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Influence of planting geometries on tuber yield and profitability of seed potatoes (*Solanum tuberosum*) in north-western plains of India

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ABSTRACT

The present field experiment was conducted during winter (*rabi)* seasons of 2018–19 and 2019–20 at ICAR-Central Potato Research Institute, Regional Station Jalandhar, Punjab to find out the suitable planting geometry and dehaulming date for enhancing the seed potato (*Solanum tuberosum* L.) yield and profitability under north-western plains of India. According to the study planting geometry and dehaulming date strongly influenced the seed size tuber yield and quality. Among the different planting geometries, paired row bed planting significantly increased the yield and number of seed size tubers when dehaulming was done after 80–90 days. Maximum gross income, net returns and benefit:cost ratio was also observed under paired row bed planting over the conventional planting geometry. Paired row bed planting increased the tuber yield by 21.7% and benefit:cost ratio by 18.6% over the control. Hence, it is concluded from the experiment that paired row bed planting is found suitable for maximizing the seed size tuber numbers, yield as well as getting the maximum economic returns.

Keywords: Benefic:cost ratio, Dehaulming, Planting geometry, Seed potato, Seed yield

Seed tuber is the most vital input involved in potato (*Solanum tuberosum* L.) cultivation, involving around 40–50% of input cost (Kushwah and Singh 2008, Sharma and Singh 2010). India has a strong indigenous seed potato production system (Singh *et al.* 2019), wherein the seed potato crops are cultivated during a period of low aphid activity and the technique is known as the 'Seed Plot Technique'. Such a window of low aphid activity generally has only 80–90 days in north-western plains of India. In this technique, it is suggested to dehaulm the seed potato crop as the population of *M. persicae* crosses the threshold limit of 20 aphids per 100 compound leaves (Kumar *et al*. 2023).

As such, 94% of the total seed potato is produced in sub-tropical plains and remaining 6% in hilly areas Sadawarti *et al*. (2019). To meet out the increasing requirement of seed tuber, it is imperative to enhance multiplication rate and yield of seed potato. Although many modern high-tech approaches, viz. tissue culture, aeroponics are known to increase seed multiplication manifold but are confined to basic seed multiplication. Moreover, these techniques are much costlier and are out of the reach of common farmers. Hence, for catering the future demand of seed potatoes, there is a need for developing the alternative cost-effective approaches involving agronomic manipulations with higher adoption level among the farmers.

Many considerations influence seed multiplication, out of which optimum planting geometry and period of dehaulming may be best alternative options as far as tuber multiplication is concerned. Currently many farmers are practicing paired row bed planting in this region. There are also advantages documented in this planting system but still the quantitative differences between the conventional ridge and furrow system and bed planting are not exactly known. Further, planting geometry used by the farmers for the seed and ware potato production is generally similar in north-western plains of India and most limiting factor for seed multiplication. Keeping in view the aforementioned facts and importance, the present study was conceived and initiated to identify the appropriate planting geometry and dehaulming date for enhancing the yield of seed size tubers in north-western plains of India.

