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Potato Agronomy Research

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Abstract

The suboptimal agronomic techniques practiced by potato growers in Ethiopia are undoubtedly one of the contributing factors to the existing low national average yield. In this paper results of the major agronomic research activities are discussed with major emphasis on those conducted since 1985.

Planting date experiments at Holetta and Emdeber indicated that early June is the optimum time for potato planting, yield decreased significantly with later plantings. A study on NPK requirement of potatoes on Holetta Nitosols showed that the current blanket recommendation of 300 kg DAP ha^{-1} is inadequate as this fertilizer is low in N. Of the major elements, N was found the most yield-limiting nutrient followed by P. In contrast, there was no response to K.

Larger seed tubers and closer spacings were both found advantageous to produce seed potatoes, while the reverse held true for ware potato production. For all tuber sizes, however, planting deeper than 15 cm decreased yield and was both time consuming and impractical. An experiment that measured the yield of whole tubers in comparison to cut seed tubers showed that suberized cut pieces yielded as good as whole tubers. Cutting is a useful practice when economic factors and input costs are considered, provided fields are free of bacterial wilt.

A study to determine of tuber bulking rates of cultivars and the extent to which these can be affected by split application of N revealed that the cultivars significantly varied in their bulking rates. Towards senescence, all the cultivars had a negative rate of bulking though with varied degrees. Split-application of N improved the negative bulking rate. Also studied were the relationships between fruit set and tuber yield, and optimization of agronomic techniques for increasing tuber yields of potatoes when grown from true potato seed.

INTRODUCTION

Ethiopia is endowed with suitable climatic and edaphic conditions for high potato productivity. However, the national average yield is estimated at 6 t ha^{-1}, which is low by any standards. One of the contributing factors to this low yield is the inadequate application of proper agronomic practices by Ethiopian potato growers.

Some of these poor practices include: improper operations on time of planting, plant population (spacing), fertilizer application, depth of planting, seed tuber quality, ridging, harvesting time and techniques, and crop rotation.

To develop a package of optimum management practices, which together with improved cultivars would increase potato yield per unit area, agronomic studies have been undertaken by the Institute of Agricultural Research (IAR) and Alemaya University of Agriculture (AUA). This paper discusses the agronomic and related physiological research conducted on potatoes in Ethiopia, with major emphasis on research conducted since 1985.

TIME OF PLANTING

An experiment was conducted at Holetta (2400 m.a.s.l.) and Emdeber (2100 m) to determine optimum planting dates for some growing areas, during the growing seasons of 1985 and 1986 (Gebremedhin and Berga 1989). These areas differ in temperature and amount, distribution and duration of rainfall (Table 1), and therefore are suitable for assessing the effects of different planting dates. A total of five different cultivars with 3 per year location were planted at 6 different sowing dates with 15-day intervals starting on 10 June and ending on 23 August of each year. A split-plot design was used with cultivars as main plots and planting dates as subplots.

Tables 2 and 3 show that tuber number, average tuber weight and total tuber yield were significantly higher with the 10 June plantings, with the exception of tuber number in 1985. Planting on 25 June was also significantly superior to later dates when all the variables were considered. The superior performance of earlier planting dates can be probably attributed to the longer time available to produce abundant foliage, initiate tubers and bulk before the onset of late blight and/or senescence.

Tables 2 and 3 also show that tuber number, average tuber weight and tuber yield varied with the cultivar, year and location. The year 1985 was better at Emdeber than at Holetta owing probably to the better weather conditions of the former location in two of those years. Emdeber had a higher mean minimum temperature and a higher amount of precipitation early and late in the season. It is known that both are important for high tuber yield. Tuber yields at Emdeber over all cultivars and both years averaged 25.7 t ha^{-1} for the first planting date and 10.6 t ha^{-1} for the last planting date. The corresponding yields at Holetta were 11.2 and 3.0 t ha^{-1}. Based on these results, it can be recommended that for Emdeber, Holetta and other areas with a similar climate, potatoes should be planted in early June.

