

Table 4. The effect of different late blight management options on marketable and total yield at Adet, Sekela and Gayint, 2006/7.

Variety	Marketable yield (t/ha)			Total yield (t/ha)		
	Chemical treatment			Chemical treatment		
	Treated	Untreate d	Mean	Treated	Untreated	Mean
Guassa	50.9	33.9	42.37^A	52.3^A	35.2^B	43.8^A
Tolcha	32.2	20.0	26.1^B	33.3^B	21.4^C	27.3^B
Local	21.85	6.45	14.1^C	24.5^C	8.4^D	16.4^C
Mean	35.0	20.1		36.7	216.5	
C V %	16.08			14.35		
LSD (5%)	V	C	V*C	V	C	V*C
	30.14	74	NS	28.5	70	40.3

Note: Means that are followed by the same letter/s are not significantly different from each other at the 5% level of significance.

Table 5: Partial budget, net benefit and marginal rate of return analysis of integrated management options of late blight of potato, 2007/08 cropping season.

Treatments	Marketable tuber yield, t/ha	Gross benefit (birr/ ha)	Total variable cost	Net benefit (birr/ha)	Marginal rate of return (%)
Treated Guassa	40.68	122040	7000	115340	40.07
Untreated Guassa	27.09	81270	6000	75270	95.99
Treated Tolcha	25.78	61872	5800	56072	22.42
Untreated Tolcha	16.02	38448	4800	33648	11.01
Treated Local	17.49	19239	3200	16039	11.22
Untreated Local	6.38	7018	2200	4818	---

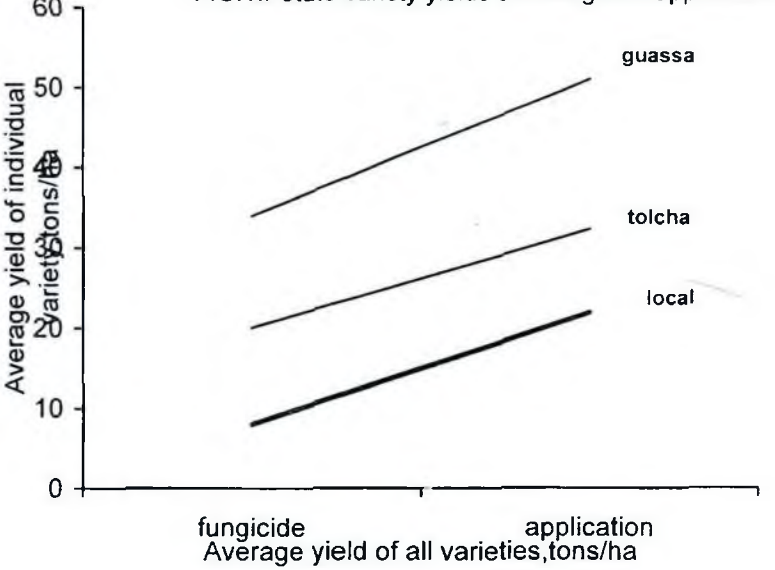
300 birr/q of Guassa **110 birr/q of local potato**

240 birr/q of Tolcha **15 birr/man day wage rate**

200 birr/kg of Ridomil **20 man-days calculated for fungicide application.**

100 birr/season of knapsack sprayer

FIG.1.Potato variety yields and fungicide application



Conclusion and Recommendation

This result showed that all the selected locations (Adet, Sekela and Gayint) are hot spot areas for late blight of potato although the severity of the disease was significantly different for the different management options and locations. The latest variety Guassa was resistant compared to Tolcha and local varieties at all locations. And Tolcha variety better resisted the disease than the local at Lay Gayint. In addition, all the plots treated with the chemical (metalaxyl 3kg/ha) resisted very significantly better than the untreated ones at all locations. But the treated Guassa is highly resistant compared to the others treated or untreated plots of the two varieties.

With regard to yield, there was a significant difference between the different management options and locations. Guassa gave the highest total yield (43.8 t/ha) at all locations followed by Tolcha (27.3 t/ha) and Local (16.4 t/ha) respectively. Besides, the treated plots gave a significant yield difference than the untreated ones. Moreover, this activity revealed the greater scope of improving Local cultivar tuber yield as high as 24.5 t/ha than untreated Tolcha which gave 21.4 t/ha.

To put it mildly, integrated management of potato late blight is the best and effective method of controlling the disease compared to solitary disease controlling tactics such as resistant variety, chemical spray and others. Therefore, use of integrated management practice is recommended to be adopted for successful suppression of the disease for the diverse agro-ecosystem. Results of economic analysis also revealed economic feasibility of the variety Guassa with and with out fungicide treatment considering both chemical as well as seed price of these varieties as a variable cost of production.

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Evaluation of the effects of alternate furrow irrigation on yield and water use efficiency of potato.

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Abstract

The objective of water management in irrigation is to provide suitable moisture to crops to obtain maximum yield with high water use efficiency. The increasing demand for water world wide and scarcity of water requires optimization of irrigation management in order to improve crop water use efficiency. This paper evaluates the effect of partial root zone drying (PRD) on yield and water use efficiency of potato. The analysis was based on agronomic parameters (plant growth and yield related data) and soil moisture data which were collected during four months of experiment (January 2007-April 2007). The response of each plant growth parameter, soil moisture and yield to three watering levels (100%, 75% and 50% of the required amount) and three furrow water application methods, i.e. conventional furrow irrigation (CFI), fixed furrow irrigation (FFI) and alternate furrow irrigation (AFI) has been evaluated. As a result maximum tuber yield, tuber size and quality, tuber weight and dry matter content were achieved under AFI. It was found that higher yield (11.75t/ha) was obtained under AFI followed by FFI (11.398 t/ha) and CFI (10.957 t/ha) under full water application level. At 75% water application level CFI resulted in better yield followed by AFI and FFI. The yield difference between CFI at 100% and AFI at 75% water supply level is only 9 %. The WUE at 75 and 50% water application level was higher under CFI compared to the other treatments. In general, up to 41.7% water saving was practically achieved by adopting Alternate Furrow Irrigation (AFI) without significantly affecting yields.

Key words: Alternate Furrow Irrigation, Partial Root Zone Drying, Water Use Efficiency

Introduction

The success of irrigation in ensuring food security and rural welfare has been impressive, but past experiences also indicate that inappropriate management of irrigation has contributed to environmental problems including excessive water depletion, water quality reduction, water logging and salinization (Mark et al., 2002).

Many countries depend on surface irrigation to grow crops for food and fiber. Without surface irrigation their agricultural production would be drastically lower and problems of unreliable food supply, insufficient rural income and unemployment would be widespread. Although precise data are lacking, estimation of surface irrigation accounts for some 80 to 90 percent of the total 7260 million hectares of irrigated land worldwide, mainly in developing countries in the tropics and sub-tropics, where hundreds of millions of farmers depend on surface irrigation to grow their crops (Yesuf, 2004).

FAO (1989) indicated the problems irrigated agriculture may have to face in the future. One of the major concerns is the generally poor efficiency with which water resources have been used for irrigation. A relatively safe estimate is that about 40 percent or more of the water diverted for irrigation is wasted at the farm level through either deep percolation or surface runoff.

Water is one of the largest renewable natural resources but fresh water is expected to emerge as a key constraint to future agricultural growth. Globally, and more particularly in developing countries, changing water availability and quality pose complex problem and management options are not easy. The changing situation comes partly from increasing demands such as population, industry and domestic requirements and partly from consequences of climatic change (Magar, 2006). Therefore, great emphasis is placed in the area of *crop physiology and crop management* with the aim to make plants more efficient in water use under dry condition (Stikic *et al.*, 2003).

Poor management of agricultural water leaves almost all parts of Ethiopia highly susceptible to rainfall variability which depicts itself in terms of prolonged dry spell and drought (Seleshi, 2006). Over 70% of the country is either arid or semi arid, characterized by low and erratic rainfall both in terms of spatial and temporal distribution (Kamara, 2002). This is one of the most challenging problems that limit agricultural production, and makes larger parts of the country vulnerable to recurrent drought.

Therefore, it is necessary to consider the on farm design and management factors that improve the water use efficiency by choosing appropriate method of irrigation water application. The overall objective of this paper is to evaluate the effect of partial root zone drying by a technique of alternate furrow irrigation on yield and water use efficiency of potato.

The concept of partial root zone drying

Partial root zone drying (PRD) is a practice of using irrigation to alternately wet and dry (at least) two spatially prescribed parts of the plant root system to *simultaneously maintain plant water status at maximum water potential* and *control vegetative growth* for prescribed parts of seasonal cycle of plant development. The reason for doing this is to control vegetative growth or improve water use efficiency or both while maintaining reproductive growth & development.

If part of the root system was allowed to dry and the remaining roots were kept well watered, chemical signals produced in the drying roots reduced stomata aperture. At the same time the fully hydrated roots maintain a favorable water status through out the aerial parts of the plant. In addition to reduced stomatal conductance, it was noted that shoot extension was also inhibited as a result of partial root drying. A surprising finding was that the effect was *temporary*, and despite the fact that part of the root system remained dry, stomatal conductance, photosynthesis and growth returned to pre-treatment levels within a few weeks (Kriedemann *et al.*, 2003).

Abscisic acid and cytokinins are plant hormones. Plant hormones can act as chemical signals (Stoll, 2000). ABA is an effective stomatal closing agent and relationship between stomatal conductance and xylem (ABA) generated from data collected in field suggest that ABA can have controlling influence and determine day to day variation in stomatal behavior as soil dries as well as leaf to leaf variation in conductance when different cultural treatments are applied. ABA induced partial stomatal closure and reduced leaf area have been considered to be the main causes for saving water in plants under PRD treatment (Davis *et al.* 2002).

It was also found that PRD caused a reduction in the levels of other plant hormones called *cytokinins*. The function of these is to stimulate transpiration and to control the development of side shoots in the canopy. The combined effect of these hormonal changes was to reduce water losses and also to reduce the total size of the leaf canopy. Armed with knowledge about the transient nature of the effect and the likely role of the chemical signals it is possible to devise irrigation schedule which keep one part of the root system , or other in a state of drying so as to maximize the production of chemical signals and hence their inhibitory effect on transpiration and growth. (Kriedemann *et al.*, 2003)

Materials and methods

The field experiment was conducted during January-April 2007 near Adet (11°17'N, 37°43'E). It is about 490 km NW of Addis Ababa and 43 km from the capital of the Amhara National Regional State (Bahir Dar). It has an altitude of 2240 m.a.s.l. and represents mid to high altitudes and high potential areas (ANRSBOA, 1999). Mean daily maximum temperature ranges from 22.5°C (July and August) to 29.4 °C (March) and the mean daily minimum temperature ranges from 5.4 °C (January) to 12.1 °C in August. Mean annual rain fall in the area is about 1238.7 mm. Soils in the study area are moderately acidic (pH=5.41) and are moderate in its organic matter content (i.e. 2.17%). The relative proportion of sand silt and clay (15%, 27% and 58% respectively) revealed that the soil of the testing site is clay in its very nature.

