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Prospects of Seed Potato Production in Ethiopia

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Summary

Shortage of good quality seed tubers of improved cultivars is the most important limiting factor to both potato productivity and production in Ethiopia. Farmers usually use as planting material very small tubers from their previous harvests. This most probably encourages virus buildup. Some farmers are forced to buy poor quality seed tubers from uncontrolled markets at very high prices. Such seed potatoes offer the best means of disease dissemination.

Past experiences have shown that there is a good prospect for producing better quality seed potatoes on farmers fields and in collaboration with agriculture-related Institutions. Partial budget analysis proved on-farm seed potato production to be a highly profitable business with a marginal return rate of 1704 at harvest and 4613 at planting, both of which are much higher than the acceptable level.

Research has been conducted to improve the efficiency of some rapid multiplication techniques under local conditions. Stem-cutting experiments revealed that the rooting abilities of stem cuttings differed with the cultivar and media. Fine sand was found to be the best locally available medium. Tuber yield increased with increasing number of stem cuttings per hill from 1 to 3 and with closer spacing. The rooting and tuber yielding ability of sprout cuttings was directly related to the number of nodes per cutting. The importance of tissue culture for the rapid multiplication of high-quality pre-basic seed is discussed.

Storage experiments showed that better quality seed tubers are obtained from diffused light stores than dark stores. The potential of True Potato Seed (TPS) for the production of relatively healthier seedling tubers were studied and improved nursery management practices were developed that resulted in higher seedling tuber yield. Moreover, the performance of different size seedling tubers in ware potato production has also been studied and proved to be satisfactory. In this paper, a sustainable seed tuber production scheme is proposed.

Introduction

Potato has a promising prospect to appreciably improve the quality of the basic diet in both rural and urban areas of the country. It also has a huge potential to produce large quantities of high quality food within a relatively short period in a large proportion of the country's available agricultural land. According to Haile-Michael (nd), 70% of the agricultural land is located between 1800–2500 m with an annual rainfall of more than 600 mm, making all this area suitable for profitable potato production provided adaptable cultivars are developed with their packages. Currently, however, potato production is limited to only less than 50,000 ha.

Shortage of good quality seed potatoes is probably the most important constraint to potato production in Ethiopia. At present, there is no institution that produces and distributes seed potatoes of improved cultivars. It is a common practice among farmers to save as planting material inferior tubers that they cannot normally sell for consumption. It is believed that this practice has contributed to potato virus buildup and subsequently to low national yield. In addition to their own seed, farmers' main sources of seed potatoes is the uncontrolled local market. Seed potatoes from local markets are not only expensive (ETB 120–180 q^{-1}, personal observation) but also are a potent means of disease dissemination. A prominent example is the rapid spread of bacterial wilt to many potato growing regions due mainly to infected seed potatoes from and around the Shashemene area. It is known that in this area bacterial wilt poses one of the major threats to potato production (Yaynu 1989).

Experiences in India and Mexico (Brown 1982), Tunisia (Horton and Monares 1985) and Korea (Horton et al. 1987), among many other countries, have shown that a sound seed potato production scheme is essential for a successful and sustainable potato production.

Conditions in Ethiopia are now ripe and favorable to launch a seed production scheme. Research has released some outstanding varieties and developed appropriate cultural packages. Moreover, past experiences have shown that there is a bright prospect for the production of better quality seed potatoes on farmers fields and in collaboration with agriculture-related institutions. This paper discusses such prospects based on past research and development activities.

MAINTENANCE AND MULTIPLICATION OF PATHOGEN-FREE SEED

A pre-requisite to a successful and sustainable seed scheme is a continuous supply and maintenance of pathogen free pre-basic seed. This prime responsibility should be taken by research institutions, in this case, the Institute of Agricultural Research (IAR) in cooperation with the Alemaya University of Agriculture (AUA).

The Ethiopian Potato Improvement Program (EPIP) of IAR has released some outstanding cultivars adaptable to a wide range of environments. Although EPIP at this moment does not have the necessary facilities such as tissue culture laboratories to clean diseased tubers (e.g. virus-infected tubers), it has every possibility to obtain clean tubers of the released cultivars from the International Potato Centre (CIP). Upon receipt, disease free tubers can be multiplied in aphid-proof screenhouses using rapid multiplication techniques (RMT). Along with multiplication, facilities for detection of the major diseases like viruses and bacterial wilt will be developed. At every stage of multiplication, the tubers will be tested for viruses and, if the need arises, for bacterial wilt before they are maintained as breeders seed and/or recommended for further multiplication of improved seed. The breeders seed should be of high health standard and pure, both genetically and physically and will be maintained at the research center.

Further multiplication of seed potatoes can be done by small farmers, large-scale private producers and interested government institutions under close supervision of researchers, as there is no national seed quality control service, at least for potatoes. Areas with low aphid population and suitable for seed potato production with regard to altitude, rainfall, and temperature have already been identified.

The growers will have to be committed to fulfil the minimum requirements for the production and storage of better quality seed. Some of these requirements will include: practice of both negative and positive selections in the course of growth, construction of diffused light store and making samples available for test of the important viruses.Now the quality standard will not be set too high as the most immediate objective is to make available "better quality seed" for potato growers in the absence of a national scheme that should start from pre-basic, basic elite, foundation, registered and certified seed, all of which will come along with the development of the industry. However, rejection of seed potatoes that cannot meet the minimum standard will be useful to avoid the collapse of the seed production scheme after initiation, as experienced in Korea (Horton et al. 1987).