MATERIALS AND METHODS

The present study was carried out at the research farm

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of ICAR-Central Potato Research Institute, Regional Station, Jalandhar, Punjab during winter (*rabi)* seasons of 2018–19 and 2019–20. Planting geometries comprised of spacing, viz. S_1, 60 cm × 20 cm; S_2, 66 cm × 15 cm; S_3, 66 cm × 20 cm; S_4, 75 cm × 15 cm; S_5, 75 cm × 20 cm and; S_6, paired row bed planting (Fig 1). Generally, 60 cm × 20 cm spacing is being followed for table as well as for seed potato cultivation in India, so S_1 (60 cm × 20 cm) served as control. Three dehaulming periods were evaluated D_1, 70 DAP; D_2, 80 DAP and; D_3, 90 DAP. The experiment was laid out in factorial completely randomized block design, with three replications. Each plot consisted of six rows of 4 m length, however, plant population as obtained in each geometry on hectare basis are shown in Table 1. Most popular potato cultivar of north-western plains, Kufri Pukhraj was selected for the studies. Well sprouted seed size whole tubers weighing 40–60 g were planted during the second week of October, i.e. 15th October of each year. Emergence was recorded at 30 days after planting, while other morphological observations were taken by tagging ten randomly selected plants from each treatment combination and observations on number of main stems, number of compound leaves per plant and plant height were recorded at 70 days after planting. The tubers were harvested manually 20 days after dehaulming. Harvested tuber were classified into three grades from each plots, viz. <25 g as small size; 25–125 g seed size and >125g over size counted and weighed and expressed in number per hectare and tuber yield per hectare, respectively. Pooled data of two years was subjected to analysis of variance (ANOVA) and statistical analysis was done according to completely randomized block design (factorial) as outlined by Gomez and Gomez (1984).

Table 1 Plant population per hectare and per cent change in plant population in different planting geometries

Planting geometry	Plant population per ha	Per cent change in population
60 × 20	83,333	-
66 ×15	1,00,000	+20.00
66 × 20	76,923	-7.69
75 × 15	86,666	+3.99
75 × 20	66,666	-20.00
Paired row bed planting	1,11,111	+33.33

RESULTS AND DISCUSSION

Morphological characters: The different planting geometries did not have significant effect on per cent plant emergence (F=1.35, P=0.28), number of shoots per stem (F=0.88, P=0.51), number of compound leaves per shoot (F=0.22, P=0.94) and plant height (F=1.05, P=0.42). Our findings are supported by the results of Masarirambi *et al.* (2012), Shamshul *et al.* (2016) and Pavek *et al.* (2018).

Tuber number and yield: The different planting geometries had significantly affected the seed size tuber number (F=19.57, P=0.00). The maximum seed size tuber number was recorded in paired row bed planting. The magnitude of per cent increase in the number of seed-size tuber in paired row bed planting was 26.99 over the standard practice. Similarly, total number of tubers were recorded maximum in paired row bed planting (F=48.70, P=0.00) (Fig 1). This increase in bed planting may be due to tendency of roots to grow horizontally rather than vertically downward in furrow planting method, might have helped to extract more nitrogen and water from soil, which enhanced more stolon and tuber formation, whereas, runoff from both the sides in ridge and furrow might led to ponding and infiltration which stimulate nitrogen leaching in the field Bradley *et al.* (2010). Fisher *et al.* (2019) recorded the increase in water use efficiency in bed planting which ultimately maximize the yield associated traits. Further, significantly highest numbers of small size tubers were recorded in S_4 (75 cm × 15 cm) (F=29.22, P=0.00), which was closely followed by S_2 (66 cm × 15 cm). Khalafalla (2001), Kumar *et al.* (2011) also suggested that closer intra-row spacing resulted in development of greater number of

