

Manipulation of agronomic practices for tuber-size distribution in potato (*Solanum tuberosum*) seed crop

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ABSTRACT

To improve the production of seed-size tubers in potato (*Solanum tuberosum* L.), 31 experiments were conducted during 1999-2003 at nine centres, situated in different agro-climatic regions of the country. Two levels each of planting spacing (60 x 15 and 60 x 10 cm), fertilizer doses (100+35+66 and 150+52+66 kg of N+P+K/ha respectively) and dates of haulm cutting (70 and 80 days after planting) were imposed on popular potato cultivars of the regions. Mean results over the locations indicated that although the yield of seed-size tuber at closer spacing (13.9 t/ha) increased by a 15.7% compared with that at wider spacing, it could not compensate for the improved seed rate of 2.22 to 2.67 t/ha. An increase in fertiliser level gave 1.6 t/ha more total tuber yield (25.3 t/ha), out of which 0.7 t/ha was in seed-size grade. Delay in haulm cutting from 70 to 80 days after planting potato improved the total tuber yield by 4.8 t/ha (21.6%), out of which 1.1 t/ha was in seed-size. Economics of potato cultivation for production of seed size tubers also favoured planting at wider spacing (60 x 15 cm), with higher fertiliser rate (150+52+66 kg of N+P+K/ha) and dehauling at 80 days after planting.

Key words: Fertilizer dose, Haulm cutting, Potato, Seed, Spacing

Potato (*Solanum tuberosum* L.) has long been recognized as a major food crop of the world. The cost of potato cultivation is considerably higher than of other major food crops like wheat, rice and maize. Seed alone accounts for approximately 50% of the total cost of cultivation (Singh *et al.*, 2000). The low rate of multiplication (5-10 times depending upon cultivar, agro-climatic conditions and crop management), high seed rate (3 to 4 t/ha) and progressive accumulation of degenerative viruses are responsible for inadequate availability of quality seed in potato. Moreover, use of small seed tubers leads to low productivity, whereas big seed tubers increase the cost of cultivation. Cutting of big tubers for planting is also not advisable as it spreads diseases, and leads to low emergence due to infection in cut tubers. India presently produces 2,000 t breeders' seed of potato annually (Pandey *et al.*, 2007). Considering that it is multiplied three times with a multiplication rate of 8 before it is supplied to the farmers as

certified seed, the total availability of potato seed stands to 1.0 million t compared with a demand of 4.2 million t per annum (Singh, 2003). To bridge this gap of demand and supply, optimum production of seed-size tubers at farmer's level is important in order to increase the potato productivity, because the farmer can further use the certified seed for 3-4 seasons. Yield-attributing characters of potato, *i.e.* number and size of tubers, are governed by several factors, out of which, spacing, fertilization rate and date of haulm cutting are important for seed-tuber production. However, information on the combined effect of these factors on seed-tuber production for different potato-growing regions of the country is not available. Keeping this in view, a multi-location experiment was conducted in the major potato-growing states of India to improve the production of seed-size tubers through agronomic manipulation.

MATERIALS AND METHODS

The experiments were conducted at nine centres lo-

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cated in different agro-climatic regions of the country. At Chhindwara (M.P.), Deesa (Gujarat), Faizabad (U.P.), Hisar (Haryana) and Patna (Bihar), experiments were conducted during 1999-2003; at Pantnagar (Uttarakhand) and Kota (Rajasthan) during 1999-2001; at Modipuram (U.P.) during 2002-2003 and at Jalandhar (Punjab) during 1999-2002, using popular potato cultivars of the respective regions. The treatments consisted of two levels each of planting spacing, viz. 60 x 15 and 60 x 10 cm, fertilizer dose, viz. 100+35+66 and 150+52+66 N+P+K (Kg/ha) respectively; and date of haulm cutting, viz. 70 and 80 days after planting. However, planting spacings at Deesa were 50 x 15 cm and 50 x 10 cm, whereas the fertility levels were 110+24+91 and 165+36+137 N+P+K (Kg/ha) at Deesa and 150+35+66 and 150+52+66 N+P+K Kg/ha at Jalandhar. Data were analysed in factorial randomised block design. The number of replications was four in the experiment at all the locations, except at Chhindwara and Pantnagar where only three replications were used. Seed tubers of 40 g size were used in planting potato. Full doses of P and K along with two-third dose of N were applied at planting, and the remaining N was given at the time of earthing-up. At all the locations the crop was planted at optimum date of planting during *rabi* (winter) season and raised following standard package of practices. The data were recorded on the number and yield of total and seed size tubers. Data were analysed by pooling over the years for each location. For working out the cost of cultivation, cost of seed tubers was taken as Rs 8,000/t and of N, P and K as Rs 48, 63.93 and 8.95/kg respectively. The selling price of seed-size tubers was taken as Rs 7,000/t and of other grades (total-seed size) as Rs 4,000/t.