In this experiment three furrow irrigation water application methods were tested. These include:

1. Conventional furrow irrigation (CFI), where every furrow is irrigated during each watering.
2. Fixed furrow irrigation (FFI), where irrigation is fixed to one of the two neighboring furrows throughout the growing period and
3. Alternating furrow irrigation (AFI) where one of the two neighboring furrows is alternately irrigated.

Each of them was tested on three separate plots. Each irrigation method was again further divided into three treatments using different levels of irrigation water application: i.e. full (100%), 75%, and 50% irrigation water application levels during each watering.

The parameter set up and treatment combinations are as follows:

Factor 2 (Water application levels)		Factor 1 (Water application methods)		
	100 %	CFI	FFI	AFI
	75%	CFI	FFI	AFI
	50%	CFI	FFI	AFI

Moreover, each treatment is replicated three times and a total of 27 plots each with an area of 18m2 (3m x 6m) were used. Four furrows were arranged on each plot. The spacing between two furrows was 75cm. The length of each furrow was limited to 6m. The spacing between plants is 30cm and between rows of plants 75 cm was provided. The spacing between treatments was kept 1m and the spacing between each block was 2m. Totally the experiment comprises of three blocks. Each block contains nine randomly arranged treatment sets. The total land required for this experiment was about 0.1014 ha (26m x 39m).

Ten years data of on maximum and minimum temperature, relative humidity, wind speed, sunshine hours and rainfall from the nearby station was collected from National Meteorological Authority. The crop water requirement and irrigation requirement of potato was estimated using CropWat 4 Windows Version 4.3 (FAO, 1989). Running this model with the aforementioned and other input data, the crop water requirement and irrigation requirement of potato at the study area was estimated.

Accordingly, the crop water requirement and irrigation requirement of potato at the study area was found to be 522mm and 430mm respectively. As a result, for each watering the full (100%) irrigation requirement level was found to be 22mm. Depending on this value, the 75% irrigation requirement level and 50% level was fixed as 16mm and 11mm respectively.

After the land preparation work, the early maturing potato variety (locally called 'Wochecha') was selected for planting. Potato seeds were allowed to properly sprout and then planting was done on 2January 2007. Plant density for each treatment was 80 seeds per $18m^2$ plot. To facilitate proper establishment of the crops, each treatment was supplied with full (100%) irrigation for two consecutive weeks before the actual treatment commenced.

Weeding and other agronomic activities were conducted on time equally for each treatment. Irrigation water was then supplied from the farm channel into the field through siphons for every treatment. Soil samples were taken for analysis of soil texture, bulk density, pH and organic matter content and soil moisture content. The analysis was made using standard procedures. The moisture content is determined using gravimetric method. To determine the agronomic parameters such as plant height, stem diameter, yield, total biomass, root dry weight, shoot dry weight and root to shoot ratio, generally 10 plants were sampled at random and marked from central two rows from each plot.

The data collected for all relevant variables were subject to analysis of variance appropriate to factorial experiment RCBD (Gomez & Gomez, 1984). Appropriate standard errors of the means (SE) and least significant difference (LSD_s) between and / or among treatments at P = 0.01 and P = 0.05 were calculated using the MSTATC computer program.

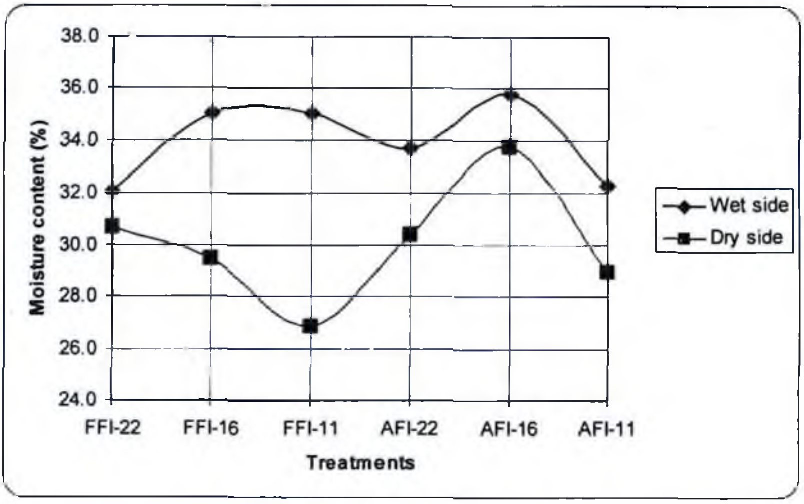
Results and discussion

Soil moisture analysis

This section presents the results of soil moisture content analysis for soil samples taken from each plot before and after every irrigation, from both wetting and drying sides of the furrows.

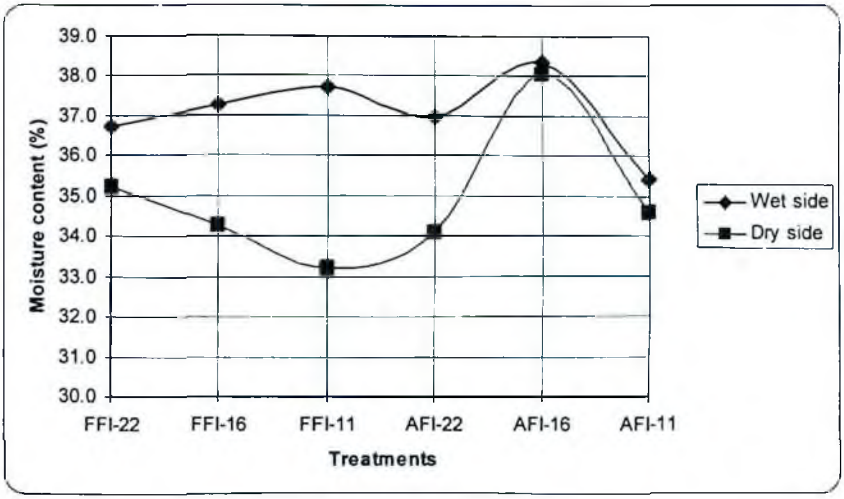
Due to the narrow spacing between furrows and the shallow and more specifically wide (onion shape) infiltration characteristic of furrow irrigation under clay soil at the experimental site, it was expected that the non irrigated part of furrows in the AFI treated and FFI treated plots to be influenced by the wetted side. However, the results of soil moisture analysis showed that there exist differences in moisture content between wet and dry sides of the furrows as well as before and after irrigation water application (Figures 1-4).

Figure 1 Moisture content at 30 cm depth both at drying and wetting side of the furrow before irrigation.



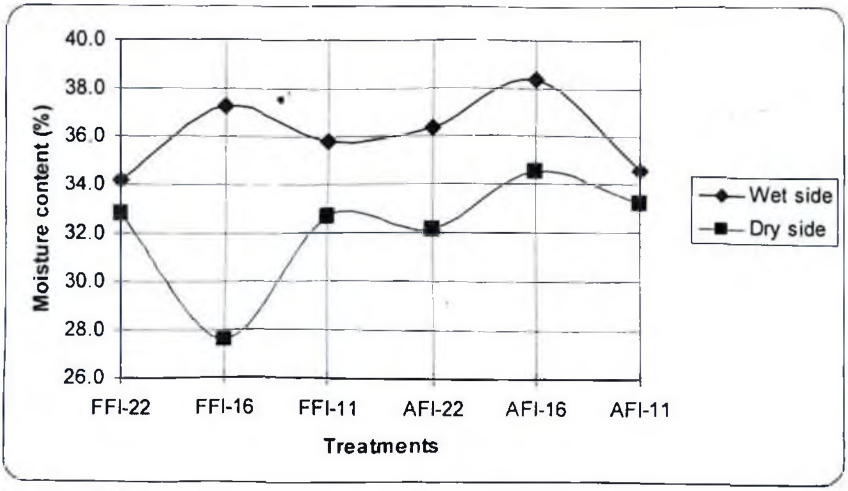
FFI-22, FFI-16, FFI-11: fixed furrow irrigation at 22mm, 16mm and 11mm water application depths respectively. AFI-22, AFI-16, AFI-11: alternate furrow irrigation at 22 mm, 16mm and 11mm water application depths respectively. 30cm-W: 30cm depth and wetting side, 30cm-D: 30cm drying side.

Figure 2 Moisture content at 30 cm depth both at drying and wetting side of the furrow before irrigation.



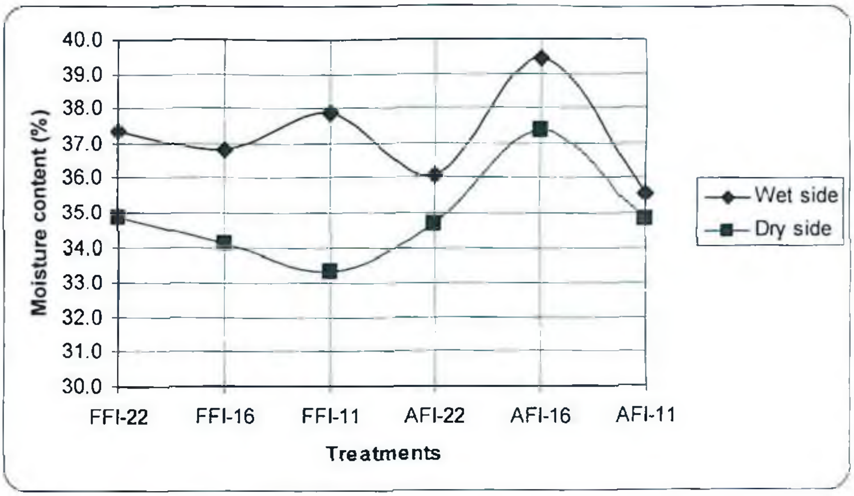
FFI-22, FFI-16, FFI-11: fixed furrow irrigation at 22mm, 16mm and 11mm water application depths respectively. AFI-22, AFI-16, AFI-11: alternate furrow irrigation at 22 mm, 16mm and 11mm water application depths respectively. 60cm-W: 60cm depth and wetting side, 60cm-D: 60cm drying side.

Figure 3 Moisture content at 60 cm depth both at drying and wetting side of the furrow before irrigation



FFI-22, FFI-16, FFI-11: fixed furrow irrigation at 22mm, 16mm and 11mm water application depths respectively. AFI-22, AFI-16, AFI-11: alternate furrow irrigation at 22 mm, 16mm and 11mm water application depths respectively. 30cm-W: 30cm depth and wetting side, 30cm-D: 30cm drying side.

Figure 4 Moisture content at 30 cm depth both at drying and wetting side of the furrow after irrigation



FFI-22, FFI-16, FFI-11: fixed furrow irrigation at 22mm, 16mm and 11mm water application depths respectively. AFI-22, AFI-16, AFI-11: alternate furrow irrigation at 22 mm, 16mm and 11mm water application depths respectively. 60cm-W: 60cm depth and wetting side, 60cm-D: 60cm drying side.

Moisture content in the wetting side exceeds that of the drying side, both before and after irrigation. This clearly justifies the existence of moisture gradient between the two sides of the furrow and existence of partial root zone drying.