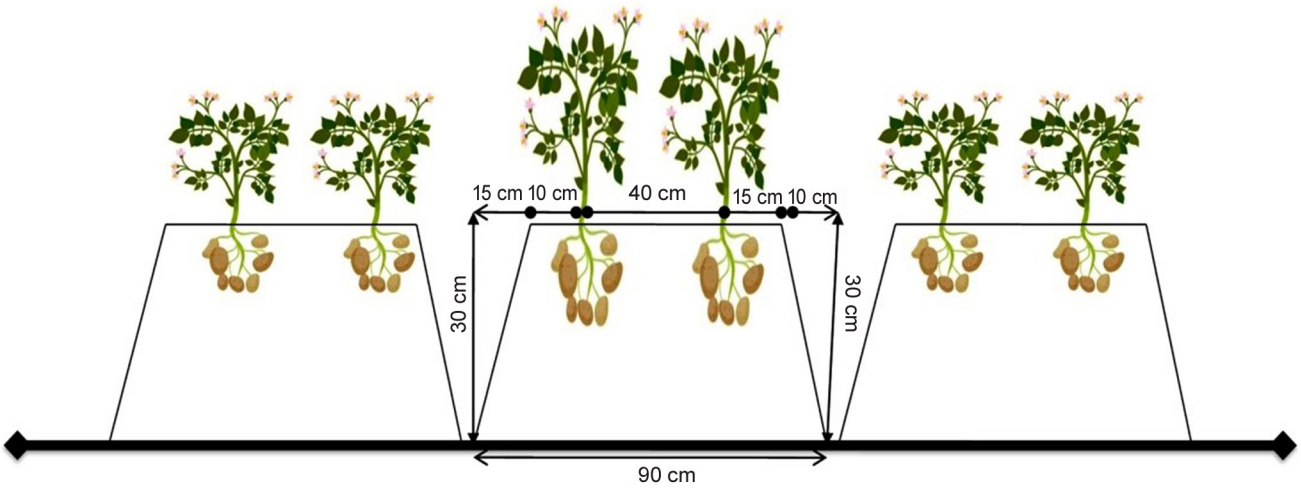

Fig 1 Illustration of pair row bed planting (PRBP) (R×R= 40 cm and P×P= 20 cm).

smaller size tubers. Zabihi-Mahmoodabad *et al.* (2010) have the opinion that increase in planting density creates competition for the nutrients within the plants that might lead to decline in tuber weight and size. Similar findings have been reported by Getachew *et al*. (2013) and Singh *et al.* (2019). On the other hand, number of large size tuber were not significantly affected by the different planting geometries (F=2.70, P=0.05), however, maximum number of large size tuber were obtained in conventional planting method.

Dehaulming duration significantly affected the number of seed size tubers (F=7.58, P=0.00) which was maximum at 80 DAP. Although number of small size tubers decreased significantly with dehaulming duration (F=37.47, P=0.00) and these were recorded maximum at dehaulming duration of 70 DAP. While, significantly maximum number of large size tubers (F=69.11, P=0.00) and total number of tubers (F=6.33, P=0.00) were recorded at dehaulming duration of 90 DAP.

Among the interactions, significantly maximum number of small size tubers (F=9.05, P=0.00) and total number of tubers (F=4.14, P=0.00) were observed in paired row bed planting at dehaulming duration of 90 days. On the other hand, significantly higher number of large size tubers were produced in traditional planting (F=2.66, P=0.03) with dehaulming duration of 90 days, however interaction of planting geometry and dehaulming duration did not have significant effect on number of seed size tubers (F=2.00, P=0.09).

A perusal of data as presented in Fig 2 revealed the significant affect amongst the planting geometries on diverse grades of tuber yield. The significant maximum seed size tuber yield (F=21.42, P=0.00); small size tubers yield (F=13.01, P=0.00) and total tubers yield (F=35.56, P=0.00) was observed in paired row bed planting except for large size tuber yield (F=2.32; P=0.08), which was recorded non-significant. Several workers (Tarkalson *et al*. 2011, Abrha *et al.* 2014) reported that inter and intra-row spacing significantly regulate the distribution of different sizes of tubers. Mishra and Pandey (2016) have observed the maximum tuber yield in bed planting. Dickson *et al.* (1992) have also found that planting of potatoes in beds increased the total and marketable tuber yield by 14%

