PROGRESS ON POTATO IMPROVEMENT IN THE SOUTHERN HIGHLANDS OF TANZANIA

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ABSTRACT

About 90% of Tanzania's total potato crop is produced in the Southern Highlands. Potatoes are gaining in importance, both as a cash and food crop, at village level as well as in urban area. There has been an expansion in the area of potatoes and an increase in the number of farmers growing the crop. However, the yield per unit area still remains low at about 5 to 7 t ha^{-1} mainly because of the use of low yielding disease-susceptible varieties, soil fertility decline, poor husbandry practices and lack of improved seed. High yielding disease-resistant varieties have been released by Uyole Agricultural Centre (UAC) for commercial production. Agronomic and plant protection studies at UAC have resulted in packages of recommendations for the various potato growing areas of the Southern Highlands. This paper highlights the main research findings, describes farmers' achievements and constraints, and discusses future research plans at UAC.

INTRODUCTION

Potatoes (*Solanum tuberosum* L.) are the third most important starchy food crop, after maize and rice, in the Southern Highlands of Tanzania. The crop is gaining in importance as both as a cash and food crop at village level as well as in urban areas. It is grown in small fields, ranging from one to two hectares, utilizing mostly family labour.

Potato production in Tanzania has increased from 109,917 t in 1965/67 to well over 300,000 t in 1988/89. About 90% of the country's total potato crop in 1988/89 was produced in the Southern Highlands. The increase in production is attributed mainly to an expansion in area under cultivation and, to a lesser extent, to increased production per unit area (Mayona, 1991). Despite the increase in production, yield per unit area is still very low (5-7 t ha^{-1}) (Jakobsen, 1980; Mayona, 1991) mainly because of the use of low yielding and disease-susceptible varieties, poor husbandry practices, unavailability of improved seed stocks, soil fertility decline, unstable prices, and poor husbandry practices.

This paper reviews potato research work carried out in the Southern Highlands, discusses farmer achievements and constraints, and outlines future research priorities and strategies.

RESEARCH REVIEW

Potato research in Tanzania started in the early 1950s with the evaluation of introduced germplasm at Tengeru, Arusha. Several varieties were released for commercial production. However, research activities were terminated in 1967 after the centre was converted to a regional headquarters for the East African Community. Research work resumed in Mbeya in 1974/75 after the establishment of Uyole Agricultural Centre (UAC).

Research activities in breeding and agronomy, including some aspects of plant protection, have concentrated on selection for adapted, high yielding disease-resistant varieties and the development of agronomic recommendation packages for potato production in various parts of the Southern Highlands.

Considerable progress has been made. The most important research finding are briefly presented below.

BREEDING

Germplasm collection, screening and evaluation

Screening and evaluation of local germplasm, as well as of genetically improved families or clones from the International Potato Centre (CIP) Peru and from neighbouring African countries, is regularly carried out to monitor yield performance, late blight and bacterial wilt reaction, earliness and other agronomic traits. Promising materials undergo preliminary yield trials and then are further tested in a series of replicated trials at various locations.

Several entries from the evaluation of CIP lines and clones at UAC have yielded well over 50 t ha^{-1} (UAC, 1991). Most of these are resistant to late blight. In addition, many of them are of intermediate maturity, indicating that two or three crops could be grown each year, which is an advantage considered important by farmers in the Southern Highlands.

Zonal cultivar trials and demonstrations

A series of trials and demonstrations in different zones facilitate the testing of materials with potential for release, before their performance is verified under farmers' field conditions. CIP clones (Table 1) and UAC crosses (Table 2) performed well in terms of yield and late blight reaction. Yield performance and late blight rating of various clones compared favourably with released varieties across three sites over six seasons (Table 3).