Table 1. Effect of date of planting on tuber number per plant, average tuber weight, and total tuber yield of different cultivars at Holetta and Emdeber in 1985 (treatment means)

Planting date	Tuber no. per plant		Average tuber wt (g)		Total tuber yield (t ha^{-1})	
	Holetta	Emdeber	Holetta	Emdeber	Holetta	Emdeber
10-06-85	6.5	9.1	42.5	89.7	13.8	31.7
25-06-85	4.9	9.2	41.3	63.7	8.8	27.8
10-07-85	4.8	13.5	29.3	43.3	5.8	24.0
25-07-85	4.8	12.2	27.8	39.9	5.7	21.2
09-08-85	5.8	11.0	25.0	41.1	5.8	19.8
23-08-85	5.3	7.7	23.6	50.7	5.2	16.7
LSD 0.05	0.23	1.69	NA	NA	1.1	5.5
Cultivars						
AL-624	6.8	11.5	26.4	49.1	7.8	23.8
AL-252	5.2	10.2	32.2	58.6	8.4	24.4
AL-100	4.0	-	36.2	-	6.2	
AL-610	-	9.8		56.5		22.8
LSD 0.05	0.57	NS	NA	NA	0.7	NS

NA = not analyzed

\- = not planted at that location

NS = not significant at $P<0.05$

Table 2. Effect of date of planting on tuber number, average tuber weight, and total tuber yield of different cultivars at Holetta and Emdeber in 1986 (treatment means)

Planting date	Tuber no per plant		ATW (g)		Total tuber yield (t ha^{-1})	
	Holetta	Emdeber	Holetta	Emdeber	Holetta	Emdeber
10-06-86	7.2	12.5	26.2	34.9	6.6	19.7
25-06-86	5.4	7.6	19.1	32.3	4.4	
10-07-86	4.9	4.1	10.4	28.9	1.4	4.1
25-07-86	2.2	4.0	16.4	26.4	.8	4.6
09-08-85	2.5	4.9	10.6	17.3	.7	3.3
23-08-85	2.6	5.4	15.3	30.7	.8	4.6
LSD 0.05	0.92	1.32	NA	NA	.91	2.3
LSD 0.01	1.23	1.66				
Cultivars						
AI-624	2.7	5.9	14.4	25.6	1.1	6.0
AI-252	4.9	7.1	19.4	29.8	4.8	10.6
AI-100	4.8	-	15.2	-	2.4	7.1
AI-610	-	6.2	-	30.9	-	-
LSD 0.05	1.13	0.77	NA	NA	0.87	1.64
LSD 0.01	1.71	1.17				

NA = not analyzed

\- = not planted at that location

Table 3. Effect of interrow and intrarow spacings on tuber yield of potato at Alemaya (1984-1990)

Spacing (cm)	Mean yield (t/ha*)
60 x 10	25.2
60 x 20	22.2
60 x 30	26.8
60 x 40	30.8
70 x 10	27.8
70 x 20	22.4
70 x 30	25.9
70 x 40	26.7
80 x 10	23.3
80 x 20	23.6
80 x 30	28.5
80 x 40	34.1

*Each value is an average of six years

Plant Population

To determine the optimum inter- and intrarow spacings, a factorial experiment in RCBD was conducted at Alemaya with the variety AL-624 for six consecutive years (1984–1990). The interrow spacings were 60, 70 and 80 cm and the intrarow spacings 10, 20, 30 and 40 cm. The results (Table 4) showed that the highest yield of 34.1 t ha^{-1} was obtained from the widest spacing of 80 x 40 cm and the lowest yield of 22.2 t ha^{-1} was from the 60 x 20 cm.

At Holetta the effect of seed tuber size (25–35 m, 35–45 mm and 45–55 m in diameter) and intrarow spacings (10, 20, 30 and 40 cm) in rows of 75 cm apart on yield and yield components was studied in a factorial experiment arranged in RCBD during 1988 and 1989 crop seasons. The result show that in both years tuber number increased significantly with an increase in seed tuber size. This is expected because larger tubers have more sprouts and hence more stems per plant.