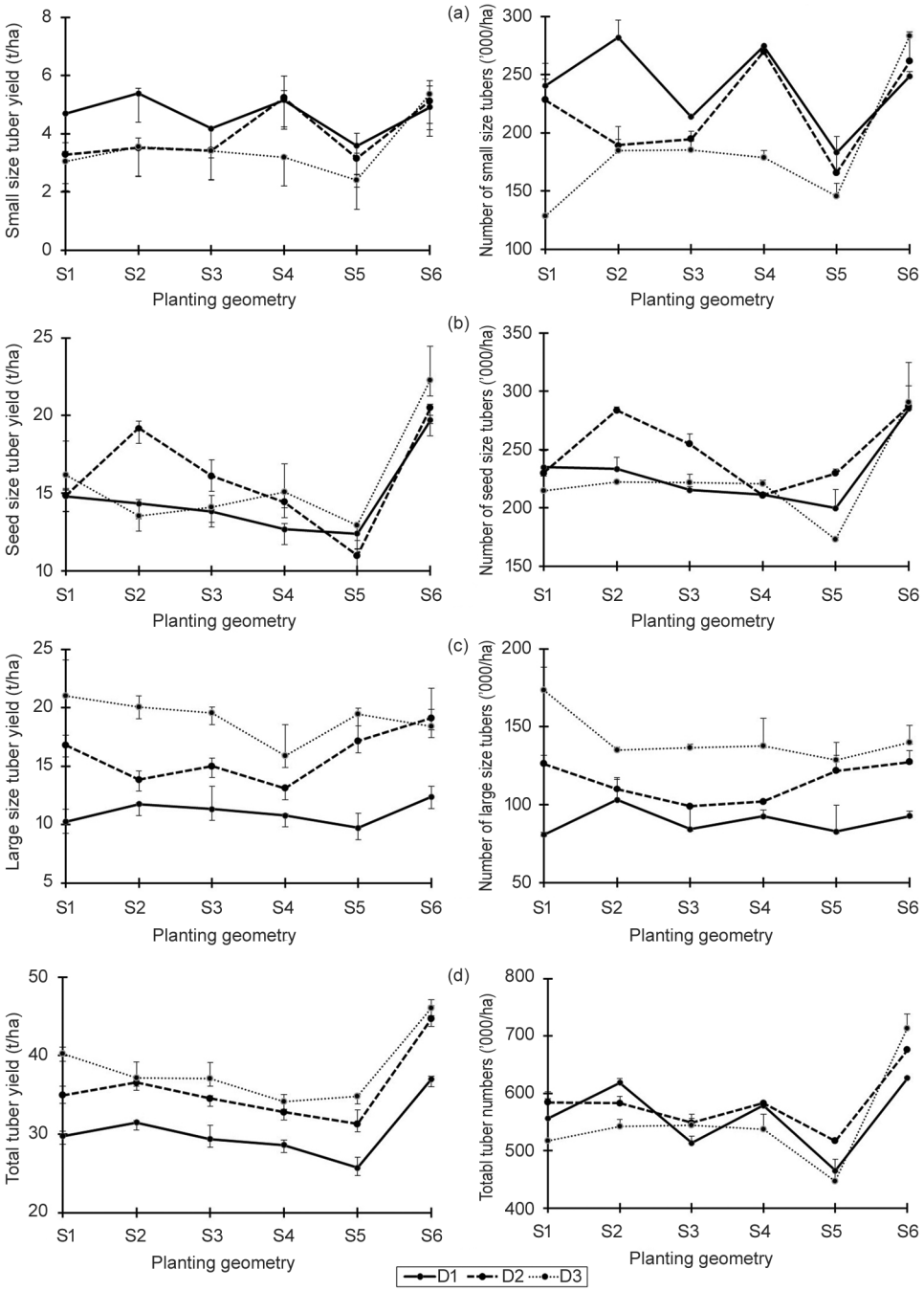

Fig 2 Effect of planting geometries and dehaulming dates on quantitative traits, i.e. tuber numbers and yield (a) small size tuber number and yield, (b) seed size tuber number and yield, (c) large size tuber number and yield and (d) total tuber number and yield. Mean±SE are displayed in error bar (P=0.05).

and 18% respectively. Bradley *et al.* (2010) observed that planting of potatoes in beds may improve the nitrogen and water use efficiency due to reduction of infiltration in the furrows. They also reported that bed planting system would provide new opportunities to manipulate the plant spacing for maximizing the use of available water and nutrient resources as well as tuber size specific markets.