RESULTS AND DISCUSSION

Spacing

Closer plant spacing resulted in significantly higher yields of total as well as seed-size tuber compared with wider spacing at all the locations, except at Pantnagar and Kota (Table 1). Although the effect of spacing on total tuber yield during 2001-2002 and on seed-size tuber yield during 1999-2000 and 2000-2001 at Chhindwara, and on seed size-tuber yield during 2001-2002 at Faizabad was not significant (Table 2), the total and seed-size tuber yields at these locations were significantly higher in the means data of all the years. The increase in total tuber yield varied from 0.30 t/ha at Kota to 4.04 t/ha at Hisar, whereas the maximum increase in seed-size tuber yield was recorded at Deesa (3.64 t/ha). Tuberization takes place during early growth of potato plant. At this stage it is not much affected by competition caused due to closer spacing. However, at later stages the competition for space increases and the availability of photosynthates for tuber

growth decreases, which results into restricted growth of the tubers, leading to the production of large proportion of seed-size tubers. Kumar *et al.* (2001) also attributed decreased availability of assimilates for individual tubers to increased planting density, thereby increasing number and yield of seed size tubers.

Closer planting required 66,667 extra seed tubers/ha weighing 2.67 t at Deesa and 55,555 extra seed tubers/ha weighing 2.22 t at other locations. Thus, while comparing the effect of spacing on tuber yield, use of additional quantity of seed in closer spacing was also considered since the seed is the costliest input in potato production, accounting for >50% of the total cost. It was observed that net improvement in total as well as seed size tuber yield under closer spacing was not significant when the additional quantity of seed tubers used was subtracted from produce (seed size or total tuber yield), at any of the location.

The number of seed size tubers showed a significant improvement at Deesa and Hisar only in closely-spaced crop, even after adjusting for the additional number of seed tubers used for raising the crop. However, since the increase in seed size tuber yield at these locations did not match the increase in number of seed size tuber, it loses its significance as the seed is sold on weight basis and not on number basis.

Fertility level

An increase in fertility level increased the total tuber yield at all the locations (Table 1). The highest increase (3.79 t/ha) was recorded at Faizabad and the lowest (0.05 t/ha) at Pantnagar. Significant increase in total yield of seed-size tuber due to improved fertility was observed at Chhindwara, Kota, Faizabad and Patna. The initial fertility status in terms of available N and P was low to medium at these locations, hence the total tuber yield responded significantly to increased rate of fertilizer application. The increase in yield of seed-size tuber was also significant under increased fertility at these locations reflecting that under the higher fertility level the bulking of small-size tubers to seed grade was more than that of seed-size tubers to large size, hence the yield of total as well as seed-size tubers improved significantly.

