

**THE UTILIZATION OF TRUE POTATO SEED (TPS)
AS AN ALTERNATIVE METHOD OF POTATO
PRODUCTION**

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**THE UTILIZATION OF TRUE POTATO SEED (TPS)
AS AN ALTERNATIVE METHOD OF POTATO
PRODUCTION**

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PROPOSITIONS

1. In the Ethiopian rain season, the possibility of growing TPS for either seed or ware potatoes does not seem promising because of the problems of poor seedling establishment and the high late blight pressure. (*this thesis*)
2. During the Ethiopian dry season, by growing TPS in a seed bed of 1 m², and with a proper nursery management, a maximum seedling tuber number of up to 1200 can be produced. A seed bed of 40 m² can produce sufficient seedling tubers to plant a hectare of land. (*this thesis*)
3. In the absence of any other chemical, soaking in water can partly break dormancy of true potato seed (TPS) probably by washing out inhibitors. (*this thesis*)
4. The multiplication rate of a conventional method of potato production, after two vegetative phases in the field, is only 92. Contrastingly, the multiplication rate of a seedling tuber production scheme under Ethiopian conditions, after one generative phase in the field and a vegetative phase in the nursery, is 450. (*this thesis*)
5. The Sub-Saharan Africa has been experiencing recurrent famine in the last two to three decades. Drought, political instability and civil wars, and locusts have all played a part in this.
6. Root crops in general and potatoes in particular could play an important role in alleviating the food shortage in some parts of Ethiopia and improve the diet of the Ethiopian farmer provided that a concerted and coordinated national effort is made to promote their production in the country.
7. Even though the seedling tuber yields of the open-pollinated (OP) TPS progenies were substantially lower than those of the hybrid progenies, their economic yields could be significantly higher because of the extra costs associated with the production of the hybrid seeds. The use of an OP progeny with an acceptable level of seedling tuber yield and tuber uniformity may be more relevant in low input farming systems than using hybrid progenies.

8. In Ethiopia, because of the scarcity, poor quality and high cost of seed tubers, a potato production system with the combined use of true potato seed (TPS) and seedling tubers can offer an alternative and partially solve these problems of seed tubers.

9. Future research on TPS should also focus on improvement of seed quality and efficient methods of production and distribution of large amounts of true potato seed (TPS). To fully exploit the potential of TPS, improvement of TPS quality through better field management practices is important.

10. Agricultural development in many underdeveloped countries must strike a balance between conservation of all natural resources and meeting the short-term needs of farming families and urban population. Agricultural sustainability should combine conservation with development.

11. Involving farmers 'first and last' helps to ensure the relevance and acceptability of research results while the process of on-farm testing also serves to demonstrate and popularize innovations.

Bereke T. Tuku

" The utilization of true potato seed (TPS) as an alternative method of potato production "

Wageningen, The Netherlands

May 3, 1994

Abstract

Potato is grown as a rainfed and irrigated crop in the cooler highlands and mid-altitude regions of the tropics. Its productivity is very low mainly due to unavailability of healthy and sufficient amount of seed potatoes to the farmers. The utilization of true potato seed (TPS) can be considered as an alternative method to produce potatoes, thereby alleviating the problems associated with seed potatoes.

The first aim of the research report in this thesis was to study problems related with poor TPS germination. The second aim was to determine the best growing season to grow TPS for seedling tuber production. The third aim was to develop appropriate seed bed management practices for maximum seedling tuber production.

Increasing nitrogen fertilization to the mother plant enhanced the rate of germination of the TPS of the open pollinated progeny (*AL 624*) and reduced that of the hybrid progeny (*AL 624 x CIP 378371.5*) without affecting the final germination percentages (FGP) of both progenies.

TPS dormancy was effectively broken by soaking in 1000-1500 ppm GA₃ for 8 hrs. Treating TPS with water can also break dormancy and maintain about 70 % germination. The latter may be considered as a cheap, readily available and practical alternative method of breaking TPS dormancy under farmers' condition.

The field and nursery experiments indicated that seedling tuber yields are very low during the rain season due to late blight (*Phytophthora infestans*) pressure, shorter sunshine hrs and a shorter growing season than the dry season.

Based on the nursery results, in the central highlands of Ethiopia, dry season production of seedling tubers in a seed bed substrate mix of 50 % forest soil and 50 % manure, and 40 - 80 g N per m² bed were found to be suitable for the production of a maximum number of seedling tubers by direct sowing methods.

Manipulation of seedling population in a seed bed is one method of producing a maximum number of usable seedling tubers. The results revealed that a plant density of 100 plants per m² seed bed was optimal for the production of a maximum number of up to 1200 seedling tubers or a total tuber weight of 29 kg per m² without hampering management operations such as weeding, fertilization and hilling up.

The research results showed that there is a considerable potential of alleviating the problems of seed potatoes by improving the TPS germination quality, seed bed production of seedling tubers and using them as seed potato source for subsequent growing seasons.

Key words: TPS, germination, dormancy, dormancy breaking chemicals, substrate, nitrogen, phosphorus, plant density, *Solanum tuberosum* L., seedling tuber yield, seedling tuber number.

Preface

I thank the International Potato Center (CIP), the Wageningen Agricultural University (WAU) and the Institute of Agricultural Research (IAR), Ethiopia, for their financial support. The technical assistance of the Ethiopian Potato Improvement Programme (EPIP) staff of the Holetta Research Center, IAR, Ethiopia is gratefully acknowledged.

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Bereke Tsehai Tuku

Wageningen, March, 1994

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CHAPTER 1

GENERAL INTRODUCTION

CHAPTER 1

GENERAL INTRODUCTION

This chapter gives a general view on the food supply, the potato production and its major constraints in Ethiopia, the potential use of true potato seed (TPS) and seedling tubers, and gives a brief outline of the research project and the thesis.

1.1. Food production in Ethiopia

Ethiopia is one of the highly populated countries in Africa. With a population of 52 million, it is exceeded only by Nigeria in the Sub-Saharan Africa. Agriculture is the mainstay of the economy, accounting for about 90 % of the national foreign exchange earnings, and it employs over 85 % of the national labour force. The sector also supplies a large portion of the raw materials required in the industrial sector.

The country is endowed with suitable climatic and edaphic conditions for production of various kinds of agricultural crops. However, due to low agricultural productivity, the recurrent drought and socio-political factors there is always a food shortage in some parts of the country. The vast majority of the Ethiopian population depends mainly on cereal food

Table 1.1. Acreage and production of the major cereal food crops and potato in Ethiopia.

Crop	Area ('000 ha)	Yield (t/ha)	Production ('000 t)
Barley	872.5	1.0	869.6
Maize	840.5	1.2	1009.5
Sorghum	725.9	1.1	782.5
Millet	152.6	0.8	122.0
Teff	1240.7	0.7	899.5
Wheat	722.0	1.0	729.1
Potato*	50.0	5.8	290.0

Source: Statistical Abstracts (1986).

*Woldeyes K. and Gigar T. (1988).

crops. Teff (*Eragrostis teff*) covers about 27 % of the land cultivated with cereals (Table 1.1). The land under potato is estimated to be 50,000 ha (Table 1.1).

Table 1.2. Mean tuber yield (t/ha) from seed tubers of potato varieties grown at seven research centers* during the rain seasons of 1985 and 1986 in Ethiopia.

Variety	1985	1986	Mean
CIP 378367.4	30	30	30
Sissay	31	25	28
UK-80-3	31	23	27
CIP 378371.5	25	27	26
AL 107	18	32	25
CIP 378329.8	24	26	25
AL 119	25	24	24
K-59 A (26)	17	30	23
CIP 378501.10	22	22	22
CIP 378501.3	20	23	21
Local	5	6	6

Source: Tuku B. T. (1988).

* Holetta, Awasa, Bako, Endibir, Jima, Nazret and Sheno.

Generally, published data on production and use of horticultural crops are very scarce and unreliable. Government statisticians usually give priority to compiling information on cereal crops and cash crops like coffee. They also face the problem of estimating the production of potatoes which are often grown in small patches scattered all over the country. Therefore, the land under root crops is not precisely known and their potential has not been adequately exploited.

1.2. The role of potato in food production in Ethiopia

Potato is mainly grown in the cooler highlands, the mid-altitude, high rainfall and semi-arid regions of Ethiopia. Although no systematic survey of the area under potato has been carried out, during the last decade the area cropped with potato seems to have increased mainly due to import of seed potatoes by aid organizations and in some instances by the government.

Based on the acreage and the national average yield, the total potato production is estimated to be 290,000 t (Table 1.1). Compared to cereal crops, potato is only a minor crop in Ethiopia. But by improving its productivity, it can play some role in alleviating the food shortage in the country.

In 1985/86, the Ethiopian Potato Improvement Programme (EPIP) has developed potato cultivars which have a yield potential of up to 30 tons/ha (Table 1.2) in experimental fields and 20-25 tons/ha using normal farmer's management practices. If they are grown during the dry season using irrigation, these yields are estimated to increase by 15-20 %.

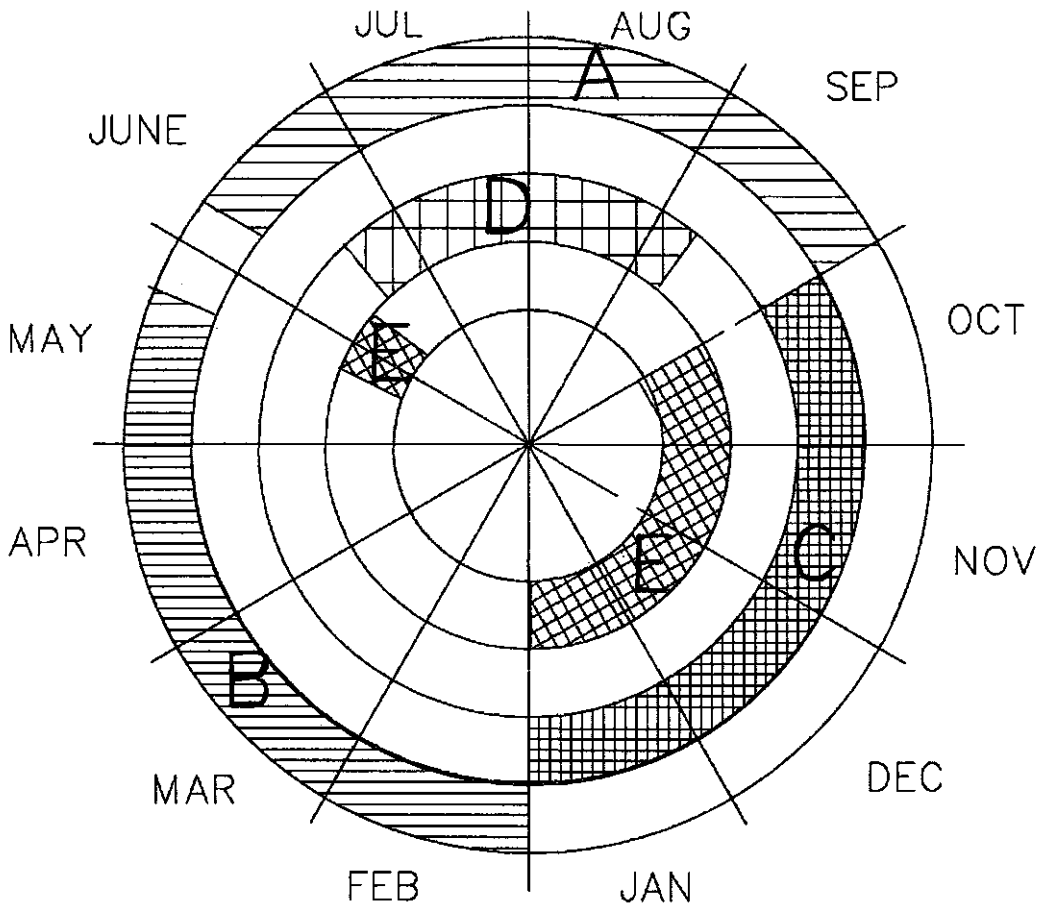
In terms of dry matter production per hectare, potatoes are among the most productive crops growing in the developing countries (Table 1.3). Its relatively short growing period makes it rank high in terms of dry matter production per day. In relation to other crops, potato is also rich in available nutrients.

With its high potential to supply a cheap high quality food within a relatively short period of time, potato has the potential to improve appreciably the quality of the basic diet in rural and urban areas of Ethiopia provided that a coordinated national effort is made to promote its production.

Table 1.3. Production of dry matter, edible energy and protein of the ten highest value food crops in developing countries.

Rank	DM* (t/ha)	DM (kg/ha/day)	Energy (MJ/ha/day)	Protein(kg/ha/day)
1	Cassava 3.0	S. Potato 22	Potato 216	Cabbage 2.0
2	Yam 2.4	Potato 18	Yam 182	Broad bean 1.6
3	Potato 2.2	Rice 18	Carrot 162	Potato 1.4
4	S. Potato 2.1	Wheat 14	Maize 159	Dry pea 1.4
5	Rice 1.9	Yam 14	Cabbage 156	Eggplant 1.4
6	Carrot 1.7	Cassava 13	S. Potato 152	Wheat 1.3
7	Cabbage 1.6	Cabbage 12	Rice 151	Lentil 1.3
8	Banana 1.5	Tomato 8	Wheat 135	Tomato 1.2
9	Wheat 1.3	G. Nuts 8	Cassava 121	Chickpea 1.1
10	Maize 1.3	Lentil 6	Eggplant 120	Carrot 1.0

Source: Horton and Fano (1985). * DM = dry matter



- Seasons:
- A = Rain season growing period
 - B = Dry season growing period
- Problems:
- C = Frost
 - D = Late blight
 - E = Storage

Fig. 1.1. Potato production calendar and the related production problems in the central highlands of Ethiopia.

1.3. Potato growing in Ethiopia

Potato (*Solanum tuberosum* L.) is one of the important potential root crops in Ethiopia. The major potato growing regions are Shewa, Gonder, Gojam and Hararghe (Woldeyes & Gigar, 1988). About 70 % of the cultivable land in Ethiopia is at an altitude ranging from 1800 to 2500 m above sea level and gets an annual rainfall of more than 600 mm (Kidanemariam, 1975). Potato is produced usually in the highlands and the mid-altitude areas of the country by subsistence farmers who grow less than one hectare on a number of small scattered fields. The land under potato is estimated to be 50,000 hectares. Most farmers grow the local varieties. The national average yield is only 5.8 t/ha. However, during the dry season when there is less pressure of late blight, this yield of the local varieties can go up to 10 t/ha using irrigation.

In the central highlands (> 2000 m) of Ethiopia, there are two distinct potato growing seasons (Fig. 1.1). The big rain season (*Kremt*), which extends from June to September, is characterized by high rainfall (900 mm). The optimum planting date is the first week of June. It is the season when farmers expect a lot of diseases and pests, the major ones being late blight (*Phytophthora infestans*) and potato tuber moth (*Phthorimaea operculella*). In the past, farmers used to grow potatoes during the rain season. But after the devastating incidence of late blight in 1985 and 1987, many farmers gave up producing potatoes during the *Kremt* season. The off (dry) season is relatively dry and extends from October to May (Appendix 1.1).

In the central highlands, between the months of October and January there is a risk of frost (Fig. 1.1) in which case farmers do not grow potatoes. Therefore, during the dry season, the period between February and May is a potato growing season. However, in the rift valley (1500-1800 m) where there is no incidence of frost, few farmers have also been growing potato between the months of October and January.

Depending on the growing season, farmers may harvest the potatoes sometime in September or May. There are no potato storage infrastructures such as diffused light stores or cold stores where farmers can keep their produce. Therefore, farmers are forced to sell their produce at a very low price.

The land races of potato grown in Ethiopia are probably from the same parentage introduced in about 1858 by a German botanist called Shimper (Pankhrust, 1964). Except for minor variations, they appear to be very similar in most of their general characteristics

(Kidanemariam, 1979). Mostly, the local varieties, under different local names, are grown widely in the country and are very susceptible to late blight (*Phytophthora infestans*) and poorly yielding. Fungicides are either not available or very expensive so that farmers cannot afford them. Recently, in a very few areas of the country, some improved varieties (Tables 1.2 and 1.4) developed by the EPIP have been introduced. However, due to the lack of a seed production system, they have not yet reached the farmers. The improved varieties are developed at the Holetta Research Center and are being distributed and tested at the different research centers. The centers are located in different agro-ecological zones of the country with differences in altitude, growing season and amount of rainfall. Therefore, this has caused a lot of variation in the yield performance of the varieties (Table 1.4). However, some varieties are more stable over locations than others.

1.4. Constraints to realize potato production in Ethiopia

The normal way to propagate potatoes is by the production of seed tubers (vegetative reproduction). From a current crop season, farmers select the small and unhealthy looking tubers that cannot otherwise be sold as ware potatoes in the market and use them as seed tubers for subsequent seasons. This practice speeds up the degeneration process. The lack of sufficient and good quality seed tubers is the most important yield limiting factor in Ethiopia. To date there is no private or government agency that produces and distributes seed potatoes of the local or improved cultivars that have been developed by research institutions in the country.

Late blight (*Phytophthora infestans*) has become such an important disease that many farmers have stopped growing potatoes during the big rain season (*Kremt*). It is important to note here that farmers do not apply fungicides to control late blight. In view of this fact the EPIP has put every effort to develop varieties which have field resistance against late blight. Potato tuber moth (*Phthorimaea operculella*), as an insect pest of the field and the store, poses a threat to potato production as well. In the research centers, the use of sex pheromone traps has been useful to reduce tuber moth population.

Ethiopia is a vast country with different agro-ecological zones. There are no varieties that can adapt to all the different agro-ecological zones of the country. The unavailability of storage for ware as well as seed potatoes, and the absence of transport and marketing infrastructure in the country have been discouraging farmers from growing potato.

Table 1.4. Mean tuber yield (t/ha) of potato varieties under the National Potato Variety trial grown at nine research centers during the 1987 and 1989 rain seasons in Ethiopia.

Variety	Research centers									Mean	CV (%)
	Holetta	Sheno	Bekoji	Sinana	Melkasa	Awasa	Jima	Adet	Bako		
K-59A-26	15	18	67	26	24	23	25	28	22	27.6	52
CIP 378367.4	14	21	43	31	14	29	25	25	17	24.3	36
CIP 378501.3	20	19	31	27	23	29	23	24	15	23.4	20
CIP 378329.7	19	23	36	28	12	26	18	29	18	23.2	30
Sissay	17	16	31	29	15	34	23	20	14	22.1	32
AL 107	15	23	25	26	16	25	17	25	19	21.2	20
CIP 378371.5	13	18	32	24	8	22	27	25	15	20.4	35
AL 119	13	18	22	23	15	30	23	20	14	19.8	26
CIP 378329.8	15	15	28	22	7	14	9	22	12	16.0	40
Mean	16	19	35	26	15	26	21	24	16	22.0	
CV (%)	15	14	36	10	37	21	25	12	18		
Local	1	7	9	12	10	14	2	5	3	7.0	
Mean	14.2	17.8	32.4	24.8	14.4	24.6	19.2	22.3	14.9	20.5	

Source: Institute of Agricultural Research (1991).

1.5. Problems associated with the use of seed tubers

1.5.1. Lack of local seed tubers

The most important constraints limiting potato production in Ethiopia are the scarcity, poor quality and high costs of seed tubers. The absence of a seed tuber multiplication, certification and distribution scheme in the country has given to farmers no option but to use the local, degenerated and physiologically poor quality seed tubers that are being saved from the previous crop, or whatever is available in the local market. Ethiopia is not unique in this respect; it is a common phenomenon in many underdeveloped countries where economic, technical and infrastructural problems related to production, handling and distribution of seed tubers have hampered the establishment of seed potato multiplication and certification schemes (Monares, 1981).

1.5.2. Quality aspects of seed tubers

The health of seed tubers is an important factor that influences the potential yield of a crop. Several diseases and pests are transmitted by tubers resulting in degeneration during their subsequent multiplication. The Ethiopian farmers usually save small and inferior seed tubers that cannot be sold as ware potatoes. This practice is believed to have contributed to the build up of different diseases and insect pests in the successive generations of the locally grown potato cultivars. In places where locally produced tubers are used, the accumulation of tuber borne diseases and insects in successive generations can result in significant yield reductions, explaining why the national average yield is only 5.8 t/ha.

Lack of appropriate storage infrastructures have caused a further decrease in quality through physiological deterioration of the seed tubers. Import of healthy and quality seed tubers from other countries can provide a solution to the disease problems of seed tubers. However, this has posed three important problems. Firstly, imported seed tubers are so expensive that an average Ethiopian farmer cannot afford them. It is estimated that the costs of seed tubers may constitute 20 - 70 % of the total cost of production of potatoes (Accatino & Malagamba, 1982; Sadik, 1983; Rashid, 1987; Malagamba & Monares, 1988). Secondly, it does not usually reach its destination at the optimum physiological stage for planting. Thirdly, the imported cultivars require high management inputs, in terms of fungicides, insecticides and fertilizers which are not available to the average farmer. Between 1985 and

1987, a total amount of 2300 tons of seed potatoes were imported from Europe. To date, out of the seven imported cultivars, Cara is the only cultivar in production on a limited scale in some parts of northern Ethiopia. The others were all completely wiped out by late blight (*Phytophthora infestans*).

1.5.3. Other constraints

In Ethiopia, the major potato production regions are in the highlands where transport and road infrastructure are either not yet developed or poor. Seed tubers are bulky and perishable and their distribution to distant and inaccessible production areas poses a formidable transport problem.

The constraints posed by the unavailability and high cost of seed tubers have become an obstacle to improve the productivity of the potato crop and to expand its cultivation in areas which have high potential for potato production. Moreover, the amount of seed tubers required for planting constitutes food that otherwise could have been consumed. It is estimated that in developing countries where yields are very low, the amount of seed tubers may represent up to 18 % of the total potato production (CIP, 1982). The problem associated with the use of seed tubers have led us to seek an alternative planting material with improved management practices that can fit into the farmer's needs and available resources, and the existing farming system. The potential of the present knowledge on true potato seed (TPS) technology should be tested to assess whether it can be adopted to the Ethiopian conditions.

1.6. Potential use of TPS and seedling tubers

1.6.1. Advantages of TPS over seed tubers

Conventionally, potato is propagated vegetatively using seed tubers. Under suitable environmental conditions, however, a potato plant can produce flowers and set berries. Inside these berries of the potato plant seeds may develop. Each berry bears about 150 - 200 seeds. These seeds can be extracted from a mature berry and air dried for use in a true potato seed planting programme. The production of botanical seeds, commonly referred to as true potato seed (TPS), may be an alternative way to propagate potatoes.

Compared to seed tubers, TPS offers several advantages. Perhaps the most important and striking advantage of true potato seed is the amount of seed required to plant a hectare of

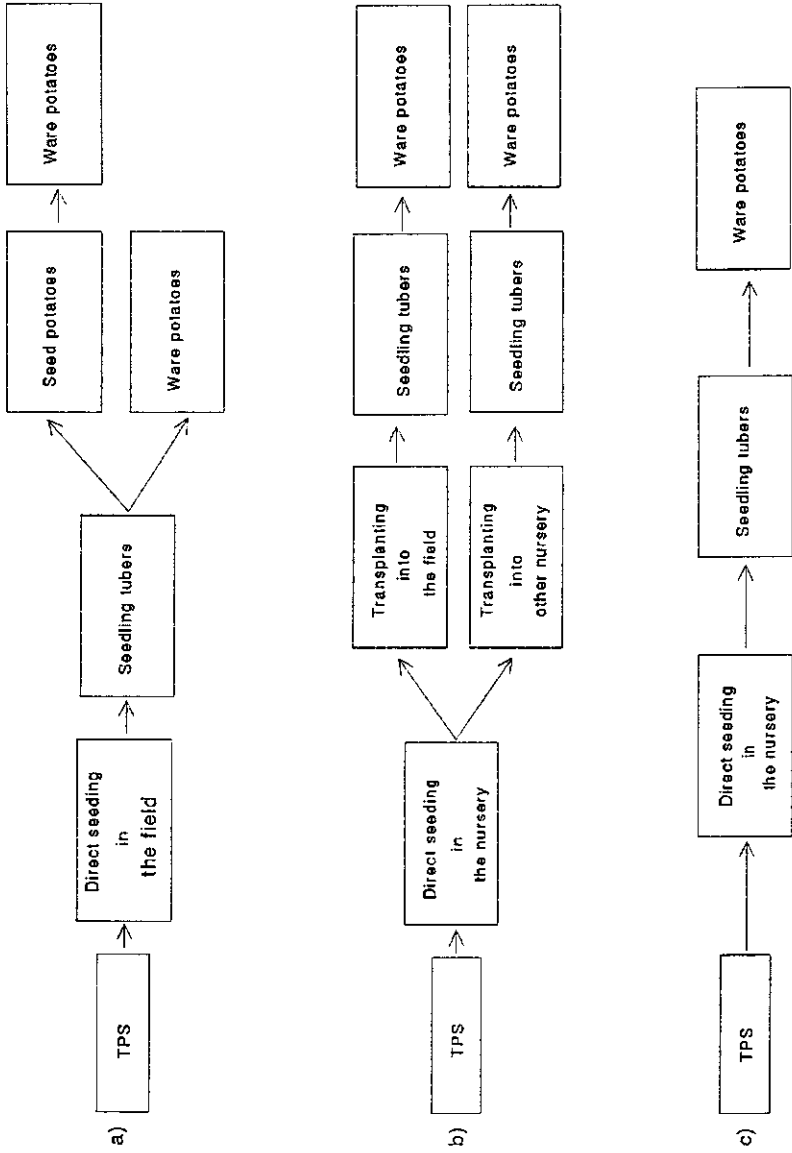


Fig. 1.2. Methods to use true potato seed (TPS).

land. For a hectare of land 150 g of TPS is needed while at least 2 tons of seed tubers is required. For subsistence farmers, in developing countries, who do not have an access to good quality seed tubers, true potato seed can be a cheaper source of planting material. TPS can easily and cheaply be stored and transported.

Traditionally potatoes are grown in cool climates. The major potato production is now in the northern latitudes and in the highlands of the tropics. With the use of TPS, potatoes can grow in warm, non-traditional potato growing areas. For subsistence farmers, in these warm, non-traditional potato growing areas, who do not have access to good quality seed tubers, TPS could be a low-cost source of high quality planting material. True potato seed is much easier to store than seed tubers. The growth vigour is much less dependent on the physiological status of the propagule. Hence, farmers using TPS could have it for planting at any time. This would allow them to fit potatoes into the farming system where seed tubers of the optimum physiological age are not available.

Very few diseases are transmitted by TPS (Accatino & Malagamba, 1983; Kim *et al.*, 1983; Li, 1983; Monares *et al.*, 1983; Sadik, 1983). TPS is known to transmit only a few viruses and one viroid, potato spindle tuber viroid, which may pose a potential problem. Nevertheless, virus transmission is much smaller than in the case of seed tubers and this is one of the advantages of TPS in warmer areas with high incidence of virus infection.

