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Impact of Planting Density and RDF Levels on Growth, Yield, and Seed Tuber Production of Potato (*Solanum tuberosum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The goal of the current study is to maximize the effects of planting density and NPK rate on potato (*Solanum tuberosum* L.) growth, yield, and seed tuber production. During the Rabi season of 2016–17, a field experiment was conducted at the Agriculture Farm of IFTM University, Moradabad, Uttar Pradesh (India), repeating each treatment into three blocks using a Randomized Block Design. The potato variety, '*Kufri Chipsona-1*' was grown in plots *i.e.* 7.5 m^2 taking seed size (2.5 cm - 3.0 cm)

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of grade 'C' and finally harvested after 100 days of sowing. Nine treatments were consisted of three levels of planting density at 40 cm × 20 cm, 30 cm × 15 cm, 20 cm × 10 cm and three levels of RDF (recommended dose of fertilizers) *i.e.* 100% RDF (NPK @ 120: 100: 100 kg ha^{-1}), 50% RDF, and 25% RDF. The grades of tuber size as well as other growth and yield metrics were noted in the observations. The findings showed that plant height, number of tubers/plant, weight, size, and yield all significantly increase with relatively modest planting density. Similarly, these characters were significantly affected by reduced levels of RDF. Maximum medium and small size tubers, 'B' grade (22.31%) and 'C' grade (25.90%) were obtained with spacing of 40 cm × 20 cm and 30 cm × 15 cm, respectively. Higher percentage of seed grade tubers were obtained by the 50% reduction of RDF. Treatment, T_2 (40 cm × 20 cm @ 50% RDF) had the highest net return (Rs. 100591.83 ha^{-1}) and the B: C ratio (1.09). It can be suggested from the findings that a plant spacing of 40cm×20cm and 50%RDF level might be the most remunerative for seed tuber production in potato crop.

Keywords: Potato; plant density; RDF; tuber yield; seed tuber; net return.

1. INTRODUCTION

The potato (*Solanum tuberosum* L.) is an annual herbaceous plant that is a member of the Solanaceae family. In the northern plains of India, potatoes rank as the fourth most significant food crop, behind rice, wheat, and maize. With an annual production of 51.31 million tonnes from an area of 2.14 million hectares, India is the second-largest potato-producing nation in the world after China. Uttar Pradesh leads the country in terms of area and potato production, with 0.61 m ha and 15.55 m tonnes, respectively [1]. It is the most extensively cultivated tuber crop globally, making a significant contribution to food security and human nutrition [2,3]. For farmers, it provides food and a source of revenue, particularly during times when grain stocks become low. More edible energy and protein are produced by potato tubers per unit area of land than by any other crop [4]. Demand for the crop is high across all socioeconomic groups. Numerous factors, including as nitrogen, cultivar, seed rate, spacing, climate, and geographic location, affect potato yield [5,6]. Almost everyone agrees that excellent productivity in all potato production systems depends on using high-quality seed. A significant amount of the yield gap that is presently limiting production is ascribed to substandard seed. Governments, researchers, development organizations, and civil society organizations are therefore very concerned about the development of the potato seed sector [7]. The process of producing seeds is very technical and requires close attention at every stage, including planting dates, spacing, fertilizer, top-dressing, irrigation, roguing, weeding, earthing up, pesticide spraying, harvesting dates, and so on [8].

Quality seed is not used by the majority of potato growers due to high costs and limited availability. Because it influences both the overall yield and the yield of graded or marketable tubers, the size of the seed tuber is a significant determinant in determining the amount of seed per unit area [9,10,11,12]. Farmers who cultivate on a small scale tend to favor tiny and medium sized seed tubers in order to lower the cost of seed. Maintaining an ideal number of plants per unit area and their spatial layout in the field are critical to the potential of guaranteeing a high yield [13,14]. One of the most crucial objectives in potato production is to maximize plant density, as this has a bearing on the cost of seeds, plant growth, yield, and ultimate crop quality [15]. In reality, the quantity and size of seed tubers sown determine plant density in the potato crop [16]. The ideal seed size and planting distance for a given habitat have been determined by a number of research [17,18,19,20,15]. Furthermore, sufficient plant spacing is not the essential requirement for productive potato farming. In order to increase tuber output and achieve desired quality, effective management of NPK fertilizers is also thought to be crucial [21]. The greater percentage of large-sized tubers may result from an increase in N supply, which is detrimental to the formation of seeds [22,23]. Consequently, the goal of the study was to assess how plant density and a lower NPK rates affected potato (*Solanum tuberosum* L.) development, yield, and seed tuber production.