Plant growth and yield parameters

Statistical analysis of most agronomic parameters using MSTATC revealed that water application method and / or irrigation water application level resulted into non-significant change in each treatment. Application of 100% level of water under alternate furrow irrigation (AFI-100%) resulted in larger plant height (19.83cm) than the conventional furrow irrigation (16.97cm) under the same water application level (Tab. 1). As the water level declines, the potato crop tends to manage the deficit by controlling its vegetative growth (physiological development) in AFI.

Table 1 Comparison of Agronomic Parameters

NO.	Treatment	Plant height (cm)	Stem diameter (mm)	Number of tubers per plant	Tuber weight (gm)	Total biomass (qt/ha)	Total yield (qt/ha)
1	CFI-100%	16.97	9.27	7.67	79.03	179.5	116.83
2	CFI-75%	19.2	9.5	9.33	77.93	197.04	124.98
3	CFI-50%	18.3	9.1	7	74.6	163.82	106.26
4	FFI-100%	18.67	9.37	7.67	86.87	201.04	126.95
5	FFI-75%	18.2	9.6	7.67	62.93	152.32	91.22
6	FFI-50%	18.4	9.3	6.33	67.6	145.91	90.48
7	AFI-100%	19.83	9.33	7.67	74.5	189.41	122.81
8	AFI-75%	17.77	9.13	6.33	82.43	170.02	108.87
9	AFI-50%	17.37	8.73	7	67.33	149.48	92.59
CV (%)	8.8	4.18	20.85	17.36	20.8	19.81	
	WAM	NS	NS	NS	NS	NS	NS
	IWAL	NS	NS	NS	NS	NS	NS
LSD(5%)	WAM X IWAL	NS	NS	NS	NS	NS	NS

NS: non-significant difference at 5% probability level, WAM: Water application method, IWAL: Irrigation water application level, CFI: conventional furrow irrigation, FFI: fixed furrow irrigation, AFI: alternate furrow irrigation, CV (%): Coefficient of variation in percent, LSD (5%): least square difference at 5%

Total yield was not significantly affected both under different water application levels and water application methods. This indicates that there were no differences in the availability of water during the growing period in all treatments. Total yield of AFI at 50% water application level was 9.259 t/ha. This is only 20.7% yield decline when compared to CFI at 100% water application level (11.683 t/ha).

Mean value of marketable yield was significantly affected by irrigation water application level (Tab. 2). AFI method gave better marketable yield than FFI at all water application level. This justifies the fact that alternating irrigation on both sides of the furrow maintains quality of potato than fixing irrigation to one side. The lowest value for marketable yield (7.017 tt/ha) was recorded at 50% water application level under FFI. Hence, as the water level declines it is better to avoid use of FFI.

Table 2 Comparison of yield and biomass performances

NO.	Treatment	Marketable yield (qt/ha)	Non-marketable yield (qt/ha)	Dry matter content (%)	Root dry weight(qt/ah)	Shoot dry weight (qt/ha)
1	CFI-100%	109.57	7.26	23.88	1.42	7.97
2	CFI-755	112.71	12.27	26.61	1.4	8.18
3	CFI-50%	91.78	14.48	22.98	1.06	7.99
4	FFI-100%	113.98	12.97	25.15	1.3	7.28
5	FFI-755	76.76	14.46	23.92	1.4	8.52
6	FFI-50%	70.17	20.32	23.07	1.13	6.17
7	AFI-100%	117.5	5.31	32.21	1.12	5.49
8	AFI-755	99.56	9.32	23.3	1.43	8.59
9	AFI-50%	83.74	8.85	23.25	1.27	7.16
	CV (%)	22.39	54.58	18.96	21.85	20.56
	WAM	21.77	6.38	NS	NS	NS
	IWAL	NS	NS	NS	NS	NS
LSD(5%)	WAM X IWAL	NS	NS	NS	NS	NS

NS: non-significant difference at 5% probability level, WAM: Water application method, IWAL: Irrigation water application level, CFI: conventional furrow irrigation, FFI: fixed furrow irrigation, AFI: alternate furrow irrigation, CV (%): Coefficient of variation in percent, LSD (5%): least square difference at 5%

In terms of non-marketable yield, significant difference was observed between FFI and [illegible] treated potato plots. The largest yield loss (20.32 qt/ha) was obtained with FFI at [illegible] irrigation water application level. AFI resulted in a lesser values of non-marketable yields under all water application depths than both FFI and CFI treated potato plots at similar water application level. Also, AFI at 100% water application depth showed the highest dry matter content (32.2%) as compared to the other treatments. In addition, AFI under half water application level yielded better dry matter content than CFI at the same level. As the water level declines from 100% IWA level to 50% level, root to shoot weight ratio revealed a gradual raise in both FFI and AFI treatments. This is likely due to increase in root density with development of water stress in each treatment.

Water Use Efficiency

AFI at 100% water application level had a better result (4.45 Kg/m^3) than CFI at the same water level (4.15 Kg/m^3). CFI and AFI showed a better water use efficiency as the water level decreases from full (100%) level to half level. When CFI and AFI are compared at 75% and 50% level, CFI resulted in a better water use efficiency than AFI. In general, through AFI water consumption can be decreased up to 58.3%. Here water use efficiency of potato was increased from 4.15 kg/m3 to 5.44 kg/m3 which are about 31% improvement.

Table 3 Comparison of the Water Use Efficiency

	Water application level (%)	Marketable yield (qt/ha)	Volume of water applied (m^3/ha)	Water use efficiency (kg/m^3)
CFI	**100**	**109.57**	**2640**	**4.15**
	75	**112.71**	**2040**	**5.53**
	50	**91.78**	**1540**	**5.96**
FFI	**100**	**113.98**	**2640**	**4.32**
	75	**76.76**	**2040**	**3.76**
	50	**70.17**	**1540**	**4.56**
AFI	**100**	**117.50**	**2640**	**4.45**
	75	**99.56**	**2040**	**4.88**
	50	**83.74**	**1540**	**5.44**

Summary and conclusion

The responses of most agronomic parameters such as plant height ,stem diameter, number of tubers per plant ,tuber weight, dry matter content, total biomass, total yield, number of plants per plot, root and shoot dry weight to water application method and / or water application level is found to be statistically non-significant. This suggests that introducing PRD at 75% and 50% water application level brought no injurious water stress to the plant. At the field also PRD treated plots showed no vigorous variation with that of the fully irrigated control treatments in terms of the crop stand, leaf color etc.

Moreover, there was no major variation in days required for each treatment to reach maturity. Normally, at research plots this variety requires 100-115 days to reach maturity. In this trial also it actually took 114 days. Stoll (2000) also stated that the effect of PRD on shoot growth and stomatal conductance occurred without any change in plant water status.

Tremendous water saving was made possible with PRD treated potato plots in this experiment. Up to 41.7% saving was practically achieved. In terms of yield, fruit size and quality, the maximum yield, tuber weight and dry matter content were achieved with AFI treated plots. Most recently, a study made by Saeed *et al.* (2005) showed also that PRD could also modify shoot growth and increase WUE in potatoes. Water saving was also possible in the conventional as well as fixed furrow irrigation methods, but both have certain demerits. FFI treated plots at 100% level followed by CFI at 75% water application level had the maximum total yield. But on the contrary, the non-marketable yield (yield loss) was larger in both cases. The mean % yield loss with decline in water level was 9.8%, 15.5% and 7.2% for CFI, FFI and AFI treated plots respectively. The lower yield reduction under AFI clearly revealed that the potentials of PRD in maintaining the quality of crop yield.

The relatively low performance of FFI could be associated with the prolonged exposure of roots to drying. It is thought that this condition may cause exposure of roots to drying soil and may bring anatomical changes in the roots such as, suberization of the epidermis, collapse of the cortex and loss of succulent secondary roots (North and Noble, 1991).

These changes are such that the roots under prolonged soil drying may function simply as transportation 'pipes' with a very low radial permeability of water. Such hydraulically isolated roots in soil would have reduced ability to sense soil drying. On the contrary, alternate watering or re watering, after long period of soil drying, may improve this situation by inducing new secondary roots (Liang *et al.*, 1996).

PRD can be seen as a more efficient irrigation strategy where a small amount of water is available particularly as it doesn't result in significant yield reductions (Stoll, 2000). Compared to other deficit irrigation techniques the yield reduction measured under PRD condition relative to control was minor (Stoll, 2000 and Dry, 1997) A consistent feature of these trials was that there was no significant reduction in yield due to PRD treatment, even though the amount of irrigation was halved. As a result yield per unit of water applied was doubled in response to PRD.

In this experiment, as compared to the control (i.e. CFI with 100% irrigation requirement level), PRD treated potato under half (50 % irrigation application level) resulted only in 23.6 % yield reduction. In terms of dry matter, the maximum dry matter content was obtained with fully irrigated PRD treated potato plots. Again, under 50% water application level, PRD plot also maintained almost the same dry matter content as that of CFI.

In addition, reducing water application level from 100 to 75% under CFI increased the WUE from 4.15 kg/m^3 to 5.44 kg/m3 respectively which is about 31.1% improvement. This has practically significant meaning in terms of bringing an improvement in the overall water management practice. It minimizes the risks associated with water logging, evaporation and deep percolation losses, leaching of minerals and salt build up in the system which may result due to excess water application. Moreover, the 41.7% water which is saved as the result of adopting AFI could be used for other beneficial purpose: i.e. to expand the irrigated area, or irrigate higher value crop or provide supplementary irrigation for rain fed crops. Reduction in pumping cost, labor and time are additional benefits of using this technique.

PRD treated potato at 50% level brought real improvement in water use efficiency as compared to the control (i.e. CFI-100%). But as the water level decreases from 100 to 75% and 50% level, the WUE of the CFI treated potato plot showed dramatic improvement from 4.15 kg/m^3, 5.53 kg/m^3 and to 5.96 kg/m^3 respectively. Hence, it implies that if one is going to adopt traditional methods, it is advisable to consider the CFI with 50% water application level for better WUE. But this method has certain disadvantages as compared to AFI which was treated with 50% level. It requires more labor and it has higher chance for evaporation as compared to AFI since in traditional systems larger surface area of water or wet soil is exposed. In addition, in terms of quality CFI treated potato had lesser dry matter content and higher value of non-marketable yield. Therefore, PRD can be adopted to enhance efficient utilization of water especially in water scarce arid and semi-arid areas.