True potato seed can be used through three different methods (Fig. 1.2), namely: (a) direct seeding to the field for the production of seed or ware potatoes; (b) seeding in the nursery and raising seedlings to be transplanted either to the field or to another seed bed for seedling tuber production; (c) direct seeding to the nursery for seedling tuber production. From our experience in Ethiopia, the latter two methods (b & c) have the potential of being adopted by the farmers easily.

Large increases in tuber yield from TPS can be expected in areas with low yields resulting from poor seed tuber quality (Kidanemariam *et al.*, 1985). Tuber yields and quality of some selected TPS progenies are comparable with those of conventional seed tubers under certain conditions in Ethiopia and elsewhere (Kim *et al.*, 1983; Li, 1983; Sikka, 1987). TPS usually produces smaller tubers but larger number of tubers per stem than the conventional seed tuber. TPS can easily be introduced into existing farming system because planting time does not depend upon the physiological age of the seed tubers and there is no effect of age of the propagule on plant development.

TPS hybrids are generally superior to open-pollinated progenies in seedling vigour and tuber yield (Accatino & Mallagamba, 1983; Kim *et al.*, 1983; Sadik, 1983).

1.6.2. Disadvantages of TPS over seed tubers

The use of TPS as planting material also presents some disadvantages. Most of these disadvantages are related to the small size of the seed or to the sexual reproduction associated with true seed production. The main disadvantages are: (a) freshly harvested TPS are dormant; (b) a major problem associated with the technique is poor germination and seedling establishment; (c) duration of the growth cycle of a TPS crop is longer than of a crop from seed tubers; (d) crops grown from TPS are less uniform in plant type and maturity; (e) plants from TPS are more susceptible to pests, diseases and competition of weeds; (f) the tubers produced from TPS are less uniform in shape, colour, size and dry matter content than tubers produced from a clone; (g) its vulnerability to environmental stress and its high labour requirement have also been reported as disadvantageous (Monares *et al.*, 1983).

1.6.3. TPS and multiplication

The production and utilization of seed tubers derived from true potato seed has a potential combination of the rapid plant development from seed tubers with high health standards and low cost of TPS (Accatino & Malagamba, 1983; Sadik, 1983; Wiersema, 1986; Sikka, 1987; Malagamba, 1988), without some of the major disadvantages of TPS. Seedling tubers can be produced in seed beds using the appropriate substrate and fertility level, optimum seedling density and better control of soil-borne and vector transmitted diseases. With good nursery management, very high yields of seedling tubers can be obtained in small areas. Wiersema (1984) reported yields up to 12 kg per m² bed. The maximum number larger than 1 g, the size found usable for multiplication, was 1242 tubers per m² meaning that approximately 40 m² of seed bed is required to produce sufficient tubers to plant a hectare. Malagamba (1988) stated that with fertile seed beds and proper nursery management, a seed bed of 10 m² can produce sufficient tubers to plant a hectare of land after one field multiplication. The yield of crops grown from small seedling tubers (5-20 g) was comparable to that of crops grown from equal size clonal seed tubers (CIP, 1982). The productivity of crops grown from seedling tubers have been higher than local cultivars in many evaluation trials carried out in some countries because of the poor health standard of the latter (Devasaiba, 1982; Devaux,

1984; Song, 1984). In Peru, seasonal variation in tuber number and mean tuber weight was observed for seedling tuber production in seed beds (Wiersema, 1985). In the warm summer season, tuber number was significantly reduced and mean tuber weight was 56 % greater than that of the winter season.

In Ethiopia, from seedlings transplanted to the field, a maximum seedling tuber yield of 29 t/ha has been reported (Yilma, 1991). When seedling tubers are produced in the field, the production of non uniform tubers has been cited as one of the disadvantages. However, the variability in plant and tuber characteristics, maturity etc. may not be seen as a problem in Ethiopia. Because of the food shortage in the country, people may not be concerned about the quality of the tuber in terms of its shape colour and size.

A potato production system with the combined use of TPS and seedling tubers can offer an alternative (CIP, 1981) and could also potentially solve some of the current problems associated with potato planting material in Ethiopia.

1.7. The research programme and outline of the thesis

The scarcity, poor quality and high cost of seed tubers are the most important constraints limiting potato production in Ethiopia. These problems have been aggravated by the absence of a seed potato multiplication, certification and distribution agency. Therefore, farmers are compelled to use the local, degenerated and physiologically poor quality potato seed tubers that are either saved from the previous crop or whatever is available in the local market. In some areas of the country, farmers have quit producing potatoes mainly because of lack of seed or were discouraged by the yearly occurrences of late blight (T. Gigar, pers. comm.).

True potato seed can be used for the production of ware potatoes. There has also been an increasing interest in the use of true potato seed for the production of seedling tubers in many countries (Bedi *et al.*, 1980; Harris, 1983; Malagamba, 1983; Wiersema, 1983). The utilization of TPS for seedling tuber production and the use of these tubers as seed tubers can be an alternative to alleviate the problem of seed potato in Ethiopia.

The main objectives of the research reported in this thesis were: (a) to study problems related to poor seed germination and seedling establishment; (b) to identify TPS progenies that can well adapt to the Ethiopian highland conditions; (c) to determine the best growing season to grow TPS for seedling tuber production and (d) to develop appropriate seed bed management practices for maximum seedling tuber production.

In **chapter 1**, a general introduction on the potato production, the major production constraints, the potential of TPS and the role that seedling tubers can play in seed potato production in Ethiopia has been presented. In **chapter 2**, the effects of nitrogen supply during TPS production on germination capacity of open and hybrid progenies are described. Several TPS dormancy breaking chemicals are evaluated in **chapter 3** with emphasis on relatively cheap, available and effective chemicals. In **chapter 4**, several open and hybrid progenies are evaluated under field conditions during two contrasting seasons to identify the most adaptable progenies and to determine the appropriate season to grow potatoes in the central highlands of Ethiopia. In **chapter 5**, from locally available substrate sources, the best ratio of seed bed substrate mixes for the production of a maximum number of seedling tubers is identified; moreover, nitrogen and phosphorus requirements are evaluated. In **chapter 6**, an attempt is made to establish the optimum plant density in the seed bed for a maximum seedling tuber number production. The practical implications in using very high plant population density is also discussed. In **chapter 7**, the main findings and the application of TPS technology are discussed and the future TPS research in Ethiopia is also indicated.

References

- Accatino, P. & P. Malagamba, 1982. Potato production from true seed. CIP Bulletin. Lima, Peru, 20 pp.
- Accatino, P. & P. Malagamba, 1983. Growing potatoes from true potato seed. Current agronomic knowledge and future prospects. In: W. L. Hooker (Ed.), Research for the Potato in the Year 2000. CIP, Lima, Peru, pp. 61.
- Bedi, A. S., P. Smale & D. Burrows, 1980. Experimental potato production in New Zealand from true seed. In: The planning conference on the production of potatoes from true seed. Manila, Philippines, 13-15 September, 1979. CIP, Lima, Peru, pp. 100 - 116.
- CIP, 1981. Annual Report. Centro Internacional de la Papa, Lima, Peru.
- CIP, 1982. Annual Report. Centro Internacional de la Papa, Lima, Peru.

- Devasaiba, K., 1982. True potato seed research in Sri Lanka. *True Potato Letter* 3 (2), CIP, Lima, Peru, pp. 2.
- Devaux, A., 1984. True potato seed development. *CIP Circular* 12 (3): 6 - 7.
- Harris, P. M., 1983. The potential for producing root and tuber crops from seed. 6th Symposium of the International Society for Tropical Rootcrops, 20 - 25 February, 1983. CIP, Lima, Peru, pp. 67 - 80.
- Horton, D. & H. Fano, 1985. Potato Atlas. CIP, Lima, Peru, 135 pp.
- Institute of Agricultural Research, 1991. Project proposal for the Ethiopian Potato Improvement Programme, Addis Ababa, Ethiopia, 35 pp.
- Kidanemariam, H. M., 1975. Potato project proposal for the Ethiopian Potato Improvement programme. Alemaya Agricultural College, Addis Ababa University, Ethiopia, 15 pp.
- Kidanemariam, H. M., 1979. Preliminary assessment of the responses of potato genotypes in the eastern, southern and central regions of Ethiopia. *Ethiopian Journal of Agricultural Sciences* 1 (1): 41 - 47.
- Kidanemariam, H. M., H. A. Mendoza & R. O. Wissar, 1985. Performance of true potato seed families derived from intermating tetraploid parental lines. *American Potato Journal* 62: 643 - 652.
- Kim, K. K., H. Y. Kim & C. H. Song, 1983. Potato production by TPS in a temperate region. In: W. L. Hooker (Ed.), *Research for the Potato in the Year 2000*. CIP, Lima, Peru, pp. 109 - 110.
- Li, J. H., 1983. Prospects for the use of true seed to grow potatoes. In: W. L. Hooker (Ed.), *Research for the Potato in the Year 2000*. CIP, Lima, Peru, pp. 17 - 18.
- Malagamba, P., 1983. Seed-bed substrates and nutrient requirements for the production of potato seedling. In: W. G. Hooker (Ed.), *Research for the Potato in the Year 2000*. CIP, Lima, Peru, pp. 127 - 128.
- Malagamba, P., 1988. Potato production from true seed in tropical climates. *HortiScience* 23 (3): 495 - 500.
- Malagamba, P., & A. Monares, 1988. True potato seed: Past and present uses. CIP, Lima, Peru, 40 pp.
- Monares, A., 1981. The potato seed system in the Andean region: the case of Peru. Ph.D. thesis, Cornell University, 203 pp.

- Monares, A., P. Malagamba & D. Horton, 1983. Prospective systems and users for true potato seed in developing countries. In: W. T. Hooker (Ed.), *Research for the Potato in the Year 2000*. CIP, Lima, Peru, pp. 134 - 136.
- Pankhrust, R., 1964. Notes on a history of Ethiopian agriculture. *Observer* 7: 210 - 240.
- Rashid, M. M., 1987. Problems of production of TPS in Bangladesh. Proceedings of the workshop on TPS research in Bangladesh. Bangladesh Agricultural Research Institute, Potato Research Center, 17 - 18 August, 1987, pp. 5 - 7.
- Sadik, S., 1983. Potato production from TPS - Present and future. In: W. L. Hooker (Ed.), *Research for the Potato in the Year 2000*. CIP, Lima, Peru, pp. 18 - 25.
- Sikka, L., 1987. Review of TPS research in Bangladesh. Proceedings of the workshop on TPS research in Bangladesh. Bangladesh Agricultural Research Institute, Potato Research Center, 17 - 18 August, 1987. pp. 8 - 17.
- Song, B. F., 1984. Use of true potato seed in China. *CIP Circular* 12 (2): 6 -7.
- Statistical Abstracts, 1986. Central Statistics Office, Addis Ababa, Ethiopia.
- Tuku, B. T., 1988. Potato research and future improvement prospects in Ethiopia. Proceedings of the 19th National Crop Improvement Committee, Institute of Agricultural Research, 22 - 26, April, 1988. Addis Abeba, Ethiopia, pp. 301 - 310.
- Wiersema, S. G., 1983. Potato seed tuber production from true seed. In: W. G. Hooker (Ed.), *Research for the Potato in the Year 2000*. CIP, Lima, Peru, pp. 186 - 187.
- Wiersema, S. G., 1984. The production and utilization of seed tubers derived from TPS. Ph.D. thesis, University of Reading, CIP, Lima, Peru. 229 pp.
- Wiersema, S. G., 1985. Production and utilization of seed tubers derived from true potato seed. Planning conference on innovative methods for propagating potatoes. CIP, Lima, Peru, pp. 95 - 116.
- Wiersema, S. G., 1986. A method of producing seed tubers from true potato seed. *Potato Research* 29: 225 - 237.

Woldeyes, K. & T. Gigar, 1988. A preliminary survey on the acreage of horticultural crops in Ethiopia. Min. of Agriculture, Addis Ababa, Ethiopia.

Yilma, S., 1991. The potential of true potato seed in potato production in Ethiopia. In: A. de Jager & A. P. Verhaegh (Eds.), *Acta Horticulturae*, 1st International Symposium on Horticultural Economics in Developing countries, 16 -23, July, 1989. Alemaya, Ethiopia. pp. 389 - 394.

Appendix 1.1. Climatic conditions at Holetta Research Center (2400 m.), Ethiopia for 1991 and 1992^a.Year 1991

Month ^b	Rainfall (mm)	Temperature °C		Sunshine duration (h)	RH (%)
		Min.	Max.		
January	24	4.6	24.2	8.8	45
February	75	7.2	23.8	7.6	54
March	118	8.5	23.3	7.2	53
April	21	7.9	24.4	8.1	42
May	37	7.6	25.9	8.0	45
June	90	8.5	23.8	5.4	62
July	232	10.2	19.5	2.6	84
August	229	10.0	19.8	3.4	82
September	173	7.9	20.9	5.3	73
October	3	3.4	22.2	8.4	48
November	0	1.5	22.5	9.2	43
December	58	2.6	22.7	8.4	47

Year 1992

Month ^b	Rainfall (mm)	Temperature °C		Sunshine duration (h)	RH (%)
		Min.	Max.		
January	57	5.7	22.4	6.5	57
February	35	8.6	22.6	6.4	64
March	59	8.2	24.8	7.6	51
April	96	8.2	24.5	7.1	56
May	35	8.0	24.2	7.5	51
June	115	6.9	22.5	5.6	67
July	191	9.0	19.4	3.1	79
August	313	10.5	18.6	1.7	84
September	112	7.5	19.7	4.5	75
October	36	5.9	20.9	6.8	61
November	0	3.2	21.5	7.9	50
December	8	3.7	22.5	8.4	53

^aData from Holetta meteorological station, Holetta, Ethiopia.

^bExcept rainfall all data are monthly means.

CHAPTER 2

NITROGEN EFFECTS ON TRUE POTATO SEED (TPS) GERMINABILITY

CHAPTER 2

NITROGEN EFFECTS ON TRUE POTATO SEED (TPS) GERMINABILITY

Abstract

The influence of N fertilization of the mother plants on true potato seed (TPS) germination of an open pollinated (*AL 624*) and a hybrid (*Al 624 x CIP 378371.5*) TPS progenies was investigated. *AL 624* had a higher coefficient of velocity (CoV) and lower number of days to 50 % germination (T_{50}) than *AL 624 x CIP 378371.5*. The final germination percentage (FGP) of the two progenies was not markedly different. There were positive and negative linear relationships between the N rates and the coefficients of velocity (CoV) of *AL 624* and *AL 624 x CIP 378371.5*, respectively. However, the T_{50} and FGP of the two progenies were not affected by the N rates.

Additional keywords: nitrogen fertilization, TPS germination.

2.1. Introduction

To fully exploit the potential of the TPS technology, the development of an appropriate method of locally produced high quality true seed, in terms of germinability, is essential. Since true potato seeds are very small (100 seed weight \approx 60 mg), seeds should germinate fast and soon develop a vigorous seedling. Rapid germination and larger seedling vigour are related to seed size (Thakur, 1987).

There is evidence indicating that by providing optimum environmental and growing conditions to the mother plant during TPS development, seed quality such as seed germination, seedling establishment and vigour can significantly be increased (Sadik, 1983). Application of supplemental nitrogen at higher levels than those required for optimum tuber yield to the mother plants improves the TPS weight and seedling vigour (Pallais, 1986; Pallais *et al.*, 1987). Increased nitrogen application to the mother plant increased seed germination rate and enhanced its uniformity in tobacco (Thomas & Rapier, 1979). High nitrogen levels are also reported to improve the germinability in tomato (*Lycopersicon esculentum*) (Varis & George, 1985) and tall fescue (*Festuca arundinacea*) (Watson & Watson, 1982).

In Ethiopia, a basic application of 300 kg diammonium phosphate (DAP) per hectare is applied for tuber production for all soil types and agroecological conditions of the country. However, the experimental evidences by Pallais (1986) indicated that nitrogen application higher than those required for tuber production can improve the yield and quality of TPS in terms of germinability and vigour. Therefore, the objective of this experiment was to investigate the effects of nitrogen on TPS germination parameters and determine the nitrogen requirement for producing quality TPS.

2.2. Materials and methods

2.2.1. Site characteristics

The experiments were carried out during the dry seasons of 1991 and 1992 at Holetta Research Center, Ethiopia (central highlands, altitude 2400 m above sea level). The dry season extends from October to May. The monthly mean RH is 46 %, and the monthly mean minimum and maximum temperatures are 7.4 °C and 24 °C respectively. The experiments were conducted between the months of February and June. The soil of the experimental field was a reddish-brown clay soil with a clay content of 54-64 % and a pH in the range of 4.7 - 5.2. The total nitrogen, available phosphorus and organic matter were medium. The base saturation is less than 50 % and the soil is classified as a Dystric Nitosol, a predominant soil type in the highlands of Ethiopia.

2.2.2. Progenies

Seeds of *AL 624* were used as a source for the open pollinated progeny (Progeny 1); and the seeds of *AL 624* x *CIP 378371.5* were used as a source for the hybrid progeny (Progeny 2).

2.2.3. Cultural practices and pollination

Because of water shortage, the field trials were irrigated every 15 days in 1991; the interval was 8 days in 1992. All measures were taken to control late blight (*Phytophthora infestans*). In 1992, just before flowering, there was an incidence of a combination of late blight and a powdery mildew-like disease. The latter was not identified. The infection was controlled with Ridomil MZ 63.5 WP at the rate of 3 kg/ha.

Just before the flowering period of the cultivar *AL 624*, from the two middle rows of the plot, eight plants of the same cultivar were selected as a source of TPS berries for germination tests. Flowers from the four plants of *AL 624* were left to form berries naturally by open-pollination (OP). The other four plants were tagged to be used as female parents for hybrid seed production. The pollen source for these plants was a male parent clone *CIP 378371.5*. Pollen, extracted from the flowers using a vibrator, was stored in gelatin capsules and left overnight to dry. Primary inflorescences of *AL 624* were emasculated before anthesis and pollinated with pollen from the clone *CIP 378371.5*. After berry set, net bags were tied around the inflorescences to prevent berry loss. Berries were harvested soon after they became soft in about 8-9 weeks after pollination.

2.2.4. Treatments and experimental design

At planting, all the field plots were fertilized with a basic application of 300 kg diammonium phosphate (138 kg N and 54 kg P₂O₅ per hectare), a rate locally recommended for potato tuber production in Ethiopia. The N treatments (0, 60, 120, 180 and 240 kg/ha of additional N) were split-applied at 3, and 6 weeks after planting, and at flowering as urea (46 % N). A plot size of 4 m x 5 m was used. The planting distances between the rows and within the row were 100 and 50 cm respectively resulting in a plant density of 2 per m². The field treatments were arranged in a randomized complete block design with four replications.

For the germination tests, 20 berries from each treatment were sampled. TPS from the berries of the open pollinated-*AL-624* (Progeny 1) and hybrid-*AL 624* x *CIP 378371.5* (Progeny 2) were extracted. The seeds were dried to a constant weight over a silica gel in a desiccator at room temperature and stored in paper bags in room temperature for 5 months. Of each treatment, 3 samples of 50 seeds each were germinated in 9 cm petri dishes using Whatman # 1 filter paper in room temperature under alternating 12 h light and darkness periods. The germination experiments were conducted in a laboratory and were arranged in 2 x 5 factorial using a completely randomized design with three replications.

2.2.5. Measurements, calculated parameters and statistical analysis

Germination counts were made daily for 16 days. Seeds were considered germinated when they showed a visible radicle protrusion through the testa. The N treatments were evaluated by the coefficient of velocity (CoV), the number of days taken to 50 % of the final germination (T_{50}), and the final germination percentage (FGP) of the seeds. The coefficient of velocity (CoV) was determined as described by Scott *et al.*, (1984) using the following formula:

$$\text{CoV} = \Sigma G_n / \Sigma (G_n * D_n) * 100 \quad (\%/day)$$

G_n = number of seeds germinated on day n

D_n = number of days after sowing

CoV was used as indicator of the rate of germination. Generally, CoV increases as more seeds germinate and with a shorter germination time (Scott *et al.*, 1984). It can, therefore, indicate the rate but also the germinability of the seeds. T_{50} was used as a measure of the median response or the time taken to 50 % germination. The FGP was used to characterize potential germination.

After transforming the percentage data to arcsin values, a standard analysis of variance was carried out to separate the progeny means. The effect of N on germination parameters was determined through orthogonal contrasts (Steel & Torrie, 1980). Regression analysis was carried out to determine the relationship between the nitrogen levels and germination parameters.

2.3. Results and discussion

There were a significantly ($P < 0.05$) higher CoV and lower T_{50} in 1991 than in 1992 (data not presented). There was not a marked difference in FGP between the years.

A significantly ($P < 0.01$) higher rate of germination, indicated by a higher CoV and lower T_{50} , was observed for Progeny 1 (OP) than for Progeny 2 (hybrid) (Tables 2.1 and 2.2). This is not in agreement with the results of Kidanemariam *et al.* (1984) who observed that hybrid TPS progenies germinate faster and grow more vigorously than open pollinated progenies. Even though no reliable data on seed weight could be taken,

presumably this difference between the two progenies could have been caused partly by an inherited larger seed weight of Progeny 1 resulting in a larger germination rate. Pallais (1987) found that an increase in 100-TPS weight resulted in an increase in seed vigour and a faster germination rate. There was not a marked difference in FGP between the two progenies.

Table 2.1. Effect of additional N rates on coefficient of velocity (CoV), time taken to 50 % germination (T_{50}) and final germination percentage (FGP) of true potato seeds in 1991.

N rate (kg/ha)	CoV (%/day)	T_{50} (days)	FGP (%)
<i>Progeny 1</i>			
0	19.7	5.0	97
60	20.6	4.0	99
120	19.9	4.7	98
180	19.7	4.7	97
240	20.3	4.0	97
	ns	ns	ns
<i>Progeny 2</i>			
0	17.4	6.0	97
60	17.1	6.0	96
120	16.6	6.1	97
180	16.4	6.0	96
240	15.4	6.3	97
	L ^a	ns	ns
<i>Progeny 1</i>	20.2	4.5	98
<i>Progeny 2</i>	16.5	6.1	97
<i>Progeny (P)</i>	**	**	ns
P x N	*	*	ns

^aLinear (L) regression equation which best fits the results.

ns = not significant, * = significant at $P < 0.05$, ** = significant at $P < 0.01$.

In 1991, N rates did not affect the germination parameters (CoV, T_{50} and FGP) of Progeny 1 (Table 2.1). The CoV of Progeny 2, however, decreased with increasing N application. In 1992, there was a contrasting difference between the two progenies in their response to N rates. The CoV of Progeny 1 showed a significant positive linear relationship with N rates, whereas that of Progeny 2 had a significant negative linear relationship (Table 2.2). Additional N did not influence the FGP of the two TPS progenies.

In this experiment, no measurements on 100-TPS weight or on nitrogen content of the seeds were taken. However, it may be safe to assume that the higher seed germination rate of Progeny 1 in response to an increased level of N could be due to an increase in 100-TPS weight as has been reported by Dayal *et al.* (1984) and Pallais *et al.* (1987) resulting in a faster germination rate and better germination. A higher 100-TPS weight has also been associated with increasing seed vigour (Pallais, 1987; Almekinders & Wiersema, 1991) and has been proposed as one of the most important seed quality characteristics for selecting higher yielding progenies (Dayal *et al.*, 1984; Thakur, 1987). Recently, Pallais and Espinola (1992) reported that TPS produced with high N had higher CoV than those produced under low N conditions. An increased application of N to the mother plant also enhanced the uniformity of germination and germination rate of other *Solanaceae* crops (Thomas & Rapier, 1979; Gray & Thomas, 1982). T_{50} and the FGP of Progeny 2 (hybrid) were not influenced by N fertilization to the mother plant (Tables 2.1 and 2.2). However, in contrast to Progeny 1, increasing N fertilization had a negative effect on the CoV of Progeny 2. There was a significant negative linear relationship between the N rate and CoV of Progeny 2 (Tables 2.1 and 2.2). Although consistent over the two years, this result is not in accord with the findings of other works done on TPS (Pallais & Espinola, 1992) and tobacco (Thomas & Rapier, 1979), where an increased application of nitrogen to the mother plant increased germination rate of the seed. It is difficult to explain why the increasing N application had a negative effect on the CoV of the hybrid progeny. Only in a few cases did additional N affect seed germination negatively. For example, the addition of N decreased the germinability of peas (cf. Soffer & Smith, 1974) and the germination rate and germination percentage of sugar beet (Inoue & Yamamoto, 1977). Increased TPS weight is generally associated with high quality seed in terms of its germination rate and total germinability (Dayal *et al.*,

1984; Pallais *et al.*, 1987). Therefore, one possible explanation is that increasing N application to the mother plant may have increased the number of branches, which in turn increases the number of inflorescences and berries, thereby producing more seeds and lowering the 100-seed weight. The lower seed weight could have reduced the germination rate of the hybrid progeny (Progeny 2). Seed contents can also have an influence on the seed quality (Dickson, 1980). According to Ching (1982) seed vigour is associated with

Table 2.2. Effect of additional N rates on coefficient of velocity (CoV), time taken to 50 % germination (T_{50}) and final germination percentage (FGP) of true potato seeds in 1992.

N rate (kg/ha)	CoV (%/day)	T_{50} (days)	FGP (%)
<i>Progeny 1</i>			
0	18.7	5.3	99
60	18.8	5.0	98
120	19.1	5.3	99
180	19.2	5.3	100
240	19.5	5.0	98
	L ^a	ns	ns
<i>Progeny 2</i>			
0	17.1	6.0	99
60	16.7	6.0	100
120	16.4	6.0	99
180	16.1	6.0	99
240	15.1	6.3	99
	-L ^a	ns	ns
<i>Progeny 1</i>	19.0	5.2	99
<i>Progeny 2</i>	16.3	6.1	99
<i>Progeny (P)</i>	**	**	ns
P x N	*	ns	ns

^aLinear (L) regression equation which best fits the results.

ns = not significant, * = significant at $P < 0.05$, ** = significant at $P < 0.01$

adenosine triphosphate (ATP) content. The final germination percentage (FGP) of the two progenies was > 96 %, and it was not influenced by the N rates (Tables 2.1 and 2.2).

CoV was affected whereas T_{50} was not influenced by N application. Even though both CoV and T_{50} can give an indication on the rate of germination, they are different measures or parameters. Generally, CoV increases as more seeds germinate and with shorter germination time (Scott *et al.*, 1984). The median response, or T_{50} , provides information on location in time and it does not measure the dispersion of responses over time.

The P x N interaction in CoV and T_{50} indicates that there were genotypical differences in response to N fertilization.

To fully exploit the potential of TPS, improvement of TPS quality through better field management practices is important. In this experiment, the FGP of the two progenies tested was not promoted by increasing the N rates. It improved only the CoV of the open pollinated progeny (Progeny 1). In fact, it reduced the CoV of the hybrid progeny (Progeny 2). This will have a practical implication in developing TPS technology in Ethiopia. First, TPS technology and its utilization have not yet reached the farmers. Secondly, fertilizers are so expensive that farmers use fertilizers only for high value crops such as teff (*Eragrostis teff*) and wheat (*Triticum aestivum*). Therefore, it is unlikely that farmers, in the near future, will apply fertilizers on potato to improve the TPS quality. The results of the experiments suggest that further studies should be carried out to determine the effect of N levels on 100-seed weight of open pollinated and hybrid progenies and its effect on the different germination parameters.