2. MATERIALS AND METHODS

The experimental location is located close to the banks of the Ram-Ganga River in the village of Lodhipur Rajput, Uttar Pradesh, India, on Delhi Road (NH-24). The district of Moradabad is located in the Central Plain Zone of the Indian climate, which spans 78.4° to 79.0° East longitude and 28.21° to 28.16° N latitude above sea level (193.23). During the Rabi season of 2016–17, the experimental field was set up using a Factorial Randomized Block Design with nine treatments and three blocks. The three planting densities at 40 cm × 20 cm (S_1), 30 cm × 15 cm (S_2), 20 cm × 10 cm (S_3) and three levels of RDF (Recommended Dose of Fertilizer) *i.e.* 100% RDF (F_1), 50% RDF (F_2), and 25% RDF (F_3) were the components of the treatments. The appropriate dose of fertilizers (RDF) was determined to be NPK@ 120:100:100 kg ha^{-1}. A basal dose of half of the nitrogen, full doses of potassium and phosphorus, and two equal splits of the remaining half of the nitrogen were applied during earthing up. The experimental site's soil has a sandy loam texture, which is ideal for producing potatoes. The variety of potato, '*Kufri Chipsona*-1' was grown in plots of 7.5 m^2 taking seed size (2.5 cm - 3.0 cm) of grade 'C' and finally harvested after 100 days of sowing. During crop growing season (October 28, 2016 – February 10, 2017), the maximum temperature of 20.0°C – 25.4°C and the minimum temperature of 6.9°C – 9.2°C were both favorable for crop growth and development. Many growth and yield parameters i.e. plant height, stolen/plant, leaf length, number of tubers/plant, tuber weight/plant, tuber yield including the grades of tuber size, were noted in the observations. The percent dry matter was calculated by dividing the dry weight by the fresh weight and multiplying the result by 100 to convert it into percent. Following the steps for two factor analysis in Randomized Block Design (RBD), the data was statistically examined using OP-state software developed by HAU, Hissar. Critical differences (C.D.) at the 5% level were computed for comparing the treatment means in cases where the ' F ' test was deemed significant, and the standard errors of mean were computed for each factor studied.

3. RESULTS AND DISCUSSION

The experiment's results have been outlined and discussed under the following headings.

3.1 Effect of Planting Density on Potato

Table 1 displays the findings demonstrating how potatoes are affected by spacing. The outcomes showed a considerable rise in plant height, number of tubers/plant, weight, size, and yield when planting density is relatively low. Maximum plant height was recorded as 18.47 cm at 30 DAS, 21.12 cm at 60 DAS and 38.84 cm at 90 DAS when plants spaced at 40cm×20cm. Maximum tubers per plant (6.27) were recorded with spacing of 20cm×10cm and at par with 40cm×20cm. Maximum tuber weight (1348.89 g) and tuber yield (298.91 q ha^{-1}) were obtained with the spacing of 40cm×20cm. The increased yield at low plant density might be due to availing proper space among the population for better growth and development. The outcomes support the conclusions made by Bussan et al. [15] and Negero [24]. Plant spacing also had an impact on marketable tuber weight and marketable tuber quantity per plant [25]. Gadana [26] reported that planting density affect potatoes growth and yield in different ways.

Different levels of spacing could not affect number of stolen/plant, leaf length and dry matter content in tubers. However, numerical values indicate that the highest value for number of stolen/pant was 2.62 at 30 DAS, 2.98 at 60 DAS and 3.24 at 90 DAS when plants spaced at 40 cm×20 cm. Maximum values for leaf length were due to wide spacing *i.e.* 16.63 cm at 30 DAS with spacing of 30 cm×15 cm whereas 17.98 cm at 60 DAS and 18.28 cm at 90 DAS with spacing of 40 cm×20 cm. Similarly, numerical values indicate that higher dry matter (>20%) was due to wide spacing (40 cm×20 cm). Khalafalla [25] found no discernible relationship between plant spacing and the quantity of stems/plants in potatoes, lends weight to these conclusions.

The key elements for maximizing tuber size were an optimal plant population, row width, and in-row seed spacing for a specific variety [12]. Significant differences were recorded for 'A', 'B' and 'C' size tubers due to varied spacing. Highest 'A' (40.25%) and 'B' (22.31%) size tubers were obtained with wider spacing (40cm×20cm) followed by 30cm×15cm. Maximum 'C' size tubers (25.90%) were recorded with closer spacing of 30cm×15cm followed by 40cm×20cm and. Georgakis et al. [27] also observed that lower planting densities were used to produce the smaller seed size categories (15–25 mm and <15 mm) than higher densities. Comparatively low density of 60 plants/m^2 produced more number of mini-tubers than high density of 100 plants/m^2 [28]. According to Mandal and Das [29], there was a noteworthy rise in the quantity of seed grade tubers when the intrarow spacing was reduced from 20 cm to 15 cm.