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Potato Seed System in the Amhara Region: Retrospect and Prospect

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Abstract

Potato is among the widely cultivated and consumed horticultural crops in the Amhara National Regional State (ANRS). It has un-substitutable role of ensuring food security agenda in the mid and high-altitude areas of the region because of its comparatively short crop cycle and high productivity per unit area. In the ANRS over 71 000 hectares of land is put under potato cultivation and supported over 600 thousand rural households.. A considerable number of people are also supported by this commodity at post production stage of wholesaling, retailing and processing of fast food. Yet average productivity of potato in ANRS is quite very low, 5 t/ha. This yield is by any standard far below world average of 15 t/ha. In contrast results of on-farm demonstration activities have indicated the possibility of elevating this yield to over 3-5 fold. One of the major reasons for this low level of productivity is unavailability of seed production and delivery system to ware potato producers. As a result traditional informal seed system has remained the entire source of seed with the small scale subsistent farmers being exclusive actors. In this system seeds of inferior quality of health and purity are recycling as seed among growers almost all the age of potato in the country. The absence of any kind of inter and intra Regions quarantine makes the matter worse through dissemination of seed borne diseases of devastating nature. Consequently, pathologically poor seed tubers have dominated this system. To ease such emerging threats of devastating diseases and respond to the need of transforming the subsistent agriculture improving the seed system and its delivery system is very crucial. In response to this urgency various attempts were made at varying level of participation. The earlier effort focused at injecting starter seeds of improved varieties. This was scattered, fragmented, lacking follow up and coordination among concerned stakeholders. Latter on the earlier effort is amended by the inclusion of organized groups of farmers-researcher-and extension system (FREG), provision of trainings, better follow up and creation of marketing system in addition to seed tuber injection. This system still is in short of institutional arrangements and provision of pathogen tested starter seed tubers that guarantee sustainability of the system. To surmount these limitations use of available tissue culture laboratory for the mass propagation of healthy nuclear seed stocks, share of responsibilities among public institutions such as regulatory body Research, Extension, Cooperative institutions, NGOs, private sectors is very important. This paper presents review of retrospects and prospects of potato seed system in the light of the earlier efforts within the Amhara National Regional State.

Introduction

Potato (***Solanum tuberosum*** L.) was introduced to Ethiopia in 1858 by a German Scientist called Schimper (Pankhrust, 1964). Availability of suitable agro-ecology and its importance in ensuring food security has helped its expansion to all over the country. In the Amhara region, over seventy thousand hectares of land is covered by potato during the year 2001/2002 (CSA, 2003). However, this production has been exclusively supported by traditional seed system which is characterized by informal multiplication and distribution of seed tubers by small scale subsistent farmers. This system is dominated by local potato cultivars with low productivity and high susceptibility to disease. As a result, unavailability of quality seed tuber of improved potato varieties has become one of the major causes for the low productivity of potato in the region.

In order to transform this scenario the research system has been making multifaceted efforts. Consequently, several improved potato varieties that give four to five fold yield advantage over the local varieties have been released. Nevertheless, potato growers have not been benefited from this result which is obtained by immense public investment mainly because of unavailability of seed production and delivery system. In order to bridge this gap various attempts that went through several modifications were made mainly by the research system and some development partners. Recently, these experiences have evolved to scaling up project of potato seed tubers. This initiative attempts to augment the informal system with better technical knowledge and improved potato varieties released by the research system. This has overcome the shortcomings of earlier undertakings with regard to scale of production. Unlike previous experiences, the scaling up project involved private seed growers in addition to development organizations and farmers organized in group that are specializing as commercial seed growers.

Apparently, such initiatives look sound and sustainable as compared to the widespread traditional seed system that has been constraining potato production in the region. However, there are still several issues that need to be addressed in order to put the potato seed system on the right track. This review paper attempts to describe retrospect and prospects of potato seed system in the region. It also analyzes constraints associated with the seed system and suggests the way forward. Since over 95% of potato area coverage and production of this region is found in the Western Amhara sub region the papers mainly focuses on experiences of potato seed system in this area.

Potato Seed tuber Demand of ANRS

During the year 2001/2002 over seventy thousand hectares of land is covered by potato in ANRS (CSA, 2003). If we assume average annual area of land occupied by potato to be 50,000 ha, the annual demand of seed tubers in the region will be 100, 000 tones with seed rate of 2 tones/ha. This potato is harvested from an area of 6666.67 ha if productivity assumed to be 15 tones per hectare. This figure is simply the annual demand for certified seed. In order to make the system sustainable the seed production should continue at various generations of seed tubers. Accordingly, in order to get 100, 000 tones of certified seed the following year the amount of seed tubers at basic stage and pre basic stage amount 13,333 tones and 1777.78 tones respectively making the total amount of seed annually needed in the region 115,110 tones produced over an area of 7674 ha. If research centers are going to be sources of starter material for 1777.78 tones pre-basic seed, they are expected to provide 237 tones of starter potato seed every year. Currently the amount of improved potato seeds is less than 1000 tones in the region which is less than 1%. As potato is a bulky crop and the infrastructure is not well developed to transport or market seed tubers easily at every corner of the region, the actual annual demand may not amount the above figure. If only 50% of the 50,000 ha is put under improved varieties seed, the tonnage of the seed demand will be 57,555 tones still indicating ample opportunity to invest on potato seed production.

Average regional productivity of potato is nearly 5 tones/ha. If improved potato varieties are used with associated production package, this productivity can be increased to 20 tones/ ha, the current regional annual production will then be increased three to fold implying the potential to boost production, ensure food security, improve income and livelihood and achieve rapid and sustainable development in the region.

However, experiences indicate that unless research, production, and marketing of both ware and seed potatoes are well integrated it will be difficult to guarantee the desired development goals. Availability of processing and marketing firms is of paramount importance to run the seed system very well (Da, 2004). In this regard, there is no single processing plant of potato in the region. Participants of the current marketing system are also not efficient in gearing potato production in to market oriented one.

Retrospect of Regional Potato Seed System

Alike many developing countries, the national and regional potato seed system is predominantly informal. This system remained too traditional and had never been improved since introduction of potato to the country. As a result multiplication, post harvest handling, distribution and marketing of seed tubers are predominantly carried out by the subsistent small scale farmers. Currently, there are emerging initiatives targeted at improving this informal and traditional system. Hence, this paper will describe the two systems independently as traditional informal and the improved informal sector.

could recommend adaptable potato varieties tested in the region. On farm demonstration of these high yielding and late blight resistant varieties created demand for seed tubers of the varieties. However, since there has not been any responsible body for production and distribution of quality seed tubers in the region, this demand could not be satisfied. The extension of potato was not full-fledged in that it missed the varietal component. This was a real challenge for the regional research centers which were not well capacitated with human resource and research and seed multiplication facilities. However, the centers followed different approaches to overcome this challenge. Following on farm demonstrations that create demand for the improved varieties, the centers started to provide starter planting material for individual farmers, public agricultural extension offices and non governmental organizations. This was also not complemented with organized training on seed production and post harvest management techniques except simple orientation on the techniques. The centers used to demonstrate diffused light seed potato storage structure that is constructed from locally available materials. This approach was fragmented and scattered and was not going on at the desired rate. Inconsistent performance of partners and inherent inconveniencies of the approach it self had negatively affected building up of community seed bank of farming community.

Later on, this approach is amended to include training on seed production techniques. The center started to make prior consent with partners not to use or sale seed tubers for table up to limited generation of the seed tubers and the purpose is to increase the volume of seed tuber in the system. The research centers kept on providing starter planting material to non governmental and governmental organizations involved in further multiplication and distribution of the seed tubers. On the other hand they directly approached the farmers by organizing them in working groups called Farmers-Research-Extension- Group (FREG) who is involved in participatory on-farm seed multiplication. This has helped to multiply seed tubers on larger area by merging plots of farmers. Collective responsibility is given to the farmers to manage the plots as per the recommendation and use the seed tubers for seed purpose until other members of the group get seed tuber that enables them to specialize as seed tuber grower. In order to increase multiplication frequency farmer who possess irrigable land or can acquire it are included in the group. Willingness to construct DLS from locally available materials and keenness to follow recommended production and post harvest packages and practices has been prerequisite to join the FREG involved in seed tuber multiplication. Organization of field days of various scales has helped the FREGs to sell their produce at motivating price. In addition the approach used the informal seed exchange system among farmers as a means of diffusion.

The scaling up project is considered as a variation or a modified version of the improved informal system in this paper. This project has capitalized on experience obtained in earlier approach. The major difference of this approach is from the earlier one is the magnitude vertically as well as horizontally involved institution and scale of operation. Vertically it has caught the attention of higher regional decision makers as it involved utilization of substantial resources, i.e., in space and time wise, it is expanded to and started at all major potato growing areas of the region. This project is primarily spread headed by the regional research system though various development organizations and farmers were also involved. Associated with the increase in magnitude of the work, the project has shared substantial human, financial and logistical resources of the research system. Normally the research system has institutional mandate of backstopping the seed system by generating new improved potato varieties and by providing starter planting material. However, the research system is being involved in facilitation and distribution of seed tubers, field inspection and approval.

Constraints of the improved informal systems

Because of unavailability of tissue culture and associated facilities, the informal seed systems activities have not been supported with pathogen tested starter seed tubers of improved varieties. Besides, the amount of starter material provided has also been inadequate because of the same problem. As a result there has been certain level of disease risks originating from the absence of any backup efforts on tissue culture and associated health status improving processes. The supports given to the system were also not sustainable because of financial, logistical and human resource constraints. Lack of efficient coordination or short-lived collaborations among stakeholders also adds to the list of constraints of the system. Lack of efficient coordination among the stakeholders is partly attributed to absence of accountability for not undertaking roles and responsibilities specified to each stakeholder.

As indicated earlier the low level of regulatory body involvement, absence functional seed health improving and insuring tissue culture laboratories in the region and unavailability of interregional and intra-regional quarantine system has been a challenge of the ongoing efforts of improving the informal seed system. Observations and reports also indicate the increasing alarms of diseases like bacterial wilt from time to time. Hence, the operation of these bodies is duly waited seriously and shortly.

Provision of starter planting material, training on seed production techniques, field inspection, approval for distribution and facilitation of marketing and distribution have been carried out by the regional research system in an effort made to facilitate the system. In principle, at least approval of seeds health standard for distribution has to be carried out by an independent regulatory body that can enforce seed policy related to seed standards set in the certification policy. Facilitation of seed tuber marketing and distribution should also need to be carried out by other responsible body.

As the objective of the improved informal seed system initiatives is producing seed tubers of better genetic potential as compared to the traditional informal system maximum attention should be given for important factors such as delineation of low aphid population areas, maintaining isolation distance from table potato production fields and possible contamination through flood and irrigation water. This is more applicable to the emerging seed growers who acquire land through rent.

Prospect of Potato Seed System in ANRS

Utilization of seeds of improved varieties with associated production packages helps to boost production and improve the livelihoods of the farming community as well as other parties involved in the agri-food system. To this effect, organizing appropriate and sustainable seed system will be of a paramount importance. Hence, this system has to ensure seed security in time, space, and amount desired. In order to do so, the seed system of potato has to mix the private (including cooperatives) and the public sectors (Pray and Ramaswami, 1993). This is particularly important as the private sector is not in a position to be involved in research, disease free seed tuber production, marketing and distribution at a desired scale. Based on prior experiences gained on improving traditional informal seed system, this paper proposes organizing of the seed system in the following fashion.

The agricultural research centers should continue working as part of the formal system that continuously evaluates series of potato germplasm for subsequent release of high yielding and disease resistant potato varieties that have desired qualities. The release mechanism that registers and recommends production of varieties promoted by research centers should also be there.

technical advice should also be provided by extension workers. This will enable the seed system to avail acceptable quality seed tuber as per the standards of the regulatory body.