At Deesa, Pantnagar, Hisar and Jalandhar, the increased fertility level failed to show any impact on the number and yield of seed-size tubers. Application of P increases the number and yield of seed-size tubers (Sud and Sharma, 2003). However, at these locations, the initial available P content was high, perhaps due to effect of fertility level on seed-size tuber yield non-significant. The total tuber yield at these locations also remained non-significant. The results are in agreement with the findings of Suman *et al.* (2003). At Modipuram, although the total tuber yield in-

Table 1. Effect of treatments on total tuber yield and number and yield of seed-size (10-40 g) tubers at different locations

Treatment	Total yield (t/ha)	Seed size		Total yield (t/ha)	Seed size		Total yield (t/ha)	Seed size		
		No. (x 10 ³ /ha)	Yield (t/ha)		No. (x 10 ³ /ha)	Yield (t/ha)		No. (x 10 ³ /ha)	Yield (t/ha)	
		Chhindwara			Deesa			Pantnagar		
<i>Row spacing (cm)</i>										
60 x 15	20.27	277.2	10.20	23.86	418.4	12.20	23.91	253.3	17.02	
60 x 10	22.18	292.5	10.74	26.43	562.1	15.84	24.52	261.8	17.62	
Mean	21.23	284.9	10.47	25.15	490.3	14.02	24.22	257.6	17.32	
SEM±	0.26	6.02	0.16	0.32	9.66	0.36	0.67	8.33	0.49	
CD (P=0.05)	0.74	NS	0.45	0.89	27.2	1.02	NS	NS	NS	
<i>Fertiliser level (N+P+K kg/ha)</i>										
100+35+66	20.00	264.7	9.85	25.11	471.4	14.07	24.19	229.6	16.81	
150+52+66	22.46	304.9	11.09	25.17	509.0	13.96	24.24	285.5	17.83	
CD (P=0.05)	0.74	17.0	0.45	NS	27.2	NS	NS	23.9	NS	
<i>Date of haulm cutting (DAP*)</i>										
70	19.95	270.0	10.34	20.68	501.4	13.11	21.89	245.7	16.21	
80	22.49	299.7	10.60	29.61	479.0	14.92	26.54	269.4	18.44	
CD (P=0.05)	0.74	17.0	NS	0.89	NS	1.02	1.91	23.9	1.40	
		Kota			Modipuram			Faizabad		
<i>Row spacing (cm)</i>										
60 x 15	17.77	194.9	7.53	23.32	486.5	13.44	27.53	450.5	14.71	
60 x 10	18.07	215.7	7.26	25.80	597.0	16.45	28.49	494.8	15.87	
Mean	17.92	205.3	7.40	24.55	541.8	14.95	28.01	472.7	15.29	
SEM±	0.20	3.66	0.17	0.45	16.23	0.50	0.31	5.13	0.22	
CD (P=0.05)	NS	10.4	NS	1.32	47.74	1.46	0.87	14.4	0.62	
<i>Fertiliser level (N+P+K kg/ha)</i>										
100+35+66	16.88	199.1	6.87	23.71	563.5	15.98	26.11	435.4	14.06	
150+52+66	18.95	211.5	7.92	25.40	520.1	13.92	29.90	509.9	16.53	
CD (P=0.05)	0.57	10.4	0.48	1.32	NS	1.46	0.87	14.4	0.62	
<i>Date of haulm cutting (DAP*)</i>										
70	17.37	201.6	7.21	22.91	552.8	15.12	25.67	439.3	14.06	
80	18.47	208.9	7.58	26.21	530.8	14.77	30.35	505.9	16.53	
CD (P=0.05)	0.57	NS	NS	1.32	NS	NS	0.87	14.4	0.62	
		Hisar			Patna			Jalandhar		
<i>Row spacing (cm)</i>										
60 x 15	17.27	215.5	7.20	23.12	373.7	11.86	30.11	408.6	14.55	
60 x 10	21.31	312.5	9.95	24.60	466.7	13.63	31.22	564.6	16.81	
Mean	19.29	264.0	8.58	23.86	420.0	12.75	30.67	486.6	15.68	
SEM±	0.49	7.36	0.40	0.27	5.90	0.19	0.27	6.19	0.24	
CD (P=0.05)	1.38	20.7	1.11	0.74	16.6	0.54	0.76	17.4	0.68	
<i>Fertiliser level (N+P+K kg/ha)</i>										
100+35+66	18.62	259.7	8.60	22.87	419.5	12.46	30.34	467.6	15.41	
150+52+66	19.96	268.4	8.55	24.85	420.8	13.03	30.99	505.7	15.96	
SEM±										
CD (P=0.05)	NS	NS	NS	0.74	NS	0.54	NS	17.4	NS	
<i>Date of haulm cutting (DAP*)</i>										
70	15.74	289.4	8.42	22.42	406.7	12.13	28.69	484.7	15.22	
80	22.84	238.6	8.72	25.30	433.6	13.36	32.64	488.5	16.15	
SEM±										
CD (P=0.05)	1.38	20.7	NS	0.74	16.6	0.54	0.76	NS	0.68	