References

- Almekinders, C. J. M. & S. G. Wiersema, 1991. Flowering and true seed production in potato (*Solanum tuberosum* L.). 1. Effects of inflorescence position, nitrogen treatment, and harvest date of berries. *Potato Research* 34: 365 - 377.
- Casamir, A. J., S. C. Pathak, S. R. Ghate & R. D. Gitaitis, 1988. Cultural practices in use of true seed of potato and screening of tuber forming *Solanum* species under hot climatic conditions. *HortScience* 23 (3): 500 - 504.

- Ching, T. M. 1982. Adenosine triphosphate and seed vigour. In: A. A. Khann (Ed.). *The physiology and biochemistry of seed development, dormancy and germination*. Elsevier, Amsterdam. pp. 487 - 506.
- CIP, 1988. Annual Report. Centro Internacional de la Papa, Lima, Peru.
- Dayal, T. R., M. D. Upadhyya & S. N. Chaturvedi, 1984. Correlation studies on 1000 true seed weight, tuber yield and other morphological traits in potato (*Solanum tuberosum* L.). *Potato Research* 27: 185 - 188.
- Dickson, M. H., 1980. Genetic aspects of seed quality. *HortiScience* 15: 771 - 773.
- Gray, D. & T. H. Thomas, 1982. Seed germination and seedling emergence as influenced by the position of development of seed on, and chemical application to, the parent plant. In: A. A. Khann (Ed.). *The physiology and biochemistry of seed development, dormancy and germination*. Elsevier, Amsterdam. pp. 81 - 110.
- Inoue, K. & R. Yamamoto, 1977. Influence of nitrogen fertilizer given to maturing sugar beet on the growth inhibitors content in seed balls. *Japanese Journal of Crop Sciences* 46: 306 - 312.
- Kidanemariam, H. M., G. C. Arndt, A. C. Macaso-Khwaja & S. J. Peloquin, 1984. Hybrid vs. open pollinated TPS families. In: *Innovative methods for propagating potatoes*. Report of the 28th planning conference, 10 - 14, December, 1984, CIP, Lima, Peru. pp. 25 - 37.
- Malagamba, P., 1988. Potato production from true seed. *HortScience* 23 (3): 495 - 499.
- Pallais, N., 1986. Technique to improve the sowing value of true potato seed. *HortScience* 21: 826.
- Pallais, N., 1987. True potato seed quality. *Theoretical Applied Genetics* 73: 784 - 792.
- Pallais, N. & N. Espinola, 1992. Seed quality as affected by nitrogen during potato seed production and moisture conditions during storage. *American Potato Journal* 69: 85 - 93.
- Pallais, N., S. Villagarcia, N. Fong, J. Tapia & R. Garcia, 1987. Effect of supplemental nitrogen on true potato seed weight. *American Potato Journal* 64: 483 - 491.
- Sadik, S., 1983. Potato production from true seed-present and future. In: W. J. Hooker (Ed.), *Research for the potato for the year 2000*. CIP, Lima, Peru. pp. 18 - 25.

- Scott, S. J., R. A. Jones & W. A. Williams, 1984. Review of the data analysis methods for seed germination. *Crop Science* 24: 1192 - 1199.
- Soffer, H. & O. E. Smith, 1974. Studies on lettuce seed quality. V. Nutritional effects. *Journal of American Society of Horticultural Science* 99: 459 - 463.
- Steel, R. G. D. & J. H. Torrie, 1980. Principles and procedures of statistics. McGraw-Hill Inc., New York, 633 pp.
- Thakur, K. C., 1987. Studies on the development of true potato seed technology. Ph. D. thesis, Himachal Pradesh University, Simla, India. 345 pp.
- Thomas, J. F. & C. D. Rapier, 1979. Germinability of tobacco seeds as affected by culture to the mother plant. *Agronomy Journal* 71: 694 - 695.
- Umaerus, M., 1987. True potato seed. EAPR proceedings, 10th triennial conference of the European Association of Potato Research. Aalborg, Denmark, 26 - 31, July 26 - 31, pp. 72 - 102.
- Varis, S. & R. A. T. George, 1985. The influence of mineral nutrition on fruit yield, seed yield and quality in tomato. *Journal of Horticultural Science* 60: 373 - 376.
- Watson, C. E. & V. H. Watson, 1982. Nitrogen and date of defoliation effects on seed yield and seed quality of tall fescue. *Agronomy Journal* 74: 891 - 893.
- Wiersema, S. G., 1986. A method of producing seed tubers from true potato seed. *Potato Research* 29: 225 - 237.

CHAPTER 3

THE INFLUENCE OF CHEMICAL TREATMENTS ON GERMINATION OF DORMANT TRUE POTATO SEED (*Solanum tuberosum* L.)

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Abstract

Several chemicals were tested for their effect on the breaking of dormancy and germination of two true potato seed (TPS) progenies. Since the dormancy of the TPS progenies was effectively broken by gibberellic acid (GA₃), another experiment was carried out using one progeny to determine the optimum GA₃ concentration and soaking time.

GA₃ improved the germination rate and the final germination percentages of the two progenies more than the other chemicals as was indicated by a higher coefficient of velocity (CoV), smaller time taken to 50 % germination (T₅₀) and higher final germination percentage (FGP). Soaking TPS for 8 hours in 1000 - 1500 ppm GA₃ was found to effectively break the dormancy and maintain a high germination rate and final germination percentage. In the absence of any other chemical, soaking in water can also be considered as an alternative means to break dormancy of TPS and maintain about 70 % germination.

Additional keywords: dormancy, dormancy breaking chemicals, TPS germination.

3.1. Introduction

3.1.1. General introduction

In the tropics, where most of the developing countries are found, the major factor limiting potato production is the high cost of importing or producing quality seed potatoes (Horton, 1987). The cost of seed tubers is estimated to be in the range of 20 - 70 % of the total cost of production (Sadik, 1983; Malagamba *et al.*, 1984; Rashid, 1987). The economic, technical and infrastructural problems related to production, storage, handling and distribution of seed tubers have hampered the establishment of seed potato multiplication and certification schemes. The use of true potato seed (TPS) for seedling tuber production has the potential for increasing potato production in these warm environments where production of quality seed tubers often is expensive (Malagamba,

1988).

In true potato seed, dormancy for a period of 3 - 6 months is one of the constraints to sowing freshly harvested seeds. The duration of the dormancy period varies among cultivars, and with conditions during growth and ripening of the berries and storage conditions of the seed (White, 1983). A long period of dormancy is particularly a problem in the rapid development of new cultivars. Moreover, it may not allow the use of freshly harvested TPS for sowing at the right planting time, thereby creating a problem of fitting seedling tuber production to a particular production season.

In true potato seed, uniform emergence and vigorous early growth are of major importance particularly in warm environments. Failure in germination or emergence results in sub-optimal plant population and uneven stands which eventually results in poor yield (personal experience in Ethiopia). An appropriate method of breaking TPS dormancy can allow the use of freshly harvested seeds, maintain a good germination, and improve yield.

A number of chemicals have been used to break seed dormancy of several seed species. In this chapter, I will only discuss the following chemicals: Gibberellic acid (GA_3), potassium nitrate (KNO_3), potassium hydroxide (KOH), ethyl alcohol (C_2H_5OH), calcium hypochlorite ($Ca(OCl_2)_2$), nitric acid (HNO_3), acetone (CH_3COCH_3), and water (H_2O). Although there may not be a general agreement as to their mechanisms of action, based on some evidences reviewed below, the chemicals considered in this experiment can have enzyme stimulation or osmotic effects, can remove germination inhibiting substances out of the seed or may increase seed coat permeability. However, the effects of these chemicals may vary depending on their concentration, treatment time and the seed species used (Taylorson & Hendricks, 1979).

3.1.2. Modes of action of dormancy breaking chemicals

3.1.2.1. *Stimulation of enzymes*: Enzyme systems are activated and rates of certain physiological processes such as respiration of the seed are increased remarkably by chemicals, thereby promoting germination (White, 1983). By stimulating amylase activity in endosperm of rice (Roy, 1973) and both amylase and protease activities of pepper and tomato (Varga & Stumpf, 1979) GA_3 improved the germination of the seeds. The possible

role of exogenous GA_3 in breaking dormancy of *Tilia platyphyllos* was also related to increased respiration activities (Nagy *et al.*, 1982).

3.1.2.2. *Osmotic effect*: When true potato seed is treated with a solution, the increasing difference in osmotic potentials of the seed and of the medium, combined with softening of the seed coat, generates a pressure great enough to force the radicle through the seed coat (White, 1983). Sadik (1979) reported that priming TPS in $KNO_3 + K_3PO_4$ at -1.25 MPa reduced the time required for germination. And lately Pallais (1989) found that osmotic priming of TPS in the light at -1.0 MPa solutions of $KNO_3 + K_3PO_4$ enhanced emergence and subsequent seedling growth.

3.1.2.3. *Removal of inhibiting substances*: Calcium hypochlorite ($Ca(OCl)_2$) leached out germination inhibiting substances from blackberry seeds and improved germination (Wensel & Smith, 1975). Soaking in water renders the seed coat permeable allowing better penetration of water and aeration, and removes germination inhibiting substances in sugar cane (Lovato, 1981). Rinsing sugar beet seeds in tap water has similar effects (H.L. Kraak, pers. commun.).

3.1.2.4. *Permeability of seed coat*: Soaking in ethanol (C_2H_5OH) eliminated the hard seed coat of *Phaseolus aurea* (Karivaratharaju *et al.*, 1974). Nitric acid (HNO_3) treatment was reported to improve germinability of dormant seed by increasing the seed coat permeability of several *Indigofora species* (cf. Maguire, 1980). The waxy layer of cashew nut seeds can also be removed by acetone (CH_3COCH_3), thereby facilitate permeability and imbibition (Subbaiah, 1982).

3.1.2.5. *Unknown effects*: The mechanism of action and the effect of potassium hydroxide (KOH) on dormancy breaking does not seem to have been investigated thoroughly. It has only been reported by Dongyu *et al.* (1989) in China to have effectively broken true potato seed dormancy and improved germination. Its mode of action was not described.

3.1.3. Breaking of dormancy of TPS

Freshly harvested true potato seeds usually have poor germination as compared to seeds aged for a period of three months or more. This poor germination is attributed to dormancy which could be defined as arrested development resulting from structural or compositional factors within the seed (Villiers, 1972). The results of studies of the different dormancy breaking chemicals on TPS suggest that its dormancy is probably controlled by a balance of inhibiting and promoting substances, perhaps endogenous abscisic acid (ABA) and gibberellins.

Various chemicals have been tested for their efficacy in breaking dormancy in true potato seeds. Calcium hypochlorite (White, 1983), potassium nitrate and potassium hydroxide (Dongyu *et al.*, 1989) have been reported to effectively broken dormancy of TPS resulting in marked improvement in germination. Gibberellic acid (Spicer & Dionne, 1961; Shu-Lock & Erickson, 1966; CIP, 1980), mixtures of GA₃ and ethrel (Song *et al.*, 1986) and distilled water (White, 1983; Song *et al.*, 1986) have also been reported to break TPS dormancy. To-date, the widely used practice in countries where TPS research is undertaken is soaking TPS with 1500 ppm GA₃ for 24 h. In all cases where chemicals have been used to break TPS dormancy there was variability in germination percentage among the genotypes tested. The use of GA₃ has proven inefficient with some TPS progenies (Simmonds, 1963; Martin, 1983; White, 1983).

The objective of this study is, therefore, to evaluate the most common seed dormancy breaking chemicals and to identify a relatively cheap and readily available chemical that can break dormancy and enhances the germination of true potato seeds.

3.2. Materials and methods

3.2.1. Experiment 1

3.2.1.1. *Seed lots:* The TPS lots used in this experiment were produced during the 1991 dry season using field-grown mother plants of cultivars *AL 624* and *AL 624* crossed with clone *CIP 378371.5*. Seed lots were extracted from berries of *AL 624* (OP) and berries borne of hand emasculated and pollinated flowers of *AL 624 x CIP 378371.5* (hybrid).

The seed was produced at Holetta Research Center, Ethiopia with an altitude of 2400 m above sea level. An effort was made to obtain a high quality seed by adding nitrogen during flowering and seed development and allowing an optimum maturity period. TPS were extracted from berries of *AL 624* (Progeny 1) and *AL 624 x CIP 378371.5* (Progeny 2).

Table 3.1. A summary of chemical treatments of true potato seed (TPS).

Chemical treatments	Formula	Concentration	Duration
1. Gibberellic acid	GA ₃	1500 ppm	24 h
2. Potassium nitrate	KNO ₃	0.2 %	24 h
3. Potassium hydroxide	KOH	1 N	1 h
4. Ethyl alcohol	C ₂ H ₅ OH	50 %	2 h
5. Calcium hypochlorite	Ca(OCl ₂) ₂	2 %	2 h
6. Nitric acid	HNO ₃	0.5 N	4 h
7. Acetone	CH ₃ COCH ₃	70 %	4 min.
8. Distilled water	H ₂ O	-	24 h

3.2.1.2. *Seed treatments and experimental design:* Seeds of each of the two progenies were placed in 8 petri dishes on Whatman # 1 filter papers and wetted with 10 ml of the treatment solutions for a specific period of time as described in Table 3.1. After the treatments, the seeds were dried to a constant weight over silica gel in a desiccator at room temperature. From each treatment, three samples of 50 seeds each were germinated in 9 cm petri dishes using Whatman # 1 filter paper in room temperature under alternating 12 h light and darkness periods. The design was completely randomized with three replications.

Freshly harvested true potato seeds which are not soaked in water (untreated dormant TPS) prior to germinating the seeds in petri dishes have a FGP of only ≤ 5 % (personal experience). Therefore, untreated true potato seeds were not included as a treatment in the experiment.

3.2.1.3. *Measurements and calculated parameters*: Germination counts were made daily for 16 days. Seeds were considered germinated when they showed a visible radicle protrusion through the testa. The seed treatments were evaluated by the coefficient of velocity (CoV), number of days taken to 50 % of the final germination (T_{50}), and the final germination percentage (FGP) of the seeds. The coefficient of velocity (CoV) was determined as described by Scott *et al.*, (1984) using the following formula:

$$\text{CoV} = \Sigma G_n / \Sigma (G_n * D_n) * 100 \quad (\%/day)$$

G_n = number of seeds germinated on day n
 D_n = number of days after sowing

CoV was used as indicator of the rate of germination. Generally, CoV increases as more seeds germinate and with a shorter germination time (Scott *et al*, 1984). It can, therefore, indicate the rate but also the germinability of the seeds. T_{50} was used as a measure of the median response or the time taken to 50% germination. The FGP was used to characterize potential germination.

The percent values were transformed to arcsin and a standard statistical analysis was done on the transformed data. A least significant difference test was used to determine significance of the treatment means.

3.2.2. Experiment 2

3.2.2.1. *Set up*: Since the dormancy of the TPS progenies tested was effectively broken by GA_3 in *experiment 1*, another experiment was designed to determine the optimum GA_3 concentration and soaking time. The same TPS lots of *experiment 1* were used for this experiment. However, due to shortage of seeds of the hybrid progeny (*AL 624 x CIP 378371.5*), only the OP progeny (*AL 624*) was tested. True potato seeds extracted from the berries of *AL 624* (OP) were placed in petri dishes on Whatman # 1 filter paper. The seeds were soaked in 10 ml solution of 0, 500, 1000, 1500 and 2000 ppm GA_3 for 8, 16, 24, 32 and 40 h each. The control (0 ppm) was a treatment with distilled water. The seeds were dried to a constant weight over silica gel in a desiccator at room temperature. Three samples of 50 seeds each were germinated in 9 cm petridishes using Whatman # 1

filter paper under alternating 12 h light and darkness. A 5 x 5 factorial experiment in completely randomized design was used.

3.2.2.2. Measurements and calculated parameters: Germination counts were made daily for 16 days. Seeds were considered germinated when they showed a visible radicle protrusion. Seed treatments were evaluated by the coefficient of velocity (CoV), the number of days taken to 50 % germination (T_{50}), and final germination percentage (FGP). The coefficient of velocity (CoV) was determined using the same procedure as in *experiment 1*. CoV was used as indicative of the rate of germination. T_{50} was used as a measure of the median response.

The effects of GA_3 and soaking period on germination parameters were determined through orthogonal contrasts (Steel & Torrie, 1980). Regression analysis was performed to describe the relationship between treatment effect and germination parameters.

3.3. Results and discussion

From our experience at the Holetta Research Center, freshly harvested true potato seeds which are not soaked in water (untreated dormant TPS) prior to germinating the seeds in petri dishes have a FGP of only $\leq 5\%$. This indicates that soaking TPS in water has the effect of removing the inhibiting substances from the seed. In the experiment, the results indicated that seeds treated with any one of the chemicals tested had a FGP higher than 5 % (Table 3.1). Therefore, the FGP can significantly be enhanced by treating with any one of the treatments tested. However, seeds treated with water had a a FGP significantly higher than seeds treated with some of the chemicals tested.

There was no significant interaction in CoV between TPS progenies and chemical treatments; CoV results are, therefore, presented as means of the two progenies. The highest CoV and lowest T_{50} was recorded in TPS treated with 1500 ppm GA_3 for 24 h (Table 3.2). Seeds with a higher germination rate may have the advantage of emerging early in the growing season. The seedlings will be able to compete more efficiently with weeds and permit post-emergence herbicide application before the weeds grow too large. The final germination percentage (FGP) of the two TPS progenies treated with 1500 ppm GA_3 was also markedly ($P < 0.01$) higher than the seeds treated with the other chemicals.

Table 3.2. Effect of pregermination treatment with chemicals on the coefficient of velocity (CoV), time taken to 50% germination (T_{50}) and final germination percentages (FGP) of true potato seeds (*Solanum tuberosum* L.).

Treatment	CoV (%/day)	T_{50} (days)		FGP (%)		Effect
		P1	P2	P1	P2	
GA ₃ 1500 ppm	20.8	4	4	99	99	Stimulation of enzymes
KNO ₃ 0.2 %	17.5	5	8	73	69	Osmotic
KOH 1 N	13.2	9	12	59	23	Unknown
Distilled H ₂ O	14.5	7	8	71	73	Removal of inhibiting substances
Ca(OCl) ₂ 2 %	19.1	11	4	55	75	Removal of inhibiting substances
HNO ₃ 0.5 N	11.2	12	15	11	13	Improve permeability
CH ₃ COCH ₃ 70 %	18.9	4	5	75	87	Improve permeability
C ₂ H ₅ OH 50 %	9.8	13	11	14	15	Improve permeability
Treatment	**	**	**	**	**	**
Progeny 1 (P1)	16.3	8.1		57.1		
Progeny 2 (P2)	14.9	8.4		56.5		
Progeny (P)	ns	ns		ns		
P x Chemical treatment	ns	*		*		

ns = not significant, * = significant at P < 0.05, ** = significant at P < 0.01

By treating with 1500 ppm GA_3 , a FGP of 99 % was recorded for each progeny. This is in agreement with the results of other researchers who found GA_3 to effectively break dormancy of true potato seed (Spicer & Dionne, 1961; Shu-Lock & Erickson, 1966; Sharon & Kishore, 1975), sesame (Ashri & Palevitch, 1979), and charlock (*Sinapsis arvensis*) (Edwards, 1976).

The mode of action of GA_3 is mainly due to its enzyme stimulating effect. Some other effects have also been reported by some researchers. For example, according to White (1983), in true potato seeds, GA_3 can also eliminate a metabolic block which inhibits the activity of the embryo and endosperm. Comparing imbibition of dormant true potato seeds and seeds treated with GA_3 , White (1983) indicated that the effect of GA_3 may also be associated with changes in the imbibition pattern. In some seed species exogenous gibberellins were also reported to overcome the inhibition by water soluble endogenous compounds (Maguire, 1984). Any chemical treatment that changes the state of balance of growth promoters, inhibiting hormones and enzymes through activation, de-activation and synthesis can lead to germination of dormant seed. The mode of action of gibberellins in enhancing germination of seeds varies depending on the species (Chen & Park, 1973; Roy, 1973; Fountain & Bewley, 1976).

KNO_3 had also a promoting effect on the FGP of the two progenies (Table 3.2). Similar results were reported where the dormancy of finger millet (Kulkarni & Basavaraju, 1976), wild oats (Hilton, 1984) and true potato seed (Dongyu *et al.*, 1989) were overcome by treating with KNO_3 . To-date, osmopriming using $KNO_3 + K_3PO_4$ is a common practice to improve the germination rate and uniformity of tomato seeds (H.L. Kraak, pers. comm.).

Chemical treatments with $Ca(OCl_2)_2$ and CH_3COCH_3 , which were reported to promote germination by removal of inhibiting substances and improving the permeability respectively, have remarkably increased the rate of germination and the FGP (Table 3.2). Their effect is more distinct on Progeny 2 than on Progeny 1. The FGP of the TPS treated with these chemicals ranged between 55 % and 87 %. Similarly, CH_3COCH_3 is also reported to promote germination of lettuce seeds by improving the permeability of the seeds (Rao *et al.*, 1976). By pre-soaking TPS in distilled water, a FGP of 71 % and 73 % was recorded for Progeny 1 and Progeny 2, respectively (Table 3.2). This is in accord with the results of Song *et al.* 1986 who reported that TPS germination was

remarkably enhanced by soaking in distilled water. Treatment with distilled water was not as effective as GA_3 in breaking dormancy and enhancing germination of TPS. However, it is comparable with some of the other chemicals tested. Considering its availability and price (Appendix 3.1), in many underdeveloping countries where chemicals are either not readily available or very expensive, water may be considered as one alternative means to break dormancy of TPS.

The lowest FGP was recorded by seeds treated with ethanol (C_2H_5OH) and nitric acid (HNO_3) (Table 3.2). However, it was much higher than the FGP of untreated seeds which is only $\leq 5\%$. There was a consistent fungal growth in all the petri dishes in which the seeds were treated with these two chemicals which eventually resulted in a very low germination rate and FGP. The fungi were identified as *Alternaria*, *Fusarium* and *Penicillium* species. As the seed lot used in this experiment was not sterilized, the seeds in all the petri dishes had equal chance of being contaminated by seed-borne fungi. The unsterilized seeds may have been contaminated by seed-borne fungi spores whose growth was presumably stimulated by HNO_3 and C_2H_5OH treatments, thereby causing a drastic reduction in seed germination. In soils infested with certain species of *Alternaria*, *Fusarium* and *Helminthosporium*, metabolites excreted by the fungi were also reported to be partially responsible for failure of seed germination (Abraham, 1978). Another possible explanation is that the concentration and treatment duration were too high so that the chemicals damaged the cell wall and weakened the seed making it vulnerable to be attacked by the fungi (H.L. Kraak, pers. comm.).

There was no significant difference between the two progeny types in the rate of germination (CoV), T_{50} and FGP (Table 3.2). This is not in agreement with the results of Kidanemariam *et al.* (1984) who reported that hybrid TPS progenies germinated faster and grew more vigorously than open-pollinated progenies. In terms of FGP, GA_3 had similar effects on the two progenies (Table 3.2). The FGP of GA_3 treated seeds was 39 % and 36 % higher, for Progeny 1 and Progeny 2 respectively, over distilled water treated seeds.

There was a significant progeny x chemical interaction. The level of TPS dormancy of different progenies vary considerably (White, 1983). Therefore, the extent to which their dormancy can be broken by the different chemicals is also expected to vary. For example, according to White (1983), soaking TPS of *Renacimiento* (OP progeny) in distilled water

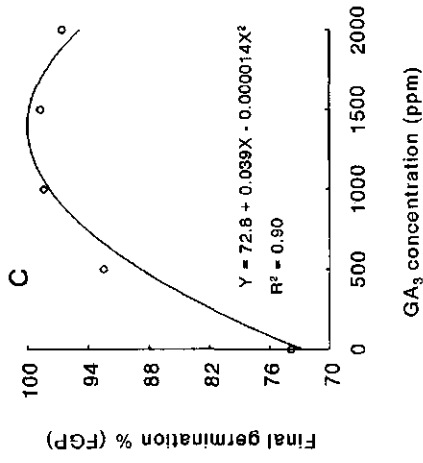
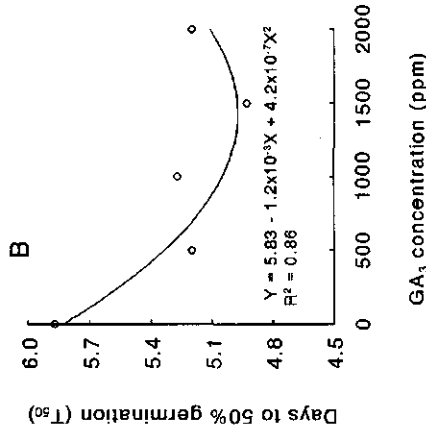
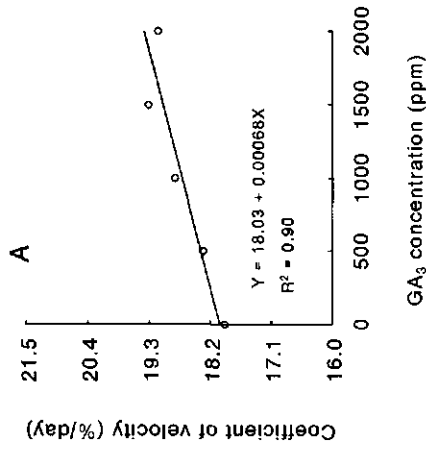


Fig. 3. 1. Relationship between GA₃ concentration and coefficient of velocity (CoV), number of days to 50 % germination (T₅₀) and final germination % (FGP). [open circles are observed values].

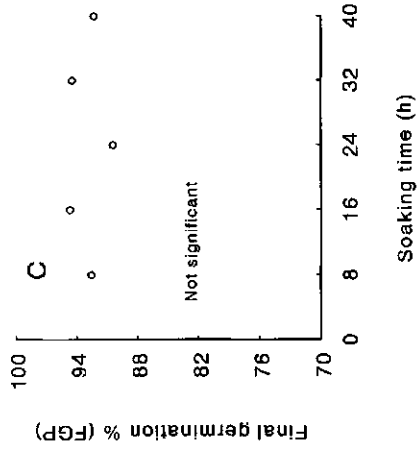
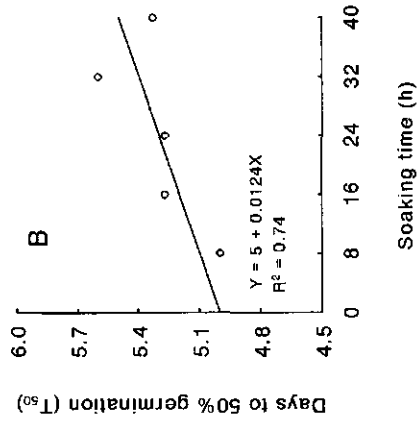
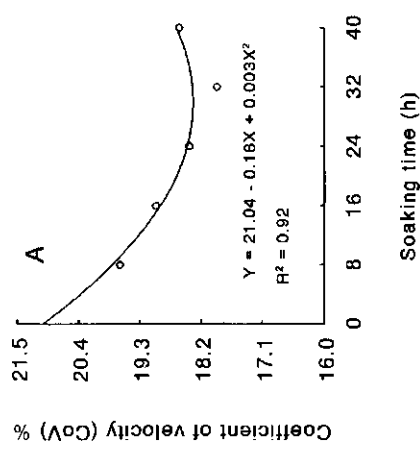


Fig. 3. 2. Relationship between soaking time (h) and coefficient of velocity (CoV), number of days to 50 % germination (T₅₀) and final germination % (FGP). [open circles are observed values].

resulted in improvement in germination but not with *Atzimba x DTO-33*. KNO_3 and growth substances such as GA_3 may effectively promote germination of dormant seeds, but their effectiveness varies depending on the species (Gupta, 1971; Harty, 1972; Hendricks & Taylorson, 1972).

