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DECENTRALIZED ON-FARM SEED POTATO PRODUCTION FROM PRE-BASIC MINITUBERS: A CASE STUDY FROM NEPAL

By S. SCHULZ†, G. J. WELLS, B. K. BANIYA, T. P. BARAKOTI, G. KHAREL, B. SAHA, B. V. THAPA *and* D. N. OJHA

Nepal Agricultural Research Council – Potato Research Programme, Khumaltar, PO Box 404, Kathmandu, Nepal

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SUMMARY

The on-farm performance of more than 150 000 pre-basic potato (*Solanum tuberosum*) minitubers of 1–10 g was monitored over two years in contrasting environments in Nepal. Average minituber productivity (grams of basic seed produced per minituber planted) was 171 g in the southern plains and 116 g in the hills. Although the performance of minitubers varied between environments, minituber sizes and potato varieties, the overall results clearly indicated that minitubers can be successfully multiplied by small-scale farmers. This technology therefore allows for the highly decentralized production of basic seed which, in turn, will reduce farmers' dependence on an unreliable and costly supply of bulky conventional seed.

INTRODUCTION

In many tropical and sub-tropical countries the demand for potatoes (*Solanum tuberosum*) or potato-based products is growing rapidly. Over the past two decades, potato production has more than doubled in developing countries with market economies owing to an increase in area and yields (Midmore, 1992). However, average potato yields of 12.7 t ha^{-1} in developing countries are still below this crop's production potential (FAO, 1991; FAO/CIP, 1995). Among other factors, lack of access to locally adapted, high-yielding varieties and to disease-free planting material at acceptable prices is an important constraint limiting potato production particularly in remote areas with a poorly developed transport infrastructure. Although potatoes can be propagated in a variety of ways, seed tubers are still the most widely used planting material. However, seed tubers can be infected by various fungi, bacteria and viruses and the gradual buildup of tuber-borne pathogens especially viruses in successively grown seed generations is generally referred to as seed degeneration. This leads to declining yields and makes it necessary to replace old seed stocks with disease-free seed.

Conventional seed production methods, such as the seed plot technique which

†Address for correspondence: IITA-Ibadan, c/o L. W. Lambourn & Co, Carolyn House, 26 Dingwall Road, Croydon CR9 3EE, UK

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applies positive and negative selection, aim to maintain seed quality by propagating seed from plants which do not show any visual disease symptoms. These methods, however, are based on low seed multiplication rates (number of seed tubers produced from one mother tuber) which vary from 1:3 to 1:15 for ordinary seed tubers according to variety, agronomic practice and physiological age of the mother tuber (Bryan *et al.*, 1981). In order to overcome these low rates, techniques employing rapid propagation methods have been introduced in seed production schemes throughout the world. Rapid propagation techniques result in multiplication rates between 1:40 and one to several thousand cuttings per year, each cutting producing five or more pre-basic minitubers. This enables seed programmes to speed up the dissemination of new varieties and to quickly flush out degenerated seed stocks of old varieties.

This paper describes a decentralized seed production scheme in Nepal and summarizes the performance of more than 150 000 minitubers multiplied by small-scale farmers in two contrasting agro-ecological zones of the country.

THE SEED MULTIPLICATION SCHEME IN NEPAL

Potatoes are a major food crop in Nepal, ranking fifth after rice, maize, wheat, and millet. They are grown on 89 000 ha, of which 67 000 ha are in the hills (mountains) where potatoes are grown between 1000 and 3000 m asl, in a warm–cool temperate climate. The remaining 22 000 ha are located in the southern plains of the terai (60–300 m asl, sub-tropical climate) where potatoes are a winter crop. Average national potato yields, however, are low at 8.1 t ha^{-1} in the hills and 10.7 t ha^{-1} in the terai (Central Bureau of Statistics, 1995). Poor seed quality is considered to be one of the factors contributing towards low potato productivity in Nepal.