Rapid Multiplication Techniques (RMT)

The conventional method of potato propagation by tubers is based on a low multiplication ratio of 1:3 to 1:15 depending on the variety, agronomic practices and the physiological age of seed tubers (Bryan et al. 1981). The conventional propagation method is thus inefficient in the attempt to multiply and distribute to farmers a reasonable amount of improved seed tubers of the released cultivars in a relatively short period. Hence, inclusion of RMT in a seed production scheme is vital, especially for rapid increase of first generation basic seed tubers. RMT are expensive as they are labor intensive and require special facilities such as insect-proof growth structures, and chemicals, but the expense is offset by the increased amount of seed produced, reduced number of seed multiplications and improved seed health (Bryan et al. 1981).

Rapid multiplication techniques include stem cuttings, sprout cuttings, apical cuttings, single-node cuttings, leaf-bud cuttings and meristem culture. In Ethiopia, stem, sprout and apical cutting methods are common.

Stem Cuttings

Propagation by stem cuttings is rapid and eliminates non-systemic diseases and pests. Carli and Njoroge (1991) obtained on average 18.5–36.4 cuttings from one mother plant of different varieties. They attributed the low number of cuttings/mother plant to the early-short day-induced tuber initiation in the tropics. However, the number of stem cuttings varied with the cultivar and source and rate of fertilizers. Each cutting produced several tubers with reasonable yield. According to Bryan et al. (1981) one mother plant can produce 20 to 60 cuttings with each cutting producing 0.5 to 1 kg of potatoes. Moreover, plants obtained from stem cuttings can be used as mother stocks. If such consistent cloning and reclining is used, it is possible to harvest 1 t yr^{-1} of potatoes from a single tuber (CIP 1974). Experience in Papua, New Guinea, (Page and Horton 1987) revealed that using the stem cuttings method, 4 kg of mother tubers produced 1.7 t in a short period.

The success of propagation by stem cuttings depends on the rooting abilities of the cuttings which is in turn dependent *inter alia* on rooting media and the cultivar (Hartmaan and Kester 1968 and Carli and Njoroge 1991). Berga et. al. (1981) found out the rooting ability of three selections and one variety of potato stem cuttings in nine locally available media, whose basic ingredients were sawdust, sand, soil and manure. Before placing the cuttings in the different media, the basal portions were dipped in a rooting powder hormone (seradix 1). The results of this study showed that stem cuttings of the selections AL-562, AL-517 and AL-204 and the variety Anita rooted in all the different media used. Nevertheless, the cultivar Anita performed best, while selection AL-517 performed poorest. When characteristics like number and lengths of roots per cutting and number of branch roots were considered, either sand alone or in mixture gave better results with a few exceptions. On the other hand, soil alone or sawdust alone or their combinations with other media performed poorly. Generally, fine sand was found to be the most favorable medium.

Rooted stem cuttings (hereafter transplants) can be transplanted either to screenhouse or to the field to produce tubers. Here the number of main stems is equal to the number or transplants per hill. Several authors including Wurr (1974) and Collins (1977) reported that tuber yield is affected by the number of stems. An experiment was thus conducted at Alemaya (Berga 1981) to determine the optimum number of transplants per hill and intrarow spacing. The number of transplants were 1, 2 and 3 $hill^{-1}$ and the intrarow spacings 15, 20, 25 and 30 cm in rows 75 cm apart. The result showed that tuber yield increased with an increase in number of transplants per hill and with closer spacings. The yields averaged 20.0, 22.7 and 24.8 t ha^{-1} for 1, 2 and 3 $hill^{-1}$ transplants and 28.9, 24.5, 18.2 and 18.2 t ha^{-1} for 15, 20, 25 and 30 cm intrarow spacings respectively. The increase in tuber yield with increasing number of transplants per hill agrees with the findings of Berga and Caesar (1990) and Berga (in press). A similar experiment was conducted at Holetta in 1988 with more treatments in number of transplants (rooted cuttings) and intrarow spacings. The results (Figure 1) revealed that tuber yield increased as the number of transplants increased, but there was no extra advantage with further increase of transplants from 3 to 4 $hill^{-1}$. Yield consistently decreased with wider intrarow spacing corroborating with findings of Berga (1981).

Sprout Cuttings

Potato propagation by sprout cutting method gives a higher multiplication ratio than the stem cutting method and ranges between 50 and 300 plants per tuber with each plant yielding up to 500 g (Bryan et al. 1981). According to Sikka (1982) the multiplication ratio using sprout cuttings can be as high as 1:900 to 1:1500. This method is routinely used by many programs to rapidly increase basic seed potatoes. At Holetta, the effect of sprout cuttings with two, four and > four nodes per cutting was studied on the propagation of four potato cultivars in 1992. The results showed that increasing the number of nodes per cutting significantly ($P<0.01$) increased the number of adventitious roots produced per cutting. After a month in sand medium, the number of roots per cutting averaged 4.9, 10.5 and 17.1 for two, four and four-node cuttings, respectively. The cultivars also varied significantly in their rooting potential. The variety AL-624 formed the highest number (14.9) of adventitious roots per cutting, while CIP-374080.5 formed the lowest (3.9). Each of the variety Sissay and cultivar K-59A (26) formed about 11 roots per cutting each. The subsequent performance in the field showed that sprout cuttings with > four nodes produced the highest number of tubers m^{-2} and the highest yield. The yield averaged 9.4, 8.4 and 6.6 t ha^{-1} for > 4, 4 and 2-node sprout cuttings. The cultivar CIP-374080.5 that rooted poorest yielded highest (12.6 t ha^{-1}), while the variety AL-625 that rooted best yielded lowest (4.5 t ha^{-1}). The low yield of the latter was associated with the susceptibility of the variety to late blight. Although this experiment has to be repeated to draw a reliable conclusion, it can be said with great certainty that using the sprout cuttings method is a useful means of rapid multiplication of the released cultivars under local conditions. Best results can be obtained if the different rapid multiplication techniques such as stem, sprout, apical, single-node and leaf bud cuttings are used concomitantly.

