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PLANTING GEOMETRY AFFECTS POTATO (*Solanum tuberosum* L.) PRODUCTIVITY AND ECONOMICS IN NORTH-WEST INDIA

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ABSTRACT

Effect of planting geometry on productivity and economics of potato was studied at research farm, School of Organic Farming, Punjab Agricultural University, Ludhiana and at farmer fields in Punjab during autumn 2016. The mean total tuber yield did not vary with change in planting geometry from 65cm x 11.5cm to 75cm x 15cm. However, the mean highest seed size (<45mm) tuber yield (11.57 t/ha) was obtained with planting geometry of 65cm x 11.5cm which was statistically at par with 75cm x 10cm. Total and seed size tubers were the highest (712 and 461 thousand/ha, respectively) under 75cm x 10cm and were statistically at par with 65cm x 11.5cm. The seed cost was the highest with 75cm x 10cm and 65cm x 11.5cm (Rs. 107800/ha, each) and the lowest (Rs. 72000/ha) with 75cm x 15cm and was 69% higher in the former cases than the latter. The planting geometries of 65cm x 15cm and 75cm x 15cm gave the higher net returns (Rs. 209100/ha and Rs. 208100/ha, respectively) when grown for seed purpose. However, for ware potato purpose the planting geometries of 65cm x 18.5cm and 75cm x 15cm gave the higher net returns.

Keywords: Planting geometry, Potato, Spacing, Tuber size, Yield

Potato (*Solanum tuberosum* L.) is one of the most widely grown tuber crops in the world, contributing immensely to human nutrition and food security (Karim *et al.,* 2010). It is the major crop amongst root and tuber crops and the third most important food crop in the world after rice and wheat being mainstay in the diets of people in many parts of the world (Struik and Wiersema, 1999). Introduced in India during late 16th or early 17thcentury, its commercial cultivation in India started around 1932. It has widely been accepted as a primary and secondary source of food and nutrition. It is a rich source of starch, protein, minerals, calcium, potassium and vitamins especially B_1 and C, in addition to a good amino acid balance like leucine, tryptophan and isoleucine (Fernando *et al.,* 2016). Its per unit time and space productivity is higher than wheat, rice and maize (Kaguongo *et al.,* 2013) and is regarded as a high security crop because of its ability to provide a high yield of high-quality product per unit input with a shorter crop cycle (Adane *et al.,* 2010). Apart from vegetable purposes, it is used for food products like potato chips, French fries and for the production of starch and alcohol.

Worldwide, approximately 373.83 million tonnes of potato is produced every year from around 19.25 million hectares and India produced 52.58 lakh tonne potato tubers from 21.85 lakh hectares (Anonymous, 2019). In India, the leading states under potato cultivation are Uttar Pradesh, West Bengal, Bihar, Gujarat, Madhya Pradesh, Punjab, Haryana, Assam, Jharkhand and Chhattisgarh (Anonymous, 2019). In Punjab, potato occupied an area of 102.97 thousand ha with a production of 2.72 million tonnes during 2018-19 (Anonymous, 2019a). The major potato growing districts in Punjab are Jalandhar, Hoshiarpur, Kapurthala, Ludhiana, Amritsar and Bathinda. About 60 per cent of the total area under potato cultivation in Punjab is under seed potato as there is a great demand of seed potatoes from Punjab by states of West Bengal, Bihar, Maharashtra, Karnataka and Gujarat. Eighty five percent seed requirement of the country is met from Punjab (Bhardwaj, 2014). Punjab has established itself as a hub of seed potato production in India. Owing to geographic advantage and absence of virus transmitting vectors from mid-October to end of January, there is a great potential to enhance the production of seed potatoes in the state by increasing area and productivity thus providing higher income to farmers and generating employment in the rural areas. The production and productivity of the crop have significantly been increased during past by a number of technological interventions *viz.,* improved varieties and matching production techniques and effective insect-pest and disease management technologies (Bisht *et al.,* 2012).