The Potato Research and Development Programmes (PRDP), with technical and financial assistance from the Swiss Government, initiated a rapid propagation scheme in 1990. Disease-free mother plants of recommended local and exotic varieties are obtained either from the International Potato Center (CIP) or produced locally by the PRDP tissue culture laboratory. All mother plants are routinely tested for six potato viruses (X, Y, leaf roll, A, M and S) using the DAS-ELISA technique. The mother plants are then multiplied *in vitro* through nodal cuttings. The resulting plantlets are subsequently transplanted into an insect-proof glasshouse for the production of minitubers. These pre-basic seed (PBS) minitubers are then sold to independent seed producer groups, preferably located at the head points of traditional seed flows, as well as to non-government organizations and government organizations for further multiplication and production of basic seed (BS). During the first one or two seasons, farmers receive on-the-job training on how to grow the minitubers. They are advised to multiply small quantities of these tubers to produce their own basic seed stock which is further multiplied in subsequent generations, applying conventional seed production techniques. In this process, increasing quantities of seed are sold by the

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farmer groups to traditional customers, thereby establishing a highly decentralized seed production scheme. From the inception of the rapid propagation scheme until 1996, more than 1.2 million minitubers have been produced and distributed to the farming community.

The effect of this technology on tuber yields in the terai and the hills was estimated by comparing on-farm yields of crops grown from basic and traditional seed. In this context, basic seed (BS) refers to seed derived from PBS minitubers whereas traditional seed refers to seed produced through conventional seed production methods. To minimize farmer effects, only crops exposed to similar agronomic practices were included. Results from more than 250 observations, collected over two years, indicated that crops derived from basic seed (BS1 to 4) yielded 15–35% more than crops from traditional seed (Wells *et al*., 1996). Furthermore, an experiment conducted in the terai by Ranjit *et al*. (1996) showed that crops heavily infected with virus yielded up to 33% less than healthy crops.

Initially, all PBS minitubers were multiplied on a few government stations and the subsequent seed generations of basic seed were sold via the national extension network in major potato-growing areas of the country. Little information was available regarding the performance of minitubers under on-farm conditions and doubts were raised as to whether farmers would be able to multiply the tiny tubers successfully. Therefore, it was decided to monitor the productivity and multiplication rates of minitubers under on-farm conditions during two terai and two hill seasons in 1993–94 and 1994–95. During this period, the Potato Research Programme sold more than 160 000 minitubers to farmer groups who either collected them directly in Kathmandu or received them through the national extension service. Transport was not generally a problem since the small tuber size allowed inexpensive transport by bus or air. Those multiplying PBS minitubers did not all report back and therefore the number of minitubers monitored differed somewhat from the total quantity distributed.

METHOD

The performance of PBS minitubers was monitored using two main indicators, productivity and multiplication rates. Productivity of PBS was measured in grams (g) of basic seed 1 (BS1) produced per minituber planted while the multiplication rate refered to the number of progeny tubers produced per minituber planted. These indicators were considered to be more appropriate than yield per unit area because (1) the main objective of this first field multiplication was to maximize the number of seed-size tubers instead of maximizing yield per unit area and (2) the planting distance of PBS minitubers varies according to size, that is, large minitubers are planted at a wider spacing than small minitubers. As seed rate is an important factor determining final tuber yield, a measurement of yield per unit area would be confounded by planting density.

Each observation represented a result obtained from one farmer multiplying minitubers of one variety of a specific size and hence sample sizes varied widely.

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Pairwise comparisons of means were carried out with the SAS programme (SAS, 1989).

RESULTS AND DISCUSSION

Productivity of PBS minitubers

Averaged over minituber sizes and years, productivity on farms was excellent in the terai with 171 g minituber^{-1} (based on 83 850 minitubers) and still good in the hills where one minituber produced 116 g basic seed (based on 71 090 minitubers). In comparison, government stations in the hills and terai multiplied more than 100 000 minitubers in 1991–92 with an average productivity of only 95 g minituber^{-1}, which clearly indicated that PBS minitubers were more successfully multiplied in farmers' fields. The significantly ($p < 0.001$) lower productivity in the hills (116 g) compared with the terai (171 g) may be explained by the following factors:

(1) the low level of nutrition owing to the unavailability of chemical fertilizer and also to the use of abandoned land, usually with poor soil fertility, to avoid soil-borne diseases and volunteer plants;
(2) the lack of irrigation facilities in most hill communities (PBS minitubers are particularly sensitive to moisture stress during the early stages of crop establishment);
(3) the occurrence of hailstorms which may damage the crop at any stage of development;
(4) the fact that terai farmers are generally more experienced in growing small-seeded crops and establishing nurseries;
(5) the insufficient plant protection measures, mainly against late blight.