Tissue Culture

Although it is not the purpose of this paper to discuss tissue culture in detail or to describe its techniques, the role that it plays in a seed production scheme is highlighted below. Tissue culture provides an excellent and efficient technique for the rapid multiplication of potatoes. It also provides a splendid opportunity to produce healthy seed tubers and nowadays this technique has become routine in many potato producing countries and constitutes an integral component of the seed production scheme. Seed production programs in Burundi, Rwanda, Kenya and Mauritius are supported by tissue culture and thus are reasonably successful. According to Horton et al. (1987), the establishment of a basic seed production scheme that used tissue culture for producing, storing and rapidly multiplying virus-free seed potato revolutionized potato production in Korea and helped the program to become profitable and sustainable.

In vitro plantlets (plantlets from tissue culture) can be used to: produce seed tubers, mother plants, induce in vitro tubers, conserve germplasm in different most efficient and reliable ways and distribute germplasm (Tovar and Dodds 1989). All these facilitate the production of high quality pre-basic seed, which can further be multiplied several times to produce certified seed for eventual production of ware potatoes.

It is therefore most timely for EPIP to own a tissue culture laboratory no matter how rustic it may be at the beginning. Refinements can be made through time. Without this, any success in seed potato production will be seriously limited.

Agronomic Research Related to Seed Potato Production

Agronomy research has been discussed in a separate paper in this proceedings. Here only those whose results can be applied to seed potato production will be briefly discussed.

Tuber Size and Intrarow Spacing

The effects of three mother tuber sizes (25–35 mm, 35–45 mm and 45–55 mm in diameter) and four intrarow spacings (10, 20, 30 and 40 cm) in rows 75 cm apart on the production of seed (20–50 mm) and ware (> 50 mm) potatoes were studied at Holetta.

Results in table 1 show that the proportion of number of seed-size tubers (20–50 mm) and total tuber number increased with closer spacings and increasing size of mother tubers. Tuber yield was also affected by both treatments in a similar pattern. It is known that larger mother seed tubers and closer intrarow spacings result in the production of more stems per unit area, which in turn bring about the production of more tubers and higher yield. This is in agreement with the findings of Berga and Caesar (1990). It can thus be concluded that for the production of seed size potatoes' use of large mother tubers and closer spacings is advantageous.

Seed Tuber Size and Type

The effect of mother tuber size (30–40 g vs 40–50 g) and type (whole vs cut) on the production of seed (20–50 mm) and ware (>50 mm) potatoes was studied with two released and three promising cultivars at Holetta.

Table 1. Effect of seed tuber size and intrarow spacing on tuber number m^{-2} (A) and tuber yield (B) ($q\ ha^{-1}$) for the different size-grades

A

Treatment Mother tub Size Spacing (mm)	10-20	20-30	Tuber size (mm) 30-40	40-50	Number >50	Total
25-35	2.7(7.4)	6.5(17.8)	11.5(31.5)	10.4(28.5)	5.4(14.8)	36.5
35-45	2.2(5.7)	6.6(17.0)	14.5(37.4)	9.4(24.2)	6.1(15.7)	38.8
45-55	2.2(4.9)	7.8(17.2)	15.6(34.5)	14.4(31.8)	5.2(11.6)	45.2
Intrarow Spacing (cm)						
10	3.4(6.6)*	11.6(22.6)	20.2(39.3)	12.3(23.9)	3.9(7.6)	51.4
20	2.0(5.2)	6.8(17.7)	14.7(38.3)	10.2(26.6)	4.7(12.2)	38.4
30	2.0(6.0)	4.9(14.6)	11.2(33.4)	9.4(28.1)	6.0(17.9)	33.5
40	2.1(6.4)	4.4(13.3)	9.5(28.8)	9.5(28.8)	7.5(22.7)	33.0

B

Mother tuber Size						
25-35 mm	1.0(0.6)	7.8(4.3)	37.3(20.7)	67.7(37.5)	66.5(36.9)	180.3
35-45 mm	0.9(0.5)	8.2(4.4)	47.0(25.4)	56.2(30.3)	73.1(39.4)	185.4
45-55 mm	1.1(0.6)	10.5(5.6)	47.8(25.6)	68.1(36.5)	59.2(31.7)	186.7
Intrarow Spacing (cm)						
10	1.3(0.7)	14.6(7.7)	60.6(31.9)	71.0(37.3)	42.6(22.4)	190.1
20	0.9(0.5)	8.8(5.0)	45.2(25.9)	64.4(36.8)	55.7(31.8)	175.0
30	0.9(0.5)	6.3(3.5)	37.1(20.7)	59.4(33.1)	75.6(42.2)	179.3
40	0.9(0.5)	5.7(3.0)	33.1(17.2)	61.7(32.1)	91.1(47.3)	192.5

There was a big variation among the cultivars in sizes of tubers produced (Table 2). About 77 and 75% of the potatoes produced by the cultivars CIP-378501.3 and Sissay were seed size. The corresponding values for the cultivars AL-624, UK-80-3 and CIP-374080.5 were 64, 42 and 27%, respectively, which indicates that some cultivars like CIP-374080.5 are not suitable for the production of seed size tubers. This problem can be partially overcome by harvesting prematurely before tuber bulking is completed, and by planting at closer spacings. The cultivars CIP-378501.3 and Sissay followed by AL-624 are most suitable for the production of seed size tubers.

Table 2 also shows that larger mother tubers (40–50 g) and cut tubers yielded a higher proportion of seed size tubers than smaller mother tubers (30–40 g) and whole tubers. The inverse was true for the production of ware potatoes.