It has been reported by several authors including Berga and Caesar (1990), that stem number per plant and tuber number per plant are positively related. In contrast to tuber number, average tuber weight decreased with an increase in mother tuber size. It is because of the negative relationship between the number of tubers produced and their size. Average tuber weight (ATW), however, increased with wider spacing. Total tuber number and the number of seed-size tubers (smaller tubers) increased with closer spacing and with increasing size of mother tubers. In contrast, the number of ware potatoes (larger potatoes) was greater with wider spacing as it can be seen from larger ATW.

Table 4. Effects of seed tuber size and intrarow spacing on tuber number, average tuber weight, and total tuber yield (treatment means)

seed tuber size(mm)	Tuber no/m²	ATW (g)	Total tuber Yield (t ha^{-1})
25-35			
	1988		
34.7	50.2	16.1	
35-45	37.5	40.1	14.3
45-55	51.9	33.3	15.0
LSD 0.05	6.2	6.6	NS
Intrarow spacing (cm)			
10	70.9	28.4	19.1
20	36.1	42.8	15.0
30	33.6	43.9	14.2
40	24.8	49.7	12.0
LSD 0.05	7.1	7.6	2.2
	1989		
Seed tuber size (mm)			
25-35	36.3	51.6	18.0
35-45	38.9	49.5	18.5
45-55	42.1	45.9	18.7
LSD 0.05			
Intrarow Spacing (cm)			
10	51.5	37.3	19.0
20	38.7	44.9	17.4
30	33.4	54.4	17.9
40	32.6	59.3	19.2
LSD 0.05	4.1	6.4	NS

Tuber yield was not significantly affected by size of mother tubers. However, intrarow spacing had a significant effect on tuber yield, but only in 1988. The closest intrarow spacing (10 cm) yielded highest (19.1 t ha^{-1}) and the widest intrarow spacing (40 cm) yielded lowest (12.0 t ha^{-1}). Both differed significantly from yields obtained from intrarow spacings of 20 or 30 cm.

From these experiments, it can be concluded that, in addition to factors mentioned above, spacing should depend on the intended use of the crop—for seed or for ware. Closer intrarow spacings of 10 or 20 cm in rows of 75 cm apart would be advantageous for seed and larger seed tubers (45–55 mm) do better than the smaller ones. Wider intrarow spacings of 30 or 40 cm are better, again on rows 75 cm apart, for ware.

FERTILIZATION

According to a review (Bereke 1988) on Bako red soils an application of 150 kg N ha^{-1} and 66 kg $P_2 0_5$ ha^{-1} under rainfed conditions resulted in a yield advantage of 32% over the control. Under irrigation, however, the yield advantage as a result of NP application decreased, probably because of insufficient application of water at critical times. When 500 t ha^{-1} FYM was used together with 50 kg N and 22 kg $P_2 0_5$ ha^{-1} the yield increased by 56% over the control. Based on this study, the above rates both with and without FYM were recommended for high tuber yield. In practice, however, this recommendation has not been used. Instead, a blanket rate of 300 kg DAP ha^{-1} is applied at planting. This recommendation has been in use at least at the research center for last 15 or more yearsTo determine the NPK requirements of potato, an experiment was conducted on Holetta (IAR) Nitosol in 1988 and 1989 crop seasons. The experiment in a factorial design with 4 levels each of N (0, 55, 110 and 165 kg ha^{-1}) and P (0, 30, 60 and 90 kg ha^{-1}); and 3 levels of K (0, 55 and 110 kg ha^{-1}) arranged in RCBD with three replications. Table 5 shows that in 1988 tuber number/m^2 increased significantly with increasing levels of N but with no significant differences between 0 and 55 kg ha^{-1} and 110 and 165 kg N ha^{-1}. Tuber number was not affected by different levels of P in 1989. Application of N had significantly increased tuber number when compared with the check, but without significant differences between the 55, 110 and 165 kg N ha^{-1}. The effect of P application was different from that of 1988. In the latter year, the highest rate (90 kg $P_2 0_5$ ha^{-1}) brought about a significant increase in tuber number. Neither in 1988 nor in 1989 number of tuber produced was affected by K application.

