



Planting geometry and seed tuber size effects on potato (*Solanum tuberosum*) productivity

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ABSTRACT

The experiment was conducted during *rabi* 2014–15 and 2015–16 at Punjab Agricultural University, Ludhiana (India) to optimize planting geometry (50 cm × 15 cm, 65 cm × 11.5 cm, 70 cm × 10.7 cm and 75 cm × 10 cm) and seed tuber size (25–35 mm, 35–45 mm, 45–55 mm) for higher seed-grade and total tuber yield of potato (*Solanum tuberosum* L.). Planting geometry didn't significantly influence the growth and productivity of potato. However, the effect of seed tuber size was significant as large (45–55 mm) and medium (35–45 mm) sized tubers produced higher yield (8.3 and 7.4 t/ha, respectively) of small sized (<35 mm) and medium sized (35–45 mm) (17.3 and 16.6 t/ha, respectively) tubers and the total tuber yield (42.9 and 42.6 t/ha, respectively). In contrast, the highest yield of large sized tubers (>45 mm) (20.2 t/ha) was obtained with small sized seed tubers. The highest net returns (₹ 381.11 thousand/ha) were obtained with medium sized seed tubers as compared to small and large sized seed tubers. Therefore, medium sized seed tubers (35–45 mm) should be used for higher seed-grade and total potato tuber yield as well as better economic returns, irrespective of the planting geometry, under Punjab conditions.

Keywords: Economic analysis, Grade-wise tuber yield, Planting geometry, Potato, Seed tuber size

The rice–wheat cropping system being the backbone of food security in South-Asia has resulted in soil health deterioration, declining water table, and air pollution affecting livability index of the region (Meena *et al.* 2020, Chaudhary *et al.* 2021). Potato (*Solanum tuberosum* L.) has the potential to reduce dependence on this system as it has almost the double productivity than rice-wheat system and can also meet the dietary requirements. India is the second largest potato producer in the world with an area of 2.17 million ha and production of 50.2 million tonnes (FAOSTAT 2021). Planting geometry, i.e. inter- and intra-row spacing is one of the major factors affecting its production, productivity and tuber size distribution (Akassa *et al.* 2014, Kumar *et al.* 2001) and also decides the extent of mechanization for field operations (Bussan *et al.* 2007). Seed is another important, voluminous and costly input representing 40–70% of its total cost of production (Yadav *et al.* 2014, Singh *et al.* 2019). Small seed tubers lead to low productivity, whereas large tubers become uneconomical due to their increased cost. Farmers prefer small sized seed tubers over the larger ones to reduce the cost (Singh *et al.* 2003) but their availability is always limited. Thus, the interactive effects of seed size

and planting geometry must be exploited to maximize the mechanization of farm operations as well as optimization of seed requirement. The present study was aimed at to investigate the effect of planting geometry and seed tuber size on grade-wise tuber yield and economics of potato production.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* 2014–15 and 2015–16 at Punjab Agricultural University, Ludhiana, India representing the Indo-Gangetic alluvial plains. The soil (0–15 cm) was loamy sand with neutral pH (7.20), normal electrical conductivity (0.24 mmhos/cm), medium organic carbon (0.60%), low available N (260 kg/ha), and high available P (42.1 kg/ha) and K (400 kg/ha). The experiment was conducted in split-plot design with three replications. The main plots consisted of four planting geometries; 50 cm × 15 cm, 65 cm × 11.5 cm, 70 cm × 10.7 cm and 75 cm × 10 cm, and sub plots three seed sizes- small (25–35 mm), medium (35–45 mm) and large (45–55 mm). Plant population was uniform in all the planting geometries. Potato cultivar Kufri Pukhraj was sown in mid-October. The seed rate for small, medium and large seed tuber grades was 3.3, 6.0 and 9.3 tonne/ha, respectively. Haulm cutting was done in the first week of January and the crop was harvested in end January. Plant height, leaf area index (LAI), dry matter accumulation (DMA) by tubers and haulm were recorded at 60 days after sowing (DAS). Number of

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stems and tubers/plant were recorded at haulm cutting. The harvested tubers were graded as small (<35 mm), medium (35-45 mm) and large (>55 mm). The prevailing cost of inputs/practices and market price were used for economic analysis. For calculating the economic returns, tubers <45 mm were considered as seed potato and >45 mm as ware potato. The pooled data were statistically analyzed by using PROC GLM in SAS 9.3 software (SAS INC, Cary NC). Multiple comparisons were made using ADJUST = TUKEY at p<0.05 to determine significant effects.