True Potato Seed Research Related to Seed Production

Propagation of potatoes by tubers is expensive, difficult to store, transport, and distribute and offers the best opportunity to propagate diseases. One attractive alternative means is the use of true potato seed (TPS). Using TPS, relatively healthier seedling tubers can be produced as most potato viruses and nematodes are not transmitted through botanical seed (Jones 1982). Moreover, TPS is less expensive than seed potatoes, easy to store and transport. Propagation by TPS is disadvantaged by lack of uniformity, longer growing period, etc., but all can be improved with proper experimentation.

Seedlings can be used for the production of ware potatoes and seedling tubers (planting material), with the latter being widely used in many countries including the People's Republic of China (Song 1984), Taiwan (Tsao and Chang 1982) and Vietnam (Malagamba and Monares 1988). Both hybrid and open-pollinated (OP) TPS can be used for seedling tuber production, with the former performing better (Haile-Michael et al. 1985), and nursery management practices for optimization of seedling tubers have been recommended (Wiersema 1984).

In Ethiopia, several experiments have been conducted on TPS. Many of these have been discussed in 'Potato Improvement Research' and 'Potato Agronomy Research', both of which are published in these proceedings and can be referred to. Here those that have not been included are dealt with.

Nursery Management for Optimizing Seedling Tuber Production

To optimize some of the nursery management practices, three experiments dealing with nursery substrate, fertilization and seedling populations have been conducted with different progeny types at Holetta.

Table 2. Effect of seed tuber size and seed tuber type on total tuber yield and size distribution of five cultivars (treatment means, 1991)

Treatment cultivar	Total Tuber yield	Tuber size distribution percent of total tuber <20 mm	20-50 mm	>50 mm
AL-624	23.9	1.8	63.6	34.6
Sissay	32.6	1.0	74.7	24.3
UK-80.3	37.7	0.3	42.0	57.7
CIP-378501.3	23.0	1.5	77.1	21.4
CIP-374080.5	29.3	0.4	27.3	72.3
LSD 0.05	4.2			
Seed tuber size				
30-40 g	28.2	0.8	52.8	46.4
40-50 g	30.4	0.9	57.9	41.3
LSD 0.05				
Seed tuber type				
Whole	290.2	0.8	54.2	45.0
Cut	295.5	0.9	56.6	42.5
LSD 0.05	NS			

Experiment 1

The effects of different media and seedling populations on the production of seedling tubers was studied with AL-624 OP TPS. Three media with different ratios of forest soil (FS), manure (M) and sand (S) on a v/v basis were used and the seedling populations were 50, 100 and 150 seedlings m^{-2} arranged in a factorial experiment in a randomized complete block design (RCBD).

Figure 1 shows that the highest yield of seedling tubers was obtained in a 50:50:0 (FS:M:S) medium and the lowest in 50:0:50 medium. This result conflicts with that of Wiersema (1984) who concluded that a medium containing 50% sand and 50% compost was suitable. Yield of seeding tubers was also affected by seedling population and there was a positive relationship between the two and agrees with the findings of Wiersema (1984).

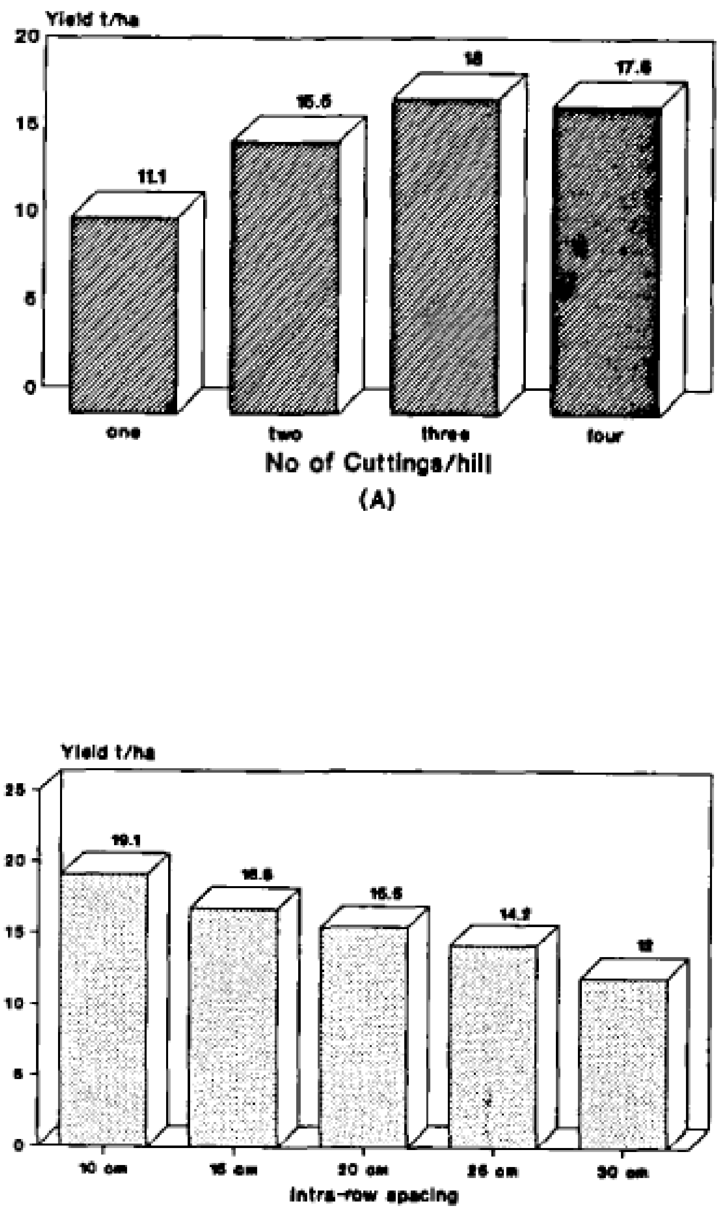

Figure 1. The effect of number of stem cuttings per hill (A) and intra–row spacing (B) on tuber yield.