In *experiment 2*, there was a significant positive linear relationship between the GA_3 concentration and coefficient of velocity (Fig. 3.1A). The rate of germination (CoV) continued to increase as the GA_3 concentration increased. The relationship between GA_3 concentration and T_{50} predicts that seeds treated with GA_3 concentration of 1000 - 1500 ppm can achieve 50 % germination in the shortest time (Fig. 3.1B). GA_3 concentration had a significant effect on the FGP until 1000 ppm with an optimum range of 1000 - 1500 ppm GA_3 (Fig. 3.1C). It is important to note that by increasing GA_3 concentration from 0 to 1000 ppm, the FGP increased drastically to about 97 %. Thereafter, FGP increased at a slower rate. The relationships between GA_3 concentration and the germination parameters in Fig. 3.1 indicated that the optimum range to break TPS dormancy falls between 1000 - 1500 ppm GA_3 .

Soaking time negatively affected the rate of germination (CoV) until 24 h, after which the effect was positive (Fig. 3.2A). The results indicate that a higher rate of germination (CoV) was obtained with 8 h soaking time. Similarly, the time taken to 50 % germination (T_{50}) was the shortest with 8 h soaking time (Fig. 3.2B). GA_3 and soaking time did not have the same effect on CoV and T_{50} . Even though both the CoV and T_{50} can give an indication on the rate of germination, they are different measures. Generally, CoV increases as more seeds germinate and with shorter germination time (Scott *et al.*, 1984). The median response, or T_{50} , provides information on location in time and it does not measure the dispersion of responses over time. The FGP was not influenced by soaking time (Fig. 3.2C). Based on these results the dormancy of TPS can be broken effectively by soaking in 1000 - 1500 ppm GA_3 for 8 h. These results are not in agreement with the almost universal recommendation of 1500 ppm GA_3 for 24 h (CIP, 1980; Spicer & Dionne, 1966).

In conclusion, even though soaking in GA_3 improved the germination rate and the total germinability of the TPS more remarkably than the other chemicals, on per litre solution base, among the chemicals tested in *experiment 1*, GA_3 was the most expensive (Appendix 3.1). Moreover, it may not be readily available in the countries where TPS has the

potential and is intended to be extended to small farmers. Therefore, in the absence of any other chemical, as it may be in many underdeveloped countries, soaking in water can be considered as an alternative means to break dormancy of TPS, and a germination of 71 - 73 % be maintained.

References

- Abraham, T. A., 1978. Inhibitory effect of culture filtrates of fungi on seed germination. *Indian Phytopathology* 31 (3): 402 - 403.
- Ashri, A. & D. Palevitch, 1979. Seed dormancy in sesame (*S. indicum*) and the effect of gibberellic acid. *Experimental Agriculture* 15 (1): 81 - 83.
- Chen, S. S. & W. M. Park, 1973. Early actions of gibberellic acid on the embryo and on the endosperm of *Avena fatua* seeds. *Plant Physiology* 52 (2): 174 - 176.
- CIP, 1980. Annual Report. Centro Internacional de la Papa, Lima, Peru.
- Dongyu, Q., Z. Tiasue & S. Bofu, 1989. Appropriate methods for breaking dormancy of true potato seed. Potato and sweet potato research in China from 1986-1989. CIP, Lima, Peru.
- Edwards, M, 1976. Dormancy in seeds of charlock (*Sinapsis arvensis* L.). Early effects of gibberellic acid on the synthesis of amino acids and protein. *Plant Physiology* 58 (5): 626 - 630.
- Fountain, D. W. & J. D. Bewley, 1976. Lettuce seed germination. Modulation of pre-germination protein synthesis by gibberellic acid, abscisic acid, and cytokinin. *Plant Physiology* 58(4): 530 - 536.
- Gupta, S. C., 1971. Effect of NAA, IAA and GA₃ on germination of brinjal (*Solanum melongena* L.) seeds. *Indian Journal of Agricultural Research* 5: 215 - 216.
- Harty, R. L., 1972. Germination requirements and dormancy effects in seeds of *Urochloa mosambicensis*. *Tropical Grasslands* 6: 17 - 24.
- Hendricks, S. B. & R. B. Taylorson, 1972. Promotion of seed germination by nitrates and cyanides. *Nature* 237: 169 - 170.

- Hilton, J. R., 1984. The influence of light and potassium nitrate on the dormancy of *Avena fatua* L. wild oat seed and its ecological significance. *New Phytology* 96: 31 - 34.
- Horton, D., 1987. Potato production, marketing and programs for developing countries. Westview press, London. 243 pp.
- Karivaratharaju, T. V., V. Ramakrishnun & D. D. Sundararji, 1974. Effect of hard seed coat on germination of green-gram. *The Indian Journal of Agricultural Sciences* 44(8): 525 - 527.
- Kidanemariam, H. M., G. C. Arndt, A. C. Macaso-Khwaja & S. J. Peloquin, 1984. Hybrid vs. open-pollinated TPS families. In: Innovative methods for propagating potatoes. Report of the 28th planning conference, 10 - 14, December, 1984, CIP, Lima, Peru, pp. 25 - 37.
- Kulkarni, G. N. & V. Basavaraju, 1976. Firm seeds in the finger millet (*Eleusine coracana* G.). *Current Science* 45: (11) 425.
- Lovato, A., 1981. Germination of seeds. In: Thomson J. R. (Ed.), Advances in research and technology of seeds. Part 6. Pudoc, Wageningen. pp. 25 - 60.
- Maguire, J. D., 1980. Seed dormancy and germination. In: Thomson J. R. (Ed.). Advances in research and technology of seeds. Part 5. Pudoc, Wageningen. pp. 41 - 67.
- Maguire, J. D., 1984. Dormancy in seeds. In: Thomson J. R. (Ed.). Advances in research and technology of seeds. Part 9. Pudoc, Wageningen. pp. 25 - 60.
- Malagamba, P., 1988. Potato production from true seed. *HortScience* 23: 495 - 500.
- Malagamba, P., A. Monares & D. Horton, 1984. Design and evaluation of different systems of potato production from true seed. In: 9th Triennial conference of European Association for Potato Research. Interlaken, Switzerland. pp. 315 - 316.
- Martin, M. W., 1983. Techniques for successful field seeding of true potato seed. *American Potato Journal* 60: 245 - 259.
- Merck E. Nederland B.V. Reagentia-Diagnostica Chemicaliën 1992/93, Amsterdam.

- Nagy, M., S. Pataky & A. Kéri, 1982. Dormancy in fruits of *Tilia platyphyllos*. VI. Possible role of exogenous GA₃ in the breaking of dormancy. *Acta Biologica* 28: 111 - 117.
- Pallais, N., 1989. Osmotic priming of true potato seed: Effects of seed age. *Potato Research* 32: 235 - 244.
- Rao, V. S., J. W. Braun & A. A. Khan, 1976. Promotive effects of organic solvents and kinetin on dark germination of lettuce seeds. *Plant Physiology* 57 (3): 446 - 449.
- Rashid, M. M., 1987. Problems of production of TPS in Bangladesh. Agricultural Research Institute, Potato Research Center. pp. 5-7.
- Roy, T., 1973. Cyclic AMP promotion and abscisic acid inhibition of α -amylase activities in the seeds of rice (*Oryza sativa* L.). *Journal of Experimental Botany* 24 (83): 1064 - 1068.
- Sadik, S., 1979. Preliminary observation of in vitro germination of true potato seed. Planning conference on the production of potatoes from true potato seed, 13 - 15, September, 1979, Manila, Philippines. pp. 36 - 51.
- Sadik, S., 1983. Potato production from true potato seed- present and future. In: W. L. Hooker (Ed.). Research for the potato for the year 2000. CIP, Lima, Peru. pp. 18 - 25.
- Scott, S. J., R. A. Jones & W. A. Williams, 1984. Review of data analysis methods for seed germination. *Crop Science* 24: 1192 - 1199.
- Sharon, M. & H. Kishore, 1975. Note on the effects of GA₃, IAA and kinetin on the germination of true dormant seeds of potato. *The Indian Journal of Agricultural Sciences* 45 (10): 490 - 493.
- Shu-Lock, L. & H. T. Erickson, 1966. Interaction of light and gibberellin on potato seed germination. *American Potato Journal* 42: 443 - 449.
- Simmonds, N. W., 1963. Experiments on the germination of potato seeds. *European Potato Journal* 61: 45 - 60.
- Song, C. H., I. G. Mok, S. Y. Kim & H. Y. Kim, 1986. A study on breaking dormancy in true potato seed. A research report of the rural development administration (Horticulture), Korea. 28 (1) 86: 85 - 90.

- Spicer, P. B. & L. A. Dionne, 1961. Use of gibberellin to hasten germination of *Solanum tuberosum* seed. *Nature* 180: 327 - 328.
- Steel, R. G. D. & J. H. Torrie, 1980. Principles and procedures of statistics. McGraw-Hill Inc. New York, 633 pp.
- Subbaiah, C. C., 1982. Effect of pre-soaking inorganic solvents on seed germination and seedling growth of cashew. *Scientia Horticulturae* 18 (2): 137 - 142.
- Taylorson, R. B. & S. B. Hendricks, 1979. Overcoming dormancy in seeds with ethanol and other anesthetics. *Planta* 145: 507 - 510.
- Varga, M. & I. Stumpf, 1979. Hastening germination of crop seeds and seedling growth with gibberellic acid. *Acta Biologica* 25 (3): 93 - 103.
- Villiers, T. A., 1972. Germination control, metabolism and pathology. In: T. T. Kozlowski (Ed.), *Seed Biology*. II. Academic press, New York, pp. 219 - 281.
- Wensel, W. G. & C. W. J. Smith, 1975. Germination tests with blackberry seeds. *Annals of Botany* (1): 11-14.
- White, J. W., 1983. Germination physiology of true potato seed. A manuscript. CIP, Lima, Peru. pp. 25.

Appendix 3.1. Price quotations for the different chemicals used in soaking the true potato seeds.

Name of chemical	Concentration	Price (Dfl)	Price per l solution (Dfl)
1. Gibberellic acid (GA ₃)	1500 ppm	25.50/g	38.00
2. Potassium nitrate (KNO ₃)	0.2 %	36.50/kg	0.07
3. Potassium hydroxide (KOH)	1.0 N	37.24/kg	1.72
4. Ethanol (C ₂ H ₅ OH)	50 %	5.00/l	2.50
5. Calcium hypochlorite CaO(Cl ₂) ₂	2.0 %	620.00/kg	2.40
6. Nitric acid (HNO ₃)	0.5 %	118.00/l	3.60
7. Acetone (CH ₃ COCH ₃)	70 %	9.70/l	6.80
8. Distilled water	-	-	-

Source: Merck E. Nederland B.V. Reagentia-Diagnostica Chemicaliën 1992/93,
Amsterdam.

CHAPTER 4

EVALUATION OF HYBRID AND OPEN-POLLINATED TRUE POTATO SEED PROGENIES DURING TWO CONTRASTING SEASONS

CHAPTER 4

EVALUATION OF HYBRID AND OPEN-POLLINATED TRUE POTATO SEED PROGENIES DURING TWO CONTRASTING SEASONS

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Abstract

Eleven open-pollinated (OP) and fourteen hybrid TPS progenies were evaluated during two contrasting seasons. During the dry season, the hybrid progenies were superior to the open-pollinated progenies in plant vigour, tuber uniformity and tuber yield. Tuber yield ranged from 28 to 67 and 25 to 42 t/ha for the hybrid and OP progenies, respectively. During the rain season, tuber yield of both TPS progeny types were low. However, the OP progenies gave a higher tuber yield than the hybrid progenies. Yields ranged from 0.1 to 8.6 and 3 to 13 t/ha for the hybrid and OP progenies, respectively. The use of first generation seedling tubers as an alternative for seed and ware potato production is discussed.

Additional keywords: vigour, uniformity, seedling tuber, yield

4.1. Introduction

Potato production has traditionally been based on using seed tubers for propagation. The use of tubers has been one of the major limiting factors due to the high cost of healthy and good quality seed tubers. The perishable nature of seed tubers and the storage, transport and distribution problems associated with it are additional production constraints.

The use of true potato seed (TPS) as an alternative means of potato production seems to be feasible as evidenced by research results at the International Potato Center (Rowe, 1974; Mendoza, 1979; Accatino & Malagamba, 1982), in China (Li & Shen, 1979) and in Bangladesh (Sadik, 1983).

A very important advantage of using TPS is the production of relatively disease free seedling tubers. The first generation seedling tubers are usually small but can be used as

seed tubers for subsequent seasons. This method has already been practised in Vietnam (Malagamba & Monares, 1988) and China (Li & Shen, 1979).

Previous results have indicated that hybrid progenies produce more vigorous plants and higher seedling tuber yields than the OP progenies (Kidanemariam *et al.*, 1985; Macaso-Khwaja & Peloquin, 1983). However, the advantage of OP progenies is that TPS seed production does not require hand pollination, and therefore, the cost of producing OP seeds is significantly lower than that of hybrid seeds.

The objective of this study was to evaluate different OP and hybrid progenies on the basis of plant vigour, seedling tuber yields and number, and seedling tuber uniformity during two contrasting seasons.

4.2. Materials and methods

Eleven open-pollinated (OP) and fourteen hybrid TPS progenies were evaluated during the 1988 dry and rain (*Kremt*) seasons at Holetta Research Center, Ethiopia. The experimental location is found in the central highlands. Its altitude is 2400 m above sea level. It has two distinct seasons. The rain season, which extends from June to September, is characterized by high rainfall (900 mm), monthly mean RH of 77 %, and monthly mean minimum and maximum temperatures of 9.2 °C and 20.0 °C, respectively. The dry season extends from October to May. Because of the risk of night frost, between the months of October and January, farmers do not grow potatoes. However, there is no occurrence of night frost between the months of February and May, and it is in this period that farmers grow potato using irrigation. A small amount of rain (200 mm) falls during the months of March and April. During the dry season the monthly mean RH is 46 %, and the monthly mean minimum and maximum temperatures are 7.4 °C and 24.9 °C, respectively.

Six weeks after having been sown in the seed beds, 40 seedlings of each of the OP and hybrid progenies were transplanted to the field. The seedlings were spaced 50 cm between rows and 10 cm within the row. Plot size was 2 m². Each set of progeny was arranged in a randomized complete block design with four replications. In both seasons no measures were taken to control the incidences of late blight (*Phytophthora infestans*). During the dry season, plant vigour was recorded 9 and 12 weeks after transplanting. At harvest, the

total seedling tuber yield and number of seedling tubers per m² were recorded. The tubers were categorized by weight and by number into < 20 g, 20 - 60 g and > 60 g. Tuber uniformity in terms of size, shape and colour were also recorded. During the harvest of the rain season, data on the seedling tuber yield was collected. The tubers were graded by weight into < 20 g, 20 - 60 g and > 60 g.

4.3. Results and discussion

4.3.1. Dry season

Tuber yield: Significant differences in seedling tuber yield in terms of weight and number were observed between the OP progenies and between the hybrid progenies (Table 4.1). Among the OP progenies, *AL 601* gave the highest seedling tuber yield of 42 t/ha. The highest yielding hybrid progeny *CIP 987003* gave seedling tuber yield of 67 t/ha. The mean seedling tuber yield (46 t/ha) of the hybrids was remarkably higher than that of the OP progenies (31 t/ha). This is in agreement with the results of several studies carried out elsewhere (Accatino, 1980; Macaso-Khwaja & Peloquin, 1983; Kidanemariam *et al.*, 1985). The results indicate that the hybrid families were superior to OP families in many of the traits studied. The average increase of the hybrids over the OP progenies was 48 % and 12 % in seedling tuber yield and tuber number, respectively. In general, the seedling tuber yield of the OP progenies was low with predominantly small tubers (<60 g). However, it is important to note that the seedling tuber yield of *AL 601* was close to the mean of the seedling tuber yield of the hybrid progenies (Table 4.1). This result suggests that even among OP progenies, there is a possibility of selecting high yielding progenies. Though the seedling tuber yields of the OP progenies were substantially lower than those of the hybrid ones, their economic yields could be significantly higher because of the higher costs associated with the production of hybrid seeds. The use of an OP progeny with an acceptable level of yield and seedling tuber uniformity may be more relevant in low input farming systems than using hybrid progenies. Such TPS seed from OP of the cultivar Kuannae has been acceptable for farmers in China. Li & Shen (1979) described the seedling tubers produced from TPS of this local cultivar as fairly uniform in terms of shape and colour with an average yield range of 23-38 t/ha depending on the region where

Table 4.1. Tuber yield, tuber number and tuber size distribution of open pollinated and hybrid TPS progenies during the dry season.

Progeny	Tuber yield (t/ha)	Tuber no/m ²	Tuber size distribution (%)					
			by weight			by number		
			<20g	20-60g	>60g	<20g	20-60g	>60g
Open pollinated								
AL 601	42	199	42	22	36	80	11	9
AL 417	35	235	33	27	40	82	11	7
AL 560	34	140	32	25	43	75	15	10
CIP 378371.5	33	149	29	31	40	70	20	10
AL 459	32	96	35	24	41	64	20	16
AL 563	32	121	30	23	47	71	15	14
OK-86-235	29	162	40	19	41	78	11	11
OK-86-240	28	99	19	28	53	59	23	18
UK-80-3	26	105	24	33	43	65	24	11
AL 107	25	116	42	22	36	76	14	10
OK-87-134	25	85	19	26	55	62	22	16
Mean	31	137	<u>31</u>	<u>26</u>	43	<u>71</u>	<u>17</u>	12
			57%			88%		
S.E.	5.8	44						
C.V.	21.0	25						
LSD (0.05)	5.2	128						
Hybrids								
CIP 987004	67	201	18	26	56	62	21	17
CIP 978001	59	124	8	29	63	36	36	28
CIP 985001	56	184	22	31	47	65	23	12
CIP 980003	53	204	21	28	51	70	17	13
CIP 985004	53	204	24	32	44	68	20	12
CIP 986004	53	133	15	24	61	55	24	21
CIP 985002	52	131	12	26	62	49	27	24
HK-87-15	51	162	14	49	37	50	39	11
CIP 984001	39	140	29	22	49	69	16	15
CIP 987001	36	137	21	32	47	65	23	12
CIP 987002	34	140	31	31	38	72	19	9
CIP 987003	34	141	29	34	37	68	22	10
CIP 981005	33	130	22	34	44	64	24	12
CIP 978004	28	110	21	29	50	68	19	13
Mean	46	153	<u>20</u>	<u>31</u>	49	<u>61</u>	<u>24</u>	15
			51%			85%		
S.E.	6.8	32						
C.V.	29.2	21						
LSD (0.05)	19.3	79						

Table 4.2. Plant vigour and tuber uniformity of open pollinated and hybrid TPS progenies during the dry season.

Progeny	Vigour*	Tuber uniformity**			
		Size	Shape	Colour	Mean
<u>Open pollinated</u>					
AL 601	9.5	2.8	3.0	3.3	3.0
CIP 378371.5	8.5	2.5	2.0	2.3	2.3
AL 417	8.3	2.8	2.5	2.8	2.7
AL 107	7.3	3.0	2.8	3.0	2.9
AL 560	6.8	3.0	3.0	3.0	3.0
OK-86-235	6.8	3.3	2.8	3.5	3.2
AL 459	6.5	2.8	2.3	3.3	2.8
AL 563	6.5	3.5	3.5	3.8	3.6
OK-86-240	5.8	2.5	3.0	3.0	2.8
OK-87-134	5.5	3.3	2.8	3.0	3.0
UK-80-3	4.8	2.8	2.8	3.5	3.0
Mean	6.9	2.9	2.8	3.1	2.9
S.E.	0.96	0.10	0.22	0.22	0.20
C.V.	13.9	25.0	16.0	14.0	15.0
LSD (0.05)	1.6	ns	0.7	0.6	0.6
<u>Hybrids</u>					
CIP 987004	9.8	3.0	3.0	2.8	2.9
CIP 985004	9.5	3.0	3.0	3.5	3.2
CIP 978001	9.3	4.0	3.8	4.3	4.0
HK-87-15	9.3	3.5	3.5	4.7	3.9
CIP 985002	9.3	3.0	3.0	3.3	3.1
CIP 985001	9.0	3.0	2.8	3.0	2.9
CIP 986004	8.5	3.0	2.8	3.0	2.9
CIP 980003	8.0	3.3	3.3	3.3	3.3
CIP 984001	8.0	3.0	2.8	3.5	3.1
CIP 987001	7.8	2.8	2.5	4.3	3.2
CIP 987002	6.8	3.3	2.8	3.8	3.3
CIP 981005	6.8	2.8	2.8	2.8	2.8
CIP 987003	6.0	3.3	3.0	3.3	3.2
CIP 978004	5.8	3.0	3.0	3.0	3.0
Mean	8.1	3.1	3.0	3.5	3.2
S.E.	0.54	0.38	0.10	0.33	0.36
C.V.	13.0	21.0	26.0	19.5	20.0
LSD (0.05)	1.55	0.96	ns	0.92	0.98

*1 = least vigorous 10 = most vigorous

**1 = least uniform 5 = most uniform

it is grown. Bedi *et al.* (1979) reported an average seedling tuber yield of 19 t/ha from 6 OP progenies of field transplanted seedlings. OP seed of selected genotypes may be produced in large quantities under field conditions without any substantial input. Malagamba (1983) has estimated true potato seed yields at Huancayo, Peru, to be about 28 kg/ha, enough for planting 360 hectares. There was a positive correlation between the tuber yield and tuber number of both the OP ($r=0.71$) and hybrid ($r=0.61$) progenies. This indicates that the high tuber yielding progenies also produced a high tuber number which is an important consideration if farmers would use the first generation seedling tubers as a source of seed potato for subsequent seasons. It should also be emphasized that the production and utilization of seedling tubers can be a good alternative to the traditional use of local seed tuber. The seedling tubers have the advantages of having a higher health standard and of being cheaper than the locally grown normal seed tubers.

Tuber size distribution: In terms of both tuber weight and number, the hybrid progenies produced a higher proportion of large size (>60 g) seedling tubers than the OP progenies. Averaged over the hybrid progenies, 49 % and 15 % of the seedling tubers by weight and number respectively were > 60 g (Table 4.1). The corresponding percentages for the OP progenies were 43 % and 12 % (Table 4.1). Eighty eight percent and 85 % (by number) of the seedling tubers of the OP and hybrid progenies respectively were < 60 g. These small size seedling tubers (<60 g) can be a useful source of seed potatoes for subsequent seasons. The larger tubers (>60 g) can be used as ware potatoes. The experience of several countries is that TPS cannot be used directly for ware potato production (Song, 1984; Tsao & Chang, 1982). However, in places where there is no seed potato production scheme, but a tradition of growing vegetables exists, the relatively high yielding OP progenies may be used directly for ware potato production. In Sri Lanka, for example, ware potatoes are produced on small farms using OP seed from the most popular local variety (Bryan, 1986).

Plant vigour and seedling tuber uniformity: The two progeny types differed in plant vigour and tuber uniformity (Table 4.2). The hybrid progenies were superior in plant vigour and tuber uniformity compared to the open-pollinated progenies. Similarly, Macaso-Khwaja & Peloquin (1983) also have found hybrids to be superior in vegetative

vigour and tuber uniformity to OP progenies. Plant vigour of the OP progenies had a positive effect on tuber yield ($r=0.79$) and on tuber number ($r=0.78$). The plant vigour of the hybrid progenies was also positively correlated with the tuber yield ($r=0.91$) and tuber number ($r=0.52$). The poor plant vigour of the OP progenies could be attributed to the high rate of selfing. The marked differences in plant vigour should have given an advantage to the hybrid seedlings at early developmental stage in the field. There was a marked difference in seedling tuber shape and colour among the OP progenies with a mean seedling tuber uniformity value of 2.9 (Table 4.2).

There was a significant difference in plant vigour and tuber uniformity between the hybrid progenies (Table 4.2) also. Averaged across the hybrid progenies, the mean values for plant vigour and seedling tuber uniformity were 8.1 and 3.2 (Table 4.2), respectively. The higher vigour of the OP progeny (*AL 601*) and the hybrid progeny (*CIP 987004*) was reflected in their higher seedling tuber yield and number (Table 4.1). The marked difference in seedling tuber uniformity between the OP progenies indicates that a possibility of selecting OP progenies with relatively uniform tubers in terms of size, shape and colour does exist. At CIP, Mendoza (1979) was able to identify TPS progenies with relatively uniform tuber characteristics such as tuber shape and colour. Lack of tuber uniformity is believed to be one of the problems in using TPS for ware potato production. However, considering the shortage of healthy seed potatoes for planting and provided that OP progenies which produce a relatively high number of seedling tubers are selected, tuber uniformity may not be such a major problem in developing countries like Ethiopia.

4.3.2. Rain season

During the rain season, because of late blight (*Phytophthora infestans*) pressure, the seedling tuber yields of both the OP and the hybrid progenies were very low (Table 4.3). In fact, the mean seedling tuber yields of the OP and hybrid progenies was 4.9 and 2.8 t/ha respectively, which was much lower than the national average yield of 5.8 t/ha. However, in contrast to the results of the dry season, the mean seedling tuber yield (4.9 t/ha) of the OP progenies was higher than the mean seedling tuber yield (2.8 t/ha) of the hybrid progenies (Table 4.3). Ninety nine percent (by weight) of the seedling tubers of both the OP and hybrid progenies were < 60 g.

Table 4.3. Tuber yield and tuber size distribution (by weight) of open pollinated and hybrid TPS progenies during the rain season.