Released varieties evaluated under farmers' field conditions generally yielded well, although yields varied across sites (Table 4). Mean yields of the variety Subira were relatively poor, especially at Usalule, Ntokela and Ivirikinge. At four out of six sites, this variety was out-yielded by local cultivars. Other characteristics, such as cooking quality and late blight rating have also been evaluated (Table 5).

Table 1. Tuber yield (t ha^{-1}) of CIP potato clones at Uyole and Kitulo compared Sasamua, a local variety (mean of two years' data)

	Uyole	Kitulo
CIP 382124.2	13	32
CIP 382135.2	18	24
CIP 382143.2	5	28
CIP 382150.2	23	27
CIP 382151.3	7	28
CIP 382169.4	13	43
CIP 382174.2	8	33
CIP 382174.3	10	31
CIP 382174.6	9	37
CIP 382171.3	26	35
CIP 382174.7	4	20
Sasamua	10	23
Mean	13	30

Table 2. Tuber yield (t ha^{-1}) of UAC crosses grown for three years at Uyole and Kitulo and two years at Kimondo

	Uyole	Kimondo	Kitulo
T-85-2-44	16	12	28
T-85-2-107	22	11	29
T-85-2-131	10	8	17
T-85-2-155	14	12	27
T-85-2-160	13	10	23
T-85-2-148	12	9	19
T-85-2-185	17	12	25
T-85-2-210	20	7	26
T-85-3-104	15	7	15
T-85-3-205	10	11	18
T-85-3-211	9	9	25
T-85-3-274	16	7	22
T-85-2-19	12	11	21
Sasamua	15	6	19

Table 3. Tuber yield (t ha^{-1}) and late blight (LB) infection rating (0 resistant - 9 highly susceptible) of 10 clones tested at three locations (mean of six years' data)

	Uyole (1800 m)	Kitulo (2800 m)	Igeri (2300 m)	LB rating
Baraka	16	14	14	3.1
Cossima	19	10	15	3.9
EAI 2329	25	12	17	2.8
Maritta	17	13	15	3.4
Sasamua	17	18	22	3.4
Tana	23	16	31	2.1
CIP 720050	23	14	33	2.9
K-110-C(8)	21	10	14	2.5
Kennebec	20	13	19	4.4
K59a (26)	26	15	27	2.4

Table 4. Tuber yield (t ha^{-1}) of three released varieties (Bulongwa, Subira and Kikondo) tested under farmers' conditions in seven villages in the Southern Highlands (mean of four years' data)

	Bulongwa	Subira	Kikondo
Igoma (Mbeya)	12	12	13
Kikondo (Mbeya)	25	16	
Isapulano (Makete)	27	13	27
Ivirikinge(Makete)	17	8	16
Unyamwanga(Rungwe)	16	10	18
Ntokela/Ndaga	13	6	15
Usalule (Njombe)	12	9	10
Mean	17	11	17

Table 5. Late blight infection rating (0 resistant - 9 highly susceptible) and test panel results[1] for the six released potato varieties

	Baraka	Sasamua	Subira	Tana	Kikondo	Bulongwa
Late blight rating	3.1	3.4	2.8	2.1	2.9	2.4
Texture 5 min. boil	1.3	1.1	0.8	1.6	2.0	1.1
Texture 10 min. boil	0.4	1.9	1.0	1.5	2.0	0.8
Consist 5 min. boil	1.0	1.7	1.0	1.5	1.2	1.7
Consist.10 min. boil	1.2	2.0	1.5	2.3	1.3	1.2
Milliners 5 min. boil	1.8	2.3	0.6	1.4	2.0	1.1
Milliners 10 min. boil	1.1	2.3	0.9	2.1	2.5	0.5
French fries colour	2.0	1.5	2.8	1.3	1.3	2.1
French fries texture	1.5	2.3	2.0	1.6	1.8	1.9
French fries milliners	2.0	3.0	1.9	1.5	2.0	0.9
Overall score, excluding late blight rating	1.4	2.0	1.4	1.6	1.9	1.3

[1]O = no good, 1 = average, 2 = good, 3 = more than good, 4 = excellent.