Experiment 2

The effect of TPS progenies and seedling population on number and yield of seedling tubers was studied. Two progenies AL-624 (OP) and AL-624 x CIP-378371.5 were planted at a population of 50, 100 and 150 m^{-2} using a factorial experiment in RCBD in the 1991 off-season and 1992 main season at Holetta.

Table 3 indicates that the hybrid progeny was superior to the OP in both tuber number and yield and most of the differences were significant ($P<0.05$), which agrees with the findings of Haile-Michael et al. (1985). Also there was a consistent and significant ($P<0.05$) increase in seedling tuber number with an increase in seedling population. In contrast, yield was not affected by the different seedling populations.

Experiment 3

In this experiment conducted in the main season of 1991 and the off-season of 1992, the effects of 3 seed-bed substrates and 3 levels each of NP on number and yield of seedling tuber were studied in a factorial experiment in RCBD.

In both years, the medium containing 5:5:0 (FS:M:S on a v/v basis) followed by 5:3:2 gave a significantly higher number and yield of seedling tubers than a medium containing 5:0:5 (Table 4). Increasing levels of N in both years and of phosphorus in the first year resulted in a significant increase in number and yield of seedling tubers, with only one exception. Wiersema (1984), however, concluded that pre-sowing application of NPK was not necessarily advantageous with regard to seedling growth.

The experience at Holetta showed that seedling tubers perform reasonably well in the production of potatoes and their performance improved with increasing size of seedling tubers (Table 5).

Generally, many research results and the exhaustive review of Umaerus (1987) show that TPS will have a bright future in seed potato production.

Storage Experiments

Since a potato tuber is a living botanical organ, it loses weight and quality during storage. Losses during storage result from diseases, pests, evaporation, and physiological and biochemical changes (Booth et al. 1983, Burton and Booth 1983 and Zaag 1986). Storage losses are highest in the tropics and sub-tropics, where the temperature is high.

In Ethiopia proper storage facilities, among the majority of the farmers, are lacking. As a result farmers are forced to sell their potatoes at low prices during harvest and buy seed potatoes at high prices at planting. If farmers save seed potatoes from their harvest, they store the potatoes either in burlap sacks or in dark rooms, which results in the formation of long and etiolated sprouts that break before or during planting leading eventually to low yields. According to Booth et al. (1983) storing potatoes in diffused light stores (DLS) developed and scientifically improved by CIP, led to the formation of sturdier and more green sprouts than storing in the traditional dark storage method. Seeds from DLS emerge earlier and more uniformly resulting in higher final tuber yields than seeds from dark storage. A study in Sri-Lanka revealed that adoption of appropriate seed storage techniques resulted in a yield increase of 133% (CIP 1983).

Table 3. Effect of TPS progenies and seedling population on tuber yield

Progenies (treat)	Tuber No/m	Tuber yield (kg/m)
	1991	
Al-624	782	5.44
Al-624 x CIP378371.5	686	6.68
LSD 0.05	118	0.80
Plant population 50 (plants m^{-2})	512	5.68
100	769	6.15
150	921	6.33
LSD 0.05	83	NS
	1992	
Progenies		
Al-624	1153	25.53
Al-624 x CIP378371.5	1217	31.40
LSD 0.05	NS	5.80
Plant population 50 (plants m^{-2})	962	26.90
100	1213	29.30
150	1380	29.10
LSD 0.05	149	NS

Table 4. Effect of seed-bed substrate and fertilization on seedling tuber production

Substrate forest soil: manure: sand	1991 Tuber No. (per m^{-2})	1991 Tuber yield (kg/m^{-2})	1992 Tuber No. (per m^{-2})	1992 Tuber yield (kg/m^{-2})
1. 5:5:0	601	8.25	1280	32.42
2. 5:3:2	565	7.32	1139	25.90
3. 5:0:5	504	5:00	819	17.78
LSD 0.05	59.7	0.86	103.8	1.51
Nitrogen (g/m^{-2})				
1. 0	531	5.13	944	19.12
2. 40	546	7.53	1081	25.12
3. 80	593	7.90	1214	31.86
LSD 0.05	NS	0.86	103.8	1.51
Phosphorous (g/m^2)				
1. 0	521	6.22	1069	25.07
2. 40	552	6.98	1097	25.22
3. 80	598	7.36	1072	25.81
LSD 0.05	59.7	0.86	NS	NS

Experiments were conducted at Holetta and Alemaya to quantify the effects of storage methods on seed tuber quality and their subsequent performance in the field. At Holetta tubers were stored in 2,3 and 4 layers on shelves of DLS and in multi-layered burlap sacks to simulate the farmers dark storage method.

Tubers stored in burlap sack produced significantly taller sprouts and lost a significantly higher weight than those stored in layers on shelves of DLS. The converse, however, was true with regard to mean sprout number (Table 6). A similar trend was also observed in 1990 with a few exceptions; but most of the differences were not significant. Generally the results of the experiment agree with those of Booth et al. (1983). Mulugeta (1992) at Alemaya also confirmed that storage of seed tubers in dark resulted in a significantly higher weight loss than storage in diffused light store. He also asserted that weight loss in storage was directly related to size of seed tubers (Table 7). Generally better quality seed tubers were obtained with storage in DLS than in dark substantiating the findings of other authors mentioned above.