Progeny	Yield (t/ha)	<u>Tuber size distribution (%)</u>		
		<20g	30-60g	>60g
<u>Open pollinated</u>				
CIP 378371.5	13.0	9	91	-
AL 560	6.6	16	83	1
AL 459	6.3	6	82	12
AL 563	4.4	12	86	2
AL 107	3.7	28	72	-
OK-86-235	3.7	12	88	-
AL 601	3.7	11	89	-
OK-86-240	3.4	13	87	-
UK-80-3	3.3	15	85	-
AL 417	3.3	36	64	-
OK-87-134	3.0	37	63	-
Mean	4.9	<u>18</u>	<u>81</u>	1
		99%		
S.E.	0.52			
C.V.	14.9			
LSD (0.05)	1.25			
<u>Hybrid</u>				
CIP 987003	8.6	22	76	2
CIP 987004	4.2	15	82	3
CIP 978001	4.2	15	85	-
CIP 986004	4.1	16	76	8
CIP 980003	3.9	24	73	3
CIP 987002	3.4	16	84	-
CIP 987001	2.8	18	79	3
CIP 985002	2.6	15	85	-
HK-87-15	2.5	18	72	-
CIP 985001	1.4	33	67	-
CIP 984001	0.6	38	62	-
CIP 978004	0.2	95	5	-
CIP 981005	0.1	100	-	-
CIP 985004	0.2	100	-	-
Mean	2.8	<u>38</u>	<u>61</u>	1
		99%		
S.E.	0.68			
C.V.	23.0			
LSD (0.05)	1.95			

Among the OP progenies, *CIP 378371.5* gave a significantly higher seedling tuber yield (13 t/ha) than the other progenies (Table 4.3). And the hybrid progeny - *CIP 987003* - produced a significantly higher seedling tuber yield (8.6 t/ha) than the other progenies. These two TPS progenies seem to relatively withstand the high late blight pressure of the rain season. It might be worthwhile to evaluate them together with other late blight resistant TPS progenies in the future.

Since 1987, several OP and hybrid progenies have been evaluated during the rain season at Holetta Research Center, Ethiopia. There are two major problems. The first is the problem of seedling establishment in the field; the second problem is that the very few seedlings established are severely infected with late blight. Therefore, during the rain season, the possibility of growing TPS in the field and producing seedling tubers to be utilized as seed potatoes or ware potatoes does not seem promising.

When the two contrasting seasons are compared, in the dry season, the mean tuber yield of 31 t/ha of the OP progenies (Table 4.1) was 530 % higher than the mean tuber yield of 4.9 t/ha in the rain season (Table 4.3). Another difference in the OP progenies is that, during the dry season, a larger proportion (43%) of the OP progeny tubers were big (>60 g) size as opposed to only 1 % during the rain season. The difference in large size tubers produced in the two seasons was even more pronounced in the hybrids.

4.4. Conclusion

During the dry season, the hybrid progenies were superior to the open-pollinated progenies in seedling tuber yield, plant vigour and tuber uniformity. Contrastingly, the OP progenies performed better than the hybrids during the rain season. However, during the rain season, the seedling tuber yields of both TPS progenies were very low. Therefore, the possibility of growing TPS in the rain season in the field for either seedling tuber or ware potato production does not seem promising. In places where there is no seed potato production scheme but where a tradition of growing vegetables exists, during the dry season, the high yielding OP and hybrid progenies can be grown for the production of both seed potatoes and ware potatoes. The small size (<60 g) seedling tubers can be a useful source of seed potatoes for the next generation, and the large size (>60 g) tubers can be used as ware potatoes. It should be emphasized that the high

yielding progenies also multiply faster than the low yielding progenies. Though the tuber yield of the OP progenies was substantially lower than that of the hybrids, their economic yield could be significantly higher because of the higher costs involved in producing hybrid seeds.

References

- Accatino, P., 1980. Evaluation of the transplanted true potato seed: hybridvs open-pollinated. CIP report of a planning conference on utilization of genetic resources of the potato. Lima, Peru, pp. 158 - 168.
- Accatino, P. & P. Malagamba, 1982. Potato production from true seed. CIP, Lima, Peru. pp. 20.
- Bedi A. S., P. Smale & B. Burrows, 1979. Experimental potato production in New Zealand. Planning conference on the production of potatoes from true seed. Manila, Philippines, pp. 100 - 116.
- Bryan, J., 1986. TPS production and distribution by CIP. *True Potato Seed Letter*. CIP, Lima, Peru. 7 (2): 3.
- Kidanemariam, H. M., G. C. Arndt, A. C. Macaso-Khwaja & S. J. Peloquin, 1985. Comparison between 4x x 2x hybrid and OP true potato seed families. *Potato Research* 28: 35 - 42.
- Li, C. H. & C. P. Shen, 1979. Production of marketable seed potatoes from botanical seed in the Peoples Republic of China. Planning conference on the production of potatoes from true seed, 13 - 15 September, 1979. Manila, Philippines, pp. 21 - 28.
- Macaso-Khwaja, A. C. & S. J. Peloquin, 1983. Tuber yields of families from OP and hybrid true potato seed. *American Potato Journal* 60: 645 - 651.
- Malagamba, P., 1983. Reducing the effect of stress during the establishment and growth of potatoes from true potato seed in hot climates. In: W. L. Hooker (Ed.), *Research for the potato in the year 2000*. CIP, Lima, Peru. pp. 125 - 126.
- Malagamba, P. & A. Monares, 1988. True Potato Seed: past and present uses. CIP, Lima, Peru, 40 pp.

- Mendoza, H. A., 1979. Preliminary results on yield and uniformity of potatoes grown from true seed. Planning conference on the production of potatoes from true seed, 13 - 15 September, 1979. Manila, Philippines, pp. 156 - 172.
- Rowe, P. R., 1974. The possibility of growing potato from botanical seed: Seed production technology. CIP, Lima, Peru. pp. 123 - 125.
- Sadik, S., 1983. Potato production from true seed - Present and future. In: W. L. Hooker (ed.), Research for the potato in the year 2000. CIP, Lima, Peru, pp. 18 - 25.
- Song, B. F., 1984. Use of true potato seed in China. *CIP Circular* 12 (2): 6 - 7.
- Tsao, S. J. & Y. M. Chang, 1982. Studies on potato production by the true seeds. Proceedings of a symposium on plant breeding, 23 - 24, September, 1981, Taichung, Taiwan, pp. 233 - 240.

CHAPTER 5

EFFECT OF SEED BED SUBSTRATE, NITROGEN AND PHOSPHORUS ON SEEDLING TUBER YIELD AND YIELD COMPONENTS OF POTATO

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Abstract

Two nursery experiments were carried out during two contrasting seasons to investigate the effect of seed bed substrate, nitrogen and phosphorus on seedling tuber yield and yield components using the TPS progeny *AL 624*. Tuber yield, tuber number and mean tuber weight per m² bed were significantly higher in the dry than in the rain season. Tuber dry matter content (TDM %) was higher in the rain than in the dry season.

Plants grown in substrate mix of 50 % forest soil and 50 % manure gave a significantly higher tuber yield and tuber yield components with a higher proportion of large size (>50 g) and a lower proportion of small size (<10 g) tubers than the other substrate mixes, without affecting the proportion of intermediate size tubers. TDM % was higher in plants grown in 50 % forest soil and 50 % sand than in plants grown in the other substrate mixes.

In both seasons, as the N rate increased, the total tuber yield, tuber yield components and the proportion of large size tubers increased, and that of small size tubers reduced. The proportion of intermediate size tubers was not influenced by N rate. In the rain season N reduced the TDM %. In the rain season, P application of up to 35 g per m² increased the tuber yield and tuber number. Tuber shape was not influenced by any one of the treatments.

In the highlands of Ethiopia, dry season production of seedling tubers in a seed bed substrate of 50 % forest soil and 50 % manure, and 40 - 80 g N per m² seed bed is recommended. In the absence of good quality seed tubers farmers can use seedling tubers as a source of seed.

Additional keywords: true potato seed, substrate, nitrogen, phosphorus, seedling tuber yield.

5.1. Introduction

In most developing countries there is no seed potato production scheme. In these countries because seed potatoes are often the most costly input in potato production (Van der Zaag & Horton, 1983), there has been an increasing interest in the use of true potato seed (TPS) for the production of potatoes (Bedi et al., 1980; Wiersema, 1983; Sadik, 1983; Harris, 1983; Malagamba, 1983). Therefore, the utilization of seedling tubers as

seed potatoes can be a useful alternative in countries where there is no seed tuber production scheme. A potato production system using seedling tubers as planting propagule is also advantageous because it can combine the low cost and high health standard of TPS and the rapid development of plants grown from seed tubers (Wiersema, 1986).

There is a potential of producing seedling tubers from TPS in areas where there is a long growing season, where either rainfall is well distributed or irrigation is available, where soils are of adequate physical structure, and where farmers have the tradition and skill of growing vegetable crops (Monares *et al.*, 1983). For the production of seedling tubers from TPS, growing the seedlings in a seed bed can be a convenient technique for many farming systems in the highlands, because seedlings can be better managed in seed beds than in field conditions. With fertile seed beds and proper nursery management, a seed bed of 10 m² can produce sufficient tubers to plant a hectare of land after one field multiplication (Malagamba, 1988). Wiersema (1986) reported seedling tuber yields of up to 12 kg per m² in a substrate mix ratio of 1:1 of peatmoss and sand. Sadik (1984), using a hybrid TPS progeny, reported that a substrate mix of sand and peatmoss gave the highest seedling tuber yield of 3.85 kg per m². Similarly, beds filled with a substrate mix of sand and peatmoss or sand and compost, mixed in equal proportions, were found suitable for the production of seedling tubers (Wiersema, 1984). The soil mix for the seed bed depends upon what is locally available. The physical and chemical characteristics of a substrate can affect TPS seedling establishment and seedling tuber yield. Field soil alone may often be unsuitable because of crusting. Sand alone or any other substrate low in organic matter is not suitable because of their low moisture holding capacity (Sadik, 1983).

The amount of chemical fertilizer to be applied to the seed bed depends on the type and the fertility level of the substrate. Since the potato crop from TPS is of a longer duration than potato grown from seed potato, its requirement for nutrients may be expected to differ. Based on several experiments, Wiersema (1985) reported that an optimum regime of fertilizer application, in a 1:1 substrate mix of peatmoss and sand, was 40 - 80 g per m² of P₂O₅ at sowing and 40 - 60 g per m² of N after plant establishment.

This paper reports on the effects of seed bed substrate, and the application of nitrogen and phosphorus on the production of seedling tubers in the highlands of Ethiopia.

5.2. Materials and methods

5.2.1. General information

All nursery experiments were carried out at the Holetta Research Center (central highlands, altitude of 2400 m above sea level) during the rain and dry seasons of 1991 and 1992, respectively. The growing periods of the rain and dry seasons extend between the months of June-September and January-May, respectively. Seeds from the clone *AL 624*, an open-pollinated TPS progeny, was used in the experiments. This progeny was, amongst others, selected by the Ethiopian Potato Improvement Programme (EPIP) because of its high yields and tuber uniformity.

5.2.2. Seed beds and treatments

Sunken seed beds 1 m x 1 m wide and 0.25 m deep were used. Pathways between beds were 1 m wide. Individual beds were separated by an open space of 0.40 m to avoid mixing up tubers of neighbouring plants. In a preliminary observation trial, using raised seed beds of 0.20 m height, the EPIP (data unpublished) observed that a substrate mix ratio of forest soil, manure and sand (5:3:2) gave a better seedling tuber yield than the regularly used nursery soil. This preliminary observation gave us the base to develop the different treatment substrate mix ratios for this experiment. Beds were filled with three thoroughly mixed substrates of forest soil, manure and sand in a ratio of 5:3:2 (S_1), 5:5:0 (S_2) and 5:0:5 (S_3), respectively to 0.20 m depth. After seedling emergence, an additional 5 cm of the respective substrate mixes was added during the growing period to substitute for hilling up. Before sowing the substrates were sterilized with quintazone at a rate of 100 ml per m² seed bed by injecting at 15 cm depth. Fertilizer treatment rates applied per m² bed were 0, 40, 80 g N and 0, 35, 70 g P as urea (46 % N) and triple superphosphate (43 % P₂O₅) respectively. All the P was mixed up with the substrate before sowing and N was split applied (four times) after plant establishment during the growing period.

To break dormancy, the seeds were treated with 1500 ppm gibberellic acid (GA₃) solution for 24 hours. Open pollinated TPS of *AL 624* were directly sown in seed beds at three seeds per plant position. During the dry season, the seed beds were shaded for four weeks to improve seedling establishment. Three weeks after emergence, seedlings were

thinned. During thinning the weakest seedlings were removed and one seedling per plant position was maintained to give 100 plants per m². Nursery beds were sprinkle - irrigated every two days by hand cans with the same volume of water per seed bed. During the rain season, there were incidences of late blight (*Phytophthora infestans*) which were controlled by spraying with Ridomil MZ 63.5 WP.

5.2.3. Design, harvest and analysis

A design of a 3 x 3 x 3 factorial experiment in 3 replications arranged in randomized complete blocks was used. Tubers were harvested when more than 90 % of the plants were mature. Only those tubers with a diameter at least thrice that of the stolon were harvested. At harvest, the weight and number of tubers per m² were recorded, and tubers were categorized by number in grades of > 50 g, 30 - 50 g, 10 - 30 g and < 10 g. Tuber uniformity, in terms of shape, was determined using CIP's scale where 1 is rated as least uniform and 5 as most uniform. Tuber dry matter content was determined from the relationship between fresh and dry weights of a sample of 2 - 3 thinly sliced tubers dried for 36 h at 80 °C. Data were analysed using the standard analysis of variance and the means were separated by LSD.

5.3. Results

There were no significant interactions between substrate, nitrogen and phosphorus in either season; results are therefore presented as means of main effects. The growing

Table 5.1. Effect of growing season on plant survival, tuber yield, tuber number and mean tuber weight per m² and TDM % of plants grown from TPS.

Growing season	Plant survival (%)	Tuber yield (kg/m ²)	Tuber number/m ²	Mean tuber weight (g)	TDM (%)
Rain	47	6.9	557	12.3	20.5
Dry	72	25.4	1080	23.3	18.0
	***	***	***	***	***

*** = significant at P < 0.001.

Table 5.2. Effect of seed bed substrates^a on plant survival percentage^b two weeks before harvest and tuber number per plant.

Substrate	<u>Rain season</u>		<u>Dry season</u>	
	Plant survival %	Tuber no/plant	Plant survival %	Tuber no/plant
5:3:2 (S ₁)	46 b	12.6 a	71 b	16.4 b
5:5:0 (S ₂)	43 b	14.2 a	68 b	19.4 a
5:0:5 (S ₃)	52 a	9.6 b	77 a	10.8 c
P<0.01	**	**	**	**

^aSubstrate mix ratio of forest soil, manure and sand by volume.

^bStatistical analysis carried out on arcsin transformed data.

Means in a column followed by the same letter are not significantly different.

period from sowing to harvest was 135 and 164 days in the rain and dry seasons, respectively. Plant survival percentage, two weeks before harvest, was significantly ($P<0.001$) higher in the dry than in the rain season (Table 5.1). The tuber yield, tuber number and mean tuber weight per m² bed were also considerably higher in the dry season than in the rain season (Table 5.1). Tuber dry matter content (TDM %), however, was higher in the rain than in the dry season.

Table 5.3. Effect of substrate on tuber size distribution as a percentage of total tuber number per m² during the dry season.

Substrate	>50 g	30-50 g	10-30 g	<10 g
5:3:2	14 ab	16	27	43 a
5:5:0	16 a	18	26	40 b
5:0:5	12 b	17	27	44 a
	**	ns	ns	*

ns = not significant, * = significant at $P<0.05$, ** = significant at $P<0.01$

Means in a column followed by the same letter are not significantly different.

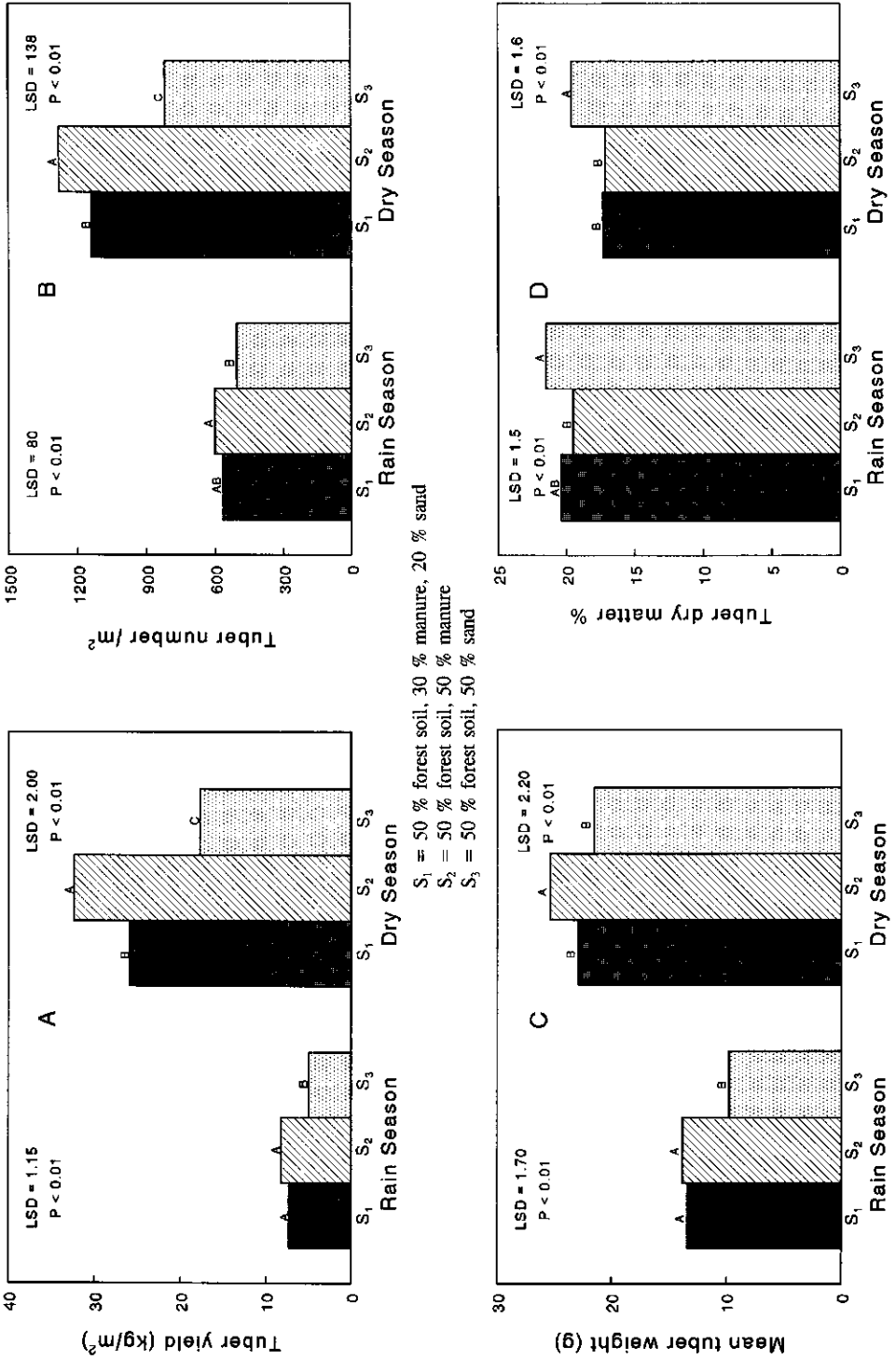


Fig. 5.1. Effect of substrate on tuber yield (A), tuber number (B), mean tuber weight (C) and tuber dry matter percent (D) during the rain and dry seasons. [Bars with the same letter within a season are not significantly different].

Table 5.4. Effect of nitrogen on seedling tuber yield, tuber number, mean tuber weight and tuber dry matter percent (TDM %) during the rain season.

N level (g/m ²)	Tuber yield (kg/m ²)	Tuber number/m ²	Mean tuber weight (g)	TDM (%)
0	5.1 b	531	9.5 b	21.5 a
40	7.5 a	546	14.1 a	20.3 ab
80	7.9 a	593	13.3 a	19.6 b
Mean	6.9	557	12.3	20.5
LSD	1.2***	ns	1.7***	1.5**

ns = not significant, ** = significant at $P < 0.01$, *** = significant at $P < 0.001$.

Means in a column followed by the same letter are not significantly different.

In both seasons, just two weeks before harvest plants grown in a substrate mix of 50 % forest soil and 50 % sand (S_3) had a significantly ($P < 0.01$) higher percent of plant survival than those grown in the other substrates (Table 5.2). In the rain season, S_2 gave a significantly ($P < 0.01$) higher tuber yield and tuber number per m² bed. However, there was no significant difference between S_1 and S_2 in tuber yield; and between S_1 and S_2 or

Table 5.5. Effect of nitrogen on seedling tuber yield, tuber number, mean tuber weight and tuber dry matter percent (TDM %) during the dry season.

N level (g/m ²)	Tuber yield (kg/m ²)	Tuber no/m ²	Mean tuber weight (g)	TDM (%)
0	19.1 c	944 b	20.0 c	17.9
40	25.1 b	1081 ab	23.4 b	18.1
80	31.9 a	1214 a	26.4 a	18.0
Mean	25.4	1080	23.3	18.0
LSD	2.0***	138***	2.2**	ns

ns = not significant, ** = significant at $P < 0.01$, *** = significant at $P < 0.001$.

Means in a column followed by the same letter are not significantly different.

Table 5.6. Effect of nitrogen on tuber size distribution as a percentage of total tuber number per m² during the dry season.

N level (g/m ²)	>50 g	30-50 g	10-30 g	<10 g
0	11 b	16	26	47 a
40	15 a	18	27	40 b
80	17 a	17	27	39 b
	**	ns	ns	**

ns = not significant, ** = significant at $P < 0.01$.

Means in a column followed by the same letter are not significantly different.

S_1 and S_3 in tuber number (Figs 5.1A, B). In the dry season, tuber yield and tuber number harvested per m² bed from S_2 were significantly ($P < 0.01$) higher than from the other 2 substrates (S_1 and S_3). Mean tuber weight produced in S_2 was the highest. However, there was no significant difference in mean tuber weight between S_1 and S_2 in the rain season, and S_1 and S_3 in the dry season (Fig. 5.1C). In the rain season, S_3 , which had the highest proportion of sand, gave a significantly higher TDM % than S_2 and no significant difference in TDM % was recorded between S_1 and S_3 (Fig. 5.1D). In the dry season, tuber dry matter percent (TDM %) was remarkably higher of plants grown in S_3 than those grown in the other two substrates (Fig. 5.1D). No difference in TDM % was observed between S_1 and S_2 .

Data on tuber size distribution are shown for the dry season only as the effects were similar in both seasons. Plants grown in S_2 had a significantly ($P < 0.01$) higher percentage of large size (>50 g) tubers and a lower percentage of small size (<10 g) tubers (Table 5.3). The percentages of intermediate size tubers, in the grade categories of 30 - 50 g and 10 - 30 g, were not influenced by the substrate type.

Percent plant survival was not influenced by either N or P applications (data not shown). The effect of N on tuber yield and mean tuber weight was similar in both seasons. Increasing N rates significantly ($P < 0.01$) increased tuber yield, tuber number and mean tuber weight (Tables 5.4 and 5.5). However, in the rain season, tuber number

Table 5.7. Effect of phosphorus on seedling tuber yield, tuber number, mean tuber weight and tuber dry matter percent (TDM %) during the rain season.

P level (g/m ²)	Tuber yield (kg/m ²)	Tuber number/m ²	Mean tuber weight (g)	TDM (%)
0	6.2 b	521 b	11.8	20.5
35	7.0 ab	552 ab	13.0	20.6
70	7.4 a	598 a	12.1	20.4
Mean	6.9	557	12.3	20.5
LSD	0.86*	60*	ns	ns

ns = not significant, * = significant at $P < 0.05$.

Means in a column followed by the same letter are not significantly different.

was not affected by N rates. Increasing N rates significantly ($P < 0.01$) reduced tuber dry matter percent only in the rain season (Table 5.4). Increasing N rate, up to 40 g per m², markedly increased the percentage of large size (>50 g) tubers and reduced the percentage of small size (<10 g) tubers (Table 5.6). Proportions of tubers in the size categories of 30 - 50 g and 10 - 30 g were not influenced by N rates.

In the rain season, P application of up to 35 g per m² significantly ($P < 0.05$) increased both tuber yield and tuber number per m² bed (Table 5.7). No significant differences were observed in tuber yield and number between P rates of 35 and 70 g per m². Mean tuber weight and tuber dry matter percent were not influenced by P rates. However, during the dry season, P application did not influence the tuber yield or tuber yield components (data not presented). In both seasons, P did not influence tuber size distribution (data not shown). Tuber shape was not influenced by either the type of substrate or fertilizer treatments (data not presented).

5.4. Discussion

There was a very contrasting difference between the seasons in plant survival, tuber yield, tuber number and mean tuber weight (Table 5.1). During the dry season, there was a better management of irrigation water at early seedling establishment stage and during the

growing period, and less late blight (*Phytophthora infestans*) pressure, as the result of which the plant survival percentage was significantly ($P < 0.001$) higher than in the rain season. The remarkably higher tuber yield and number during the dry season could also possibly be attributed to the longer sunshine hours (Appendix 1.1) and longer growing period resulting in an increased radiation interception. During the rain season, which is characterized by high rainfall (900 mm), monthly mean RH of 77 % and monthly mean minimum and maximum temperatures of 9.2 °C and 20.0 °C respectively, there was a high pressure of late blight (*Phytophthora infestans*) that may have contributed to the lower plant survival and consequently lower tuber yield and tuber number. Usually dry seasons are associated with high tuber dry matter content (Burton, 1966). However, in this experiment TDM % was higher in the rain season than in the dry season, and this could be due to the frequent irrigation application during the dry season. When the purpose is to utilize seedling tubers as seed potatoes for subsequent seasons, the number of seedling tubers above a certain minimum grade is a more important factor to consider than tuber yield. During the dry season, by growing TPS in a seed bed of 1 m², a maximum seedling tuber number of up to 1079, which is almost twice that of the rain season (Table 5.1), can be produced. A seed bed of 40 m² can produce sufficient seedling tubers to plant a hectare of land.

Plants growing in a substrate mix with a higher proportion of sand (S₃) had a better survival rate than those grown in S₁ and S₂ (Table 5.2). During the growing period, plants growing in S₁ and S₂ had more vigorous vegetative growth and earlier canopy closure than the plants growing in S₃ which may have been caused by the relatively higher fertility status of S₁ and S₂ (Appendix 5.1). Because of competition between the vigorous plants growing in S₁ and S₂ during the entire growing period, less vigorous seedlings are likely to have been eliminated, thereby reducing the percentage of surviving plants at harvest. However, the increase in survival rate of plants growing in S₃ was offset by the lower tuber number per plant (Table 5.2), which consequently reduced the tuber yield and tuber number per m² seed bed (Figs 5.1A, B), and the mean tuber weight (Fig. 5.1C).

The kind of seed bed substrate mix to be used in a particular area may depend on its availability in the vicinity where the seed bed is established and also on its relative fertility status. For example, a substrate mix of 50 % peatmoss and 50 % sand in Peru (Malagamba, 1983), 50 % manure and 50 % sand in India (Upadhy *et al.*, 1986), and

33 % of manure, sub-soil and sand each in Bangladesh (Sikka, 1987) resulted in a vigorous growth and better survival of seedlings raised from TPS. Lately, in Iran (Mortazavi, 1993) a substrate mix of 60 % soil, 20 % manure and 20 % sand gave a better seedling emergence and a higher tuber yield.