Establishment of services that facilitate marketing and distribution

Unless the seed growers get motivating price for their seed, sustainability of the seed production scheme will not be guaranteed. Hence, there has to be a service that assists or facilitates marketing and distribution of the improved seeds after the seed tubers are approved for distribution. Some of the mechanisms can be certifying the seed tubers produced, creating demand, providing credit for table potato producers to encourage them use the improved seed tubers, facilitating marketing by organizing and availing information for seed potato producers and users. This facilitation work can be jointly done by the extension services, farmers' cooperatives and cooperatives promotion agencies. In order to create strong market for seed potato table potato growers should get reasonable price that encourage them to use improved seeds. Hence, agribusiness firms should be encouraged to invest on establishment of processing plants or efficient market firms.

The ideal seed system is a flush out system, where certified seeds are not recycled under farmers' condition. This system helps to reduce disease risks and diseases build up. It also makes demand of seed tubers stable and creates encouraging market for the farmers. However, until improvement is observed on the seed bank of the community cycling of certified seed tubers at most twice by table potato producers can be advised. This is important in places where infrastructure is lacking and the farmers are resource poor. However, this has to be allowed only when disease risks associated with doing so is minimal and this will be based on advice of the development agents in the area. Incidence of diseases, presence of mixture, and overall management of the plot are some of the criteria to be considered. This has additional advantage of decreasing production cost.

Establishment Quarantine and Certification Procedures

Seed tubers produced in the informal system do not have health standards and any sprouted potato tubers are exchanged and planted as seed tuber. The improved informal system has also been checking seed tubers based on physical symptomatic expression. This procedure is not valid for latent viral and bacterial diseases of potato. Therefore, testing incidence of important diseases should be carried out following appropriate pathological procedures whenever there are doubts on the health standard of the plants. Yun (2004) states the importance of standardizing incidence judgment while undertaking inspection of seed tubers production fields. Seed tuber certification has to be based on this result. Transport, marketing and utilization of seed tubers for table potato production should be supported by certificate. This helps to exclude movement and wider use of uncertified seed tubers produced informally by various parties. In addition, the regional plant health clinic laboratories have to frequently check incidence and distribution of selected diseases and assist the regulatory body by providing information used for marking areas that need to be quarantined. Similarly, monitoring populations of important vectors of potato diseases has to be made on areas specialized for seed potato production.

Who should produce seed?

So far the predominant seed producers are small scale subsistent farmers. In the improved informal seed system which is at its infancy, governmental and non governmental organization, trained small scale seed farmers, and private commercial seed growers have participated in seed tuber production. There is growing interest and a good beginning of undertaking the seed production work by trained small scale seed farmers, and private small scale commercial seed growers. Under the existing situation the seed growers do not have the facilities such as tissue culture laboratory, and screen houses. Hence, these seed growers can not be involved in multiplication of tissue culture plantlets and early generation multiplications of seed tubers. The regional research centers should, at least, possess screen house primarily meant for undertaking rapid multiplication of early generation seed tubers. Involvement of the public institutions in multiplication of certified seeds has to be minimized gradually until the seed growers get the capacity to produce economic scale seed tubers. Meanwhile, investors who have better financial and logistical capacity have to be encouraged to invest on tissue culture facilities and screen houses.

The role of public institutions should be maximized on technical support, facilitation and regulatory role that help to improve the capacity of the seed growers and the quality of the seed tubers produced. Similarly, non governmental organizations should also take part in capacity building, facilitation of production and marketing. Involvement of NGOs and parastatal enterprises like Ethiopian Seed Enterprise (ESE) in seed tuber production and distribution should not be ruled out. As compared to grain crops potato seed system has several constraints. However, unlike those crops, potato seed production and distribution has not been assisted by projects that have objective of improving the seed system. Hence, the regional government has to encourage public institutions, and other development organizations to be involved in potato seed production schemes.

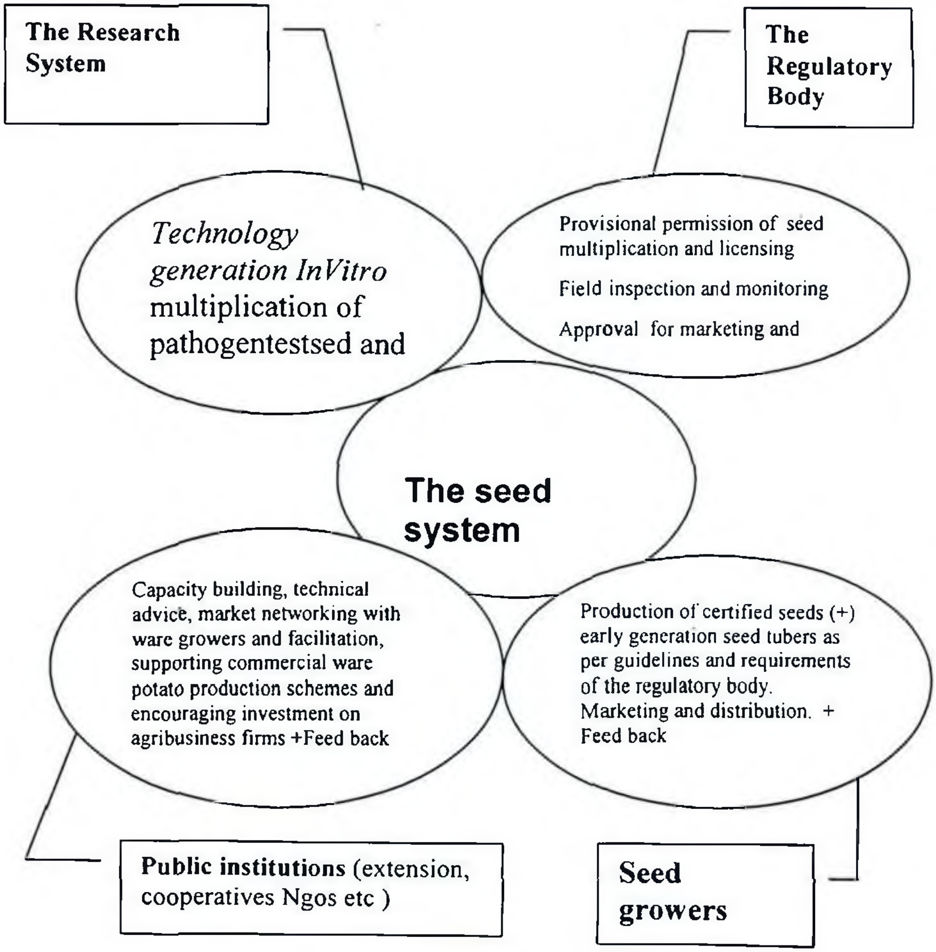

Figure 2. Schematic illustration of proposed potato seed system

As started in the scaling up and scale out project, seed tuber production has to be undertaken in isolated highland areas. Acquisition of land in these areas is simple for small scale farmers who have their own land or can get easy access. The rest however should secure land through lease, rent, and share cropping or contracting small scale farmers. Land renting may not enable the seed producers to obtain suitable land for seed tuber production. In addition they may not get relevant information such as crop history of plots. The latter may result in prohibitive cost of seed tubers. As beginners, many of the small scale commercial seed producers have limited financial and logistical capacity. Awareness on ethical issues is also limited among these groups. Therefore, while maximizing involvement of the regulatory body care has to be taken not to hamper flourishing interest of this business venture.

Seed growers acquire starter seed tuber from research centers by covering only cost of multiplication. As the varieties are developed by public research system, seed growers do not pay royalty fee or the cost of developing the variety. Hence, the price of certified seed tuber sold by seed growers should be regulated in such a way that it reflects this indirect subsidy.

Summary

Potato is playing pivotal role in ensuring food security of the population in marginal highland areas of the region. It has also immense potential to boost investment in the agri-food system. On the other hand, potato is susceptible to a wide variety of pests and diseases. The fact that it is conventionally propagated by vegetative means aggravates risks from disease transmission. Despite availability of improved varieties, involvement of the private sector and public institutions has been almost non existent in multiplication, marketing and distribution of seed tubers in general. Therefore alike many regions of the nation, potato production has been constrained by unavailability of quality seed tubers in ANRS. Traditional informal seed system entirely run by subsistent small scale farmers has been supporting several thousand households and covers thousands of hectares of area covered by ware potato in the region. As this system has been exclusively dependent on genetically, physically pathologically inferior potato cultivars, several initiatives were started to improve this system. Recently encouraging results have been obtained on possibility of ensuring food security and improving the livelihood of small scale potato farmers through seed and ware potato production. This is particularly exemplified in scaling up projects of seed potato production. However, unavailability adequate facilities, lack of coordination among stakeholders, shortage financial and logistical support, lack of awareness on financial and economic advantages of using quality seed tubers, minimal role of the regulatory body etc have been challenges of the various seed production initiatives started in the region.

In order to guarantee sustainability and expansion of such initiatives the traditional informal seed system has to be improved with clear roles and responsibilities of the stakeholders.

As there is plenty of improved adaptable, high yielding and disease resistant varieties tested and released/recommended for the region, the system has to be based on pathogen tested starter planting material of these varieties. Research centers which will be sources of these materials have to be capacitated, at least, with facilities like Diffused Light Store, screen house, irrigation infrastructure etc. Management of screen houses and undertaking the Rapid Multiplication Techniques, management of diffused light store, seed production fields etc demands substantial amount of man power. In recognition of these activities the research centers should be staffed with adequate man power.

Seed growers should also build their technical knowledge and preliminary physical facilities that help them produce and handle, at least, certified quality seed tubers at appropriate condition.

The system has to be augmented with strict and functional regulatory framework that sets quality and ethical standards, requirements, approval mechanisms that include strict monitoring and field inspection. Mechanism of averting risk associated with infestation of diseases including integrated disease management, vector populations monitoring system and quarantine service has to be thought.

Roles of public institutions have to be maximized on capacity building, facilitation of marketing and distribution by networking of ware and seed potato production, technical advice and monitoring of production fields.

Involving public institutions, parastatal organizations, NGOs (that have the capacity to produce quality seed tuber) in multiplication of early generation and certified seed tubers production helps to improve the seed stock of improved varieties in the region rapidly. Seed production scheme with out market oriented or commercial ware potato production system can not be sustainable. Hence, investment on agribusiness firms that market or process potato is vital. Given its multifaceted advantage this has to be done even by public fund until it gets the attention of the private sector.

In the era of globalization the improved informal system will be a strategy that helps to converge or compete with trans national seed companies. Avoiding such amendments and lack of intensive public support to this system might have serious repercussion on the food security and livelihood of the subsistent small scale farmers who can not afford purchase of costly seeds produced else where. This is particularly important as the country is currently striving to be member of World Trade Organization.