As illustrated in Fig. 1, minituber size significantly ($p < 0.05$) affected productivity in both environments. Minitubers of 1–5 g produced almost twice as much as minitubers weighing < 1 g while those weighing > 5 g produced about three times as much. This can be explained by the fact that tuber yield per plant is related to the number of stems per plant which is itself determined by the size of the seed tuber (Wiersema, 1987; Allen *et al.*, 1992). In addition, small-sized minitubers, owing to their reduced nutrient and water reserves, are more prone to moisture and temperature stress. This is more likely to occur in the non-irrigated situation of the hills and may explain the more pronounced effect of minituber size on productivity in the hills.

Productivity also varied between different cultivars and environments (Table 1). In the hills, all minituber sizes of Kufri Jyoti and Achirana Inta performed poorly, except minitubers of Achirana Inta weighting > 5 g. Their average productivity of 81 g was significantly ($p < 0.01$) lower than the productivity of the other cultivars and seed sizes which produced on average 137 g. Under terai conditions, the productivity of Achirana Inta was also low, but minitubers of Kufri Jyoti > 1 g in size yielded significantly ($p < 0.001$) better in the terai than in

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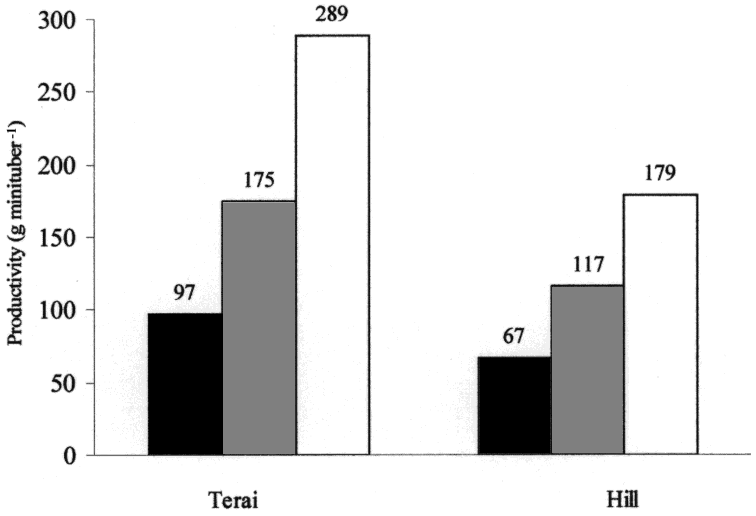


Fig. 1. Productivity (grams (g) of basic seed (BS1) per minituber planted) of minitubers < 1 g (■), 1–5 g (▩) and > 5 g (□) in size grown in the terai and hills, averaged over cultivars and two seasons. Terai: p (< 1 g *vs.* 1–5 g = 0) > T = 0.0014; p (1–5 g *vs.* > 5 g = 0) > T = 0.0006; Hill: p (< 1 g *vs.* 1–5 g = 0) > T = 0.0338; p (1–5 g *vs.* > 5 g = 0) > T = 0.0193.

Table 1. Minituber productivity (grams (g) of basic seed (BS1) produced per minituber planted) in the terai and hills, averaged over two seasons.

		Terai			Hill		
Cultivar	Size (g)	Number of minitubers	Productivity	s.e.	Number of minitubers	Productivity	s.e.†
Kufri	< 1	815	32	11.9	3050	94	27.6
Jyoti	1–5	11 172	212	21.6	10 247	97	18.3
	> 5	4975	236	21.4	200	89	x
Achirana	< 1	1045	37	9.5	5105	26	8.2
Inta	1–5	1793	84	12.4	10 375	79	10.1
	> 5	—	—	—	436	182	x
Desiree	< 1	4212	46	12.2	1850	16	6.0
	1–5	3993	94	28.7	14 405	119	20.9
	> 5	—	—	—	1620	193	55.4
Cardinal‡	< 1	1832	200	82.5	2925	108	39.9
	1–5	9647	200	17.8	11 051	162	20.7
	> 5	540	578	169.3	1045	188	41.5
NPI-106	< 1	—	—	—	700	215	x
	1–5	—	—	—	5180	162	43.6
	> 5	—	—	—	900	211	99.6
Kufri	< 1	3865	123	34.1	—	—	—
Sindhuri	1–5	39 946	166	13.4	—	—	—
	> 5	—	—	—	—	—	—
Three local	< 1	—	—	—	400	91	21.4
cultivars§	1–5	—	—	—	1398	57	9.7
	> 5	—	—	—	200	14	x

†x refers to a sample size of 1, ‡ one season only; § Kathmandu Local, Syangdorje, Sarkari Seto.