*DAP= Days after planting

Table 2. Effect of treatments on total yield and seed-size (10-40 g) tuber yield at Chhindwara, Deesa and Faizabad during different years

Treatment	Total yield (t/ha)				Seed size-tuber yield (t/ha)			
	1999-00	2000-01	2001-02	2002-03	1999-00	2000-01	2001-02	2002-03
Chhindwara								
<i>Row spacing (cm)</i>								
60 x 15	19.58	19.49	21.89	20.12	11.95	12.88	8.32	7.64
60 x 10	21.80	21.69	22.93	22.29	11.93	12.18	9.55	9.28
SEm±	0.53	0.29	0.66	0.24	0.30	0.25	0.24	0.17
CD(P=0.05)	1.59	0.89	NS	0.72	NS	NS	0.74	0.50
<i>Fertiliser level (N+P+K kg/ha)</i>								
100+35+66	19.33	19.11	21.45	20.06	11.34	12.03	8.28	7.73
150+52+66	22.05	22.06	23.37	22.35	12.54	13.02	9.59	9.19
SEm±								
CD (P=0.05)	1.59	0.89	NS	0.72	0.92	0.75	0.74	0.50
<i>Date of haulm cutting (DAP*)</i>								
70	20.39	19.88	20.21	19.34	12.09	12.66	8.50	8.10
80	20.99	21.30	24.61	23.07	11.79	12.40	9.38	8.82
SEm±								
CD (P=0.05)	NS	0.89	1.99	0.72	NS	NS	0.74	0.50
Deesa								
<i>Row spacing (cm)</i>								
60 x 15	21.73	23.54	19.54	30.63	9.81	14.51	11.07	13.40
60 x 10	25.45	25.28	21.88	33.11	12.79	18.60	14.79	17.17
SEm±	0.71	0.54	0.49	0.76	0.61	0.41	0.50	0.76
CD (P=0.05)	2.10	1.58	1.43	2.25	1.80	1.21	1.47	2.25
<i>Fertiliser level (N+P+K kg/ha)</i>								
100+35+66	23.58	24.35	20.76	31.77	11.37	17.04	12.31	15.57
150+52+66	23.59	24.47	20.66	31.97	11.23	16.07	13.54	15.01
SEm±								
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
<i>Date of haulm cutting (DAP*)</i>								
70	19.68	19.44	16.53	27.06	11.71	14.60	11.15	14.98
80	27.50	29.37	24.88	36.70	10.89	18.51	14.70	15.60
SEm±								
CD (P=0.05)	2.10	1.58	1.43	2.25	NS	1.21	1.47	NS
Faizabad								
<i>Row spacing (cm)</i>								
60 x 15	12.67	29.90	36.43	31.12	9.94	13.91	16.66	18.34
60 x 10	14.33	31.97	34.14	33.52	11.24	14.88	17.05	20.33
SEm±	0.11	0.21	0.39	0.39	0.08	0.10	0.41	0.35
CD (P=0.05)	0.32	0.63	1.16	1.16	0.25	0.29	NS	1.02
<i>Fertiliser level (N+P+K kg/ha)</i>								
100+35+66	11.72	29.00	32.59	31.14	9.20	13.50	15.12	18.43
150+52+66	15.27	32.86	37.98	33.50	11.99	15.28	18.60	20.33
SEm±								
CD (P=0.05)	0.32	0.63	1.16	1.16	0.25	0.29	1.20	1.02
<i>Date of haulm cutting (DAP*)</i>								
70	12.45	30.16	30.72	29.33	9.90	14.04	14.64	17.65
80	11.54	31.71	39.85	35.32	11.28	14.75	19.08	21.02
SEm±								
CD (P=0.05)	0.32	0.63	1.16	1.16	0.25	0.23	1.20	1.02