AGRONOMY

Spacing and plant density

Spacing and plant density experiments have been carried out across locations and seasons in the Southern Highlands to establish recommendations for optimum yields. To achieve the recommended plant density of 53,000 to 55,555 plants per hectare, potatoes should be planted at a spacing of 60-75 cm between rows and 25-30 cm between hills. Seed requirements have been determined according to tuber size as follows: small tubers (less than 60 g) 10-15 100 kg bags ha^{-1}; medium sized tubers (60-120 g) 20-25 100 bags ha^{-1}; large tubers (more than 120 g) 30 100 kg bags ha^{-1}).

Planting dates

Time of planting studies have been carried out to determine the optimum planting times at four sites differing in altitude and rainfall pattern (UAC, 1984/85, 1990/91). In high altitude areas, such as Kitulo (2800 m above sea level) and Igeri (2300 m above sea level), the best yields were obtained when potatoes were planted in September or October. For mid-altitude areas, such as Uyole and Nkundi (both 1800 m above sea level), planting is best done soon after the onset of the rains in November or December, making possible a second planting in February. Delayed planting has consistently resulted in a drastic reduction in yield.

Seed size and seed treatment

The effect of three seed sizes (small, medium and large) and two seed treatments (de-sprouting and chitting) on the yield of potatoes has been investigated at Kitulo, Kimondo and Uyole, all in Mbeya Region. Results have been inconsistent. At Uyole and Kimondo, neither seed size nor seed treatment had any significant effect on potato yield. At Kitulo, however, large and medium sized tubers gave significantly higher yields than small sized tubers. De-sprouting and chitting also increased yields from all grades of seed tubers at Kitulo (UAC, 1981-1984).

Fertilization

The response of potatoes to nitrogen and phosphorus fertilization has been studied for four seasons at Uyole, Igeri, Kitulo, Nkundi and Mbimba (1982-1986). Three levels of nitrogen were used (0, 80 and 120 kg ha^{-1}) and three levels of phosphorus (0, 60 and 90 kg ha^{-1}). Responses varied from location to location. At Uyole and Igeri, there was a linear response to nitrogen and phosphorus

(Figures 1a and b). At Kitulo, fertilizer response was linear up to 100 kg N and 30 kg P ha^{-1}. However, soils at this site are known to be deficient in phosphorus and yields were extremely poor in the absence of phosphorus fertilizer even at the highest levels of nitrogen application (Figure 1c). At Nkundi and Mbimba, a quadratic response was apparent, with maximum yields obtained at 90 kg N and 20 kg P ha^{-1} at Nkundi (Figure 1d) and 90 kg N and 30 kg P ha^{-1} at Mbimba (Figure 1e).

Considering the high cost of fertilizers, soil fertility differences and farmers financial resources, there is a need to avoid blanket recommendations whenever possible. Economic analyses have been used to develop fertilizer recommendations for a number of locations (Table 6), which will need to be reviewed from time to time as input prices change.