Tuber yield increased significantly and consistently with an increase in the levels of N and P applied in both years. In contrast, K did not have any effect on yield. Absence of response by potato plants to K application in this experiment confirms the general belief that Ethiopian soils are rich in K and hence there is no need for application. This, however, may not hold true for all potato- growing areas of the country, as K contents of different soils across locations may vary.

Interaction values (data not shown) indicated that in 1988 the lowest tuber yield of 17.2 t ha^{-1} was obtained from the check and the highest yield of 36.5 t ha^{-1} from the highest rate of NPK (165/90/110 N $P_2 0_5$) application. Application of the highest rates of NP (165/90) alone also gave a high yield of 36.3 t ha^{-1}, which was only 0.2 t ha^{-1} less than the yield from the highest rate of NPK. In 1989 the highest yield of 27.1 t ha^{-1} was obtained with the application of the highest rate of NP

(165/90) and yield decreased to 21.9 t ha^{-1} with the highest rate of NPK (165/90/110 kg ha^{-1} of $N/P_2O_5/K_2O$). These results clearly indicate that potatoes do not respond to K application on Holetta Nitosol. Yield data showed that N is most important for yield increase followed by P.

It was also observed that plants that did not receive fertilizers were short, yellow and produced less foliage than those fertilized. The symptom of P deficiency was observed early in the course of growth followed by that of N with the latter being more pronounced. From this experiment, however, it was not possible to give any recommendations even for Holetta area, since an economic feasibility study of fertilizer application on potatoes need to be conducted.

Depth of Planting

To examine the effects of seed tuber size and depth of planting (ridge height) an experiment was conducted with the variety Sissay at Holetta (IAR), in the 1989 and 1990 crop seasons. The experiment was factorial comprising three seed tuber sizes (25–35, 35–45 and 45–55 mm in diameter) and six depths of planting or ridge heights (10, 15, 20, 25, 30 and 35 cm) with three replications.

Significantly, both more tubers/m^2 and higher tuber yields were produced when larger seed tubers were planted. The reverse, however, was true with average tuber weight (Tables 7 and 8). A similar result was obtained in India (Singh et al. 1980). Such a relation could be attributed to the more stems produced by larger seed tubers. Several authors including Iritani et al. (1972) and Berga (in press) have reported that the number of stems is positively related to tuber number and total tuber yield and negatively to average related tuber weight.

In 1989, depth of planting had no effect on any of the variables considered (Table 6) but in 1990 all were significantly affected (Table 7). Here, tuber number, total and marketable yields decreased significantly with deeper planting depths. Yield of green tubers was highest at a depth of 10 cm. This is because shallowly set tubers, if not properly covered with sufficient soil, are exposed to sunlight resulting in green color. Green tubers, though not edible, are marketable as they can be used for planting.

Planting at a 15 cm depth followed by 10 and 20 cm, performed best. In that order, planting deeper than 20 cm was found to be not only time-consuming and hence expensive, but also impractical.

Table 5. Effect of NPK on tuber number/m² at Holetta

Treatment	Tuber number/m²	
	1988	1989
0 kg N ha⁻¹	63.9	45.9
55 kg N ha⁻¹	64.6	64.5
110 kg N ha⁻¹	73.0	69.3
165 kg N ha⁻¹	76.0	67.6
LSD 0.05	5.2	5.2
0 kg N ha⁻¹	67.7	59.2
30 kg N ha⁻¹	68.2	59.2
60 kg N ha⁻¹	72.4	61.9
90 kg N ha⁻¹	69.2	67.0
LSD 0.05	NS	5.2
0 kg N ha⁻¹	66.2	59.2
55 kg N ha⁻¹	70.0	64.1
110 kg N ha⁻¹	71.9	60.9
LSD 0.05	NS	NS

Table 6. Effects of tuber size and depth of planting on tuber number/m², average tuber weight, marketable tubers, and total tuber yield