Plants grown in S_2 gave a higher tuber yield and number per m^2 , and mean tuber weight per m^2 bed (Figs 5.1A, B, C) which could be attributed to the higher nutrient and organic matter contents (Appendex 5.1) and better water holding capacity of S_2 . Plants grown in S_2 gave a highest yield of 32.4 kg per m^2 in the dry season. This yield is by far much higher than seedling tuber yields per m^2 bed reported so far. For example, Sadik (1984), using a hybrid TPS progeny, reported a highest tuber yield of 3.85 kg per m^2 in a substrate mix of 50 % peatmoss and 50 % sand. Wiersema (1984) recorded a maximum seedling tuber yield of 12 kg per m^2 seed bed in a substrate mix of 50 % each of peatmoss and sand. The results of these experiments and work done by other researchers suggest that TPS grown on a substrate mix with a relatively high organic matter gives a higher seedling tuber yield. The kind of organic matter to be used will depend mainly on its availability or its price. In the central highlands of Ethiopia, for example, peatmoss is not available. Forest soil and manure are readily available and could be a good source of organic matter. In both seasons, the higher TDM % recorded by tubers grown in the substrate with a higher % of sand (S_3) was due to its adequate drainage capacity. Since tuber shape is mainly genetically controlled (Harris, 1992) it was not influenced by either the substrate type or fertilizer applications. However, in some cultivars tuber shape is also reported to be influenced by cultural and environmental conditions but more in those with long rather than round tubers (cf Storey & Davies, 1992). As with other aspects of fertilizer response, the effects of type of substrate on tuber size may vary depending on the fertility of the substrate and the variety. Therefore, the higher proportion of large size (> 50 g) tubers and lower % of small size tubers (< 10 g) of plants grown in S_2 may have been presumably due to the better fertility status of S_2 .

Increasing N rates significantly increased tuber yield, tuber number and mean tuber weight. The positive effect of N on tuber yield could be attributed to its effect on size of the crop canopy. The increase in tuber yield by N fertilization is due to increased radiation interception (Millard & Marshall, 1986). But lately, Firman & Allen (1988) concluded that any increase in tuber yield by the addition of N fertilizer is achieved by

effects on leaf area duration. The dry season had a longer growing period and less cloudy weather than the rain season.

The increased N rates significantly ($P < 0.01$) reduced the tuber dry matter percent in the rain season. This is in agreement with findings of numerous researchers in which they reported a reduction in TDM % with increasing N rates (Jenkins & Nelson, 1992; MacKerron & Davies, 1986; Painter & Augustin, 1976), while others indicated that N does not affect TDM % (Millard & Marshall, 1986).

Increasing N rate up to 40 g per m² increased the proportion of large size (> 50 g) tubers and reduced the proportion of small size (< 10 g) tubers; P did not influence tuber size distribution. This is in accord with most of the results of experiments reviewed by Perrenoud (1983) where N increased the proportion of large tubers and P had rather no effect on tuber size. As N level increases, the reduction of the proportion of small size (< 10 g) tubers and the increase of the proportion of large size (> 50 g) tubers, without affecting the intermediate size (30-50 g and 10-30 g) tubers, could be due to a continuous and gradual shift from one size class to the larger ones (Struik *et al.*, 1991). Other researchers (Dubetz & Bole, 1975; Vitosh *et al.*, 1980) found that N had no effect on the proportion of large tubers (> 50 or 55 mm), whereas Wilcox & Hoff (1970) reported that N increased tubers over 48 mm in one experiment and reduced it in another one.

Though P had a positive effect on tuber yield and number during the rain season, the response to P was smaller than the response to N. This could be attributed to a smaller increase in leaf area index due to P compared with the response to N (Dyson & Watson, 1971). Similarly, on P-deficient soil in Ruanda, Haverkort (1985) showed that N fertilizer had a strong positive influence on ground cover throughout the season and extended the growing period. P led to earlier closure of the crop canopy, but did not lengthen the growing period. P does not seem to have either a marked, as in this experiment, or a consistent effect on TDM %. However, Kunkel & Holstad (1972) have reported a decrease in TDM % as amount of P applied increased.

In an experiment of this type where different types of growing media, and different nitrogen and phosphorus levels are used, interactions are usually expected. However, in these experiments there was a consistent lack of significant interactions between the substrate types, nitrogen and phosphorus rates used.

Based on the results of these experiments, in dry season, in a seed bed of a substrate

mix of 50 % forest soil and 50 % manure (S₂), 40 - 80 g per m² of nitrogen will give a maximum seedling tuber yield and number. These results suggest also that there is a good potential of producing seed potatoes from TPS in seed beds in warm climates of the tropical highlands. Planting TPS in seed beds can best fit to the home garden vegetable growing farming conditions of the highlands. Manure and forest soil, which were found to be best substrates, are usually readily available not very far from the farmer's homestead farm. In the absence of healthy and good quality seed tubers, farmers can use seedling tubers as a source of seed potatoes.

References

- Bedi, A. S., P. Smale & D. Burrows, 1980. Experimental potato production in New Zealand from true seed. In: The planning conference on the production of potatoes from true seed. Manila, Philippines, 13 - 15, September, 1979, CIP, Lima, Peru, pp. 100 - 116.
- Burton, W. G., 1966. The potato: A survey of its history and of the factors influencing its yield, nutritive value, quality and storage. H. Veenman and Zonen, Wageningen. 382 pp.
- Dubetz, S. & J. B. Bole, 1975. Effect of nitrogen, phosphorus and potassium fertilizers on yield components and specific gravity of potatoes. *American Potato Journal* 52: 399-405.
- Dyson, P. W. & D. J. Watson, 1971. An analysis of the effects of nutrient supply on the growth of potato crops. *Annals of Applied Biology* 69: 47 - 63.
- Firman, D. M. & E. J. Allen, 1988. Field measurements of the photosynthetic rate of potatoes grown with different amounts of nitrogen fertilizer. *Journal of Agricultural Science* 111: 85 - 90.
- Harris, P. M., 1983. The potential for producing root and tuber crops from seed. Sixth symposium of the International Society for Tropical Rootcrops. 20 - 25, February, 1983, CIP, Lima, Peru, pp. 67 - 80.
- Harris, P. M., 1992. Mineral nutrition. In: P. M. Harris (Ed.). The Potato Crop: The scientific basis for improvement. Chapman and Hall, London, pp. 162 - 213.
- Haverkort, A. J., 1985. Relationship between intercepted radiation and yield of potato crops under tropical highland conditions of central Africa. Ph.D. thesis, University of Reading, 259 pp.

- Jenkins, P. D. & D. G. Nelson, 1992. Aspects of nitrogen fertilizer rate on tuber dry matter content of potato cv. Record. *Potato Research* 35: 127 - 132.
- Kunkel R. & N. Holstad, 1972. Potato chip color, specific gravity and fertilization of potatoes with N-P-K. *American Potato Journal* 49: 43-62.
- Malagamba, P., 1983. Seed-bed substrates and nutrient requirements for the production of potato seedlings. In: W. G. Hooker (Ed.), Research for the potato in the year 2000. CIP, Lima, Peru, pp. 127 - 128.
- Malagamba, P., 1988. Potato production from true seed. *HortScience* 23 (3): 495 - 499.
- MacKerron, D. K. L. & H. V. Davies, 1986. Markers for maturity and senescence in the potato crop. *Potato Research* 29: 427 - 436.
- Millard, P. & B. Marshall, 1986. Growth, nitrogen uptake and partitioning within the potato (*Solanum tuberosum* L.) crop, in relation to nitrogen application. *Journal of Agricultural Science* 107: 421 - 429.
- Monares, N., P. Malagamba & D. Horton, 1983. Prospective systems and users for true potato seed in developing countries. In: W. G. Hooker (Ed.), Research for the potato in the year 2000. CIP, Lima, Peru, pp. 134 - 136.
- Mortazavi, A., 1993. Evaluation of different TPS planting methods in Asfahan and Fereydan, Iran. 12th Triennial Conference of the European Association for Potato Research. 18 - 23, July, 1993, Paris, pp. 230 - 231.
- Painter, C. G. & J. Augustine, 1976. The effects of soil moisture and nitrogen on yield and quality of Russet Burbank potatoes. *American Potato Journal* 53: 275 - 284.
- Perrenoud, S., 1983. Potato: fertilizers for yield and quality. *International Potash Institute Bulletin* No. 8, 84 pp.
- Sadik, S., 1983. Potato production from true seed - Present and future. In: W. G. Hooker (Ed.), Research for the potato in the year 2000. CIP, Lima, Peru, pp. 18 - 25.
- Sadik, S., 1984. Seedling tuber production in seed-beds. *True Potato Seed Letter* 5 (2): pp. 2 - 3.

- Sikka, L., 1987. Review of TPS research in Bangladesh. Proceedings of a workshop on TPS research in Bangladesh. Bangladesh Agricultural Research Institute. 17 - 18, August, 1987, Dhaka, pp. 8 - 17.
- Storey, R. M. J. & H. V. Davies, 1992. Tuber quality. In: P. M. Harris (Ed.), *The Potato Crop: The scientific bases for improvement*. Chapman and Hall, London, pp. 507 - 569.
- Struik, P. C., D. Vreugdenhil, A. J. Haverkort, C. B. Bus & R. Dankert, 1991. Possible mechanisms of size hierarchy among tubers on one stem of a potato (*Solanum tuberosum* L.) plant. *Potato Research* 34: 187 - 203.
- Upadhyha, M. D., T. R. Dayal, R. Chandra, & A. N. Singh, 1986. Potential of true potato seed for the production of commercial potato crop in India. *The Journal of Indian Potato Association* 13: 29 - 34.
- Vitosh, M. L., J. W. Noling, G. W. Bird & R. W. Chase, 1980. The joint action of nitrogen and nematicides on *Pratylenchus penetrans* and potato yield. *American Potato Journal* 57: 101-111.
- Wiersema, S. G., 1983. Potato seed tuber production from true seed. In: W. G. Hooker (Ed.), *Research for the potato in the year 2000*. CIP, Lima, Peru, pp. 186 - 187.
- Wiersema, S. G., 1984. Production and utilization of seed tubers derived from TPS. Ph.D. thesis, University of Reading, CIP, Lima, Peru. 229 pp.
- Wiersema, S. G., 1985. Production and utilization of seed tubers derived from true potato seed. In: *Innovative Methods for the Propagation of Potatoes*, CIP, Lima, Peru, pp. 95 - 116.
- Wiersema, S. G., 1986. A method of producing seed tubers from true potato seed. *Potato Research* 29: 225 - 237.
- Wilcox, G. E. & J. Hoff, 1970. Nitrogen fertilization of potatoes for early summer harvest. *American Potato Journal* 47: 99 - 102.
- Zaag, D. E. van der & D. Horton, 1983. Potato production and utilization in world perspective with special reference to the tropics and sub-tropics. *Potato Research* 26: 323 - 362.

Appendix 5.1. Physical and chemical characteristics^a of the substrates^b.

Substrates	Sand %	Silt %	Clay %	pH	Organic matter %	Total N %	Available		EC mmhos/cm
							P (ppm)	K (ppm)	
5:3:2	59	21	20	6.2	8.2	0.23	78	91	0.77
5:5:0	45	35	20	6.2	19.9	0.33	89	357	1.19
5:0:5	73	13	14	7.0	3.7	0.06	11	20	0.17

^aSubstrates analysed by soils laboratory, Holetta Research Center, Ethiopia.

^bSubstrate mix ratio of forest soil, manure and sand by volume.

CHAPTER 6

EFFECT OF PLANT DENSITY ON SEEDLING TUBER YIELD AND YIELD COMPONENTS OF PLANTS GROWN FROM TRUE POTATO SEED

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Abstract

Nursery experiments were carried out during two contrasting seasons to evaluate the effect of density of plants grown from true potato seed (TPS) on seedling tuber yield and yield components. In both seasons, increasing plant density decreased plant survival rate, increased total tuber number per m², and reduced tuber number per plant and mean tuber weight but did not influence the total tuber yield per m². With increasing density, the proportion of number of tubers < 10 g increased whereas that of tubers > 50 g decreased. The positive effect of increasing density on total tuber number was mainly due to a significant increase in the number and proportion of small (<10 g) size tubers. The proportion of number of tubers in the grades 10 - 30 g and 30 - 50 g was either reduced or not affected by increasing density. Plant density did not influence tuber dry matter content. There was an increase of 61 % and 179 % in total tuber number and mean tuber weight respectively in the dry over the rain season. The practical implications in terms of seed bed agronomic management for maximum seedling tuber production and the potential of producing seed as well as ware potatoes from TPS are discussed.

Additional keywords: true potato seed, tuber number, tuber yield, tuber quality, season.

6.1. Introduction

Seedling tubers are produced from first generation plants grown from true potato seed in a seed bed or in a field. In countries where a seed production scheme does not exist, seedling tubers can be multiplied in the field and could be a good source of seed for subsequent seasons. Therefore, the number of seedling tubers that can be produced in the seed bed is of great importance. By manipulating the plant density in a seed bed, an optimum plant population density can be determined whereby a maximum number of usable tubers (>1 g) can be produced. TPS planting usually requires a much higher plant population than using the normal seed tubers for an optimum tuber yield (Sadik, 1983; Tsao, 1985). By growing TPS in a seed bed with a seedling population of 100 plants per m² up to 1500 seedling tubers per m² can be produced (CIP, 1982; CIP, 1985). In

experiments carried out in farmers' fields in warm, humid areas in Peru, seedling tuber production in field beds ranged from 400 - 800 tubers per m² (CIP, 1985). In the lowland (240 m) and arid zone coastal desert of Peru, the optimum plant population was observed to be between 100 to 150 plants per m² of bed, with a total tuber yield and number of 12 kg and 1242 tubers per m², respectively (Wiersema, 1984).

When producing seedling tubers in the seed bed, the most important yield parameters that can be manipulated are (1) the number of seedling tubers per plant (2) the seedling tuber yield per plant (3) the number of seedling tubers per unit area (4) the seedling tuber yield per unit area and (5) the mean weight per seedling tuber. The yield parameters that may be favoured most will depend on the intended use of the seedling tubers. Since the main objective is to use the seedling tubers as seed potatoes, the yield parameters should be manipulated in such away that a maximum number of usable seedling tubers are produced that can be used as a seed source for the next generation.

In a glasshouse experiment, a higher plant density of *in vitro* propagated plantlets resulted in more tubers per m² but fewer tubers per plant (Lommen & Struik, 1992). In a field situation, number of tubers per stem may increase (Wurr, 1974) or remain constant (Vander Zaag *et al.*, 1990) at lower plant densities. At higher plant densities, number of tubers per unit area increases (Ifenkwe & Allen, 1978). Average weights per tuber are reported to be higher at lower densities (Vander Zaag *et al.*, 1990; Bremner & Taha, 1966). Tuber yields per plant were higher at lower plant densities (Bremner & Taha, 1966) and using higher plant densities, tuber yield per unit area may be increased (Bremner & Taha, 1966). If these glasshouse or field management practices or techniques are also effective on TPS seedlings grown in seed beds, they could be used to manipulate seedling tuber production. It should be emphasized, however, that management practices that should be adopted in the glasshouse or the field are different from those in the seed bed. The objective of these experiments was, therefore, to determine an optimum TPS seedling density in the seed bed which produces a maximum number of tubers without hindering agronomic practices such as weeding, hilling up, fertilization, etc.

6.2. Materials and methods

The experiments were carried out at the Holetta Research Center (central highlands, altitude of 2400 m above sea level) in Ethiopia, during the rain and dry seasons of 1991 and 1992 respectively. The growing period of the rain season and dry season extends between the months of June - September and January - May, respectively.

Sprinkler irrigated sunken seed beds, 1 x 1 m and 0.25 m deep, were used and filled with a 5:5 substrate mix ratio of forest soil and manure to 0.20 m depth. Pathways between beds were 1 m wide. Individual beds were separated by an open space of 0.40 m to avoid mixing up tubers of neighbouring plants. After seedling emergence, an additional 5 cm of the same substrate mix was added during the growing period to substitute for hilling up. Before sowing, the substrates were treated with quintazone at a rate of 100 ml per m² seed bed by injecting at 15 cm depth. Open-pollinated (OP) true potato seed of *AL 624* and hybrid seed of *AL 624 x CIP 378371.5* were directly sown in seed beds at three seeds per plant position. During the dry season the seed beds were shaded for four weeks to improve seedling establishment. Three weeks after emergence seedlings were thinned. During thinning the weakest seedlings were removed and one seedling per plant position was maintained to give 50, 100 or 150 plants per m². Fifty g of N as urea (46% N) and 70 g of P as triple superphosphate (43% P₂O₅) were applied. The total amount of P was applied at sowing while N was applied in split dose in four applications during the growing season. During the rain season appropriate measures were taken to control late blight (*Phytophthora infestans*).

Treatments were arranged in factorial experiments in randomized complete block designs with three replications. At harvest the number of surviving plants were counted. Tubers were harvested when more than 90 % of the plants were mature. Only those tubers with a diameter of at least thrice that of the stolon were harvested. At harvest, the weight and number of tubers per m² was recorded, and tubers were categorized by number in grades of > 50 g, 30 - 50 g, 10 - 30 g and < 10 g. Tuber dry matter percent (TDM %) was determined from the relationship between fresh and dry weights of a sample of 2 - 3 thinly sliced tubers dried for 36 h at 80 °C.

6.3. Results

There were no significant interactions between TPS progenies and plant densities; results are therefore presented as means of the two progenies.

Table 6.1. Effect of density of plants grown from TPS on plant survival percentage.

No. plants/m ²	Plant survival percentage (%) ^a	
	Rain season	Dry season
50	92 a	80 a
100	89 a	78 a
150	78 b	64 b
	***	**

^aStatistical analysis carried out on arcsin transformed data.

** = significant at $P < 0.01$, *** = significant at $P < 0.001$

Plant survival rate was higher in the rain than in the dry season (Table 6.1). Total tuber yield and all other tuber yield components were higher in the dry than in the rain season.

The hybrid (*AL 624 x CIP 378371.5*) progeny gave significantly higher total tuber yield and mean tuber weight than the open pollinated (*AL 624*) progeny (data not presented). But the total tuber number and number of tubers per plant of the hybrid progeny was either similar or lower than for the open pollinated progeny. There was no difference in TDM % between the two progenies.

Plant survival rate decreased with increasing plant density (Table 6.1). There was no significant difference, however, in plant survival rate between plant densities of 50 and 100 plants per m². In both seasons, increasing plant density significantly increased total tuber number per m² and reduced tuber number per plant and mean tuber weight without affecting the total tuber yield (Tables 6.2 and 6.4).

The effects of density on percentage of number of tubers weighing < 10 g and > 50 g were similar in both seasons (Tables 6.3 and 6.5). With increasing plant density,

Table 6.2. Effect of density of plants grown from TPS on the total tuber weight (kg/m^2) and number per m^2 , tuber number per plant and mean tuber weight (g) during the rain season.

No. plants per m^2	Tuber yield (kg/m^2)	Tuber no. per m^2	Tuber no. per plant	Mean tuber weight (g)
50	5.7	512 c	11 a	11.2 a
100	6.2	769 b	9 b	8.2 b
150	6.3	921 a	8 b	6.9 b
Mean	6.1	734	9	8.8
LSD ($P < 0.001$)	ns	119	1.5	1.4

Means in a column followed by the same letter are not statistically different.

Table 6.3. Effect of density of plants grown from TPS on tuber size distribution as a percentage^a of total tuber number per m^2 during the rain season.

No. plants per m^2	> 50 g	30-50 g	10-30 g	< 10 g
50	2 a	7 a	28 a	63 b
100	1 b	4 ab	24 b	71 a
150	1 b	3 b	23 b	73 a
	*	**	**	**

^aStatistical analysis carried out on arcsin transformed data.

* = significant at $P < 0.05$, ** = significant at $P < 0.01$.

Means in a column followed by the same letter are not statistically different.

percentage of number of tubers weighing < 10 g increased; contrastingly percentage of number of tubers weighing > 50 g decreased. In the rain season, percentage of number of tubers in the grades 10 - 30 g and 30 - 50 g decreased with increasing plant density

(Table 6.3); whereas in the dry season they were not affected by density (Table 6.5). Plant density did not influence TDM content (data not presented).

Table 6.4. Effect of density of plants grown from TPS on total tuber weight (kg/m²) and number per m², tuber number per plant and mean tuber weight (g) during the dry season.

No. plants per m ²	Tuber yield (kg/m ²)	Tuber no. per m ²	Tuber no. per plant	Mean tuber weight (g)
50	26.9	962 b	25 a	28.2 a
100	29.4	1213 a	16 b	24.2 ab
150	29.2	1380 a	14 b	21.0 b
Mean	28.5	1185	18	24.5
LSD (P<0.001)	ns	212	6	4.1

Means in a column followed by the same letter are not statistically different.

Table 6.5. Effect of density of plants grown from TPS on tuber size distribution as a percentage^a of total tuber number per m² during the dry season.

No. plants per m ²	> 50 g	30-50 g	10-30 g	< 10 g
50	17 a	16	25	42 b
100	15 ab	17	21	47 ab
150	12 b	16	20	52 a
	**	ns	ns	*

^aStatistical analysis carried out on arcsin transformed data.

ns = not significant, * = significant at P<0.05, ** = significant at P<0.01

Means in a column followed by the same letter are not statistically different.

6.4. Discussion

Comparison of seedling tuber yields in both seasons shows that total tuber yields in terms of weight and number per m², number of tubers per plant and mean tuber weight was

lower in the rain than in the dry season. The lower tuber yields in the rain season appear to result mainly from the low light intensity caused by the frequent cloudy weather and late blight (*Phytophthora infestans*) pressure, and a shorter growing period.

Increasing plant density in a seed bed reduced the rate of surviving plants at harvest. Averaged over the two seasons, at a density of 50 plants per m², 86 % of the plants survived compared to 71 % at 150 plants per m². Competition for light could be one of the possible reasons for the low plant survival rate at closer spacings. TPS seedlings also start to die earlier at high plant populations than at low populations (Wiersema, 1984). Therefore, it can be assumed that the natural selection pressure for competitive and vigorous plants was considerably higher in plots with 150 plants per m² than those with 50 plants per m². It is also important to emphasize that a plant population of 150 plants per m² made it difficult to implement the routine seed bed cultural practices such as weeding, fertilization, hilling up, etc. during the growing period, without damaging the seedlings, which could eventually reduce the rate of surviving plants at harvest.

There was no significant interaction between TPS progenies and plant densities. The similar response of the TPS progenies to the increasing plant densities was not in agreement with the findings of Vander Zaag *et al.*, (1990) where the response of potato plants to different population densities under field conditions was influenced by cultivar. The hybrid progeny was superior to the open-pollinated progeny in total tuber yield and mean tuber weight which was in accord with previous results (Macaso-Khwaja & Peloquin, 1983; Kidanemariam *et al.*, 1985). But the total tuber number of the OP was either higher or similar to the hybrid progeny. The advantage of an OP progeny is that TPS production does not require hand pollination, and therefore, the cost of producing OP seeds is considerably lower than that of the hybrid seeds.

Total tuber number per m² increased, without influencing total tuber yield per m², at a closer spacing. Similarly, in the glasshouse, minituber yield per m² was not influenced by plant densities ranging from 50 to 800 plants per m² whereas the minituber number increased at higher plant densities (Lommen & Struik, 1992). The positive effect of high plant density on total tuber number appears to result from a fast canopy cover resulting in more light interception and a higher natural selection for vigorous plants. Under field conditions in a normal crop, intercepted radiation was highly correlated with fresh tuber yield when plant density varied (Vander Zaag *et al.*, 1990). The increase in total tuber

number, without affecting the total tuber yield, as the plant density increases resulted in a lower mean tuber weight confirming field results of Bremner & Taha (1966) and Vander Zaag & Demagante (1987). Tuber number per plant was significantly reduced with a closer plant spacing. Similar effects of density on tuber number per stem were observed using in vitro propagated plantlets in the glasshouse (Lommen & Struik, 1992), in the seed bed (Wiersema, 1986) and in the field (Bremner & Taha, 1966; Wurr, 1974) although not always (Vander Zaag *et al.*, 1990).

When tuber size distribution is considered, the positive effect of increasing plant density on total tuber number was mainly due to an increase in the number of smaller (<10 g) tubers (Tables 6.3 and 6.5). During the growing period, as some of the small and weak plants in the high density plots get eliminated in the process of competition, they may have already formed small tubers thereby increasing the total number of tubers at harvest. Since the proportion of number of tubers < 10 g increased and that of > 50 g decreased with increasing plant population density, there seems to be a negative effect of high plant density on these two tuber size categories. The percentage of number of tubers 10 - 30 g and 30 - 50 g was either reduced or not affected as the plant spacings became closer. Therefore, a higher plant population has the advantage of producing a higher percentage of number of tubers weighing < 10 g which could be either multiplied further in the field or directly used as a seed source for subsequent seasons.

Plant density did not influence the TDM %. This was not in agreement with field results of Wurr & Allen (1974) where high stem densities produced tubers with higher tuber dry matter contents than similar-sized tubers from low stem densities.

Practical implications: When TPS seedlings are grown in a seed bed, the experience is that production of seedling tubers for seed rather than ware is expected to become more widely adopted. Therefore, the total number of seedling tubers that can be produced per m² is of great importance when we consider to use the tubers as a source of seed potatoes for subsequent seasons. Averaged over all densities, there was an increase of 61 % and 179 % in total tuber number and mean tuber weight respectively in the dry over the rain season. And considering the extra expenses incurred in controlling late blight (*Phytophthora infestans*) during the rain season, in the highlands of Ethiopia, seedling tubers should be produced during the dry season.

The experimental results indicated that increasing plant density in a seed bed had a positive effect on the total seedling tuber number. The optimum plant population to be adopted, however, seems to be mainly determined by seed bed agronomic considerations and the extent to which the higher plant populations can affect the total tuber number. The production of a maximum number of seedling tubers in seed bed requires a practical and efficient agronomic nursery management practices. The nursery management of the experimental plots with the highest plant population density of 150 plants per m² was associated with problems in weeding, fertilization and hilling operations which often resulted in plant damages. Moreover, considering the fact that plant densities of 100 and 150 plants per m² did not result in significant differences in total tuber number, a plant density of 100 plants per m² is suggested to be adequate for the production of a maximum number of up to 1200 seedling tubers per m².

Production of hybrid TPS is much more expensive and technically more demanding than open pollinated seeds. Preliminary results in India, Peru and Chile indicated that the cost of producing 1 kg of hybrid TPS without emasculation varies from 40 to 150 US \$ (CIP, 1984; CIP, 1985; CIP, 1986) compared to 178 to 244 US \$ with emasculation of the flowers of the female plants (CIP, 1986). Thus, the production of hybrid seeds does not seem feasible for the near future at the small-farm level in the tropics. Moreover, based on our experimental results, the open pollinated progeny (*AL 624*) produced either similar or in some cases higher total tuber number per m² seed bed than the hybrid progeny (*AL 624 x CIP 378371.5*). It appears, therefore, that the use of open pollinated TPS for seedling tuber production should be considered by small farmers in the tropics.