creased significantly under the higher fertility level, the same could not be translated in seed-size tuber yield, which showed a significant decrease. This indicates that

the seed tubers bulked to larger size, hence the total tuber yield increased at the expense of seed-size tuber yield with increased fertility.

Haulm cutting

Delay in haulm cutting by 10 days (from 70 to 80 days after planting) recorded significant increase in total tuber yield at all the locations (Table 1). The highest increase (45.1%) was observed at Hisar and the minimum (6.33%) at Kota. The increase in total tuber yield due to delay in date of haulm cutting may be attributed to the fact that all the varieties used at different locations had a maturity period of >90 days (Pandey *et al.*, 2006) and the tuber bulking continues till maturity. Hence the cessation of bulking was dependent entirely on the date of haulm cutting. Therefore, a delay in haulm cutting increased the duration of bulking by 10 days which resulted in significantly higher total tuber yield at all the locations. Kumar *et al.* (2002) and Patel *et al.* (2002) also reported increase in total tuber yield due to delay in dehauling.

Significant increase in total tuber yield was also reflected in significant increase in the yield of seed-size tuber due to delay in haulm cutting at Deesa, Pantnagar, Faizabad and Patna. Although the effect of haulm-cutting date on the yield of seed-size tuber was not consistent in different years at Deesa (Table 2), the increase in their yield due to delayed haulm cutting was found significant in the mean of different years. The increase in total tuber yield also significantly increased the yield of seed-size tuber. Kumar *et al.* (2001) also reported increase in their tuber yield with delay in haulm cutting up to or beyond 80 days. However, at Chhindwara, Kota and Hisar the increase in their yield was non-significant despite significant increase in total tuber yield, indicating that with delay in haulm cutting the bulking of seed size tubers to big size was greater than that of small-size tubers to seed size. At

Modipuram, the delay in haulm-cutting date recorded a non-significant decrease (2.3%) in the yield of seed-size tuber. However, this decrease of 0.35 t/ha in seed-tuber yield was well compensated with 3.0 t/ha increase in total tuber yield. It indicates that there was a uniform shifting of tubers of different grades to the higher grades with delay in haulm cutting at Modipuram, resulting in higher yield of total tubers without increase in that of seed-size tuber.

In general, the yield of seed-size tuber either increased significantly or remained unchanged due to delay in haulm cutting, along with significant increase in total tuber yield at all the locations, indicating that the delay in haulm-cutting (a non-monetary input) is beneficial for the overall productivity of the system.

Interaction effects

Total tuber yield at Faizabad and Kota and the yield of seed-size tuber at Faizabad were not affected due to spacing at lower fertility levels (Table 3). However, these parameters increased significantly at closer spacing when the fertility level was increased. The initial available N and P contents of the soil at these locations were low to medium. This shows that at low fertilizer-application rate, the competition for nutrients was present even in widely spaced crop, which became less or absent at higher fertility level even for closely spaced crop.

The interaction effect of the date of haulm cutting and fertility level was significant on total yield and seed-size tuber yield at Deesa (Table 4). Although the total tuber yield increased significantly due to delay in haulm cutting at both the fertility levels, the increase in the yield of seed-size tuber was significant due to this factor only at in-

Table 3. Interaction effect of spacing and fertility on total yield and seed size (10–40 g) tuber yield at Faizabad and Kota

Fertiliser level (N+P+K kg/ha)	Faizabad				Kota	
	60 x 15 cm	60 x 10 cm	60 x 15 cm	60 x 10 cm	60 x 15 cm	60 x 10 cm
	Total yield (t/ha)		Seed-size tuber yield (t/ha)		Total yield (t/ha)	
100+35+66	26.31	25.92	13.84	14.28	17.41	16.36
150+52+66	28.74	31.07	15.58	17.47	18.13	19.77
SEm±	0.44	0.31	0.28			
CD (P=0.05)	1.23	0.87	0.81			