Major constraints in potato production are heavy initial input costs, sensitivity to environmental changes, market fluctuations and perishable nature of the produce. Among all these constraints, the higher initial input costs have significant effect on area under this

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crop. Inputs include cost on field preparation, seed, fertilizers, plant protection, and weed control, etc. Seed cost of potato cultivation is higher, because it requires bulk of seeds, about 40 q/ha.

A major objective of seed potato production is to produce more number of seed size tubers (<45 mm) and to get the same its agronomic practices are required to be optimized. Masarirambi *et al.* (2012) observed that it is important to generate Information on interrelationships of plant populations and tuber sizes in relation to growth and the subsequent yield. Plant population studies in potato are never thought to be out dated because newly developed cultivars have unique tuber characteristics and evolving industries constantly come up with new tuber size requirement. Planting geometry is one of the most important management practices in potato production and depends on type of variety, fertility status of soil, machinery, plant architecture or growth habit etc. Therefore, the same planting geometry may not be suitable for optimum yields under different situations. Though, many studies have been conducted to establish the optimal combination of seed size and planting distance for a certain environment (Bussan *et al.,* 2007), yet there is need to optimize planting geometry for higher seed potato production.

The ever increasing and dynamic mechanization in potato production demands varied planting geometries for table and seed potato production. Thus, keeping in view the existing and futuristic machinery with farmers in Punjab, the present studies were planned to optimize planting geometry for higher seed size tuber productivity.

MATERIALS AND METHODS

Multi-location field trials were conducted in Punjab during autumn season *i.e.* October, 2016 - January, 2017. The region is characterized by sub-tropical and semi-arid type of climate. A total of seven trials were conducted - three in Bathinda district, three in Jalandhar district and one at research farm, School of Organic Farming, Punjab Agricultural University, Ludhiana. The varieties used were Kufri Jyoti in Jalandhar, Kufri Pukhraj at Ludhiana and Kufri Chipsona-3 in Bathinda. Five planting geometries with row to row and tuber to tuber spacing of 75cm x 10cm (1,33,333 plants/ha), 75cm x 15cm (88,888 plants/ha), 65cm x 11.5cm (1,33,779 plants/ha), 65cm x 15cm (1,02,564 plants/ha) and 65cm x 18.5cm (83,160 plants/ha) were evaluated under randomized complete block design in three replications at all the locations. The rationale to select these planting geometries was to facilitate mechanical intercultural operations with different types of available machinery. The recommended package of practices for cultivation of potato in Punjab (Anonymous, 2016) was followed to raise the crop. Planting was done in last week of October, 2016 and the crop was de-haulmed in 1st week of January, 2017 and tubers were harvested after 3 weeks of haulm cutting. The crop was raised with 50 tonnes of farmyard manure on fresh weight basis along with 187.5 kg N, 62.5 kg P_2O_5 and 62.5 kg K_2O ha^{-1}. Whole farmyard manure, phosphorus and potash and half of nitrogenous fertilizer were applied at the time of field preparation and the remaining half dose of nitrogenous fertilizer was applied at the time of earthing-up at 25 days after planting the tubers. Seed tubers were treated by spraying Monceren 250 SC for control of black scurf caused by *Rhizoctonia solani*. Weeds were controlled by post-emergence application of Gramaxone @ 1250 ml/ha. The crop was sprayed twice with Mancozeb @ 1750 g/ha and once with Ridomil Gold @ 1750g/ha. Digging of potatoes was done manually and tubers were subjected to size grading, i.e. ware potato/table potato (>45 mm diameter) and seed potato (<45 mm diameter) (Anonymous, 2016). The data on total and size wise number of tubers were recorded at Ludhiana only. Benefit-cost analysis was done by using the variable seed cost and gross returns from the potato production by using the formula given by Timsina (2010). The tuber yield from each plot was recorded and converted into yield per hectare. The data were analysed by using computer software package Statistical Package for Social Science (SPSS).