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the hills. NPI-106, which is recommended only for the hills, did extremely well in this environment. All 700 minitubers of this cultivar, <1 g in size, were multiplied by the same experienced farmer group. This resulted in an impressive productivity of 215 g minituber^{-1} which highlights the production potential of PBS minitubers of this cultivar under well-managed conditions. In comparison 400 minitubers, all <1 g in size, of three local cultivars, Kathmandu Local, Sarkari Seto and Syangdorje, which were multiplied by the same farmer group during the same season had a significantly ($p < 0.05$) lower productivity of 91 g. These results clearly indicate that the productivity of PBS minitubers differs greatly between cultivars. The overall performance of Cardinal, Desiree and Kufri Sindhuri was satisfactory, particularly for large-sized minitubers. Cardinal did very well under terai conditions, but it should be noted that the results are based on one season's data only.

Multiplication rates of minitubers

Multiplication rates(MR = number of BS1 tubers produced per minituber planted) were primarily affected by minituber size and to a lesser extent by cultivar and environment (Tables 2, 3 and 4).

Table 2 illustrates the impact of minituber size on the multiplication rate. In both the hill and terai environments larger minitubers produced significantly ($p < 0.05$) more progeny tubers. PBS minitubers of 1–5 g produced almost twice as many progeny tubers as PBS minitubers of <1 g which produced 3.3 and 2.4 progeny tubers in the terai and hills respectively. Minitubers of >5 g produced more than seven tubers in both environments.

No significant ($p > 0.05$) differences were observed between the average MR of the hills (4.5) and that of the terai (5.0). Taking into consideration that the average productivity in the hills was 32% less than in the terai, this result implies that the reduced productivity in the hills was not due to reduced numbers of tubers produced but rather to reduced tuber weight. This indicates that crop husbandry practices such as plant nutrition, plant protection and irrigation in the hills were sub-optimal particularly in the latter part of the growing season when

Table 2. Minituber multiplication rates (MR, total number of basic seed (BS1) tubers produced per minituber planted) in the terai and hills by minituber size (g), averaged over cultivars and two seasons.

	Terai		Hill	
Size	Number planted	MR	Number planted	MR
<1	7919	3.3	12 230	2.4
1–5	54 506	5.0	45 898	4.4
>5	5515	7.2	3901	7.6

Terai: p (<1 g *vs.* 1–5 g $= 0$) $>$ T $= 0.0336$; p (1–5 g *vs.* >5 g $= 0$) $>$ T $= 0.0202$; Hill: p (<1 g *vs.* 1–5 g $= 0$) $>$ T $= 0.0220$; p (1–5 g *vs.* >5 g $= 0$) $>$ T $= 0.0010$.

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Table 3. Minituber multiplication rates (MR, number of basic seed (BS1) tubers produced per minituber planted) in the terai by cultivar and minituber size, averaged over two seasons.

	Minituber		Multiplication rates				
			Seed size			Cumulative	
Cultivar	Size (g)	Number planted	<35 mm	35–55 mm	>55 mm	MR	s.e.
Kufri	<1	815	0.5	0.5	0.1	1.1	0.08
Jyoti	1–5	10 672	1.5	3.4	0.6	5.5	0.47
	>5	4975	3.1	3.1	0.9	7.0	1.50
Achirana	<1	545	0.8	0.6	0.1	1.6	0.05
Inta	1–5	1793	0.7	1.5	0.2	2.4	0.24
	>5	—	—	—	—	—	—
Desiree	<1	1612	0.7	0.3	0.2	1.1	0.32
	1–5	3474	1.1	0.9	0.3	2.3	0.73
	>5	—	—	—	—	—	—
Cardinal†	<1	1832	1.4	2.4	0.7	4.4	1.33
	1–5	9147	0.9	2.2	0.8	3.9	0.28
	>5	540	1.7	3.8	2.3	7.8	1.80
Kufri	<1	3115	2.7	2.6	0.4	5.8	2.70
Sindhuri	1–5	29 420	2.7	3.1	0.5	6.3	0.53
	>5	—	—	—	—	—	—

†one season only.

bulking-up occurs. Protection from late blight disease is not as widespread in the hills as in the terai, and this might be one of the causes of reduced tuber weight, resulting from premature senescence of the crop.