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Contract farming: Prospect towards sustainable supply of raw potato for processing plants in Northwestern Ethiopia

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Abstract

Contract farming is one of the strategies adopted by the government of Ethiopia in order to transform the subsistent agriculture to market oriented commercial farming. This strategy is particularly prescribed for densely populated high and mid altitude areas of the country. To realize this strategy, various contractual production initiatives are emerging in Northwestern Ethiopia. The interest of the private sector to invest on processing plants of selected commodities is also growing. Given the vast area of production and rich experience available in the region, potato has become one of the commodities that could catch this attention. However, there has not been ample experience on contractual farming of bulky and perishable horticultural commodities such as potato in the region. This study was therefore carried to critically analyze availability of enabling environment for potato contractual farming in Northwestern Ethiopia. The study was conducted at selected districts of Awi zone where potato is extensively produced. Results of this study indicated that contractual farming of potato can be safely realized in the area to ease the prevalent constraint related to marketing of potato in the area. Moreover, such scheme can also help trigger farmers to improve the productivity of this crop through utilization of improved varieties and associated production packages. Reviewed literatures on experiences of various countries have also proved that these commodities fit best to contract farming once the scheme is put in place under enabling environment. This however does not rule out the fact that bulky and perishable products' sensitivity to various factors as contrasted with grain crops. Availability of extensive production areas and possibility to further expand production area; prospect to boost productivity; improvement on the infrastructure situation, and emerging farmers organization, favorable policy environment towards contract farming etc are opportunities that allow realization of the contractual farming schemes for a sustainable supply of raw potato for the processing plant to be constructed. On the other hand, as the existing production system is unlikely to satisfy the demand of the processing plant in terms of quality, production scale, and year round supply, extensive efforts need to be done in changing the mind set of the producers and placement of an efficient institutional support to it. Further improvement of the infrastructure situation is also vital to guarantee easy and timely supply of agricultural inputs and out puts.

Introduction

Eaton and Shepherd (2001), define contract farming as a forward agreement between farmers and processing and/or marketing firms for the production and supply of agricultural products, frequently at predetermined prices. Usually the agribusiness firm is the one who specifies what to produce or how to produce or resources used for production. In return, the farmers agree to provide the produce at the desired volume, quality and time under guaranteed market from the firm.

In Ethiopia, well-organized contract farming that offer better and cost effective in put utilization, mechanization and extension service system is considered as strategic option to transform the subsistent agriculture to market oriented commercial farming (FDRE Ministry of Information, 2003). It is particularly prescribed for densely populated mid and high altitude areas where small-scale farmers occupy agricultural land. On the other hand, except limited experiences on seed production and emerging scale-up initiatives on production of selected crops, contractual production is not wide spread in the region.

Potato is among widely grown crop in the mid and high altitude areas the region. Hence, it could be one of the priority crops proposed for contractual production with agribusiness firm in the area. As bulky and perishable crop its production is recommended with processing plants.

Realization of effective contractual farming scheme, however, demands critical analysis of available opportunities and constraints. Such analysis will help design proper strategies that can maximize the available opportunities, overcome constraints, and minimize potential threats. Repercussion of ill planned and managed out grower scheme could be disastrous for both parties. Hence, this study was conducted with the objective of assessing possibilities of establishing successful contractual farming of potato that integrates potato production and processing for mutual and long lasting benefit of the partners. Thus, this paper attempts to review the potential advantages that contractual farming of potato can offer and availability of enabling environment for effective contractual production scheme. It also suggests the formula of the contractual farming and role of various partners in the scheme.

Methodology

The study was made through collection and analysis of secondary data and reviewing of various related literatures. Supplementary primary data were also collected by arranging field visit. The fieldwork was carried at three districts of Awi administrative zone. These were Banja shikudad, Fagita Lekoma and Ankesha Guagussa. These districts were selected based on current production status, potentials for expansion and proximity to the planned processing plant. In each of the districts brainstorming sessions were held with relevant parties working on agriculture and rural development at zonal and woreda levels. Discussions were also made with farmers and leaders of farmers' cooperatives.

During the discussion, focuses were given on available opportunities of contract farming and potential roles of various stake holders, *i.e.* public institutions, farmers, farmers organizations, the sponsor, other the private sector partners involved in improving the infrastructure situation, input supply, guarantee sustainable seed system, provision of extension service, contract specification, pricing, strengthening farmers cooperatives etc. Observations were also made on the infrastructure situation and availability of useful facilities like seed and ware potato stores.

Result and Discussion

Potato: Is it the right crop for contract farming in the study Area?

In Northwestern Ethiopia, potato is produced in densely populated highland areas where crop enterprise choice is limited. Most of the extreme high land areas are now resource poor because of low productivity of other crops grown in the area. This poor productivity is mainly attributed to land degradation associated with long years of irrational use of natural resources (ANRS & UNECA, 1996). Many of the farmers in these areas rely on potato and few other low priced crops for cash. However, its role as an important cash generating crop is minimal because of various constraints. Its importance as vital food crop, however, is unsubstitutable for many of the farm households, particularly during the rainy summer months. Available agro ecological advantages, its importance in ensuring food security to the farming community and other peculiar features of the crop have justified extensive production of potato in the high altitude areas of the region.

Potato as bulky and highly perishable crop has several constraints on its marketing. These constraints have impeded adoption of new potato production technologies and utilization of modern inputs. As a result productivity of potato in the area is far below the potential yield that can be accrued.

Contract production with processing plants allows the farmers in these marginal areas to have market and reasonable price for their major agricultural produce, potato. This will motivate producers to adopt improved technologies and management techniques that help to boost production and improve quality. Under contractual farming, the desired commodities are produced at specified volume, delivery time and quality standards. Such practices can help change farmers' production culture from subsistent farming to commercial farming.

As a bulky and highly productive crop, potato production is labor intensive. It creates immense employment opportunity in seed and ware potato production, cleaning, sorting and grading, storage, transport and marketing aspects. The rural development policy gives priority to development projects that tend to make best use of available resources such as land and labor. Therefore, the aforementioned peculiar characteristics of the crop make it the right commodity that fits to the government's strategy.

Contract production of bulky horticultural crops like potato is more justified as compared to grain crops that are not sensitive to post harvest handling and do not require strict quality control (Rehber, 1998). Global experiences also indicate that share of contract and integration made between processors and producers of such commodities are quite high. As the agricultural land in most of the potato producing areas is predominantly occupied by small-scale farmers, acquisition of land that allow large scale private farms is very difficult or impossible. Under this situation processing plants can get reliable supply of the raw potato through contract farming. If carefully handled such hundreds and thousands of subsistent farmers based contract farming of potato production is socially and politically acceptable.

Does enabling environments are Available for Potato?

Production status, utilization and potential

Production status

The 2001/2002 cropping season statistical report of the area covered by potato was over seventy thousand hectares (CSA 2003). This region shares nearly 50 percent of area allotted to potato nationally. In the Amhara region there are three production systems, viz., rainfed, irrigated and residual moisture. Of all these the rainfed production system is the dominant one. These systems enable to evenly distribute production across seasons with minimum intervention. Hence, it assures year round availability of the produce and overcoming of inherent storage problem associated with the commodity especially during the harvesting time of the main rainy season production at which supply of fresh potato to the market tremendously increases and the price abruptly falls. The availability of potato processing plant or efficient market firm in the area therefore helps to buffer market related problems and get fair mutual benefit among the parties. Unfortunately, there is neither a processing plant nor efficient market firm that can do so in the area.

Constraints: Diseases, insect pests, traditional management practices, unavailability of seeds of improved potato varieties are among the major production constraints of potato in the area. However, there are readily available production technologies that can help curb these problems. As long as the farmers get motivating market price that can justify their cost of production, farmers can easily adopt these technologies. During the field visits strong affinity of farmers to the high yielding and disease resistant potato varieties was observed. As the crop is quite popular and most of the farmers have quite good experience of potato production, there will not be a challenge in expanding potato production in the area.

Utilization

On the average 8.79% or 29 322 tones of the total annual produce is sold at market. This produce is consumed either by urban residents in the vicinity of the production areas or traded to distant places. The remaining 91% is utilized for household consumption and seed at producers level (Table-2). As there is no any potato processing plant in the vicinity of the production area, potato produced by the farmers is marketed as it is with out any value addition. Currently, few one-person operated mobile chipmakers are seen in the urban centers like Bahir Dar.

Table-1 Estimate of holders, area, production and yield of potato for private peasant holdings for both season for the Amhara Region in the year 2001/2002

No	Zone	No of holders	Area in hectares	Average land /holder (ha)	Production in tones	Yield in tones/ha
1	North Gonder	42 700	22 02.95	0.052	23134.84	10.5
2	South Gonder	190 070	23 760.71	0.125	165417.97	6.92
3	East Gojjam	121 860	16 603.07	0.136	32827.90	1.98
4	West Gojjam	123 701	14 072.02	0.114	46106.57	3.28
5	**Awi**	**82101**	**13 823.41**	**0.168**	**65941.93**	**4.77**
	Total	**560 432**	**70,462.16**	-	**333,429.22**	-
	Average	-	-	**0.126**		**5.49**

***Source :** FDRE, Centeral Agricultural Census Commision, 2003*

Potato producers commonly consume it by cooking it in boiling water or in the form of sauce. However, now a day it is common to see variety of foods prepared from potato in many of the restaurants especially during the fasting season of the orthodox Christians. Price offered to farmers during these seasons is relatively better and farmers usually target these seasons under irrigated production. New market outlets like Metema have become opportunities for potato marketing even though the market price fluctuates across seasons following the supply pattern. Potato growers in the area ascribe the following two reasons for their consumption of large proportion of their producer at the household level. The first reason the is excess supply of the dominant growing season produce to confined market and associated too low price offered to justify the cost of taking the produce to the market or the time elapsed to do so. The second reason is that most of the farmers run out of food during this period and are also unable to sell their produce with reasonable price that can permit them purchase and supplement their diet with other food crops. It is anticipated that offering motivating market price as compared to what is presented now definitely lets growers sale more of their produce. Generally, because of inefficient traditional storage methods, inadequate transport and handling facilities the post harvest loss of potato is very high.

Table 2: Potato production and percent of utilization in Amhara region in 2001/2002 cropping season

No	Zone	Production (t)	Percent Utilization						Sale (t)
			HH Consm.	Seed	Others	Wage in kind	Animal Feed	Sale	
1	N.Gonder	23134.8	82.91	10.17	0.9	0.11	-	5.9	1364.95
2	S.Gonder	1,654,18	75.87	15.07	0.64	1.84	-	6.58	10884.5
6	E.Gojjam	32827.9	61.14	21.08	0.65	1.56	0.24	15.33	5032.5
7	W.Gojjam	46106.6	65.19	20.29	0.38	1.17	0.01	12.97	5980.0
9	Awi	659,41.9	67.59	21.29	0.52	1.42	-	9.19	6060.1
	Total	333429.2							29322.1/ (8.79 %)

***Source :** FDRE, Centeral Agricultural Census Commision, 2001/02*

Production Potential

The total area of land covered by potato and volume of produce harvested during 2001/2002 *meher* and *belg* cropping seasons from the five administrative zones of Northwestern Ethiopia was 70,462.16 ha and 333,429.22 tones, respectively (CSA, 2003). The average productivity during this season was about 4.7 qt/ha (Table 1). As indicated earlier the amount of potato sold at market is about 30,000 tones. This demand for fresh consumption may increase with increase in population and increasing market out lets to distant areas. Therefore, it is important at least to reserve the existing area or volume of production and produce additional volume to guarantee new supply for the processing plant. This will help to overcome problems emerging from relying only on existing production volume. This could be extra contractual marketing contrary to the uneconomical price offered from other market competitors.