Table 1. Potato tuber yield under different planting geometries

Planting geometry (cm x cm)	Tuber yield (t/ha)											
	Jalandhar			Bathinda			Ludhiana			Mean of all locations		
	<45 mm	>45 mm	Total	<45 Mm	>45 mm	Total	<45 mm	>45 mm	Total	<45 Mm	>45 mm	Total
75 x 10	11.66	5.25	16.91	11.00	14.40	25.40	10.80	19.96	30.76	11.16	13.20	24.36
75 x 15	12.97	6.78	19.75	8.33	12.10	20.43	7.57	23.03	30.60	9.62	13.97	23.59
65 x 11.5	12.57	4.94	17.51	11.03	14.17	25.20	11.10	20.01	31.11	11.57	13.04	24.61
65 x 15	12.45	5.30	17.75	9.77	13.47	23.23	9.31	20.73	30.04	10.51	13.17	23.68
65 x 18.5	12.04	6.88	18.92	8.87	13.00	21.87	6.9	23.60	30.50	9.26	14.49	23.79
CD (0.05)	0.81	0.75	NS	0.31	1.21	NS	1.04	1.72	NS	0.88	0.97	NS

RESULTS AND DISCUSSION

Total tuber yield

Potato tuber yield is the function of assimilation of carbon in the production and translocation of photosynthates. The mean and location-wise total tuber yield did not vary significantly with change in planting geometry (Table 1) and this might be due compensation of lesser plant population by development of large sized tubers. However, the location-wise productivity varied from 16.9 - 18.9 t/ha in Jalandhar, 21.9 - 25.4 t/ha in Bathinda and 30.0-30.8 t/ha at Ludhiana. The higher productivity at Ludhiana might be due to better management of crop at research farm than at farmers' fields.

Seed potato (<45mm) tuber yield

The mean highest seed size tuber yield was obtained with planting geometry of 65cm x 11.5cm and it was statistically at par with 75cm x 10cm but both were significantly higher than all the other planting geometries (Table 1). It might be due to higher plant population resulting in more number of small sized tubers because of increased inter-plant competition at closely spaced plants (Table 2). The yield of seed tubers per hectare increases with decreasing plant spacing (Alemayew *et al.,* 2015, Sidhu *et al.,* 1982). The combination of large size seed tuber and narrow spacing produce many small seed size tubers (Rajadurai, 1994). At closer spacing, there is high number of plants per unit area which brings about an increased ground cover that enables more light interception, consequently influencing photosynthesis (Harnet *et al.,* 2014). In Bathinda and at Ludhiana, the highest seed size tuber yield was recorded with 65cm x 11.5cm and it was statistically at par with 75cm x 10cm at both the locations. However, in Jalandhar, the highest seed size tuber yield was obtained with 75cm x 15cm and it was statistically at par with 65cm x 11.5cm and 65cm x 15cm.

Ware potato (>45mm) tuber yield

Ware potato is mainly used for eating and processing purposes. The proportion of processing grade tubers (>45mm) in the total produce is crucial as it directly affects the overall recovery of processed product. The mean highest ware potato yield was obtained with planting geometry of 65cm x 18.5cm (Table 1) and it was statistically at par with planting geometry of 75cm x 15cm but significantly higher than all the other planting geometries.

Among the locations, the ware potato tuber yield relative to seed potato tuber yield was higher in Bathinda and at Ludhiana whereas it was otherwise in Jalandhar. In Jalandhar and at Ludhiana, the highest ware potato tuber yield was recorded with 65cm x 18.5cm and it was statistically at par with 75cm x 15cm at both the

Table 2. Size-wise and total number of potato tubers at Ludhiana

Planting geometry (cm x cm)	Number (,000/ha)		
	Tuber size		
	<45mm	>45mm	Total
75 x 10	461	250	712
75 x 15	303	221	524
65 x 11.5	412	261	673
65 x 15	349	225	574
65 x 18.5	266	239	505
CD (0.05)	58	NS	71

Table 3. Economic analysis of seed potato production under different planting geometries (Mean of all locations)