Table 5. Effect of sizes of seedling tubers on tuber number, tuber yield and tuber size distribution (treatment means)

Seedling tuber size (g)	Tuber no. (per m^{2})	Tuber yield t ha^{-1}	Size distribution % of total yield <20 mm	20-50	>50 mm
5-10	52.4	9.1	12.9	84.2	2.9
10-25	54.7	8.6	12.1	85.4	2.5
25-50	68.6	9.8	14.0	84.1	1.9
LSD 0.05	14.4	3.0	-	-	-
			1990		
5-10	77.6	21.2	7.8	84.0	8.5
10-25	89.0	27.0	6.7	74.6	18.7
25-50	90.6	24.3	7.9	81.4	15.9
LSD 0.05	NS	5.1	-	-	-

Table 6. Effect of method of storage on mean sprout number, sprout length and tuber weight loss after 190 days and after 245 days of storage

	Mean sprout (No./tuber)	Mean sprout length (mm)	Mean tuber weight loss per tuber
Treatment			
Two layers	3.4	11.8	9.8
Three layers	3.8	11.2	6.6
Four layers	4.0	11.0	6.0
Bur lap sack	2.8	23.7	11.6
LSD 0.05	0.7	4.1	3.3
Two layers	5.0	13.7	27.8
Three layers	4.7	15.1	23.2
Four layers	3.7	16.5	20.7
Bur lap sack	4.3	39.3	27.3
LSD 0.05	NS	7.6	NS

Table 7. Effect of storage method and seed tuber size on tuber weight loss

Seed tuber size	Storage method diffused light	Dark	Mean
	Weight loss (s)		
30-40	5.2	7.5	6.4
41-50	7.5	9.5	8.5*
51-60	8.7	12.3	10.5*
Mean	7.1	9.7**	

Source: Mulugeta (1992)

Table 8. Effect of method of storage on subsequent performance of seed tubers in the field

Storage	Tuber No. m^{-2}	Av. tuber weight (g)	Total yield t ha^{-1}
		1989	
2 Layers, DLS*	64.4	34.0	21.7
3 Layers, DLS	54.5	39.0	20.8
4 Layers, DLS	63.6	35.0	22.1
Burlap sack	52.5	39.0	20.4
LSD 0.05	9.0	NS	NS
		1990	
2 Layers, DLS	75.0	56.0	40.0
3 Layers, DLS	86.0	46.0	39.5
4 Layers, DLS	79.6	49.0	38.7
Burlap sack	69.9	57.0	39.2
LSD 0.05	NS	NS	NS

* DLS, Diffused Light Store

The quality difference in seed tubers did not bring about a corresponding yield difference in the field, but more tubers were produced from tubers of DLS than burlap sack. The difference, however, was significant only in 1989 (Table 8).

In this study, unlike others (Booth et al. 1983), yield differences due to differences in seed quality were not significant. Because here maximum care was taken to prevent the breakage of long and etiolated sprouts of burlap sack-stored tubers during and before planting. Since such care cannot be taken normally, better quality seed tubers are expected to yield significantly higher than poor quality seed tubers.

On-farm Technology Demonstration and Seed Potato Production

To demonstrate new potato technologies, two field days were organized by EPIP in 1991 for the farmers and extension agents of the Ministry of Agriculture (MOA) in Welmera Awraja. The first field day coincided with full canopy development. During this visit, the participants proved for themselves that while the new varieties Sissay and CIP-378501.3 had full ground cover, the local cultivar was completely wiped out by late blight. The second field day coincided with harvest and the farmers themselves harvested equal number of plants from each variety and confirmed the enormous yield differences. Moreover, the harvested potatoes were boiled separately and the farmers participated in the evaluation of the table quality of the varieties. Also demonstrated was the diffused light store (DLS) for storage of seed potatoes.

Shortly after the second field day a large number of farmers requested seed tubers of the improved varieties, especially CIP-378501.3. This was a challenge for EPIP as it uld not satisfy the farmers needs. A few farmers, however, were selected from Rogie, Misrak Shollaber, and Welmera Chocke, all in the Welmera Awraja, to pro..uce seed potatoes under the supervision of researchers from IAR and staff of MOA. The following agreement was signed between IAR/MOA and the selected farmers.

IAR and MOA (involvement of the latter is in the third task)

1. Supply initial seed tubers (to be paid back in kind) and fertilizer
2. Plant potatoes following the recommended cultural practices
3. Consistent supervision during the course of growth and giving the necessary technical advice

Farmers

1. Build diffused light store
2. Perform cultural practices as per recommendation
3. Pay back the initial planting material at harvest
4. Save seed for themselves and sell the rest as seed potatoes to neighboring farmers

Everything was implemented as planned and encouraging results were obtained. Table 9 shows tuber yields of the improved varieties and the local check. The improved varieties Sissay using the recommended agronomic practices resulted in mean yield increase of 20.4 t ha^{-1} and CIP-378501.3 14.6 t ha^{-1}, over the control, which is equivalent to 200 and 143% yield increase respectively. Tuber yields were highest at Welmera Chocke, but the highest yield difference between the improved and the traditional technologies was obtained at Rogie.

To see whether or not the improved technologies were economically feasible, a partial budget analysis was conducted. Local prices for freshly harvested (ETB 50 q^{-1}) and sprouted seed potatoes (ETB 150 q^{-1} were used to estimate the value of the produce. Costs that varied (costs of labor for planting, irrigation, weeding and earthling up, fertilizers and construction of DLS) were considered. Although the farmers practice had lower costs, the recommended potato technologies fetched a significantly higher net benefit (Table 10). The net benefits at harvest using the farmers and improved technologies, respectively were ETB 4780 and 13566 ha^{-1}. At planting the net benefit from the recommended technologies was even higher (ETB 42166) and the MRR to investment amounted to 1704% at harvest and 4613% at planting.