There are couples of options to guarantee supply of economic scale to the processing plants. The first option is increasing productivity per unit area/unit time. The regional average productivity of potato is about 4.7 tones /ha (CSA, 2003). Under the existing production system utilization of seeds of improved varieties is almost nil. Despite poor soil fertility and pressing diseases and insect pest problems, utilization of agrochemicals is also negligible. On the other hand, productivity of over 30 t/ha is obtained from research station using improved varieties and their recommended production package. If 10% (7 046.2 ha) of the area under potato production indicated above is put under intensive production system and average productivity is increased three fold, *i.e.* from 4.7 tones/ha to 18.8 tones /ha (which is conservative speculation) and additional yield of 14.1 tones/ha (i.e. 18.8-4.7= 14.1) is obtained per hectare, the total production will increase by 99,351.42 tons (14.1 x 7 046.2). This will avail 40 tones of potato per day for a potato processing plant that works for 250 days a year.

There are various opportunities that help to realize this strategy. To mention some;

- There is wide gap between the actual productivity and potential yield that can be obtained from the crop in the zone. This clearly indicates an ample opportunity to boost potato production.
- There are sufficient numbers of high yielding and disease tolerant improved varieties tested and released for the area.
- There are sufficient information on recommended packages that gets along with the improved varieties.
- The contractual production scheme will put in place more efficient technology transfer mechanism.

- Motivating market price, access to credit and desired agricultural inputs will be facilitated with the contractual farming
- The presence of rich potato production experience among the growers will help overcome resistance feared in new intervention areas if other requirements are met

Increasing area allotted to potato production is the second option. The average area allotted to potato per household is 0.126 ha. Unless this figure is increased, the total number of farmers that need to be brought under contract to obtain reasonable area of land that sustains the processing plant will be too high. The total area required may also be spatially scattered over larger geographical area. Increasing area allotted for potato helps to increase supply, justify extension service given to farmers and other administrative matters associated with contractual farming. From the average land holding of about 1.25 ha that a farm household owns, area allotted by a farmer for potato can be increased to 0.25 ha. And this can be easily achieved in the high land areas where crop choice is limited. As the crop is highly productive as compared to grain crops, area increment can be easily achieved in the mid altitudes as long as there is reliable market for the produce. These agro ecologies are natural agro ecologies for potato. Naturally, potatoes produced in such areas have more accumulation of carbohydrates in the tuber indicating their suitability for processing Such potatoes have better fresh to processed conversion rate.

The vast area in northwestern Ethiopia possesses the *Woina dega* (1500-2300 m.a.s.l.) and the *Dega* (above 2300) agro ecologies. Even though, suitability of the soil factors can vary from site to site, production can be assured despite some variability that can be experienced on the yield. Substantial amount of land put under irrigation, and residual moisture production system is also another opportunity that helps boost production area and productivity. In addition, guaranteed and reasonable price offered to farmers under the contract farming will definitely let the farmers sale more of their produce. Under this circumstance, instead of absolute dependence on potato as food, the farmers will opt to other supplemental food crops.

Infrastructure

Road, transport, and telecommunication

It is believed that road accessibility help to easily transport the produce to where the processing plant is located and deliver in puts to the farmers. It also simplifies extension service delivery and monitoring. Towns of many of the major potato producing districts are accessible by all weather or dry weather roads. Particularly, all the production areas of Awi administrative zone are accessible and many of them are found along the fine asphalt road. These areas are suitable to easily implement the contractual production scheme. Regarding feeder roads that connect production fields found some kilometers away from district towns or highways, many of them need maintenance to allow accessibility by trucks. On-going feeder roads construction projects in some of the districts definitely helps to alleviate the problems. Such accomplishments can help investment on provision of better transport facility. Under the existing situation, agricultural produces are transported to market centers by pack animals. The same is true for collection of inputs such as seed and fertilizers. Animal drawn carts are popular in some areas. Heavy trucks are rarely used and their movement is restricted in space or season.

Concerning telecommunication, almost all the district towns of the target areas have access to telecommunication service, international direct dialing and fax. Currently, the wireless telephone and mobile cell phone technology is expanding to the rural villages or production areas. For instance, over 90% of the rural kebeles have got the wireless telephone service in place in Awi administrative zone. Generally, the better status of telecommunication infrastructure in the target area helps to simplify communication among various parties involved in contractual production arrangements. In nutshell, arrangements for input supply, produce collection, transporting, marketing and monitoring of other activities will be made in cost effective way

Institutional Environment

Research Service

Adet and Gondar agricultural research centers are mandated to undertake research on crops and natural resources management constraints of northwestern Ethiopia. So far Adet agricultural research center has released two potato varieties for the area. Moreover, there are several varieties that are tested and recommended for production in the area. These varieties are high yielders and resistant or tolerant to late blight of potato, a highly devastating fungal disease of potato that causes substantial yield loss of the local potato cultivars in the in the area. Some of these varieties have desirable qualities that suit them for the consumption of processing plants. Optimum fertilizer rates, plant spacing *etc* are also recommended. Availability of such technologies allows early entry into the contractual farming of potato between producers and processing plants. Besides presence of the research center in the vicinity helps to easily address challenges that might be experienced in the course of the contractual farming.

In put supply

There are various in put specifically agrochemicals suppliers in the area. Utilization of these modern inputs, however, is not widely spread because of various reasons. As to potato, despite availability of high yielding and disease resistant potato varieties, there is no responsible body that multiplies and distributes seeds of these varieties. Thus, shortage of seed tuber of improved potato varieties has been the challenge of research and development work on potato.

Under the attempt of transferring the technologies generated by the research system to the farmers, the two research centers are undertaking potato seed tubers scaling up project in major potato production areas together with various stakeholders. Such initiative definitely helps potato development but the seed production has to stand by it self to assure its sustainability. The gap observed on seed tuber of potato certainly creates a business opportunity on seed tubers production for the vast small-scale potato growers of the area.

With contractual farming utilization of modern agricultural inputs along with responsive improved varieties will certainly increase. In order to ensure sustainability of this increased utilization, the inputs have to be availed at the desired amount and time at all the production areas with reasonable price.

Extension service

Personal communication made with extension workers in the project area indicates that unavailability of attractive market price has been one of the factors that hindered earlier successful extension supports given to the farmers on potato production. There was a situation where the farmers failed to cover cost of external inputs they used. Consequently, nowadays, the extension support given to potato is minimal. Utilization of modern agricultural inputs is negligible and hence productivity is very low, *i.e.* less than 5 tones per hectare as compared to over 30 tones per hectare that can be potentially reaped. With the contractual arrangement, that helps to overcome market risk and offers reasonable price, remarkable improvement can be made on productivity of potato.

Under the attempt of transforming the subsistent agriculture to market oriented commercial agriculture, the government has adopted a new extension approach that involves training and advisory service for farmers at farmers training centers (FTC). The training centers are expected to harness farmers with modern production techniques and concepts of farming for market through training and technical advice. They will also assist in input arrangement, utilization and marketing of agricultural produce. In contract farming scheme they are expected to play additional roles in field and farmers selection, implementing the right crop management practices and production and harvest schedule.

Currently, many of peasant associations at the major potato growing districts of the area have got the FTCs in place. The FTCs are staffed with three development agents trained at diploma level and specialized in areas of crop production, livestock production and natural resource management. If they are capacitated with necessary facilities and are trained in concepts and principles of contractual farming, the FTCs will easily be able to realize the contractual farming of potato. Experts at district level will technically backstop the development agents at FTCs. But it is important that the development agents should not be compelled to undertake unrelated assignments that share their time and effort. Minot (1993) suggests the farmer to extension agent ratio not to exceed 200:1.

Farmers' organizations

As an out come of the proclamation that the government of Ethiopia declared to establish and promote various types of cooperatives in line with international cooperatives principles, different form of cooperatives are flourishing in the area. As the coops are formally organized and legally registered or recognized entities they are serving as a bridge to get access to the community in any kind of development endeavor.

Multipurpose agricultural cooperatives; multipurpose agricultural cooperative union; Irrigation water users cooperatives; saving and credit cooperatives are cooperative forms that are currently operating in the agriculture sector in the area. Most often, these cooperatives participate in the provision and supply of agricultural inputs and marketing of agricultural products.

The average land holding per households in the area is too small. Hence, the number of heterogeneous farmers that should come to the contractual scheme will be too high to acquire area of economic scale that has to be covered by potato for the consumption of processing plant. To this end farmers cooperative will be ideal partners in dealing with the processing plant in all necessary arrangements to be made for firm contractual agreement. This may include representation for association members in delivery of the contracted volume of produce at the right time. Moreover, the co-operatives may help in purchase and distribution of inputs. They also can arrange finance for farmers from their own source or other financial institutions.

The co-operatives are also helpful in mobilizing their members for construction or maintenance and management of feeder roads, irrigation ditches, and construction of centralized storage facilities.

In order to take advantage of the potential role of the cooperatives the cooperatives have to be managed or advised with trained manpower. Most of the management bodies of the cooperatives are not well experienced in managing contractual production of perishable horticultural crops like potato. Hence, they need extensive capacity building in planning, implementing and monitoring of contractual production schemes. Most of the cooperatives have also financial constraints. Therefore, credit facility has to be made available to them with reasonable interest rate. Personal communication made during the field visit showed that the coverage of cooperatives as a percent of the total households is less than 50% in most of the areas. This figure implies that cooperatives promotion agents at respective districts need to work aggressively in order to get adequate number of farmers under the cooperatives.

Credit facility

Shortage of cash is considered to be one of the factors that hinder farmer's adoption of new technologies. Lack of credit service with reasonable interest rate and pay back period is reported by farmers in the study areas. As stated above cooperatives have financial constraint to overcome this problem. This indicates the fact that the cooperatives can not easily provide credit from their own source unless they get sustainable and reliable financial sources providing them with the required amount at the right time.

The SACCOs, which are considered to be emerging local banks of farmers, and other forms of cooperatives are expected to be the prime source of credit to the farmers that satisfy the requirement of their members.

Legal and Policy Environment

Legal

In Ethiopia contracts are supposed to be made between parties in accordance with the provisions of contract laws stated in the 1960s civil code (art.1675 and following). Even though, there has not been ample experience on contractual production schemes and damages caused by the non-performance of the partners, the result of this study indicates that there are few newly initiated contract farming schemes that had suffered from such consequences. No legal enforcement mechanism is in place to suit the contract in agricultural production. Hence, either or both of the parties who fail to comply with the contract agreement can go their own way. Arbitration body is also not clearly indicated with the consent of the parties and defined guidelines. Sometimes, the contract parties may fail to clearly state the object and specification of the contract because of technical gaps associated with unavailability of responsible institution put in place to provide this service. As a result, they may end with controversies and divorce after several resources are used to realize the scheme. There is also a situation where other parties who feel they are 'loosers' in the contractual production scheme, usually the traders, perform illegally to obstruct the contractual production schemes.