Seed size (mm)	Tuber (number/m²)	Average tuber weight (g)	Marketable tuber (t ha⁻¹)	Total tuber yield (t ha⁻¹)
25-35	24.8	39.4	7.9	9.5
35-45	27.1	39.8	8.8	10.7
45-55	39.9	29.5	9.5	11.7
LSD 0.05	4.6	4.9	.5	1.1
Depth of planting (cm)				
10	34.4	33.4	9.2	11.3
15	29.5	37.6	9.0	10.8
20	30.2	35.7	8.6	10.4
25	30.3	36.6	8.8	10.7
30	29.7	36.1	8.6	10.3
35	29.4	37.9	8.3	10.3
LSD 0.05	NS	NS	NS	NS

NS = not significant at $P<0.05$

Seed Tuber Size and Type

Traditionally, tubers are used for potato propagation. This practice, especially in Ethiopia, is a major limiting factor because the cost of seed tubers accounts for about 50% of the total cost of production (ACA 1981). In Ethiopia, since seed tubers are sold on a weight basis, the proportion of seed cost becomes even higher when big whole tubers are used, whose effects on yield have not been quantified locally.

To determine the effect of different sizes of seed tubers (30–40 g vs. 40–50 g) and types (whole vs. cut) on yield components and tuber yields, an experiment was conducted on Holetta Nitosols with two released varieties—AL-624 and Sissay— and three other outstanding cultivars—UK-80.3, CIP-378501.3 and CIP-374080.5—in the 1991 and 1992 growing seasons. Results of the first year are be discussed here.

Table 8 reveals that neither seed tuber size nor seed tuber type significantly affected tuber dry mater content (DMC), tuber number, and total tuber yield. Iritani et al. (1992) also did not find yield difference between cut and whole seed tubers. Whole tubers, however, produced tubers with a significantly higher average tuber weight, whose effect nevertheless was not reflected in the yield.

Table 8 also shows that the cultivars varied significantly in all the variables considered. The cultivar UK-80-.3 had a significantly higher DMC, average tuber weight and tuber yield, while the cultivar Sissay produced the biggest number of tubers/m^2 but with a low average tuber weight. The large difference between cultivars in tuber number and tuber size enables to select cultivars either for seed or ware potato production. Those that produce many but smaller tubers are good for seed production and the opposite holds true for ware potato production.

Time of Harvest

In the absence of storage technologies in Ethiopia, for both ware and seed potatoes, farmers keep potatoes in the ground for a long period. This remarkably reduced tuber yield. A study on extended harvesting period in Alemaya revealed that yield of marketable tubers was reduced by 60% when tubers were harvested at 210 days after planting when compared with harvesting at 120 days (Berga 1984).

Table 7. Effects of tuber size and depth of planting on stem number per plant, tuber number/m^2, yield of green tubers, average tuber weight, marketable yield and total tuber yield (treatment means), 1990

Seed size (mm)	Tuber (number/ m^2)	Yield of green (t ha^{-1})	Average tuber weight (g)	Marketable yield (t ha^{-1})	Total tuber yield
25-35	39.2	4.2	46.1	15.6	17.8
35-45	45.6	4.4	41.0	16.0	18.1
45-55	67.6	3.5	30.3	16.5	20.2
LSD 0.05	2.8	1.2	4.3	NS	1.6
Depth of planting (cm)					
10	58.6	8.4	36.0	16.3	19.7
15	51.8	4.2	40.6	18.1	19.8
20	51.0	3.8	38.6	15.7	18.6
25	47.7	2.2	39.8	15.6	18.1
30	49.6	3.0	37.3	14.6	17.7
35	46.1	2.6	41/6	15.8	18.3
LSD 0.05	7.4	1.1	6.1	2.0	2.0

NS = not significant

Table 8. Effects of seed tuber size and tuber type on dry matter content, tuber number, average tuber weight, and total tuber yield of five cultivars (treatment means), 1991.