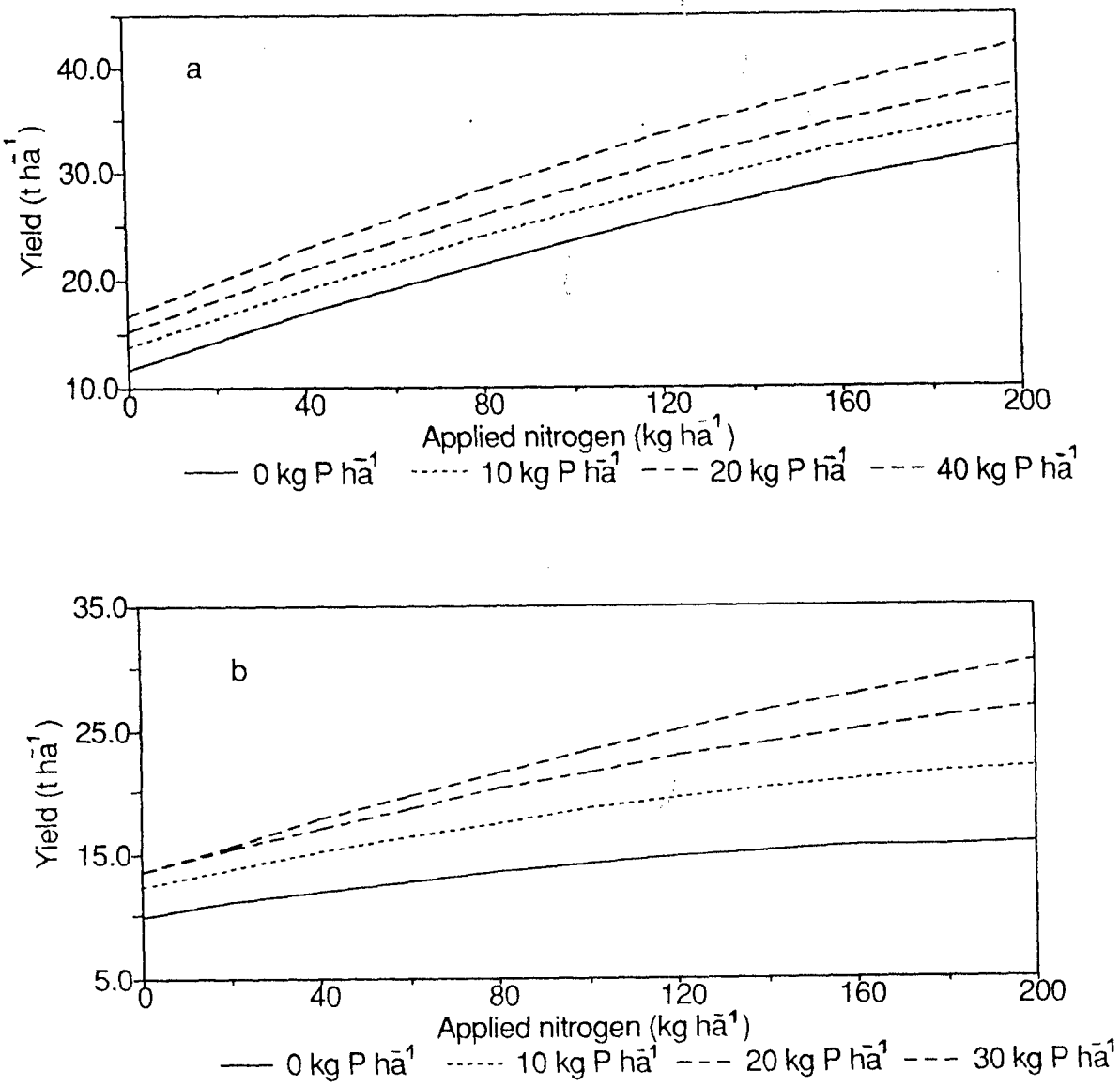

Figure 1. Predicted potato yields for different combinations of nitrogen and phosphorus fertilizer a. Uyole, b. Igeri