Further the data revealed in Fig 2 represented the increasing trend of large size tuber yield and total tuber yield with progression in dehaulming intervals, wherein, reverse trend was noticed as far as small size tuber yield was concerned. Although dehaulming durations didn't significantly affected the seed size tubers yield (F=2.12, P=0.15). The significantly maximum small size tuber yield (F=16.31, P=0.00) was recorded at dehaulming duration of 70 DAP, whereas, maximum large size tuber yield (F=58.30, P=0.00) and total tuber yield (F=76.65, P=0.00) was recorded at dehaulming duration of 90 DAP, respectively.

In case of interactions between planting geometry and dehaulming duration, paired row bed planting resulted in the maximum seed size tuber yield at dehaulming duration 80 DAP (F=3.72, P=0.00). However, the yield of small size tubers was found more in S_2 with dehaulming at 70 DAP (F=2.93, P=0.02). No significant effect was observed amongst the different planting geometries and dehaulming duration on the yield of large size tubers (F=1.58, P=0.19) and total tuber yield (F=0.97, P=0.49), respectively. Reduction in over-size tuber yield along with an increase in the yield of lower grades with increase in plant density has also been reported by Guarda and Giulliari (1983), Kushwah and Singh (2008). Beside these effects, other physiological moderations caused by partial root drying are such as an enhanced root system in bed planting and increased ability to take up soil nutrients (e.g. nitrogen) (Kirda *et al.* 2005).

Benefit:cost ratio: Adoption of any technology at farm level is directly linked to benefit associated with it. Significantly highest gross income (548351₹/ha) (F=43.72, P=0.00), net returns (411252 ₹/ha) (F=32.51, P=0.00) and benefit cost ratio (3.00: 1) (F=12.42, P=0.00) was obtained in paired row bed planting (Table 2). Although, cost of cultivation remained maximum in paired row bed planting, due to higher seed cost in this treatment. The gross income was 27.19% and net returns were 33.14% higher in paired row bed planting compared to conventional production system (S_1). The maximum net returns and benefit:cost ratio in paired row bed planting were due to higher small seed size tuber yield since these fetched premium prices and ultimately total tuber yield. In addition, large market for the under-size tubers also exists which are sold as truthfully labeled or as general farmer trusted seed and exists as an alternate, informal seed-chain (Kadian *et al.* 2007).

Trend analysis: In order to understand the impact of different planting geometries on yield and benefit:cost ratio, trend line analysis was studied. Trend lines in positive and negative coordinate plane represent gain and loss in yield and benefit:cost ratio, respectively. In paired row bed planting, an increase of 18.6% in benefit:cost ratio

Table 2 Cost of cultivation and net profit under different planting geometries of potato

Planting geometry	Total cost of cultivation (₹/ha)				Gross Income (₹/ha)				Net return (₹/ha)				B:C ratio			
	70 DAP	80 DAP	90 DAP	Mean	70 DAP	80 DAP	90 DAP	Mean	70 DAP	80 DAP	90 DAP	Mean	70 DAP	80 DAP	90 DAP	Mean
S_1	122249	122249	122249	122249	398062	423174	472146	431127	275813	300925	349897	308878	2.26	2.47	2.87	2.53
S_2	130484	130484	130484	130484	417105	469184	434611	440300	286621	338700	304127	309816	2.20	2.60	2.33	2.38
S_3	118244	118244	118244	118244	381942	430368	436309	416206	263698	312124	318065	297962	2.23	2.64	2.69	2.52
S_4	123959	123959	123959	123959	379752	426365	417464	407860	255793	302406	293505	283901	2.06	2.44	2.37	2.29
S_5	113249	113249	113249	113249	335538	365163	398056	366252	222289	251914	284807	253003	1.96	2.22	2.52	2.23
S_6	137099	137099	137099	137099	493141	563058	588855	548351	356042	425959	451756	411252	2.60	3.11	3.30	3.00
Mean	-	-	-		400923	446218	457907		276709	322004	333693		2.22	2.58	2.68	
CD (P=0.05)																
S		-					25612				25612				0.20	
D		-					18111				18111				0.14	
S × D		-					NS				NS				NS	

Variable cost rates: Urea, DAP and MOP per quintal are ₹577.00, 2400.00 and 1880.00, respectively; Seed of potato per quintal are ₹1250.00; Labour per man day are ₹300.00; Sale of potato seed: Small, Seed, Large size per quintal are ₹2000.00, 1500.00 and 800.00, respectively as per local market prevailing prices.
Treatment details are given under Materials and Methods.