	DMC (%)	Tuber (no./m^2)	ATW (g)	Total tuber yield (t ha^{-1})
AL-624	21.9	58.9	40.1	23.9
Sissay	22.8	67.6	51.0	32.6
UK-80-3	25.3	41.0	90.4	37.7
CIP-378501.3	21.2	40.2	59.1	23.0
CIP-374080.5	22.6	38.7	85.8	29.3
LSD 0.05	1.9	9.4	17.0	41.6
Seed tuber size (cm)				
30-40	22.2	47.4	67.2	28.2
40-50	22.9	51.1	63.3	30.4
LSD 0.05	NS	NS	NS	NS
Seed tuber type				
Whole	22.6	48.8	69.4	29.0
Cut	23.0	49.7	61.2	29.5
LSD 0.05	NS	NS	6.7	NS

The sole contributor to the loss was potato tuber moth. A similar study at Holetta (Gebre-Medhin 1987) resulted in a significant reduction in yield as harvesting was delayed from about 125 days to 230 days. According to this study, the yield loss of marketable tubers after 229 days was 72.6% in 1983/84 and 100% in 1985/86. Yield reduction ensued from, insects, diseases, decay and sprouting. The rise in loss with time indicates that pest problems of a crop accumulate as time goes on if that crop is continuously grown without a well studied rotation and proper control measures.

To alleviate yield losses associated with delayed harvesting, proper storage structures should be used—(diffused light store) for the seed and (dark but ventilated store) for the ware potatoes.

Fruit Set and Tuber Yield

To study the relationship between fruit set and tuber yield an experiment was conducted at Holetta with the cultivar CIP-378371.5 in 1989 and 1990. The treatments included the removal of floral buds or flowers, young fruits, and non removal.

Table 9 shows that in 1989 the removal of either flowers or fruits did not affect tuber number, average tuber weight and tuber yield. In contrast, in 1990 the check plants (plants that produced fruits, hence TPS) performed significantly poorer in all the variables considered. It is known that fruits and tubers are both sink organs and compete for photosynthates. This competition may have a significant negative effect on both, only when the photosynthate is limiting, which can ensue from adverse growth conditions, pests or limited physiological potential. The results of this study suggest that in addition to the conclusion given by Haile Michael (1975) the relationship between fruit set and tuber yield may depend on the environment in which potatoes are grown. The results, however, are not conclusive to discourage TPS production even when the main interest is tuber production.

Tuber Bulking Rate

A bulking rate trial was conducted at Holetta with the released varieties Sissay and CIP-378501.3 and the promising cultivars CIP-374080.5 and UK-80.3 in 1991 and 1992. To see if bulking rate is affected by time of application, N was applied, at a rate of 165 kg ha^{-1} either all at planting or split-applied in two equal halves. Five harvests were made at two-week intervals starting from the first harvest at 2 weeks from tuber initiation.

Tuber bulking with time was poorest with the variety CIP-378501.3 and this variety reached its peak bulking earliest in about 67 days after planting, after which yield somewhat decreased. Bulking with the variety Sissay increased at an increasing rate up to the third harvest (69 DAP) thereafter bulking increased at a decreasing rate until the fourth harvest (84 DAP), after that yield decreased. With the remaining two cultivars, bulking increased at an increasing rate until the fourth harvest, which was 87 DAP for CIP-374080.5 and 90 DAP for UK-80.3. Thereafter, yield decreased sharply.

Table 9. Effects of flower and fruit removal on number of tubers, average tuber weight, and tuber yield of potatoes

Treatment	Tuber (no./m^2)	ATW (g)	Tuber yield (t ha^{-1})
		1989	
FBR	41.9	52.1	21.8
YFR	45.0	54.0	24.2
NR	37.2	52.1	19.4
LSD 0.05	NS	NS	NS
		1990	
FBR	16.7	105.2	17.7
YFR	20.0	90.9	18.0
NR	13.8	77.1	10.5
LSD 0.05	4.2	13.8	4.8

FBR = flower bud removal
YFR = young fruit removal
NR = no removal = check
NS = not significant at $p < 0.05$

Although not significant, varieties reacted differently to time of N application The varieties Sissay and CIP-378501.3 performed somewhat better with the application of all N at planting, while the opposite held true for the cultivars CIP-374080.5 and UK-80.3. The effect exerted on the latter two was higher than on the former two.