Generally, attention is given to contract farming by the government as a way out of the subsistence farming. However, unless legal enforcement mechanism for its implementation is put in place both the agribusiness firm and the farmers may loose interest to work in this venture. The problem could be more threatening to processing plants than it is to market firms. Processing plants initial investment cost is obviously very high and lack of confidence on ensuring raw material supply in cost effective way affects its feasibility. By default this could be failure of the strategy. Hence, the government has to work to bring simple and unbureaucratic legal enforcement mechanisms that sustainably benefit all the parties. Examining the existing law and making amendments to suits the law with agricultural contracts in general and perishable agricultural commodities in particular is of a paramount importance (Kunkel and Larison, 2007). Apart from increasing bargaining power of farmers through establishment of farmers associations, laws that enable the government to play role in price regulation to overcome abuse of market power is also vital.

Policy

There are various policy related issues that support contractual farming. One of these supportive policies is land ownership right that considers land as a public property that can not be soled. This policy favors contract farming in stead of large estate plantation. Since cooperatives have significant role in working as partners with agribusiness firms, policy of the government that promotes establishment and strengthening of cooperatives also favors contractual farming. Other enabling policy environment created by the government includes public research and extension service that offers small-scale farmers the advantage of free access to re arch and extension service.

Yet there are also various supportive roles to be played in favor of contract farming. These could be increasing role of NGOs as facilitators of contract farming. This is vital as there is lack of experience on contract farming among farmers and public develo nent institutions. The roles that can be played by the NGOs includes capacity building for the coops management, provision of training and other technical assistance to farmers an l development agents, improving financial strength of coops to enable them offer credit service to contract farmers, support on availing important inputs such as seed tubers, contract evaluation and discussion with farmers, arbitration and dispute resolution.

Formulating proper arbitration and conflict resolution procedures and assigning responsible and concerned actors is also vital to build trust among contract partners and encourage agribusiness firms to enter to the venture.

Overall promotion and support given to contract farming also needs to be institutionalized. This doe not avoid working in partnership with various stakeholders. Instead, it simply assigns chief institution in charge of leading and coordinating other partners rather than leading the overall activities by ad hoc committees that have other responsibilities. In addition, such arrangement helps to incorporate any support and assistance given to contract farming in annual plan of work and allocate the necessary budgetary support. It also helps to assign responsible personnel and to put accountability for success achieved or failure encountered.

The extension agent together with the sponsor will also make necessary arrangement between the sponsor and non members/working groups/ to let them find credit for purchase of inputs. Obviously, the non members do not get credit service from cooperatives that provide credit service only to their members.

Production management will be carried out by the farmers with technical support of the public extension agents as per production arrangement to be made based on the demand of the processing plant plant.

Conversion ratio of the fresh potato to processed one varies depending on the variety (Xie *et al*, 2004). The production area speculated for the contractual farming is also based on the assumption that the farmers will use improved varieties and associated production packages. Hence, the farmers are expected to use improved varieties with recommended agronomic practices. For mutual benefit of the farmer and the sponsor, disease build up has to be prevented using available chemical, cultural, host plant resistance etc methods.

Information centers need to be placed at or beneath centralized collection centers of the cooperatives or FTCs who follow the day-to-day operation and arrange transport of the produce by communicating the sponsor.

For bulky and perishable crops like potato, temporary storage at collection centers amidst production centers is very important. Handling materials of standard size like wooden crates should also be available to ease handling and transport and at the same time overcome damages that can be encountered by using inappropriate handling materials.

The sponsor is also expected to make regular monitoring together with the extension agent and cooperatives' leaders on production status.

It is also suggested that the sponsor should have its own personnel to regularly monitor production status and purchase the product based on information it obtains. Inspection of the product and purchase should be made ir the presence of the farmers or their representatives at the storage or loading center. Weighing of the produce has to be transparent with regard to proper functioning of the weighing equipment, its unit of measurement, total volume or weight and conversion to monetary terms. The sponsor or the cooperatives are expected to bring weighing equipment and its accessories.

The contract format

The proposed out grower scheme will be new in its kind to the study area. Moreover, the contract has threat that comes from alternative markets. On the other hand, acquisition of raw materials sourcing from distant areas may be uneconomical to the sponsor. Hence, to build confidence between the producers and the sponsor and among various parties involved in the scheme, the formal agreement is suggested as best option. Formal agreement will be made between the sponsor and farmers cooperatives or farmers working groups when applicable. The agreement format should consist detail conditions and obligations of the parties involved and needs to be endorsed by the local government bodies or the *kebeles* to effect its implementation. In the case of farmer working groups, the group will take collective responsibility to undertake the obligations and be accountable for failure to do so. Once the farmers cooperative makes the formal agreement with the sponsor, it can again make agreement with the farmers. This agreement can be formal or informal. Since the cooperatives can use their internal regulations to let their members abide the contract regulation, they can make informal agreement which can be simple registration. However, in order to increase the degree of trust making formal agreement is suggested. The Specification of the contract should include contract duration, quality standard, production quotas, cultivation practices to be followed, crop delivery arrangement, pricing, payment procedures etc.

The important reasons behind failure of contractual farming schemes are availability of alternatives ways for the firm to secure the agricultural produce it needs or option that may trigger the farmers for extra contractual marketing. Therefore the contract needs to be carefully handled based on periodic price review and reasonable profit sharing.

Conclusion and Recommendation

Importance of contract farming in improving the livelihood of small scale farmers has been exemplified by several developing countries in the world. Social and economic advantage it offers to small scale farmers has helped contractual farming schemes to enjoying political support from developing these countries. In addition, the advent of globalization and expansion of global trade in fresh and processed products have been driving forces that increased the roles of contractual farming schemes (Silva, 2005).

Alike many other developing countries, contractual farming has got good political support from the government of FDRE. Currently, it is considered as an important strategic option available to transform the subsistent and traditional agriculture in mid to high altitude areas to market oriented agriculture. Other supportive policies and strategies are also making favorable environment to contractual farming.

In Northwestern Ethiopia, there is no well developed experience on contractual farming especially on horticultural crops like potato. However, availability of favorable natural factors for production of potato, ample production experience in the area, diversity of potato production system that exists, availability of promising aspects of infrastructure situation, encouraging policy are found to be some of the factors that justify establishment of potato processing plant that operates with raw material supplied through contractual farming scheme in this part of the country.

On the other hand, problems related to infrastructure situation specifically; accessibility of production areas to feeder roads, adequacy and efficiency of irrigation schemes, transport, storage and handling facilities or materials have to be properly tackled. Proper implementation of the contractual scheme can not be realized without responsible, well integrated, and long-term institutional support given to it. Particularly, formulating arbitration guidelines, putting legal enforcement mechanisms in place are of paramount importance. No one can think of the contractual scheme without well organized seed system. Hence, a seed system that can deliver healthy and quality seed tubers of the desired potato varieties has to be installed. Strengthening managerial, financial and logistical capacity of cooperatives is also vital. Similarly, awareness on concepts of contract farming and principle of farming for market has to be created for farmers and development workers at grass root level. In planning of contract schemes, lack of commitment or inconsistent follow up, or irregular involvement of relevant stakeholders can cause detrimental repercussions on this strategy. Hence, proper planning and well coordinated implementation has to be made with defined roles and responsibilities of the stakeholders.

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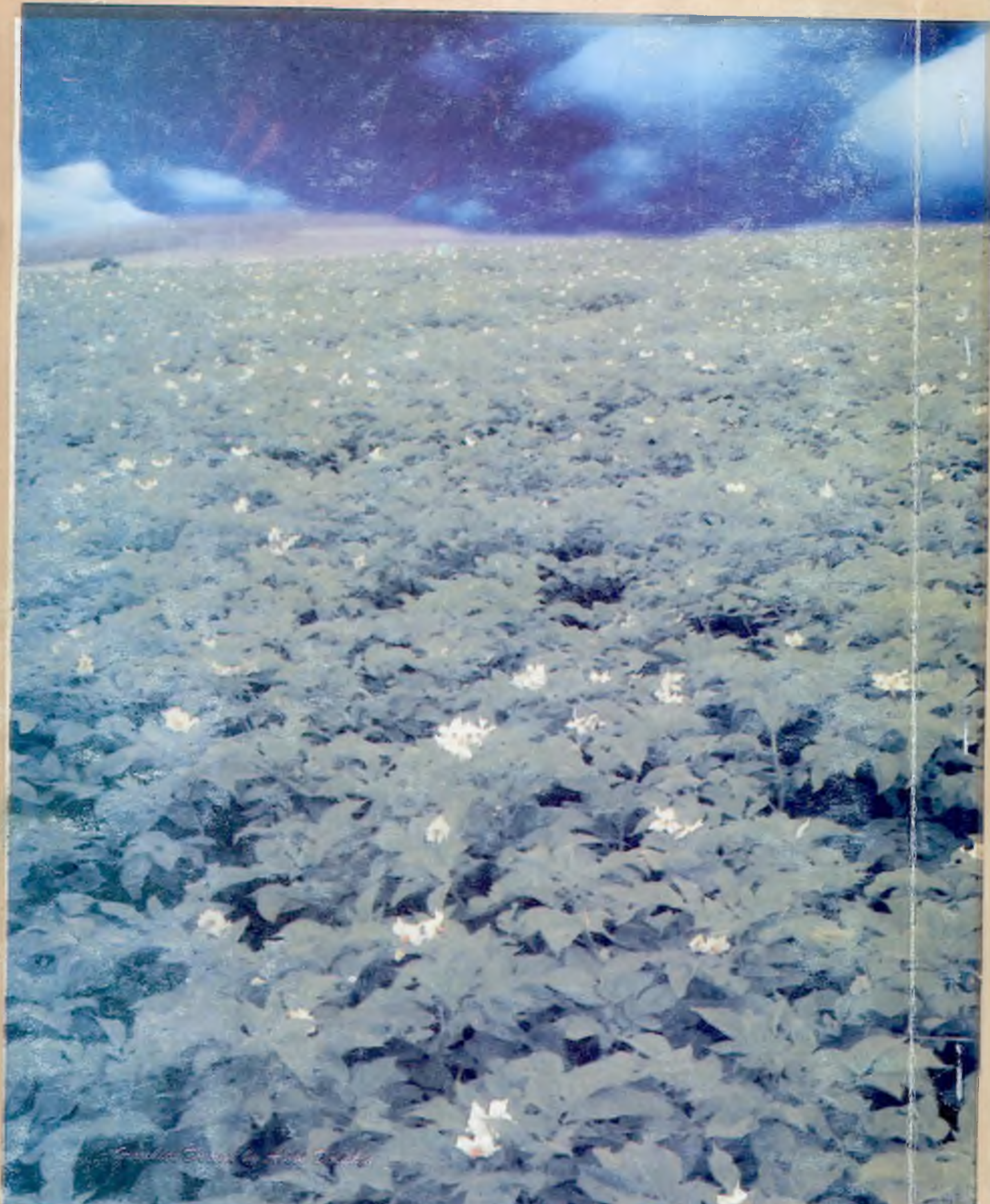

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