The most important consideration in the experiments was the production of a maximum number of seedling tubers, not ware potatoes, to be used as a seed source for subsequent growing seasons. The experiences in Taiwan (Tsao & Chang, 1982) and China (Song, 1984) also suggest that TPS seedlings are difficult to use for direct ware production. This conclusion was mainly based on works done under field conditions where early seedling establishment is difficult, disease and insect pest attacks are more prevalent and the seedling tuber yield is very low with a high proportion of small seedling tubers. The seed bed scenario is different. In the seed bed, all the adverse field conditions could be easily controlled or managed. Based on the results of the experiments, by growing TPS seedlings in a seed bed during the dry season and with appropriate agronomic practices,

there is a potential of producing seedling tubers for seed as well as ware potatoes. In our experimental plots, the proportion of number of tubers > 30 g produced in the dry season suggest that there may be a prospect of using some portion of the first generation seedling tubers as ware potatoes. Averaged over all densities, 31 % of the total tuber number produced in the dry season are tubers weighing > 30 g compared to only 6 % in the rain season. Tuber size of > 30 g is acceptable for consumption as potato consumers in developing countries generally accept tubers \geq 20 g (Wiersema, 1986). Alternatively, the smaller tuber grades (<30 g) can be a useful source of seed potatoes for the following generations as evidenced on experimental (Wiersema & Cabello, 1986) as well as farmers' fields (Rhoades, 1985). Provided care is taken during the early crop establishment in the field, tuber yield of plants grown from even small (<10 g) seedling tubers equals to those from large size tubers (CIP, 1983).

References

- Bremner, P. M. & M. A. Taha, 1966. Studies in potato agronomy. I. The effects of variety, seed size and spacing on growth, development and yield. *Journal of Agricultural Science* 66: 241 - 252.
- CIP, 1982. Annual Report. Centro Internacional de la Papa, Lima, Peru.
- CIP, 1983. Annual Report. Centro Internacional de la Papa, Lima, Peru.
- CIP, 1984. Annual Report. Centro Internacional de la Papa, Lima, Peru.
- CIP, 1985. Annual Report. Centro Internacional de la Papa, Lima, Peru.
- CIP, 1986. Annual Report. Centro Internacional de la Papa, Lima, Peru.
- Ifenkwe, O. P. & E. J. Allen, 1978. Effects of row width and plant density on growth and yield of two maincrop potato varieties. 2. Number of tubers, total and graded yield and their relationships with above ground stem densities. *Journal of Agricultural Science* 91: 279 - 289.
- Kidanemariam, H. M., G. C. Arndt, A. C. Macaso-Kwaja & S. J. Peloquin, 1985. Comparison between 4x x 2x hybrid and OP true potato seed families. *Potato Research* 28: 35 - 42.

- Lommen, W. J. M. & P. C. Struik, 1992. Production of potato minitubers by repeated harvesting: Effects of crop husbandry on yield parametres. *Potato Research* 35: 419 - 432.
- Macaso-Khwaja, A. C. & S. J. Peloquin, 1983. Tuber yields of families from OP and hybrid true potato seed. *American Potato Journal* 60: 645 - 651.
- Rhoades, R. E., 1985. Traditional potato production and farmers' selection of varieties in eastern Nepal. Potatoes in food systems research series, Report No. 2, CIP, Lima, Peru, 52 pp.
- Sadik, S. 1983. Potato production from true seed - Present and future. In: W. G. Hooker (Ed.), Research for the potato for the year 2000. CIP, Lima, Peru. pp. 18 - 25.
- Song, B., 1984. Use of true potato seed in China. *CIP Circular* 12 (2): 6 - 7.
- Tsao, S. J., 1985. Studies on the field use of potato true seeds in tuber production. *Journal of Agricultural Research of China* 32: 341 - 347.
- Tsao, S. J. & Y. M. Chang, 1982. Studies on potato production by true seed. In: Hsieh & Liu (Eds.), Proceedings of a symposium on plant breeding, 23 - 24, September, 1981, Taichung, Taiwan, pp. 233 - 240.
- Vander Zaag, P. & A. L. Demagante, 1987. Potato (*Solanum* spp.) in an isohyperthermic environment. I. Agronomic management. *Field Crops Research* 17: 199 - 217.
- Vander Zaag, P., A. L. Demagante & E. E. Ewing, 1990. Influence of plant spacing on potato morphology, growth and yield under two contrasting environments. *Potato Research* 33: 313 - 323.
- Wiersema, S. G. 1984. The production and utilization of seed tubers derived TPS. Ph.D. thesis, University of Reading, CIP, Lima, Peru. 229 pp.
- Wiersema, S. G., 1986. The effect of density on tuber yield in plants grown from true potato seed in seed beds during two contrasting seasons. *American Potato Journal* 63: 465 - 472.
- Wiersema, S. G. & R. Cabello, 1986. Comparative performance of different-sized seed tubers derived from true potato seed. *American Potato Journal* 63: 241 - 249.

Wurr, D. C. E., 1974. Some effects of seed size and spacing on the yield and grading of two maincrop potato varieties. I. Final yield and its relationship to plant population. *Journal of Agricultural Science* 82: 37 - 45.

Wurr, D. C. E. & E. J. Allen, 1974. Some effects of planting density and variety on the relationship between tuber size and tuber dry matter percentage in potatoes. *Journal of Agricultural Science* 82: 277 - 282.

CHAPTER 7

GENERAL DISCUSSION

CHAPTER 7

GENERAL DISCUSSION

In this chapter the main research findings and the application of TPS technology are discussed. Different methods of potato production and multiplication systems are described; the potential alternatives of improving the multiplication rate in the production systems are also discussed. A brief description of the status of TPS in the farming systems of two countries and of its potential in other developing countries is given. The future line of investigation in TPS in Ethiopia is also indicated.

7.1. Production of high quality TPS

The quality of TPS produced is one of the important components in the success of true potato seed technology for potato production in the developing countries. In general, quality seed has a high germinability and will produce uniform and vigorous seedlings under various environmental conditions (Dickson, 1980). The potential of utilization of TPS seems to be mainly in the cool highlands and hot tropical areas where in most cases a seed potato production, certification and distribution system does not exist. Therefore, production of good TPS quality which has high germinability and ability to produce vigorous seedlings in the seed bed or in the field under the adverse environmental conditions of the tropics is essential.

Field management practices during TPS production such as availability of high level of nitrogen is generally associated with the production of vigorous seed (Gray & Thomas, 1982, Soffer & Smith, 1974). The results reported in **chapter 2** indicated that nitrogen did not affect the total germination percentage of either the open pollinated or the hybrid progeny. Only the coefficient of velocity (CoV) of the open pollinated progeny was positively influenced by increasing the nitrogen level. However, it should be realized that the increase in seed quality by adding nitrogen has to be sufficiently high to justify higher production costs that should be incurred by the grower. In Ethiopia TPS technology has not been extended or transferred to the farmers. Moreover, fertilizer costs are high and farmers have the tradition of applying fertilizers to crops such as tef (*Eragrostis tef*) and wheat (*Triticum*

aestivum) which they think are of high value. Therefore, it seems unlikely that nitrogen fertilization to improve TPS quality will be adopted by farmers. Other alternative and affordable cultural practices for the production of high quality seed such as optimum environmental condition, stage of berry maturity, storage conditions, etc. should be identified.

7.2. Breaking of TPS dormancy

The length of the dormancy period depends on the type of the TPS progeny. For example, TPS of *AL 624* can stay dormant 2 - 3 months whereas some progenies remain dormant for 6 months (pers. experience). The problem of dormancy in TPS has traditionally been solved by gibberellic acid (GA_3) treatment. The research results in **chapter 3** have also indicated that under laboratory conditions, treating freshly harvested TPS with 1000 - 1500 ppm GA_3 for 8 h breaks dormancy and enhances germinability. Compared with the other chemicals tested (in **chapter 3**), GA_3 is the most expensive and may not be readily available in places where TPS technology is intended to be applicable or where it has the potential for adoption. It has also been demonstrated that young TPS seedlings that are induced to germinate with GA_3 are not vigorous in the field (CIP, 1991). Our experimental results have indicated that about 70 % germination can be reached by just soaking the seeds in water for 24 h. For the farmers in the tropics, where they do not have access to chemicals, treating the dormant seeds with water is the cheapest and most practical method of breaking dormancy. The germinability of the water treated seeds is lower than GA_3 treated seeds, but this could be compensated probably by its better seedling vigour and performance in the seed bed or the field. The field or nursery performance, in terms of germinability, seedling survival and vigour, of the TPS treated by different chemicals need further investigation.

7.3. Seedling tuber production

7.3.1. Seasons

Under the tropical growing conditions, seedling tubers are mainly intended to be used as seed potatoes for subsequent seasons. Tuber yield parameters should be manipulated by choosing the appropriate season and nursery management in such a way that a maximum number of

useable tubers is produced. In the central highlands of Ethiopia, there is a potential for small farmers to produce seedling tubers in nurseries during both the rain and dry season. The research results in **chapters 5 and 6** have indicated that total tuber yields in terms of weight and number per m², number of tubers per plant and mean tuber weight were higher in the dry season than in the rain season. In the nursery, there was an average increase of 61 % in total tuber number per m² in the dry season over the rain season. The low yield during the rain season could be attributed to the problem of seedling establishment, high late blight pressure, cloudy weather and shorter growing period. In the dry season, availability of irrigation water can pose a major problem. However, seed beds can be established along small streams and rivers on which traditionally farmers depend to raise vegetable seedlings.

As it has been indicated in **chapter 4**, under the highland conditions of Ethiopia, field production of seedling tubers in the dry season also seems to have some future prospect. On a research level a mean tuber yield of 31 and 46 tons per hectare can be attained using open pollinated and hybrid progenies, respectively. This yield is much higher than the national average yield (5.8 t/ha). In the rain season, most of the transplanted seedlings are wiped away by late blight at their establishment period. The yield of most open pollinated and hybrid progenies is less than 5 tons/ha.

7.3.2. Progenies

Generally, hybrid progenies are superior to open pollinated progenies in terms of total tuber yield (Macaso-Khwaja & Peloquin, 1983; Kidanemariam *et al.*, 1985). The results of the nursery experiments have confirmed this in that the hybrid (*AL 624 x CIP 378371.5*) gave a significantly higher total tuber yield and mean tuber weight than the open pollinated progeny (*AL 624*). However, when the purpose is to utilize seedling tubers as seed potatoes for subsequent seasons, the number of seedling tubers above a certain minimum grade is more important than tuber yield. Results of the nursery experiments (**chapters 5 and 6**) showed that the total seedling tuber number per m² seed bed of the open pollinated progeny was either higher or comparable to that of the hybrid progenies. Moreover, the economic yield of the open pollinated progenies could be substantially higher because of the higher costs involved in producing hybrid seeds.

7.3.3. Field vs Nursery

Seedling tubers can be produced either in the field or in the nursery. Under the highland conditions of Ethiopia, direct seeding of TPS in the field was not successful mainly due to poor soil conditions and poor land levelling which is partly caused by the slopy nature of the terrain. As a result the germination is poor, not uniform and seedling survival is low. Transplanting seedlings into the field, however, seems to have some potential of producing seedling tubers. As it has been indicated in **chapter 4**, in the dry season, a mean tuber number of 137 and 153 per m² can be produced by transplanting into the field using open pollinated and hybrid progenies, respectively. The yield of some open pollinated progenies such as *AL 417* and *AL 601* was in the range of 200 - 235 seedling tubers per m². With systematic and proper selection of progenies which have high TPS germination rate and seedling survival in the field after transplanting, and with better field management, the seedling tuber yield can be much more higher than this.

One obvious advantage of using transplants into the field is that it allows to select and transplant only the most vigorous and healthy looking seedlings. Since the main purpose is to produce seed tubers, it allows farmers to improve the quality of seedling tubers by upgrading the field management practices. Simple selection methods, such as roguing out of plants with virus symptoms and selection of tubers at harvest would improve the quality of the seedling tubers (Fig. 7.1, system B; for explanation see p. 106). In China, for example, in areas with low level of virus infection, field selection of transplanted seedlings produced better quality seedling tubers than the virus infected and unselected seedlings (Li & Shen, 1979). At Holetta Research Center also, by roguing out virus-like symptoms in the field, the yield of *Sissay*, a cultivar grown by some farmers, has substantially increased in the subsequent generations. When compared with nursery, field production of seedling tubers has, however, some disadvantages: (a) the field preparation and management costs in terms of labour, chemicals, irrigation, etc. are high; (b) it is not easily manageable because of the relatively larger acreage; (c) the seedling tuber yield is low.

When the field growing conditions such as soil and land levelling, irrigation water and length of growing period are not suitable for the production of healthy seedling tubers, seedling tuber production in the nursery would be appropriate. Using an appropriate TPS progeny of which the seeds have good quality in terms of total germinability, and with an optimum seed bed substrate, plant density and fertilization, there is a potential of producing

up to 1200 or 29 kg seedling tubers, by number and by weight respectively, per m² seed bed (chapter 6). Based on these research results, with an appropriate nursery management, a seed bed of 40 m² can produce sufficient seedling tubers to plant a hectare of land. Seedling tuber production in the nursery, as compared to the field, has several advantages: (a) there is a possibility of producing seedling tubers with at least 2 crops per year because it does not depend on the growing season; (b) seed bed preparation and management costs such as labour, chemicals, irrigation, etc. are low; (c) it is easily manageable because of the smaller area required; (d) the seedling tuber production per unit area is much higher than in the field; (e) all the agronomic practices such as weeding, irrigation, fertilization, etc. can be easily managed; (f) relatively healthier seedling tubers can be produced since the growing conditions can be controlled better in the nursery than in the field.

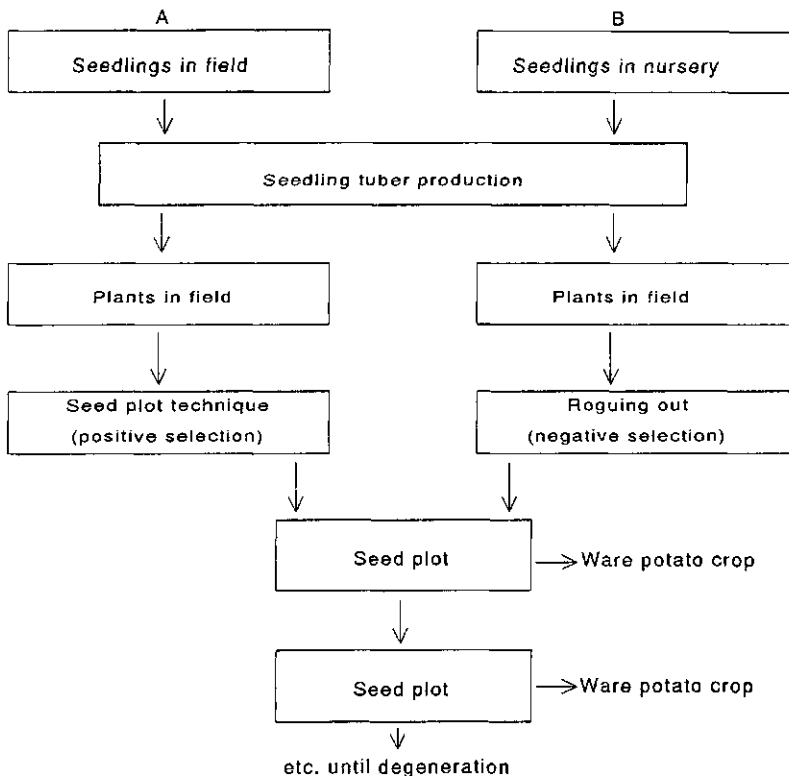


Fig. 7.1 Alternative systems of improving the quality of seedling tubers produced either in the field (A) or in the nursery (B).

The health standard of the seedling tubers produced in the field or in the nursery can be easily improved further in the field in the subsequent years. There are two simple and appropriate alternative methods (Fig. 7.1 systems A and B) of improving the quality and health standard of the seedling tubers: (A) *The "on-farm seed improvement by the potato seed plot technique"* (Bryan, 1983): This is essentially a positive selection. The principle of the technique is improving the farmer's seed stock by selecting the best plants from a current crop, at harvest storing the seed potatoes from these selections separately, and using them the following season to plant the seed plot. The process is repeated each cropping season by selecting the best plants from the current seed plot for the new seed plot. The remaining tubers of the current seed plot are used as seed for the farmer's ware potato crop.

(B) *Roguing out of plants with virus symptoms*: This is basically a negative selection. Plants which are infected with virus-like symptoms are identified, staked and removed from the field. The roguing can be carried out throughout the season at regular intervals. At harvest, the tubers to plant the seed plot for the following season are stored separately. The remaining tubers from the unmarked plants of the current seed plot are used as seed for the farmers' ware potato crop. The process of roguing out of diseased plants is repeated each cropping season until the crop starts degenerating. This method was proven to be useful at the Holetta Research Center where the yield of *Sissay*, a cultivar grown by some farmers, has substantially improved by roguing out plants infected by virus-like symptoms for only one cropping season (B. Lemaga, pers. comm.).

7.3.4. Nursery management

Seedling tuber production in the nursery requires the identification of an appropriate substrate in terms of its availability, fertility level and probably price. The experimental results in **chapter 5** indicate that a substrate with a high proportion of organic matter is essential. The appropriate substrate which can give a maximum number of seedling tubers was a mix of 50 % forest soil and 50 % manure. This substrate has 20 % organic matter. The cattle manure which was collected from outdoor grazing animals had low salt concentration and the high proportion of manure used did not appear to damage the seedlings. Usually cattle manure and chicken manure from intensive feed lots would pose problems of high salt concentration (Wiersema, 1984). Peatmoss and horse manure with low toxic elements and salt concentration are also reported to be good sources of organic matter (Wiersema, 1984).

However, peatmoss is not readily available to farmers and horse manure will not be available in an amount large enough to be used as a substrate either. A seed bed substrate can be used for several growing seasons. Therefore, disinfecting it with chemicals such as quintazone would be required. Sometimes chemicals may either be not available or expensive. Therefore, steam treatment, using an open-drum method (Fig. 7.2), seems to be more practical and cheaper than treating with chemicals. It is a local method where the top cover of the drum or barrel is removed, small nail-size holes are made and welded half way length wise from inside part of the barrel. The barrel is partly filled with water and substrate is put on top of the cover. As the water is heated, the steam escapes through the small holes and sterilize the substrate. At one time a substrate volume of 0.35 - 0.40 m³ can be sterilized. This method was found useful and practical under the conditions of the Holetta Research Center in Ethiopia. The only disadvantage of using this method is that the substrate has to be removed from the seed bed when it has to be treated.

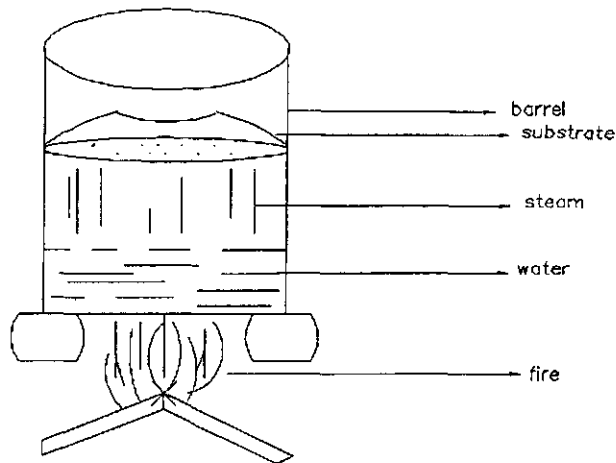


Fig. 7.2 Substrate treatment using an open - drum method.

Because of the high seedling density used in the seed bed, and since the potato crop from TPS seedling is of a longer duration, its fertilizer requirement is likely to be different from a crop grown from normal seed tubers. Young TPS seedlings are sensitive to high salt concentration (Wiersema, 1984). Therefore, it may not be advisable to apply all the required

amount of fertilizer at planting or transplanting. The nursery experimental results in **chapter 5** have indicated that a split-application of 40 - 80 g of N per m² increased the seedling tuber yield. The spreading of the N fertilizer application throughout the growing period is likely to improve the fertilizer uptake efficiency because of low losses of nutrients through leaching.

Direct seeding of TPS in the field is unlikely to be feasible in the future (Martin, 1983). This may be more so in the underdeveloped countries where the land preparation and field management practices are poor. Early seedling growth is very sensitive to the harsh biotic and abiotic conditions in the field. However, when TPS are directly sown in the seed bed, most of the biotic problems and management practices such as mulching, shading, weeding, irrigation, fertilization, hilling up, etc. are better controlled and managed than in the field. It is also cheaper in terms of its labour requirement. When thinning to the desired seedling density, the weak seedlings can also be removed, thereby increasing the proportion of vigorous seedlings, and as a result the seedling tuber yield at harvest. Moreover, thinning reduces the heterozygosity of the population especially in the open pollinated lines (Wiersema, 1984).

There is a possibility of producing seedling tubers by either direct seeding or transplanting to the seed bed. At the Holetta Research Center, establishment of TPS seedlings on a seed bed by direct seeding and transplanting were compared during the rain and dry seasons. Method of seedling establishment in the seed bed did not affect tuber yield and tuber yield components (B.T. Tuku, unpublished).

In the nursery experiment, the tuber yield per m² seed bed was not influenced by the seedling density (**chapter 6**). However, the tuber number substantially increased as the seedling density increased. Plant density also affected the seedling tuber size distribution. Therefore, seedling population in a nursery can be considered as a method by which seedling tuber number and size can be manipulated. Increasing seedling density in a seed bed had a positive effect on the total seedling tuber number. However, the optimum seedling density to be maintained is dictated by the agronomic considerations and the effect to which the higher seedling populations can positively affect the total tuber number. Even though the highest seedling density of 150 plants per m² resulted in a maximum number of seedling tubers, it was associated with problems in weeding, fertilization and hilling operations which often resulted in plant damage. Therefore, 100 plants per m² was found to be the optimum

density.

7.4. Potato production and multiplication systems

In this section, schemes for a conventional method of potato production in the field and seedling tuber production in the nursery, and their respective multiplication rates are discussed. Two systems of potato production and multiplication schemes, depending on the nature and condition under which it is grown or multiplied, can be identified.

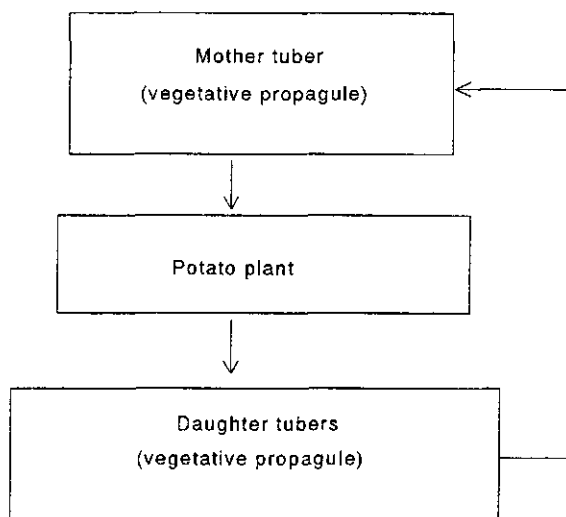


Fig. 7.3 A scheme of a conventional method of potato production.

7.4.1. Conventional method of potato multiplication in the field.

The scheme starts with a vegetative propagule (mother tuber) and ends up with a vegetative propagule (Fig. 7.3). It starts with five mother tubers per m^2 each producing a plant (Fig. 7.4). After one generation, 48 tubers per m^2 are produced. Therefore, the multiplication rate is:

$$\text{Multiplication rate} = \frac{\text{No. of tubers harvested per } m^2}{\text{No. of tubers planted per } m^2} = 48/5 = 9.6$$

There is a potential of improving the multiplication rate. Stem density (number of stems per m^2) can be increased by improving the number of sprouts planted per m^2 , the planting method (less sprout damage) and soil conditions. These, in turn, will increase the number of harvestable tubers per m^2 and as a result the multiplication rate. There is also the possibility of increasing the number of tubers per stem and the proportion of harvestable tubers by appropriate fertilization and irrigation methods.

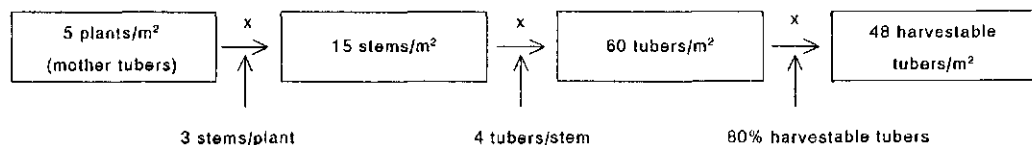


Fig. 7.4 Assumptions made in the scheme of a conventional method of potato production.

7.4.2. Seedling tuber production in the nursery

In this section, a seedling tuber production scheme and its multiplication rate are discussed. The scheme has a generative phase in the field and a vegetative phase in the nursery (Fig. 7.5).

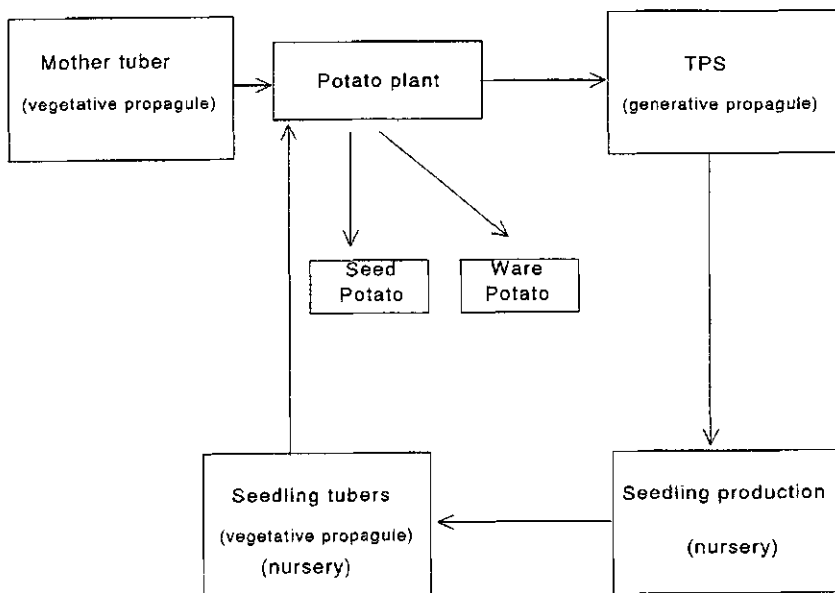


Fig. 7.5 A scheme of seedling tuber production in the nursery.

Agronomic practices in the field and the environmental conditions under which the mother plants are grown can influence the quality of the TPS produced. In the nursery, seed bed management practices, as indicated by the experiments, would also determine the number of seedling tubers that can be produced per m² seed bed. However, in the seedling tuber production scheme in Fig. 7.5, some theoretical assumptions are made as shown in Fig. 7.6.

The scheme has two phases (Fig. 7.5). The first phase is in the field where it starts with four mother tubers (a vegetative propagule) per m² and after one generation or growing season, it produces TPS (a generative propagule). In the second phase, TPS is sown in the nursery for seedling tuber production. Therefore, after one generation in the field and one in the nursery, the four mother tubers per m² initially planted in the field will produce 9360 seedling tubers. The multiplication rate is, therefore, 2340 (9360/4) after two seasons, compared to 92.2 (9.6²) in the case of the conventional method of vegetative reproduction.