RESULTS AND DISCUSSION

Effect of planting geometry: Planting geometry had non-significant effect on growth (plant height, DMA and LAI), yield attributes (stems/plant), grade-wise and total tuber yield and economic returns (Table 1). The non-significant effect might be due to uniform plant population (13.3 plants/m²) in all the planting geometries. Further, number of stems/plant apart from being a varietal character also depend upon seed tuber size and their physiological status, hence, it was not influenced as the cultivar and seed size were uniform in all the planting geometries. Kumar *et al.* (2012), Akassa *et al.* (2014) and Dagne (2015) also observed non-significant differences in number of stems/plant with planting geometries. Singh *et al.* (1995), Kumar *et al.* (2001) and Kumar (2012) also observed non-significant influence of planting geometry on the grade-wise and total tuber yield. However, the number of tubers/plant was significantly higher with wider row spacing of 65, 70 and 75 cm as compared to the narrow row spacing of 50 cm which might be due to more available space for tuber development at wider row spacing. Bohl *et al.* (2011) also reported higher number of tubers/plant at 30 and 40 cm in-row spacing as compared to 20 cm regardless of seed size. Non-significant influence of planting geometries on economic parameters was due to similar seed rate (13.3 plant/m²) and other cultural operations.

Effect of seed size

Effect on growth: The size of seed tubers had a significant effect on growth of crop (Table 1). The highest plant height and LAI were with large sized seed tubers which were statistically similar to medium sized seed tubers and the both were significantly higher than small sized seed tubers (Table 1). The highest DMA by tubers and haulm was obtained with large sized tubers and it was significantly higher than small and medium sized seed tubers. The medium sized seed tubers produced significantly higher tuber and haulm DMA as compared to small sized seed tubers. The higher plant height, LAI and DMA in tubers and haulm with large seed tubers might be due to the more availability of nutrients (stored food) to the plant resulting in early emergence and establishment and thus, more growth and development of plants. Kumar *et al.* (2009), Ebrahim *et al.* (2018) and Nasir and Akassa (2018) also observed higher plant height, dry matter/plant and LAI with large sized seed tubers.

Table 1 Planting geometry and seed size effect on growth, grade-wise tuber yield, total tuber yield and economics

Treatment	Growth attributes			Yield attributes		Tuber yield (t/ha)			Economics					
	Plant height (cm)	LAI	DMA in tuber (g/plant)	DMA in haulm (g/plant)	No. of stems/plant	No. of tubers/plant	<35 mm	35-45 mm	>45 mm	Total	Cost of cultivation	Gross returns	Net returns	B:C
<i>Planting geometry (cm × cm)</i>														
50 × 15	43.9	3.06	40.21	12.44	3.69	8.94	7.1	15.1	19.6	41.8	154.76	504.97	350.21	2.46
65 × 11.5	44.2	3.01	41.05	12.71	4.31	10.01	6.6	16.3	18.8	41.7	154.76	513.35	358.60	2.50
70 × 10.7	45.9	2.89	41.65	12.43	4.53	10.33	7.5	16.2	18.4	42.0	154.76	524.67	369.92	2.61
75 × 10	45.7	2.86	40.46	12.17	4.19	9.89	7.1	15.8	18.0	40.8	154.76	508.44	353.69	2.48
SEm±	1.21	0.07	0.99	0.34	0.22	0.27	0.51	0.56	0.77	0.70		10.15	10.14	0.07
CD (P=0.05)	NS	NS	NS	NS	NS	0.84	NS	NS	NS	NS		NS	NS	NS
<i>Seed size (mm)</i>														
25-35	41.6	2.48	35.74	10.21	3.19	8.54	5.5	13.6	20.2	39.2	105.46	451.25	345.79	3.30
35-45	45.9	3.11	42.48	13.08	4.35	10.10	7.4	16.6	18.6	42.6	151.36	532.47	381.11	2.54
45-55	47.2	3.27	44.31	14.02	5.00	10.75	8.3	17.3	17.3	42.9	207.46	554.86	347.41	1.69
SEm±	0.76	0.08	0.57	0.27	0.15	0.31	0.13	0.23	0.19	0.33		5.14	5.13	0.04
CD (P=0.05)	2.2	0.22	1.64	0.78	0.44	0.89	0.4	0.7	0.6	0.9		14.80	14.79	0.12