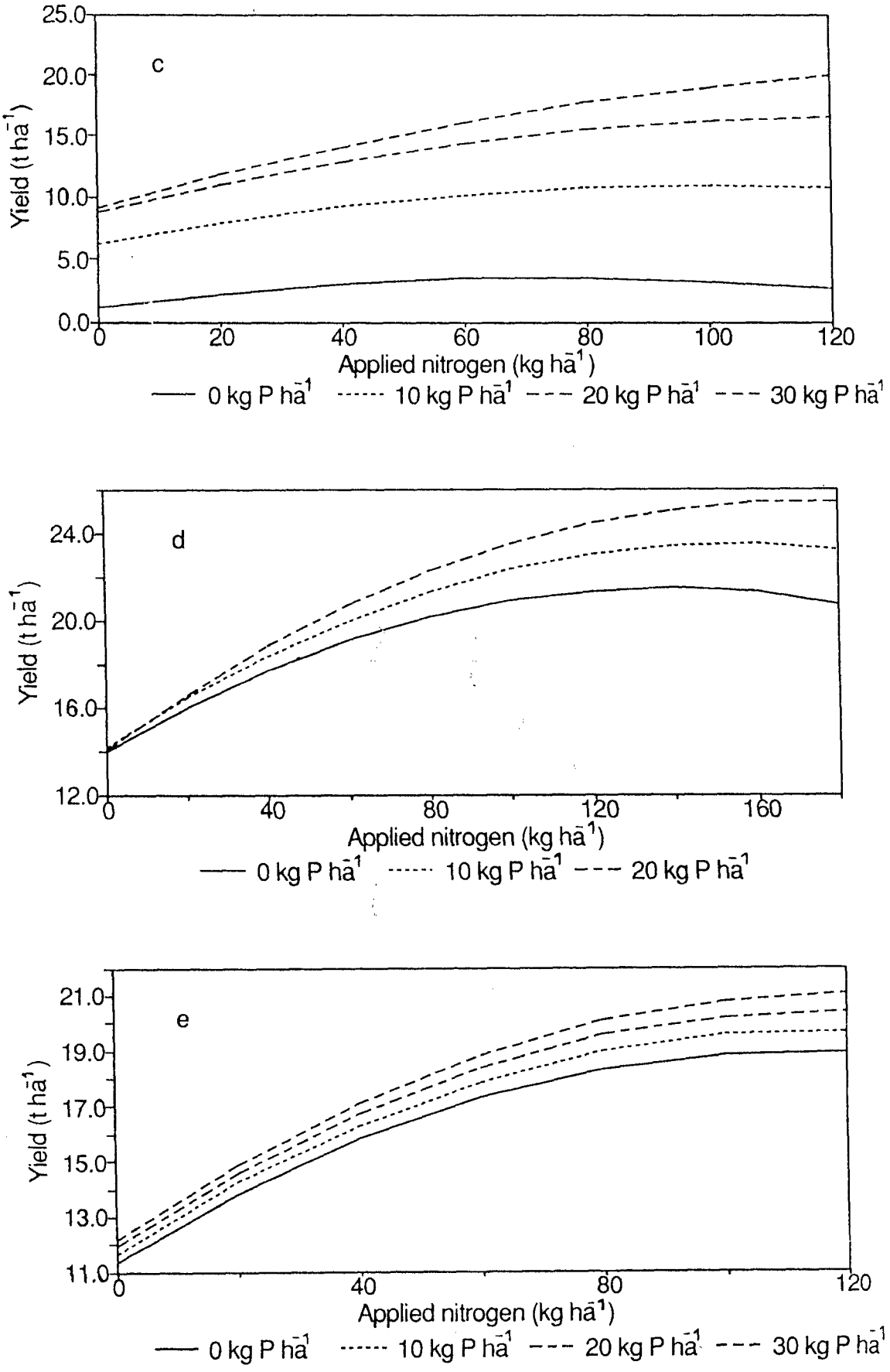

Figure 1. Predicted potato yields for different combinations of nitrogen and phosphorus fertilizer
c. Kitulo, d. Nkundi, e. Mbimba

Table 6. Fertilizer recommendations (number of 50 kg bags of triple superphosphate (TSP) or urea needed ha^{-1}) at three levels of costs for potatoes grown at five locations in the Southern Highlands

	Optimum		Medium		Low	
	TSP	Urea	TSP	Urea	TSP	Urea
Uyole	2	7	1	4	0	2
Kitulo	3	3	2	2	2	0
Igeri	2	7	2	3	1	1
Nkundi	1	4	1	3	0	3
Mbimba	2	4	1	4	0	2

PLANT PROTECTION

Weed control

Weed competition in potatoes is strongest during the first four to five weeks after the emergence of the potato seedlings. Experiments to study the effect of time and frequency of weeding have shown that the best potato yields are obtained when the crop is kept free from weeds until the fifth week after emergency.