Table 4. Interaction effect of haulm cutting and fertility on total yield and seed size (10–40 g) tuber yield at Deesa

Fertiliser level (N+P+K kg/ha)	Date of haulm cutting (DAP)			
	70	80	70	80
	Total yield (t/ha)		Seed size yield (t/ha)	
100+35+66	21.11	29.13	13.84	14.30
150+52+66	20.25	30.10	12.38	15.55
SEm±	0.45	0.51		
CD (P=0.05)	1.25	1.43		

creased fertility. This indicates that the increase in total tuber yield was not proportionate in different grades.

At Chhindwara the total yield and seed size-tuber yield increased significantly at closer spacing when haulms were cut at 70 days, but remained non-significant when haulm cutting was delayed by 10 days, indicating that the beneficial effect was negated by the delay (Table 5). Closer spacing along with delayed haulm cutting produced significantly higher yield of total and seed-size tubers at

Deesa compared with other combinations, showing that the competition for space was minimal and tubers bulked up to 80 days. The results were same at Kota for total tuber yield, but the effect of interaction between spacing and haulm cutting was not consistent on the yield of seed-size tubers.

Economics

The economics in general was in favour of wider spac-

Table 5. Interaction effect of spacing and haulm cutting on total yield and seed size (10–40 g) tuber yield at Chhindwara, Deesa and Kota

Date of haulm cutting (DAP*)	Chhindwara				Deesa				Kota			
	60 × 15 (cm)	60 × 10 (cm)	60 × 15 (cm)	60 × 10 (cm)	60 × 15 (cm)	60 × 10 (cm)	60 × 15 (cm)	60 × 10 (cm)	60 × 15 (cm)	60 × 10 (cm)	60 × 15 (cm)	60 × 10 (cm)
	Total yield (t/ha)		Seed-size tuber yield (t/ha)		Total yield (t/ha)		Seed-size tuber yield (t/ha)		Total yield (t/ha)		Seed-size tuber yield (t/ha)	
70	18.57	21.34	9.80	10.87	20.07	21.29	12.29	13.94	17.78	16.96	7.74	6.68
80	21.97	23.02	10.59	10.61	27.65	31.57	12.11	17.73	17.76	19.18	7.32	7.84
SEm±	0.37	0.23	0.45	0.51	0.28	0.24						
CD (P=0.05)	1.05	0.64	1.25	1.43	0.81	0.69						

Table 6. Cost of cultivation and net returns (x10³ Rs/ha), and B : C ratio of seed potato production