Apart from minituber size, MRs were influenced by cultivar although to a lesser extent (Tables 3 and 4). MRs of Achirana Inta were disappointing in the hills as well as in the terai. In both environments the average MR of Achirana Inta was significantly ($p < 0.01$) lower than the average MR of the other cultivars. In the terai, however, minitubers of Kufri Sindhuri produced on average significantly ($p < 0.001$) more progeny tubers than the other cultivars, demonstrating this cultivar's good adaptation to terai climatic conditions. In contrast, NPI-106 appeared to be well-adapted to the hill environment. Cardinal performed well in both environments whereas minitubers of Desiree appeared to produce more progeny tubers in the hills than in the terai. It should be noted, however, that only small numbers of minitubers of Achirana Inta and Desiree were multiplied in the terai compared with those in the hills. This suggests a farmer effect rather than a varietal effect.

CONCLUSIONS

The overall results clearly indicate that small-scale farmers were able to multiply minitubers successfully. This technology, particularly if applied in conjunction

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Table 4. Minituber multiplication rates (MR, number of basic seed (BS1) tubers produced per minituber planted) in the hills by cultivar and minituber size, averaged over two seasons.

	Minituber		Multiplication rates				
			Seed size			Cumulative	
Cultivar	Size (g)	Number planted	<35 mm	35–55 mm	>55 mm	MR	s.e.†
Kufri	<1	3000	0.8	1.4	0.4	2.6	0.29
Jyoti	1–5	9322	1.3	2.1	0.3	3.7	0.59
	>5	—	—	—	—	—	—
Achirana	<1	5005	0.6	0.3	0.0	0.9	0.16
Inta	1–5	9005	1.7	1.7	0.2	3.6	0.47
	>5	436	0.9	3.2	0.2	4.3	x
Desiree	<1	1800	0.9	0.7	0.0	1.6	0.86
	1–5	12 535	2.3	1.9	0.5	4.7	0.74
	>5	1520	2.5	3.9	1.2	7.6	2.84
Cardinal‡	<1	1725	1.9	2.4	0.3	4.6	1.46
	1–5	10 471	1.9	3.2	0.5	5.6	0.59
	>5	1045	1.6	3.6	0.5	5.8	0.69
NPI-106	<1	700	0.7	5.8	0.2	6.7	x
	1–5	4565	1.9	2.4	0.5	4.8	0.91
	>5	900	3.4	5.1	1.6	10.2	4.59

†x refers to a sample size of 1; ‡one season only.

with traditional seed production techniques, will enable farmers to produce their own high quality seed and therefore will reduce their dependence on unreliable and expensive supplies of conventional seed. This in turn will contribute to an overall increase in potato productivity and production and, at the same time, will reduce the pressure on national governments to intervene in seed production and distribution systems.

However, important factors for the success of this technology are the provision of technical advice to farmers who are inexperienced at growing the tiny tubers and, at least under Nepali climatic conditions, the availability of irrigation during crop establishment. Moreover, farmers with little or no experience at multiplying PBS should be encouraged to use large-sized minitubers initially, preferably of cultivars which are well-adapted to their environment. In the case of Nepal, cultivars such as Kufri Sindhuri and Cardinal can be recommended for the terai and Desiree, Cardinal, and NPI-106 for the hills.

Minitubers can be transported by air or land at comparatively low cost because of their small size. This implies that their use is not restricted to a limited distance from the production site. Therefore, countries whose potato industry is too small to justify the investment required for the establishment of a rapid propagation facility could collaborate at a regional level either by importing minitubers or by operating one rapid propagation facility jointly with a neighbouring country. The facility established in Nepal, for instance, could be extended to satisfy seed

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demands from neighbouring countries of the Hindukush Himalayan region which, in turn, might further reduce the costs of production through economies of scale.

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