The efficacy of herbicides has been evaluated for three years; there were no significant differences between the seven herbicides tested. Metribuzin applied at a rate of 0.75 kg of active ingredient (a.i.) and linuron applied at 2.0 kg a.i. per hectare, as well as a mixture of the two at these concentrations, gave good control of both broad leaved and grassy weeds (UAC, 1987/88). Paraquat (gramoxone), when applied before or at 10% emergence, controlled weeds for up to 21 days, particularly when applied under wet and humid weather conditions, after which mechanical weeding became necessary.

Disease Control

Plant protection research has been concerned mainly with the control of late blight (*Phytopthora infestans* L.) which can cause yield reductions ranging from 50 to 98% (Nsemwa, 1992, personal communication).

Among fungicides tested in the 1980s, mancozeb (Dithane M45) gave good control of late blight disease when sprayed once or twice a week at a rate of 5 kg ha^{-1}. Cost benefit analysis has shown that spraying once per week is the most economical and this is therefore the recommended treatment (Table 7).

Table 7. Potato tuber yield, late blight disease index and net returns for different frequencies of late blight fungicide spray

	Yield (t ha^{-1})	Disease index[1] (%)	Net return (TSh ha^{-1})[2]
Unsprayed	9.7	68.0	192 000
Sprayed once per week	20.0	36.3	244 272
Sprayed twice per week	21.7	24.7	122 545

[1]Disease index (%) calculated as SM/M x 100/5, where SM is the sum of individual plant disease scores, n is the total number of plants assessed, and 5 is maximum disease incidence in the disease scores. [2]TSh 300-400 = US$1, very approximately, 1992.

ACHIEVEMENTS AND CONSTRAINTS

There have been no adoption studies to evaluate the extent to which recommendations resulting from potato research activities at UAC have benefited the small farmer in the Southern Highlands, but observations indicate that production technology has been adopted in some areas, especially where village introduction trials and farmers' field days have been conducted. Farmers who have attended short training courses on potato production offered by UAC from time to time may also have facilitated the diffusion of potato production technology.

Adoption of improved varieties and crop husbandry practices can be seen in the Mporoto Mountains, Njombe and Dabaga in Iringa, Nkasi District in Sumbawanga, as well as in most villages surrounding UAC Because of market demand, potatoes are now grown in places that have not previously been potato producing areas. Seed potato production is currently being undertaken on a large scale by some farmers in Njombe and on the Kitulo Plateau.

Despite this expansion in area, the yield of potatoes per unit area still remains at 5-7 t ha^{-1}. The main constraints to increased potato production in the Southern Highlands have been identified and are listed below.

- *Improved varieties.* Although improved potato varieties have been released, their adoption has been slow, mainly because of a lack of organized seed potato production schemes. The quantity of improved seed potatoes currently produced is less that 1% of estimated seed requirements in the Southern Highlands.

- *Credit facilities.* There is a lack of credit facilities for farmers who want to engage in commercial potato production and who are willing to adopt the recommended production technology. Fungicides and fertilizers are expensive inputs, which many small farmers can not afford without access to credit facilities.

- *Late blight disease.* Many farmers, either through ignorance or tradition, are still growing poor yielding, disease-susceptible varieties and are faced with complex pest and disease problems, especially late blight. This situation makes potato production less than it might otherwise be since farmers have to depend heavily on the use of chemicals if they are to keep the diseases under control.