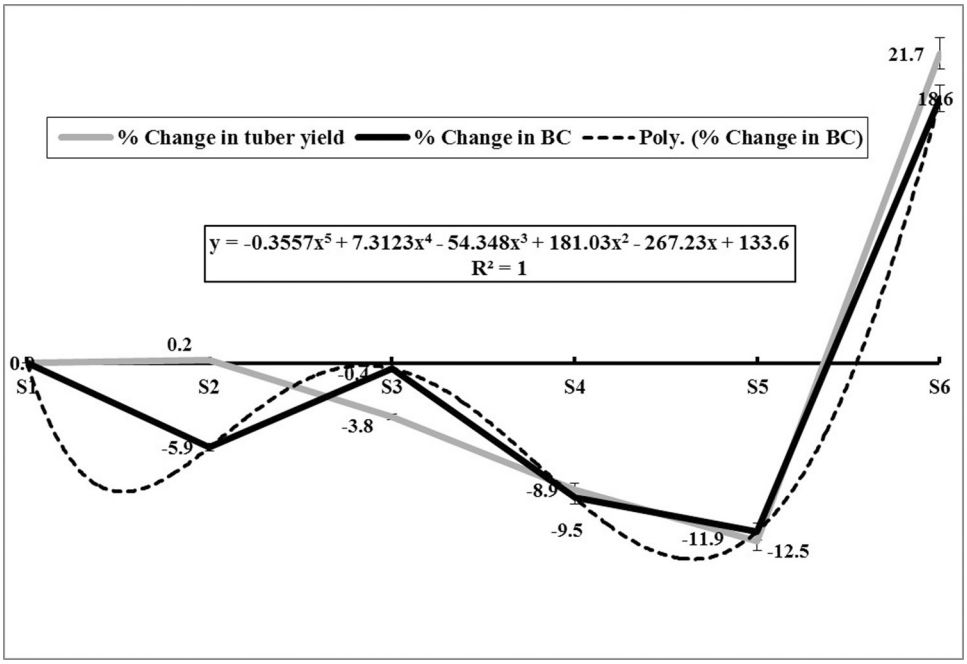

Fig 3 Effect of planting geometries on per cent change in tuber yield and benefit:cost ratio.

and 21.7% in tuber yield was noticed over conventional planting (Fig 3). Widening the inter row spacing, viz. (75 cm × 15cm) or (75 cm × 20 cm) showed decline in the tuber yield and B:C ratio to the tune of -8.9, -11.9 and -9.5, -12.5, respectively compared to control. A little gain 0.2% in yield with planting geometry (66 cm × 15 cm), whereas, decline of -5.9% in B:C ratio was recorded. Similarly, both yield and B:C decreased -3.8% and -0.4% respectively were noticed with planting geometry (66 cm × 20 cm). In potato cultivation, B:C ratio entirely dependent upon the purpose of growing the crop *e.g.* seed or table or processing. Our findings are supported by Kaur *et al*. (2019) who reported high density planting leads to increase the seed productivity.

As India is the second largest potato producer in the world and demand for quality seed potatoes is increasing gradually. Paired row bed planting resulted in the maximum yield and number of seed size tubers, highest net returns and B:C ratio, when dehaulming was done 80–90 days after planting. Therefore, paired row bed planting geometry can be recommended after through and multi-location testing for maximizing the seed size tuber yield and returns.

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