LAI, Leaf area index; DMA, Dry matter accumulation; B:C, Benefit cost ratio.

Effect on yield attributing characters, total and grade-wise tuber yield: The highest number of stems/plant was obtained with large sized seed tubers and it was significantly higher than all the other grades of seed tubers (Table 1). The highest number of tubers/plant was with large sized seed tubers which were statistically at par with medium sized tubers and the both were significantly better than small sized tubers. The higher number of stems/plant with large and medium sized seed tubers might be due to higher number of eyes/tuber on large sized seed tubers which consequently produced higher number of stems/plant and ultimately the higher tubers/plant (Kumar *et al.* 2015). Nasir and Akassa (2018) and Ebrahim *et al.* (2018) also reported higher number of stems and tubers/plant with large sized seed tubers.

The small sized (<35 mm) tuber yield increased significantly with increasing seed tuber size from 25-35 mm to 45-55 mm. The highest small sized tuber yield (8.3 t/ha) was obtained with large seed tubers which was significantly higher than all the other seed sized tubers, whereas the lowest yield of small sized tubers (5.5 t/ha) was produced by the small seed tubers. Medium and large sized seed tubers produced 36.0 and 52.5% higher small sized tuber yield, respectively as compared to small sized seed tubers. The highest medium sized tuber yield (17.3 t/ha) was obtained with large seed tubers which was statistically similar to that obtained with medium seed tubers (16.6 t/ha) and both were significantly higher than small seed tubers. The significantly highest yield of large tubers (>45 mm) (20.2 t/ha) was obtained with small seed tubers. Medium sized seed tubers also gave significantly higher yield of large sized tubers than with large seed tubers. The lowest yield of large sized tuber (17.3 t/ha) was obtained with large seed tubers. The highest total tuber yield (42.9 t/ha) was obtained with the large seed tubers and it was statistically at par with the medium seed tubers (42.6 t/ha) but significantly higher than small tubers. The medium seed tubers also recorded significantly higher total tuber yield than small seed tubers. The medium and large seed tubers produced 8.6 and 9.5% higher total tuber yield, respectively than the small seed tubers. Thus, it is clear that yield of small sized tubers increased while that of large sized tubers decreased with increase in size of seed tubers. It might be due to more number of tubers/plant in large and medium sized tubers (Table 1) which might have increased the competition among the tubers within the plant leading to more small sized tubers. Dagne *et al.* (2018) also reported the maximum yield of small sized tubers with large sized seed tubers. Kumar (2012) also reported increase in tuber yield of 25-50 g grade tubers with increase in size of seed tubers. The higher yield of large sized tubers with small sized seed tubers might be due to small seed tubers producing less number of tubers and stems/plant (Table 1) which might have reduced the competition among tubers for photosynthates leading to higher yield of large sized tubers. Increase in total tuber yield with medium and large seed tubers might be due to increase in number of tubers and stems/plant and tuber DMA/plant. Ebrahim *et al.* (2018) also reported higher total tuber yield with medium to large sizes.