Planting geometry (cm x cm)	Gross returns (Rs,000/ha) from sale of <45mm tubers	Gross returns (Rs,000/ha) from sale of >45mm tubers	Overall gross returns (Rs,000/ha)	Quantity of seed required for planting one ha (t/ha)	Variable cost of seed (Rs,000/ha)	Net returns (Rs,000/ha)
75 x 10	221.2	84.4	305.6	5.99	107.8	197.8
75 x 15	190.8	89.3	280.1	4.00	72.0	208.1
65 x 11.5	229.5	83.4	312.9	5.99	107.8	205.0
65 x 15	208.4	84.2	292.6	4.64	83.5	209.1
65 x 18.5	183.6	92.6	276.2	3.87	69.7	206.6

Price: >45mm size @ Rs 5800/tonne; <45mm size @ Rs18000/tonne

locations and significantly better than the other planting geometries. However, In Bathinda, the highest ware potato tuber yield was recorded with 75cm x 10cm and it was statistically at par with 65cm x 11.5cm and 65cm x 15cm. The higher ware potato tuber yield in wider spacing might be due to minimum competition among plants for space, resources and light and increased photosynthesis efficiency for higher photo assimilation production and ultimately resulting in increased ware potato tuber yield (Tesfaye *et al.,* 2013, Getachew *et al.,* 2012, Masarirambi *et al.,* 2012, Wurr *et al.,* 1993).

Total and size wise number of tubers

The number of total tubers and the seed size tubers were the highest with planting geometry of 75cm x 10cm and it was statistically at par with 65cm x 11.5cm and the both were significantly higher than all the other planting geometries (Table 2). This might be due to the higher number of plants produced at closer plant spacing than plants at wider spacing which led to the production of higher number of total tubers. The lesser competition for resources in wider intra row spacing results in increased number of tubers per plant (Tesfaye *et al.,* 2013). However, the ware potato tuber number was not affected significantly with planting geometries. In seed production programme, the number of tubers assumes more importance over the size of tubers (Park *et al.,* 2009). Zebenay (2015) also reported that the production of total number of tubers per hill increased as plants grown at narrow plant spacing and decreased at wider plant spacing. Rajadurai (1994) observed that number of tuber per plant increases with increasing seed tuber size and planting space. Thus, planting geometries of 75cm x 10cm and 65cm x 11.5cm are better suited for seed potato production.

Economics of potato production

The cost of production is the major factor that influences the profitability of agricultural production. The total gross returns were the highest with 65cm x 11.5cm and the lowest with 65cm x 18.5cm due to higher seed size tuber yield and their higher price in the former (Table 3). The highest gross returns from seed size tubers were obtained with 65cm x 11.5cm and the lowest with 65cm x 18.5cm. The highest gross returns from ware potato tubers were obtained with 65cm x 18.5cm and the lowest with 65cm x 11.5cm. The seed cost was found to be the major cost attributing variable among all the variable costs. The seed cost was the highest with 75cm x 10cm and 65cm x 11.5cm and the lowest with 75cm x 15cm, the cost being 69% higher in former case than the latter. The net returns were higher with 65cm x 15cm and 75cm x 15cm. Thus, for seed potato production to have higher number of seed sized tubers, the planting geometries of 75cm x 15cm or 65cm x 15cm, depending upon the available machinery, are the best suited. However, the planting geometries of 75cm x 15cm or 65cm x 18.5cm are the best suited for ware potato purpose.

In conclusion, this study showed that autumn potato grown for seed potato production gives higher productivity and economic returns when planted at 65cm x 11.5cm or 75cm x 15cm. Whereas, for ware potato production, the planting at 65cm x 18.5cm or 75cm x 15cm gives higher productivity and economic returns.

Authors' contribution

Conceptualization and designing of research work (CSA); Execution of field/lab experiments and data collection (ASS,MS); Data analysis and interpretation of results (ASS, MS); Preparation of manuscript (CSA, MT).

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