In this system there is also a potential of improving the multiplication rate. Firstly, the selection of TPS progeny which flowers profusely, and produce fertile flowers and pollen is critical for an increased percentage of berry set. Secondly, using a well prepared seed bed and an appropriate substrate, the seedling emergence and survival rate can be improved. Thirdly, using an appropriate seed bed substrate, plant density and fertilizers, the number of seedling tubers produced per m² can significantly be increased, thereby, increasing the multiplication rate.

7.4.3. Seedling tuber production in the nursery under Ethiopian conditions

The potential of seedling tubers produced in the seed bed has been discussed in length in the previous chapters. It is not intended to revolutionize and replace potato production using normal clonal tubers. It can only be considered as an alternative in places where there is the absence of healthy and large quantities of seed potatoes.

The scheme of seedling tuber production in the nursery in Fig. 7.5. is considered to fit into the Ethiopian potato growing conditions. However, on the basis of the research results, the local growing conditions and the existing field management practices in the central highlands of Ethiopia, some of the assumptions made in the system (Fig. 7.6) are modified to fit into the Ethiopian condition, as shown in Fig. 7.7. There are some potato varieties that flower profusely, but the percentage of berry set is low (25%). Moreover, about 25 % of the berries abscise either naturally or mechanically by field workers during field operations such

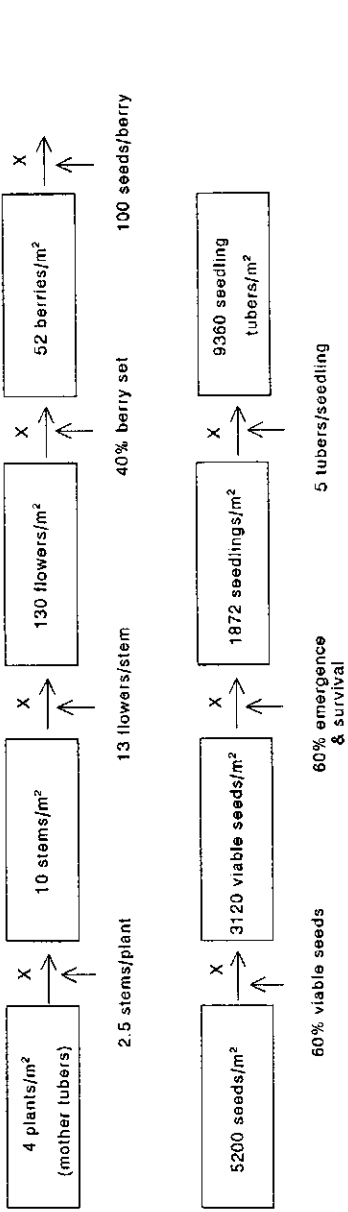


Fig. 7.6. Assumptions made in the scheme of seedling tuber production in the nursery under normal conditions.

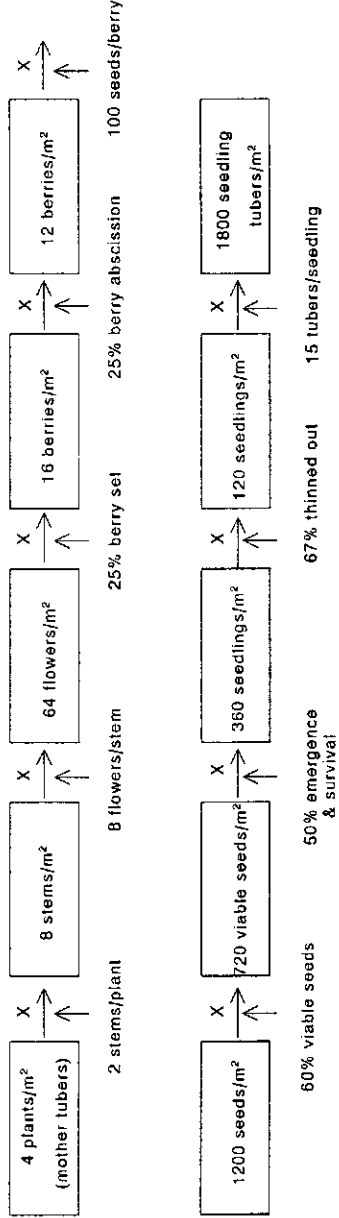


Fig. 7.7. Assumptions made in the scheme of seedling tuber production in the nursery under the Ethiopian conditions.

as irrigation. Therefore, the number of flowers and berries per m² is generally lower than what is assumed in Fig. 7.6.

The experimental results in chapter 3 indicated that dormancy of TPS can be effectively broken by soaking in 1000 - 1500 ppm GA₃ for 8 h. However, GA₃ is expensive and it is not readily available in Ethiopia. Therefore, in the scheme soaking of TPS in water for 8 h is considered as a cheap and realistic alternative to break the dormancy and maintain 70 % germination. Under the seed bed condition the seedling emergence will, therefore, be lower than 70 %. Both the poor berry setting and berry abscission, and the breaking of dormancy with water will eventually reduce the total number of viable seedlings that can be produced per m².

In the nursery, a seedling population of 100 per m² will be maintained. At this density, none of the nursery management practices are hindered and the tuber number per m² is substantially high. Three seeds per plant position are directly sown. The number of seeds required per m² seed bed is, therefore, 300 of which 67 % of the seedling are thinned out.

For all practical purposes, the number of plants per m² was taken as four. The multiplication rate is, therefore, 450 (1800/4). After one generation in the field and one in the nursery, seeds collected from a single plant in the field can produce 450 seedling tubers in the nursery. These seedling tubers can be used as seed or ware potatoes.

7.5. Transfer of TPS technology

The potential of TPS as an alternative for potato production has been realized in the mid eighties in Ethiopia with some encouraging results obtained by the Alemaya Agricultural University and lately by the Institute of Agricultural Research, Ethiopia. However, the TPS technology has not been studied under farmers' conditions to see how it fits into the local farming system. And thus the technology has not been transferred to the farmer yet.

It seems that there may be a potential of adoption of TPS technology in the highlands of Ethiopia because (a) good quality seed potatoes are not available to the farmer and seedling tubers could be a realistic alternative; (b) there is already a tradition of vegetable growing using transplants by small farmers in areas where there are small streams and rivers; (c) family labour can be available during the dry season when the seedling tuber is intended to be produced.

There are no reliable data on the acreage under TPS production or the extent to which the technology has been transferred to the farmers in Ethiopia. Therefore, as an example, a very brief description of the status of TPS in practice in The People's Republic of China and Egypt is presented.

7.5.1. The People's Republic of China

Research on TPS started in China during the late 50's in the Inner Mongolia region (Malagamba & Monares, 1988). It was initiated because of the high incidence of virus diseases which had reduced potato yields. As early as 1978, 1000 kg TPS was shipped from Inner Mongolia to other regions of the country (Umaerus, 1987). Selected farmers produce big quantities of TPS from open pollinated, high yielding and late blight resistant potato varieties. TPS is mainly produced in the mountainous regions of south-west and are distributed to other regions of the country. About 15,000 ha of potatoes are cultivated in China (Bo Fu, 1984). Usually seedlings are raised in seed beds and transplanted to the field for ware potato production. The smaller seedling tubers are kept by farmers as a seed source for the following seasons. The seedling tubers are propagated for 5 - 6 growing seasons before they are being replaced with new seedling tubers (Malagamba & Monares, 1988).

7.5.2. Egypt

In Egypt the seed potato system is based on locally produced tubers and importing seed potatoes from Europe for planting in the winter and spring seasons (Crissman *et al.*, 1991). This is because only 3 % of the total seed potato requirement is produced by the Egyptian seed production programme. The seed potatoes locally produced by farmers are likely to have a low yield potential due to virus build-up. The major research emphasis on TPS has been the production of seedling tubers as an alternative planting material. There is a high adoption potential of TPS due to the rapid progress made in the development of improved progenies and agronomic practices (CIP, 1992). To-date, a private company and many cooperatives are involved in commercial seedling tuber production (Crissman *et al.*, 1991) and a limited amount of seedling tubers produced by the research centers have been distributed to farmers (Sabaa *et al.*, 1991). Production costs for sufficient seedling tubers to plant a hectare were 53 % of the costs to plant one hectare with locally produced seed tubers (El Bedewy & Crissman, 1991).

7.5.3 Potential in developing countries

The brief overview on the status of TPS in practice in the two countries indicates that TPS technology has the potential of being adopted by farmers in developing countries. The fact that the national seed programmes cannot supply the farmers with good quality seed potatoes in large quantities is the main reason for its potential of being extended to small farmers in the future.

The development of improved progenies and appropriate agronomic practices by CIP and other -local- research institutes also seems to have contributed to the increased interest in the TPS technology. This trend, I believe, will continue for the future in the developing countries where either good quality seed potatoes are not available or seed potato costs are estimated to constitute 20 - 70 % of the total production costs (Accatino & Malagamba, 1982; Sadik, 1983; Rashid, 1987; Malagamba & Monares, 1988). Currently, there are several on-farm evaluation of the TPS technology in Bangladesh, India, Indonesia, Nicaragua, Rwanda, Paraguay and Sri Lanka.

7.6. Future research on TPS in Ethiopia

There are few areas in TPS that should be researched on so that the technology can be developed and adopted by the farmer as a package.

7.6.1. Selection of TPS progenies

Varietal development is one of the main objectives of the Ethiopian Potato Improvement Programme. Yield and disease resistance are the major criteria used in selecting the varieties. Not all potato varieties do flower or set berries under the highland conditions. Therefore, flowering, berry setting and TPS production could also be considered as one criterion in varietal development. This will enable the farmer to get high tuber yield and at the same time harvest a better TPS yield from the selected varieties.

7.6.2. Storability of seedling tubers

Storing seed potatoes under diffused light storage (DLS) conditions have been found to be a cheap and suitable method in CIP (Booth *et al.*, 1983). This technology has also been verified under farmers condition in Ethiopia. Because of their large ratio of skin surface area

to volume, seedling tubers are expected to lose relatively more water during storage in DLS per unit weight. However, information on their storability, compared with clonal seed potatoes, will indicate on how they should fit to the potato production calendar and the local farming system.

7.6.3. Socio-economic study of producing seedling tubers

Once the seedling tuber production scheme have been developed and verified that it fits into the local farming conditions, a socio-economic evaluation of the scheme would be required to see how it competes with other methods of producing planting material. In Egypt, for example, costs for sufficient seedling tubers to plant a hectare were about 53 % of the costs to plant a hectare with locally produced seed potatoes (El Bedewy & Crissman, 1991). The socio-economic study will also provide scientists with new information on certain production problems that require further improvement, and formulate recommendations appropriate for small scale farmers.

References

- Accatino, P. & P. Malagamba, 1982. Potato production from true seed. CIP Bulletin. Lima, Peru, pp. 20.
- Bo Fu S., 1984. Use of true potato seed in China. *CIP Circular* 12 (2); 6 -7.
- Booth, R. H., R. L. Shaw & A. T. Yupanqui, 1983. Use of natural diffused light for storage of seed tubers. In: W. J. Hooker (Ed.). *Research for the year 2000*. CIP, Lima, Peru. pp. 665 - 666.
- Bryan, J. E., 1983. On-farm seed improvement by potato seed plot technique. Technical Information Bulletin 7. CIP, Lima, Peru. 11 pp.
- CIP, 1991. Annual Report. Centro Internacional de la Papa, Lima, Peru.
- CIP, 1992. Annual Report. Centro Internacional de la Papa, Lima, Peru.
- Crissman, C., El Bedewy R., Sabaa, M. F. & Sharaf M. F., 1991. Agro-economic evaluation of different types of potato planting materials in Egypt. Working paper series No. 1. CIP, Lima, Peru. 22 pp.

- Dickson, M. H., 1980. Genetic aspects of seed quality. *HortScience* 15: 771 - 773.
- El Bedewy, R. & Crissman, C., 1991. Cost of seedling tubers produced from true potato seed: An estimate based on experimental production in Egypt. Working paper series No. 3. CIP, Lima, Peru. pp. 10.
- Gray, D. & T. H. Thomas, 1982. Seed germination and seedling emergence as influenced by the position of the development of seed on, and chemical application to, the parent plant. In: A. A. Khan (ed.). *The physiology and biochemistry of seed development, dormancy and germination*, Elsevier, New York. pp. 81 - 110.
- Kidanemariam, H. M., G. C. Arndt, A. C. Macaso-Khwaja & S. J. Peloquin, 1985. Comparison between 4x x 2x hybrid and OP true potato seed families. *Potato Research* 28: 35 - 42.
- Li, C. H. & C. P. Shen, 1979. Production of marketable seed potatoes from botanical seed in the People's Republic of China. In: *The planning conference on the production of potatoes from true seed*. Manila, Philippines, 13 - 15 September, 1979, CIP, Lima, Peru, pp. 21 - 28.
- Macaso-Khwaja, A. C. & S. J. Peloquin, 1983. Tuber yield of families from OP and hybrid true potato seed. *American Potato Journal* 60: 645 - 651.
- Malagamba, P. & A. Monares, 1988. True potato seed: past and present uses. CIP, Lima, Peru. pp. 11 - 17.
- Martin, M. W. 1983. Techniques for successful field sowing of true potato seed. *American Potato Journal* 60: 245 - 259.
- Rashid, M. M., 1987. Problems of production of TPS in Bangladesh. Proceedings of the workshop on TPS research in Bangladesh. Bangladesh Agricultural Research Institute, Potato Research Center, 17 - 18 August, 1987, pp. 5 - 7.
- Sabaa, M. F., El Bedewy R., Crissman C. & Sharaf M. F., 1991. Agro-economic evaluation of different types of potato planting materials for the spring season in Egypt. Working paper series No. 2. CIP, Lima, Peru. pp. 10.
- Sadik, S., 1983. Potato production from TPS - Present and future. In: W. L. Hooker (Ed.), *Research for the potato in the year 2000*. CIP, Lima, Peru, pp. 18 - 25.

- Soffer, H. & O. E. Smith, 1984. Studies on the lettuce seed quality. V. Nutritional effects. *Journal of American Society of Horticultural Science* 99: 459 - 463.
- Umaerus, M., 1987. True potato seed. Proceedings of the 10th Triennial Conference of the European Association for Potato Research (EAPR), Aalborg, Denmark, 26 - 31 July, 1987. pp. 72 - 102.
- Wiersema, S. G. 1984. The production and utilization of seed tubers derived from TPS. Ph. D. Thesis, University of Reading, CIP, Lima, Peru. 229 pp.

SUMMARY

SUMMARY

The potential of true potato seed (TPS) technology can fully be exploited by the development of appropriate methods of locally producing high quality seeds in terms of their germinability and the availability of cheaper and practical dormancy breaking chemicals. Since TPS are very small, seeds should germinate fast and soon develop vigorous seedlings so as to compete with fast growing weeds.

Nitrogen fertilization to the mother plant affected TPS germinability. The open pollinated (OP) progeny (*AL 624*) had a higher germination rate than the hybrid progeny (*AL 624 x CIP 378371.5*). The results also indicated that the effect of N on germinability was progeny - dependent. Increasing N rates positively affected the germination rate of the OP progeny whereas that of the hybrid progeny was negatively affected without markedly affecting the final germination percentages (FGP).

TPS is dormant for a period of 3 - 6 months. This is one of the constraints to sowing freshly harvested seeds. Different chemicals were tested for their effect on breaking dormancy. The germination rate and the FGP of the two progenies tested were more enhanced by GA_3 than by the other treatments. GA_3 was further investigated to determine the optimum concentration and soaking time. Soaking for 8 hrs in 1000 - 1500 ppm GA_3 can effectively break the dormancy and maintain a higher germination rate and a FGP > 96 %. However, in the absence of any other chemicals, soaking TPS in water can be considered as a cheap and realistic alternative method to break the dormancy and maintain about 70 % germination.

Field experiments were conducted during two contrasting seasons to evaluate the performance of 14 OP and 11 hybrid TPS progenies. During the rain season, the seedling tuber yield of both progeny types was very low mainly due to late blight (*Phytophthora infestans*) pressure. However, the OP progenies gave relatively higher tuber yield than the hybrid progenies. During the dry season, the hybrid progenies were superior to the OP progenies in plant vigour, tuber uniformity and tuber yield. The results, however, indicated that there is a possibility of selecting high yielding progenies from the OP progenies. This

is promising since the production of OP seed is much cheaper than of hybrid seed. The possibility of growing TPS in the field during the rain season does not seem promising without adequate late blight control.

Two nursery experiments were carried out during two contrasting seasons to investigate the effect of seed bed substrate, nitrogen and phosphorus on seedling tuber yield and yield components using an open pollinated TPS progeny *AL 624*. Seedling tuber yield and other tuber yield components were significantly higher in the dry than in the rain season. The lower tuber yield in the rain season is attributed to the high late blight (*Phytophthora infestans*) pressure, short sunshine hrs and a short growing period. Seed beds of 1 x 1 m and 0.25 m depth filled with a substrate mix of 50 % forest soil and 50 % manure were found to be suitable for the production of a large number of seedling tubers by direct sowing methods. During the dry season, as the N rate increased, the total seedling tuber yield, seedling tuber number and the mean tuber yield increased; also the proportion of the large size (> 50 g) tubers increased whereas that of the small size (< 10 g) tubers reduced without influencing the proportion of the intermediate size tubers. In the dry season, P application did not affect seedling tuber yield and other yield components. However, in the rain season, P rates of up to 35 g per m² significantly increased both seedling tuber yield and seedling tuber number. In both seasons, P did not influence tuber size distribution. Based on these results, in the central highlands of Ethiopia, dry season production of seedling tubers in a seed bed substrate mix of 50 % forest soil and 50 % manure, and 40 - 80 g N per m² bed can be recommended. These seedling tubers can be a good source of seed for subsequent multiplications in the field.

By manipulating the seedling population in a seed bed, an optimum plant density can be obtained for the production of a maximum number of seedling tubers. The results revealed that a plant density of 100 plants per m² seed bed was optimal for the production of a maximum number of up to 1200 seedling tubers or a total tuber weight of 29 kg per m² without hampering management operations such as weeding, fertilization and hilling up. Increasing plant density from 50 to 100 seedlings per m² had a positive effect on the proportion of seedling tubers weighing < 10 g, while that of larger seedling tubers (< 50 g) was negatively affected.

The production of seedling tubers in seed beds may partially alleviate the problems of seed potatoes in countries where a seed potato production scheme does not exist. A seed bed of 40 m² can produce sufficient seedling tubers to plant a hectare of land. Production of seedling tubers in a seed bed may also allow at least two crops per year since growing conditions and disease infections can easily be controlled.

The multiplication rate of the conventional method of potato production, after two vegetative phases in the field, is only 92. Contrastingly, the multiplication rate of the seedling tuber production in the nursery under Ethiopian conditions, after one generative phase in the field and a vegetative phase in the nursery, is 450. In both production systems, there is a potential of improving the multiplication rates.

TPS seems to have potential for adoption in areas where healthy seed potatoes are either unavailable or costly, where there is no consumer preference for certain tuber qualities and where farmers have the tradition and experience of growing vegetables.

SAMENVATTING

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De mogelijkheden van de TPS (True Potato Seed; botanisch zaad) technologie kunnen slechts volledig worden benut indien er geschikte methoden zijn ontwikkeld voor de productie ter plekke van zaad van hoge kwaliteit. Bij kwaliteit gaat het vooral om het kiemvermogen van het zaad. Daarnaast moeten er goedkope en praktische methoden beschikbaar zijn om de kiemrust van het zaad te breken. Aangezien botanische zaden van de aardappel zeer klein zijn, is het zeer gewenst dat de zaden snel kiemen en spoedig een zaailing met een groot groeivermogen en een grote concurrentiekracht ontwikkelen.

De stikstofbemesting van de moederplant beïnvloedt het kiemvermogen van het aardappelzaad sterk. *AL 624* (een via open bestuiving - OP - tot stand gekomen nakomelingschap) had een hogere kiemsnelheid dan het hybride (*AL 624 x CIP 378371.5*) nakomelingschap. Uit de resultaten van het onderzoek bleek ook dat het effect van N op het kiemvermogen afhankelijk was van het nakomelingschap. Bij hogere N bemesting werd het kiemvermogen van het OP nakomelingschap verhoogd terwijl bij de hybride juist een verlaging werd geconstateerd. In beide gevallen was er geen sprake van een invloed op de uiteindelijke kiemkracht.

Botanisch zaad is gedurende 1 - 3 maanden in rust. Deze kiemrust maakt benutting van het zaad direct na de oogst onmogelijk. Verschillende chemicaliën werden getest op hun vermogen de kiemrust te breken. Het gibberellinezuur GA_3 bleek de grootste effecten te hebben en werd nader onderzocht teneinde de optimale concentratie en de optimale behandelingsduur te bepalen. Acht uur weken in een oplossing van 1000 - 1500 ppm bleek afdoende om de kiemrust volledig te breken en een hoge kiemsnelheid en een grote kiemkracht te realiseren. Het weken van de zaden in water bleek echter ook reeds een groot positief effect te hebben. Zonder toevoeging van chemicaliën bleek weken in water reeds te leiden tot een kiemkracht van 70 %, terwijl onbehandeld zaad kort na de oogst doorgaans slechts voor ongeveer 5 % kiemt.

In veldproeven gedurende qua omstandigheden zeer onderscheiden teeltseizoenen werden 14 OP nakomelingschappen en 11 hybride nakomelingschappen getest op hun opbrengend

vermogen. Tijdens het regenseizoen was de opbrengst aan zaailingknollen van beide groepen nakomelingschappen zeer laag, vooral vanwege de grote ziektedruk. De OP nakomelingschappen gaven iets hogere knolopbrengsten dan de hybride nakomelingschappen. Tijdens het droge seizoen waren het groeivermogen van de planten, de uniformiteit van de knollen en de knolopbrengsten van de hybride nakomelingschappen echter veel hoger dan die van de OP nakomelingschappen. Uit de resultaten kwam echter wel naar voren dat het mogelijk is hoog-opbrengende OP nakomelingschappen te selecteren. Van dergelijke nakomelingschappen is de zaadproductie veel goedkoper. De teelt van aardappel uit zaad in de volle grond is gedurende het regenseizoen echter niet goed mogelijk zonder inzet van gewasbeschermingsmiddelen.

Gedurende sterk verschillende groeiseizoenen werden experimenten uitgevoerd in kweekbedden om het effect van het substraat, de stikstofgift en de fosforgift op de opbrengst aan zaailingknollen en de opbrengstcomponenten te onderzoeken. Daarbij werd gebruik gemaakt van het OP nakomelingschap *AL 624*. De knolopbrengsten en de verschillende opbrengstcomponenten waren alle hoger in het droge groeiseizoen dan in het regenseizoen, vooral vanwege een lagere ziektedruk, meer zonneschijn en een langere groeiperiode. Kweekbedden van 1 x 1 m en 0.25 m diep, gevuld met een substraat bestaande uit 50 % bosgrond en 50 % organische mest bleken zeer geschikt om bij directe zaai van TPS een zeer hoog aantal knollen per oppervlakte-eenheid van voldoende grootte te produceren. Stikstof bleek gedurende het droge seizoen de totale knolopbrengst te verhogen, zowel door een positief effect op het aantal knollen per oppervlakte-eenheid als door een hoger gemiddeld knolgewicht. Bovendien trad er een verschuiving in de sortering op van de zeer kleine (< 10 g) naar de zeer grote (> 50 g) maten.

De bemesting met P had in het droge seizoen geen effect. In het regenseizoen daarentegen leidde een beperkte P bemesting reeds tot een hogere knolopbrengst, vooral als gevolg van een positief effect op het knolaantal.

Op grond van deze resultaten wordt gesuggereerd in Ethiopië zaailingknollen te produceren in kweekbedden met een substraat bestaande uit 50 % bosgrond en 50 % organische mest, met een extra N bemesting van 40 tot 80 g per m². Deze zaailingknollen kunnen dan vervolgens worden benut voor een vermeerdering in de volle grond.

Uit de proeven met verschillende standdichtheden kwam naar voren dat een dichtheid van 100 zaailingen per m^2 kan resulteren in een produktie van maar liefst 1200 knollen per m^2 en een knolopbrengst van 29 kg per m^2 . Bij een dergelijke dichtheid hoeven nog geen problemen met handmatige verzorging (wieden, bemesten, aanaarden, e.d.) te worden verwacht. Verhoging van de plantdichtheid van 50 naar 100 zaailingen per m^2 resulteerde wel in een verhoging van het aandeel zeer kleine knollen.

Op grond van dit onderzoek kan geconcludeerd worden dat de produktie van zaailingknollen in kweekbedden een goede oplossing biedt voor pootgoedproduktie in landen waarin een centraal geregeld programma van pootgoedproduktie ontbreekt. Op een areaal van 40 m^2 kweekbed kan voldoende pootgoed worden geproduceerd voor een hele hectare. Dit systeem maakt meerdere oogsten per jaar mogelijk omdat de beheersing van de condities en de bestrijding van ziekten veel beter uitvoerbaar zijn dan in het volle veld.

De vermeerderingsfactor bij de conventionele methode van pootgoedvermeerdering bij aardappel is na twee cycli van vegetatieve vermeerdering slechts ongeveer 92. Na een generatieve fase in het veld en een vegetatieve vermeerdering via de teelt van zaailingen in kweekbedden kan daarentegen onder Ethiopische omstandigheden een vermeerderingsfactor van 450 worden gerealiseerd. Overigens kan in beide systemen van pootgoedproduktie de vermeerderingssnelheid nog danig verbeterd worden.

De TPS technologie lijkt te kunnen worden aan- en toegepast in gebieden waar gezond pootgoed niet beschikbaar of te duur is, vooral indien consumenten minder kieskeurig zijn ten aanzien van de kwaliteit van consumptie-aardappelen en waar de boeren een traditie en ervaring hebben op het gebied van het telen van groente-gewassen.

Curriculum vitae

Bereke Tsehai Tuku was born on 5 March, 1952 in Adi kemene, Ethiopia. He obtained his B. Sc. in Plant Sciences in 1977 at the Alemaya College of Agriculture, Addis Ababa University, Ethiopia. Between 1978 and 1980 he worked as a research officer in the Institute of Agricultural Research (IAR), Ethiopia. In 1982 he took a masters degree in Horticulture from California State University, USA. In the period between 1982 and 1984, he worked as a horticulturist in the Institute of Agricultural Research. And between the period 1985 and 1990, he served as a national potato research team leader and coordinator of the Department of Horticulture in the same institute.

Since 1990 he has worked at the Department of Agronomy, Wageningen Agricultural University. He has been supervised by Prof. P.C. Struik, of the Department of Agronomy and Dr. Hailemichael Kidanemariam, of the International Potato Center, Nairobi, Kenya. The field and laboratory experiments were carried out at the Holetta Research Center, Ethiopia and the Plant Genetics Resource Center/Ethiopia (PGRC/E). He has been financially supported by the International Potato Center (CIP), the Wageningen Agricultural University and the Institute of Agricultural Research (IAR), Ethiopia.