Yield decreases during the latter part of growth can be described by the negative bulking rates presented in Table 10. Bulking rate (BR) was computed as follows:

$BR = Y_2 - Y_1$

where = Y_2 = yield ha^{-1} at the last harvest
Y_1 = yield ha^{-1} at immediate previous harvest
T_1 = days between two consecutive harvests

Table 10. Effects of time of N application on bulking rates of four cultivars ar different stages from tuber initiation (TI) (treatment means)

Nitrogen application	15-30 days from TI	30-45 days from TI	45-60 days from TI	60-75 days from TI (q ha^{-1}/day)
All at planting	6.1	10.6	6.1	-4.3
Split application	10.6	10.1	7.3	-1.9
Cultivars				
Sissay	11.1	11.8	8.8	-1.6
CIP-378501.3	4.6	6.6	-0.5	-0.2
CIP-374080.5	9.0	10.7	11.1	-4.9
UK-80.3	8.8	12.3	10.5	-5.8

* Tuber initiation with all cultivars took place 3-4 weeks after planting.

Table 11. Effects of direct seeding and transplanting on tuber number and tuber yield of two TPS progenies

Progenies	Tuber no/m^2	Tuber yield (kg/m^2)
	1991	
Al-624	840	5.38
Al 624 x CIP 378371.5	829	7.05
LSD 0.05	NS	0.68
Planting system		
Direct seeding	860	6.22
Transplanting	808	6.22
LSD 0.05	NS	NS
	1992	
Al-624	1212	25.709
Al-624 x cip 378371.5	1400	30.60
LSD 0.05	142	3.3
Planting system		
Direct seeding	1323	27.40
Transplanting	1290	28.90
LSD 0.05	NS	NS

NS = not significant

The negative bulking rate commenced earliest in the variety CIP-

378501.3 but the rate of decrease was lowest. With the remaining cultivar the negative bulking rate came late. The cultivars CIP-374080.5 and UK-80.3 exhibited the highest negative rates. Split application of N decreased the rate of negative bulking. Yield decreases towards senescence could be attributed to resorption as indicated by Cho and Iritatni (1983). i.e., if the amount of photosynthate does not suffice the need to sustain growth, the plant starts to feed on the tubers formed. Moreover, fresh yield can decrease because of loss of water from tubers, especially if soil temperatures are high.

From this experiment, it is clear that these cultivars can be harvested some weeks before the onset of senescence. But for more conclusive results, the experiment should be repeated for more years at several locations.

TPS AGRONOMY

System of Planting

At Holetta, a similar trial was conducted in 1991 and 1992 with OP (AL-624) and hybrid (AL-624 x CIP-378371.5) progenies. Table 11 indicates that method of planting did not have a significant effect on either tuber number or yield. While this result is in conflict with the results at Alemaya, and Kanzikweraw et al. (1991) it is in agreement with that of Wiersema (1984). The table also shows that the hybrid progenies did better than the OP. This is in agreement with the results of many workers, including Haile-Michael et al. (1985).

Spacing

To determine the optimum intrarow spacing for TPS, seedlings were planted at 10, 15, 20 and 30 cm intrarow spacings in rows of 70 cm apart. Results of five consecutive years (Table 12) showed that tuber yield was highest (23.0 t ha^{-1}) with the closest spacing and was lowest 15.4 with the widest spacing. However, the proportion of small tubers increased with closer spacing (data not given). A similar result was obtained at Holetta in 1992 (unpublished data). A positive relationship between wider spacing and yield of large tubers seems to be an established fact and has been mentioned elsewhere in this paper.

Method and Time of Fertilizer Application

At AUA the effects of both method and time of fertilizer application on TPS seedling performance were studied. Fertilizer application on one side of the seedling, two sides of the seedling, in ring form and under the seedling did not bring about a significant increase in tuber yield.

Comparatively, however, application on both sides of the seedling and under the seedling gave better results (Table 13). Fertilizer application time of planting, one month after planting, (MAP), 2 MAP and 3 MAP did not affect tuber yields of the seedlings either. These results are, however, not conclusive and therefore need further investigation.

Number of Seedlings

Experiments were conducted at both Alemaya and Holetta to see if the number of seedlings planted per hill affect tuber yield.

At Alemaya, although the results did not vary significantly, three or four seedlings outyielded one or two seedlings per hill (Table 14). At Holetta a similar trend was obtained, but the differences were more pronounced and significant.