Effect on economics: The highest cost of cultivation was recorded with large seed tubers and the lowest with small seed tubers (Table 1). The highest gross returns were obtained with large seed tubers and it was significantly higher than medium and small seed tubers. The highest net returns were recorded with medium seed tubers and it was significantly higher than rest of the seed tuber grades. The small and large seed tubers had statistically similar net returns. The medium seed tubers recorded 10.21 and 9.7% higher net returns as compared to small and large seed tubers, respectively. The highest B:C ratio was obtained with small seed tubers and it was significantly higher than rest of the seed tuber sizes. The medium seed tubers also gave significantly higher B:C ratio than large seed tubers. The increase in cost of cultivation with increase in seed tuber size was due to increased seed rate/ha with increase in seed tuber size. Singh and Bhatnagar (2014) also reported increased seed rate and cost of production with large sized seed tubers. The higher net returns with medium sized seed tubers were due to significantly lower tuber yield and gross returns with small sized seed tubers while the large sized seed tubers had the higher cost of production, hence, both the seed tuber grades resulted in lower net returns as compared to medium sized seed tubers. Dagne (2015) also reported the highest net returns with medium sized seed tubers. The higher B:C ratio with small and medium sized seed tubers was due to their lower cost of cultivation as compared to large sized seed tubers. Although, the net returns were higher with medium and large tubers as compared to the small tubers, but increase in net returns was not proportionate to the cost of cultivation which ultimately decreased the B:C ratio with large seed tubers. Singh and Bhatnagar (2014) also reported decreased B:C ratio with increase in seed tuber size. Interaction effects of planting geometry and seed size were non-significant for all the studied parameters.

Correlation among the yield attributes, tuber yield and economic parameters: DMA in tubers and stems was significantly and positively correlated with each other and with small and medium sized, and total tuber yield; however, large sized tuber yield had significant negative correlation (Table 2). The possible reason of positive correlation between tuber and haulm DMA might be that development of potato tubers depend on supply of carbohydrates from the foliage as large amount of dry matter is transferred from the haulm to the tubers (Moorby 1970). A significant positive correlation existed between number of tubers and stems/plant with each other ($R=0.918$) and with small, medium and total tuber yield ($R= 0.832, 0.927$ and 0.803 , respectively for number of tubers/plant and $R= 0.890, 0.959$ and 0.835 , respectively for number of stems/plant). However, there was significant negative correlation between number of stems and tubers/plant with large sized tuber yield ($R= -0.936$ and -0.885 , respectively). The negative correlation of large sized tuber yield with number of tubers and stems/plant might be due to more number of stems/plant resulting in more number of tubers/plant which might have increased the competition among tubers for photosynthates, thus

Table 2 Correlation among the different yield attributes, grade-wise and total tuber yield and economic parameters

Parameter	Tuber DMA	Haulm DMA	Tuber no./plant	Stem no./plant	Tuber yield (<35 mm)	Tuber yield (35-45 mm)	Tuber yield (>45 mm)	Total yield
Haulm DMA	0.891**							
Tuber no./plant	0.907**	0.866**						
Stem no./plant	0.949**	0.857**	0.918**					
Tuber yield (<35 mm)	0.835**	0.916**	0.832**	0.890**				
Tuber yield (35-45 mm)	0.968**	0.931**	0.927**	0.959**	0.892**			
Tuber yield (>45 mm)	-0.872**	-0.781**	-0.885**	-0.936**	-0.852**	-0.888**		
Total yield	0.855**	0.947**	0.803**	0.835**	0.913**	0.915**	-0.689*	
Net return (₹)	0.437 ^{NS}	0.274 ^{NS}	0.353 ^{NS}	0.326 ^{NS}	0.286 ^{NS}	0.433 ^{NS}	-0.184 ^{NS}	0.482 ^{NS}

*Significant at P= 0.05 level; **Significant at P = 0.01 level

decreasing the size of tubers within the plant having more number of tubers and stems/plant. Small and medium sized tuber yield showed a significant positive correlation with each other (R= 0.892) and with total tuber yield (R= 0.913 and 0.915, respectively). However, large sized tuber yield showed a significant negative correlation with small, medium sized and total tuber yield (R= -0.852, -0.888 and -0.689, respectively).

The non-significant effect of planting geometry on potato productivity and the highest net returns with medium sized seed tubers indicated that medium sized seed tubers, at planting geometry as per the available farm machinery, may be used for better economic returns in North-West India.

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