Location	Cost of cultivation	Net returns	B : C ratio	Cost of cultivation	Net returns	B : C ratio	Cost of cultivation	Net returns	B : C ratio
<i>Row spacing (cm)</i>	Chhindwara			Deesa			Pantnagar		
60 x 15	59.4	52.3	1.88	69.8	62.3	1.89	57.9	88.8	2.53
60 x 10	77.2	43.8	1.57	91.1	62.1	1.68	75.7	75.3	1.99
<i>Fertiliser level (N+P+K kg/ha)</i>									
100+35+66	66.5	43.0	1.65	78.5	64.1	1.82	65.0	82.2	2.26
150+52+66	70.0	53.1	1.76	82.4	60.2	1.73	68.5	81.9	2.20
<i>Date of haulm cutting (DAP*)</i>									
70	68.3	42.5	1.62	80.4	41.6	1.52	66.8	69.4	2.04
80	68.3	53.5	1.78	80.4	82.8	2.03	66.8	94.7	2.42
<i>Row spacing (cm)</i>	Kota			Modipuram			Faizabad		
60 x 15	59.4	34.3	1.58	57.9	75.7	2.31	57.9	96.4	2.67
60 x 10	77.2	16.9	1.22	75.7	76.9	2.02	75.7	85.9	2.14
<i>Fertiliser level (N+P+K kg/ha)</i>									
100+35+66	66.5	21.6	1.32	65.0	77.8	2.20	65.0	81.6	2.26
150+52+66	70.0	29.5	1.42	68.5	74.8	2.09	68.5	100.7	2.47
<i>Date of haulm cutting (DAP*)</i>									
70	68.3	22.8	1.33	66.8	70.2	2.05	66.8	78.1	2.17
80	68.3	28.3	1.41	66.8	82.4	2.23	66.8	104.2	2.56
<i>Row spacing (cm)</i>	Hisar			Patna			Jalandhar		
60 x 15	59.2	31.5	1.53	63.8	64.2	2.01	60.4	103.7	2.72
60 x 10	77.0	38.1	1.49	81.6	57.7	1.71	78.2	97.1	2.24
<i>Fertiliser level (N+P+K kg/ha)</i>									
100+35+66	66.3	33.9	1.51	71.0	57.9	1.82	68.8	98.8	2.44
150+52+66	69.9	35.6	1.51	74.5	64.0	1.86	69.9	102.0	2.46
<i>Date of haulm cutting (DAP*)</i>									
70	68.1	20.1	1.30	72.7	53.4	1.73	69.3	91.1	2.31
80	68.1	49.4	1.73	72.7	68.6	1.94	69.3	110.0	2.58

ing. Although the gross returns were higher with closer spacing at all the locations, the net returns did not improve except at Hisar and Modipuram (Table 6). The beneficial effect of increased gross return on net return was negated due to increased cost of cultivation under closer spacing, which was Rs 21,336/ha more at Deesa and Rs 17,784/ha more at other locations. The decrease in net return due to closer spacing ranged from Rs 136/ha at Deesa to Rs 17,394/ha at Kota. Positive net returns due to closer spacing were recorded at Modipuram where it improved marginally (1.5%), and at Hisar where the improvement was substantial (21.1%) over wider spacing. Increase in net returns at Hisar was on account of highest increase in total tuber yield (4.04 t/ha) due to closer spacing. Benefit : cost ratio declined at all the locations under closer spacing, because the increase in gross returns was not in proportion to the cost of cultivation under closer spacing.

An increase in fertilization increased the cost of cultivation by Rs 3,823/ha at Deesa, Rs 1,113/ha at Jalandhar and Rs 3,512/ha at other locations. The increase in net return under higher fertility at Chhindwara (Rs 10,048/ha), Kota (Rs 7,918/ha), Faizabad (Rs 19,058/ha) and Patna (Rs 6,118/ha) was due to significant increase in total yield as well as seed-size tuber yield. However, at Jalandhar, only P dose was increased whereas the doses of N and K remained the same under higher fertility level. As a result the increase in cost of cultivation was marginal. Hence a slight increase of 0.65 t/ha in total tuber yield and 0.55 t/ha in the yield of seed-size tuber translated into Rs 3,137/ha higher net returns. The net returns declined with increase in fertilizer rate at Deesa (Rs 3,913/ha) and Modipuram (Rs 2,932/ha) due to significant decrease in the yield of seed-size tuber.

Date of haulm cutting is a non-monetary input, hence the cost of cultivation was not affected and any change in net returns was solely dependent upon gross return, which in turn was dependent upon tuber yield. Since the total tuber yield increased significantly along with increase in the yield of seed-size tuber at all the locations except Modipuram, the gross as well as net returns also increased with delay in haulm cutting by 10 days. The highest in-

crease of Rs 41,150/ha was recorded at Deesa, whereas the lowest was at Kota (Rs 5,510/ha). The respective increase in total tuber yield were also the highest (8.93 t/ha) and lowest (1.1 t/ha) at these locations due to delay in haulm cutting.

It may be concluded that seed tubers should be planted at 60 x 15 cm with higher doses of fertilizers (150 kg N + 52 kg P + 66 kg K/ha) and haulm cutting should be done at 80 days after planting for obtaining higher productivity and profitability from seed-potato crop.

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