3.2 Effect of RDF Levels on Potato

The results showing effects of levels of RDF on potato are presented in Table 2. Different levels of RDF had a marked influence on plant height. The maximum plant height measured with 100% RDF application was 17.87 cm at 45 DAS, 22.39 cm at 60 DAS, and 38.18 cm at 90 DAS. At 45 and 90 DAS, 50% RDF was found to be comparable. Significant decrease in plant height at 60 DAS by reduction of RDF might be due to insufficient availability of nutrients for metabolic activities. According to Mona et al. [30], potato plants grew noticeably faster when NPK levels were raised.

The amount of stolen per plant during different phases of crop growth could not be impacted by varying RDF levels. Similarly, leaf length at 45 DAS was not affected due to reduction of RDF by 25%. Leaf length at 60 DAS and 90 DAS was not significantly affected by reduction of RDF by 50%. Because 100% RDF was determined to be on par with 50% RDF, maximum leaf length was recorded at 60 DAS (18.24 cm) and 90 DAS (18.74 cm). Present findings are agreed by Taya et al. [31].

The 25% reduction in RDF did not significantly affect the number of tubers/plant. Nonetheless, numerical figures show that 100% RDF was used to capture the greatest number of tubers/plant (6.13). With a 50% reduction in RDF, no discernible decrease in tuber weight/plant was seen. Highest tuber weight/pant (1222.22 g) was recorded with 50% reduction of RDF and found at par with application of 100% RDF. The outcomes concur with the findings of Ogedegbe et al. [32].

100% RDF produced the highest tuber yield (296.75 q ha^{-1}), followed by 50% RDF. Mona et al. [30] and Faten et al. [33] reported increased tuber yield in response to increased NPK dosage. Adhikari [34] achieved a high yield of tubers by increasing the NPK to 100:100:100 kg ha^{-1}. Potatoes' dry matter (DM) content is a crucial quality characteristic that establishes its solid composition, which includes sugars, starches, and protein. According to Dingenen et al. [35], the processing industry typically accepts 18–20% DM. Like the effect of spacing, dry matter per cent in tubers could not be affected by reduced levels of RDF. Best results may be sought due to interaction between spacing and RDF levels.

Significant differences were recorded for different potato tuber sizes due to reduced levels of RDF. Highest 'A' size tubers were obtained with 100% RDF (41.06%) followed by 50% RDF (38.52%) whereas higher 'B' and 'C' size tubers were obtained by reduction of RDF up to 50%. The reduction in fertility levels from 100% RDF of NPK to 50% RDF of NPK resulted in a considerable increase in the production and quantity of seed grade tubers [29].