Table 11 presents total on-farm tuber yield and yield of seed potatoes and their distribution. Of the total yields produced, yields of seed potatoes accounted for 87% at Rogie, 81.2% at Misrak Shollaber and 85.7% at Welmera Choke. From their harvest the contact farmers paid back the initial amount they got from IAR, satisfied their needs and sold some to neighboring farmers at ETB 140-180 q^{-1}. All the contact farmers also built DLS.

In 1987 and 1988 EPIP in collaboration with four producers cooperatives produced 100 t of improved seed potatoes using a seed plot technique where both negative and positive selections were practiced.

From these, it can be concluded that farmers' participation in the production of improved seed potatoes will help establish and sustain a successful seed scheme as evidenced in several countries including Burundi (Rueda et al. 1991).

Table 9. Mean yield (t ha^{-1}) of improved and local potato cultivars in on-farm demonstration and seed production trial, 1992

Cultivar	Location			
	Rogie	Misrak Shollaber	Welmera Choke	Mean
Local	7.0	8.5	15.0	D10.2
Sissay	28.5	-	32.5	30.6
CIP-378501.3	-	24.8	-	24.8
Yield advantage (t ha^{-1})	21.5	16.3	17.6	18.5

Table 10. Partial budget analysis of on-farm potato production using traditional and improved technologies, 1992

Factor Variable cost (ETB ha^{-1})	Local	Improved
Labor for planting	180	160
Fertilizer	-	294
Labor for irrigation	20	30
Labor for weeding & hilling	120	190
Building potato store	-	60
Total variable costs	320	734
Average yield (t ha^{-1})	10.2	28.6
Gross benefit *- at harvest	5100	14300
- at planting	-	42900
Net benefit - at harvest	4780	13566
- at planting	-	42166
Marginal rate of return - at harvest	5100	14300
-at planting		9030

*Costs of produce are evaluated at 50 ETB q^{-1} at harvest and 150 ETB q^{-1} at planting sprout for the improved cultivars

Table 11. Production and distribution of improved potato seed tubers

Production site	Total production (q)	Selected for seed production	Amount distributed (q) Contact farmers	Neighbor farmers	Paid back
Rogie	230	20	16	2(1)	2
MSB	162	13	10	1(1)	2
WCR	21	18	2	14(8)	2

* Figures in parentheses indicate number of farmers who bought improved seed potatoes from the contact farmers

CONCLUSION

A sustainable seed potato program is a prerequisite for a successful potato production in Ethiopia. Pre-conditions for the establishment of a seed production scheme are reasonably fulfilled as research has released suitable varieties and developed appropriate agronomic packages for seed potato production including storage.

Our experience has shown that farmers are capable and ready to produce quality tubers of the released cultivars using improved technologies. This will have a great impact on overall seed potato production in the country. Partial budget analysis revealed that on-farm seed potato production is economically very attractive for the farmers and it will remain so in the foreseeable future. Utilization of TPS for the production of seed potatoes has a very bright future, especially in the developing countries like Ethiopia.

References

1. Berga Lemaga. 1981. The influence of media, age of mother stocks, and number of leaves on rooting ability of potato (*Solanum tuberosum* L.) stem cuttings. MSc thesis, Alemaya College of Agriculture, Addis Ababa University. 83 p.
2. [illegible] Daylength and main stem number effects on yield components and tuber yields of potatoes (*Solanum tuberosum* L.) cv. Erntestolz. Accepted for publication in EJAS in April 1993.
3. Berga Lemaga and K.Caesar. 1990. Relationships between numbers of main stems and yield components of potato (*Solanum tuberosum* L.) cv. Erntestolz as influenced by different daylengths. Potato Research 33:257-267.
4. Berga Lemaga, H.Micael K.Mariam and Taye Bezuneh. 1981. The influence of different media on the rooting ability of potato stem cuttings. Eth. J. of Agric. Sci. 3(2):113-120.