In general, the use of TPS as an alternative means of potato production looks promising, especially in the off season, when late blight pressure is low. Agronomic research work has to be strengthened to develop a full production package for TPS.

Table 12. Effect of intra-row spacing on the yield of TPS seedlings

Intrarow spacing (cm)	1981	1982	1983	1984	1985	1986	Mean
10	32.02	27.92	27.41	10.07	16.02	24.55	23.00
15	28.87	29.05	12.08	8.29	12.79	20.35	17.76
20	27.46	25.49	23.46	8.48	12.61	20.00	19.58
30	15.46	23.33	13.31	9.00	11.34	23.11	15.43
Mean	25.95	26.84	18.34	8.96	13.19	22.00	

Table 13. Effect of method of fertilizer application on tuber yield of OP seedlings at Alemaya (means of 4 years)

Fertilizer application	*Tuber yield* ($t\ ha^{-1}$)
One side dressing	18.3
Two side dressings	20.9
Ring form	17.5
Under the seedling	20.9

Table 14. Effect of number of seedlings per hill on tuber yield of potato seedlings from 1982 to 1986

Number of seedling/hill	Tuber yield (t ha^{-1})					
	1982	1983	1984	1985	1986	Mean
One	19.2	21.6	9.2	16.7	23.8	18.1
Two	19.2	19.4	8.2	13.5	23.8	16.8
Three	20.2	25.1	10.0	18.4	27.4	20.2
Four	21.4	20.9	9.2	18.4	26.4	19.3
Mean	20.0	21.8	9.2	16.8	25.4	

CONCLUSION AND RECOMMENDATIONS

Results of agronomic experiments revealed that most of the cultural practices currently in use are suboptimal and tuber yields can be increased considerably if improved practices are adopted. It is thus vital to conduct on-farm trials of the improved technologies to see whether or not they are economically feasible for Ethiopian potato growers.

Most of the agronomic experiments were conducted at one or two locations and with a few cultivars. In the future, however, it will be useful to include more locations and more cultivars. This will help develop specific recommendations, without which the success of improving the yield of potato at a national level will be questionable.

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Discussion

Q. **Mengistu Hulluka:** Why is it top cutting of vines perform better in sweet potato ? Does this practice apply on Irish potato ?

A. **Berga:** The top parts are physiologically more active because of the presence of a higher quantity of phytohormones like auxins that favor rooting and gibberellins that favor vegetative growth. In the younger cuttings cell division and growth are also much more promoted than in the older cuttings. This holds true for most cuttings, including potatoes. The higher amount of carbohydrate found in top parts as compared to lower parts also contributes to better rooting of cuttings of the former (top portions).

A. **Emana Getu:** One of the bottlenecks of potato production in Ethiopia is potato tuber moth. Have you seen the effect of some of the agronomic practices you mentioned on potato tuber moth, like the use of fertilizers, the number of leaves, etc.

Q. **Berga:** We have not related fertilization and number of leaves to damage by PTM. It is not clear to me why we should relate number of leaves to PTM. Nevertheless, we have observed that shallow planting increases PTM damage. Erratic irrigation that results soil crack, especially on Vertisols also promotes PTM damage. The most important relationship we observed was that with delay in harvest there is a rapid increase in PTM infestation, especially if harvesting is extended to post-rainy season.

Q. **Aberra Deresa:** Potato is becoming an important crops in the lowland areas around Nazret, But I have not seen any agronomic or improvement research on potato for the lowland areas, is that because of resource limitation or that the lowland area is not your mandate ?

A. **Berga:** I concur with you that potato is important in the lowlands. We also have interest to do research around the Nazret area to develop appropriate cultivars that are heat tolerant. We used to do variety trials at Nazret, but these were discontinued because of changes in the rationale. We have discussed this point with Dr. Seifu and have reached agreement. Improvement research at Nazret will resume with more appropriate clones for that climate. We will also be delighted to do agronomy research in collaboration with the Nazret Horticulture staff or we can provide materials if they want to conduct agronomic experiments on their own.