- *Soil erosion and deforestation.* Soil erosion and a decline in soil fertility, resulting from deforestation, the planting of potatoes on very steep slopes, a lack of crop rotation, and minimal or no use of fertilizers and manures, contribute to poor yields.

- *Access.* Many potato producing areas are not easily accessible, especially during the rainy season, resulting in high transportation costs. Lack of storage facilities and delayed availability of transport have frequently resulted in poor prices and heavy losses because of the perishable nature of the crop.

- *Marketing.* The lack of an organized marketing system causes unfavourable fluctuations in producer prices, which sometimes fall below the economic threshold for potato production.

SEQUENCE OF INNOVATIONS

Adoption of innovations by farmers is a stepwise process. It depends on perceptions of financial risk, as well as on labour constraints. In potatoes, experience has shown that adoption of an innovations tends to follow the sequence described below and summarized in Table 8.

1. *Zero management level.* The poor yields obtained with minimal management may encourage smallholders to adopt improved husbandry techniques, especially once the smallholders have been exposed to on-farm experiments and demonstrations.

2. *Weeding and earthling up.* Even using local varieties, farmers who plant potatoes on well prepared land, with at least two hand weedings within the first five weeks after emergence, followed by earthling up, may achieve yields of up to 10-15 t ha^{-1}.

3. *Use of improved varieties and fertilizers, pest and disease control.* To further increase yields, the farmer is likely to adopt improved varieties, and take steps to improve soil fertility and control diseases. Planting high yielding varieties (such as Sasamua, Kikondo, Subira or Tana) applying fertilizer (for example, urea at the rate of three 50 kg bags ha^{-1}) to improve soil fertility, and spraying fungicides at the recommended frequency, should result in high yields, ranging from 20 to 25 t ha^{-1}, depending on soil type and location.

4. *Improved husbandry, disease and pest control and additional fertilizer.* Once these high yields have been achieved the farmer may be encouraged to adopt more improvements, or to modify some husbandry practices, for example by planting at the right time, and using three 50 kg bags of triple superphosphate as well as four to seven bags of urea ha^{-1}, increasing plant density to 50,000 plants ha^{-1}, and ensuring adequate control of pests and diseases. These husbandry practices may increase yields to 30-35 t ha^{-1}. However, to sustain this yield level, the smallholder must also practice crop rotation to minimize the risk of bacterial wilt, control soil erosion and maintain soil fertility.

Table 8. Sequence in which improved technology tends to be adopted by smallholder potato producers in the Southern Highlands

Component	Content	Yield (t ha^{-1})
Zero management level	Extremely low management (unusual situation)	3 - 7
Weeding and earthing up	Two weedings at least, followed by earthing up, planted on virgin land	10 - 15
Use of improved varieties and fertilizer, pest and disease control	Use varieties resistant to late blight (e.g. Kikondo, Subira), 2 or 3 fungicide and insecticide sprays, 3 weedings plus earthing up, 3 bags urea ha^{-1}	20 - 25
Improved husbandry practices (e.g. optimum planting date and density), improved disease and pest control, additional fertilizer improvement	Planting closer to optimum date, plant density increased to 50,000 plants ha^{-1}, 4 or 5 fungicide and insecticide sprays, 3 50 kg bags tripple superphosphate and 4-7 bags urea ha^{-1}.	30 - 35

PRIORITIES AND STRATEGIES FOR FUTURE RESEARCH

The future for potato production in the Southern Highlands appears bright. However, increased production will depend heavily on the removal of current production constraints. The following research activities are planned for the future.

- Continue with the development and screening of germplasm for high yielding, good quality, and bacterial wilt and late blight disease resistant races.

- Carry out on-farm research to develop and verify management recommendation packages for groups of farmers with varying levels of access to production inputs.

- Improve seed potato production, distribution and storage to increase supplies of improved, high yielding, disease-resistant seed potatoes.

- Enhance research-extension-farmer linkages to facilitate the adoption of good potato seed production practices.

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