5. Booth, R.H., R.L. Shaw and A.T Yupanqui. 1983. Use of natural diffused light for the storage of seed tubers. In W.J. Hooker. (ed.). "Proceedings International Congress: Research for the potato in the year 2000". pp. 65-68, CIP, Lima, Peru.
6. Brown, K.J. 1982. Current development in the research program of CIP in relation to seed potato production *In*: S. Neganga and F. Shideler (eds). Potato seed production for Tropical Africa, pp 2-4, CIP.
7. Bryan. J.E., M.T. Jackson and N.G. Melandez. 1981. Rapid multiplication techniques for potatoes. CIP, Lima. Peru. 20 p.
8. Burton, W.G., and R.H. Broth. 1983 Post-harvest technology for developing country tropical climates. *In*: W.J. Hooker (ed.) "Proceedings International congress: Research for the potato in the year 2000" pp. 40-44, CIP, Lima, para.
9. Carli, C and P.K. Njoroge. 1991. The utilization of rapid multiplication techniques for potato basic seed production in Kenya. *In*: L.J.C Autrey, G.L.T. Hunt, N. Govinden and P. Ferre (eds). Proceedings of the second Triennial Meeting and conference of the African potato Association, pp. 51-58., Mauritius 22-27 July 1990, Reduit, Mauritius. African potato Association.
10. Collins, W.P. 1977. Analysis of growth in Kennebec with emphasis on the relationship between stem number and yield Am. Potato J. 54:33-40.
11. Haile-Michael Kidane-Mariam n.d. Project in Kennebec with emphasis on the relationship between stem number and yield Am. Potato J. 54:33-40.
12. Haile-Michael Kidane-Mariam n.d. Project proposal: Ethiopian potato improvement program. Alemaya College of Agriculture, Addis Ababa University.
13. Haile-Michael Kidane-Mariam, G.C, Arndt, A.C. Macaso-Khwaya and S.J. Peloquin. 1985. Comparison between 4x X 2x hybrid and OP true potato seed families. Potato Research 28:35-42.
14. Hartmann, H.T. and D.E. Kester. 1968. Plant propagation: principles and practices. 2nd ed., Prentice-Hall, Inc., Engle cliffs. New Jersy.
15. Horton. D. and A. Manares. 1985. A small, effective seed multiplication program: Tunisia, 13P CIP, Lima, Peru.
16. Horton, D.E., Y.C. Kin, B.H. Hahn, K.K. Kim, I.G. Mok, and B.N. Lee. 1987. Korea's seed potato program: Organization, impact and issues CIP in collaboration with Republic of Korea Ministry of Agriculture and Fisheries Rural Development administration, 68 P.
17. International Potato Center. 1974. Annual Report, Lima. Peru.
18. International Potato Center. 1983. Annual Repot, Lima, Peru.
19. Jones, R.A.C. 1982. Tests for transmission of four potato virus through potato true seed. Annuals of Applied Biology 100:315-320.
20. Malagamba, P and A. Monases. 1988. True Potato seed: Past and present uses, Lima. Peru, CIP, pp. 11-12.
21. Mulugeta Taye. 1992. Effect of storage methods, tuber size and spacing on the growth and yield of potato (*Solanum tuberosum* L.). MSc thesis. Alemaya University of Agriculture.
22. Page, T.O. and D.E. Horton. 1987. South Asian Program for Potato Research and Development (SAPPRAD). Five-year Review (1982-1986), 161 p.

23. Rueda, J.L., P. Pozy. C. Muvira, Z. Nzoyihere, C. Turner and E. Nigongabo. 1991. The development and acceptance of potato seed production under farmer conditions in *Burundi: In*: L.J.C. Autrey, G.L.T, Hunt, N. Govinden and P. Ferre (eds). Proceedings of the second Triennial Meeting and conference of the African Potato Association pp. 71-76. Mauritius 22-27 July 1990. Reduit, Mauritius. Africa. PP. 131-138. CIP.
24. Sikka L. 1982. Innovations in potato seed production and strategy of seed production in tropical countries. *In*: S. Nganga and F. Shideler (eds). Potato seed production for Tropical Africa, pp. 131-138, CIP.
25. Song, B. 1984. Use of true potato seed in China. CIP Circular 12(2):6-7.
26. Tovar, P and J.H. Dodds. 1986. Tissue Culture propagation of potato: CIP slide training series 1-5, 12P. CIP.
27. Tsao, S.J. and Y.M Chang. 1982. Studies on potato production by true seeds. *In*: Hsieh & Liu (eds). Proceedings of ad symposium on plant breeding, pp. 233-240. Taichung, Taiwan, 23-24 September 1981. Agricultural Association of China. Council for development and planning.
28. Umaerus, M. 1987. True potato seed *In*: Proceedings of 10th Triennial conference of the European association for Potato Research. PP 72-102. Aalborg, Denmark, 1987.
29. Wiersema, S.G. 1984. The production and utilization of seed tubers derived from true potato seed. PhD thesis, University of Reading. 229 p.
30. Wurr, D.C.E. 1974. Some effects of seed size and spacing on the yield and grading of two main crop potato varieties; II. Bulking rate. J. Agric. Sci., Camb. 82: 47-52.
31. Yaynu Hiskias. 1989. Characteristics of insolates of *Pseudomonas Solanacearum* in Ethiopia Ethiop. J. Agric. Sci. 11(1):7-13.
32. Zaag, D.E Vander. 1986. Planting, manuring and weed control in potatoes. Wageningen, the Netherlands. 24 p.

DISCUSSION

Alemseged Aregai: What are the quality factors used to determine potato seeds prior of propagation? How many generation systems can be used to multiply seed potato?

Berga: The most important factor is that the seed tubers should be pathogen free, especially viruses. They should also be pure both genetically and physically. They also have to be in good physiological condition. In many countries, size is also an important quality factor, with sizes of 30–50 g being most preferred.

This depends on the healths of seed tubers, as long as you have healthy tubers you can continue with multiplication. If you observe diseases, then you have to stop multiplication and ask for disease free ones from the breeder. It is, therefore, difficult to give a figure, as this may depend on the management in multiplication and disease incidence. Nowadays, with the available biotechnology, in tissue culture, it is not difficult to clean tubers from pathogens.

Asnakew W/Ab: Explain in brief your recommendation. Sound and sustainable seed program that can function and that can guarantee seed production. Sustainable means a program that can function for a long time, sustain itself. A program that is reliable and functional in the system. Using available facilities and preferably local experts. We have no tissue culture at IAR, a National Research Institute. In many other countries in Africa T.C. is used as a routings activity. This will tell you where we are in T.C.

Tesfaye Abebe: Can you explain the relationship between seed tuber healths and delayed harvesting? This is because you have stated that earlier harvesting before foliage gets yellow is better to the health of the seed tuber.

Berga: Crop for seed production should be harvested after the crop has attained physiological maturity and after tubers of seed size have been formed. If harvesting is delayed until senescence, pathogens in the foliage, especially fingers, will get sufficient time to be translocated to the tubers. Hence, the tubers will be infected, a good example in sate blight. If harvesting is excessively extended, insects also become a big problem, especially potato tuber moth. There is therefore a negative relationship between seed tuber health and delay in harvest.