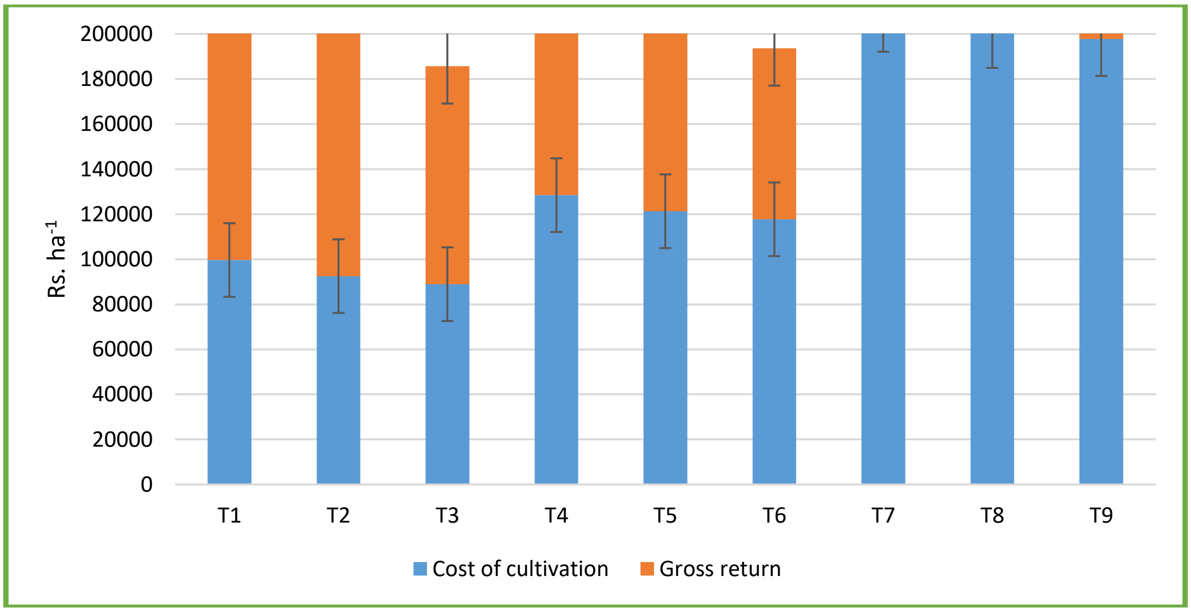

Fig. 1. Treatment wise cost of cultivation and gross return of potato

Table 1. Effect of planting density on potato crop

Spacing	Plant height (cm)			No. Stolen/plant			Leaf length (cm)			No. of tuber/plant	Tuber weight/ plant (g)	Tuber yield (q ha^{-1})	Dry matter (%)	A size tuber (>4cm) (%)	B size tuber (3-4cm) (%)	C size tuber (2.5-3cm) (%)
	45 DAS	60 DAS	90 DAS	45 DAS	60 DAS	90 DAS	45 DAS	60 DAS	90 DAS							
40cm×20cm	18.47^{a}	21.12^{a}	38.84^{a}	2.62	2.98	3.24	16.59	17.98	18.28	5.73^{a}	1348.89^{a}	298.91^{a}	20.39	40.25^{a}	22.31^{a}	22.10^{b}
30cm×15cm	16.11^{b}	20.16^{a}	34.22^{b}	2.56	2.87	2.98	16.63	16.99	17.32	5.20^{b}	1052.22^{b}	291.20^{b}	19.62	35.53^{b}	21.61^{a}	25.90^{a}
20cm×10cm	13.84^{c}	17.55^{b}	31.28^{c}	2.56	2.91	3.07	15.14	16.22	17.03	6.27^{a}	800.00^{c}	234.14^{c}	18.59	28.18^{c}	18.66^{b}	10.41^{c}
S.E.(m)±	0.48	0.64	0.86	0.13	0.17	0.13	0.50	0.52	0.47	0.26	55.99	2.38	0.52	0.79	0.66	0.72
C.D. at 5%	1.44	1.94	2.59	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.78	169.29	7.20	N.S.	2.38	1.98	2.18

N.S.- Non-significant; DAS- Days after sowing; A size tuber- Super grade; B size tuber- medium grade; C size tuber- seed tuber grade

Table 2. Effect of reduced levels of RDF on potato crop

RDF level	Plant height (cm)			No. Stolen/plant			Leaf length (cm)			No. of tuber/ plant	Tuber weight/plant (g)	Tuber yield (q ha^{-1})	Dry matter (%)	A size tuber (>4cm) (%)	B size tuber (3-4cm) (%)	C size tuber (2.5-3cm) (%)
	45 DAS	60 DAS	90 DAS	45 DAS	60 DAS	90 DAS	45 DAS	60 DAS	90 DAS							
100% RDF	17.87^{a}	22.39^{a}	38.18^{a}	2.49	2.82	2.91	16.13	17.16^{a}	17.54^{a}	6.13	1194.44^{a}	296.75^{a}	20.40	41.06^{a}	22.11^{a}	22.31^{a}
50% RDF	16.78^{a}	19.60^{b}	36.29^{a}	2.53	2.93	3.24	16.81	18.24^{a}	18.74^{a}	5.49	1222.22^{a}	286.85^{b}	19.48	38.52^{b}	22.22^{a}	21.42^{a}
25% RDF	13.78^{b}	16.84^{c}	29.88^{b}	2.71	3.00	3.13	15.42	15.79^{b}	16.34^{b}	5.58	784.445^{b}	240.65^{c}	18.73	24.37^{c}	17.24^{b}	14.68^{b}
S.E.(m)±	0.48	0.64	0.86	0.13	0.17	0.13	0.50	0.52	0.47	0.26	55.99	2.38	0.52	0.79	0.66	0.76
C.D. at 5%	1.44	1.94	2.59	N.S.	N.S.	N.S.	N.S.	1.57	1.41	N.S.	169.29	7.20	N.S.	2.38	1.98	2.31

N.S.- Non-significant; DAS- Days after sowing; A size tuber- Super grade; B size tuber- medium grade; C size tuber- seed tuber grade

Table 3. Combined effect of plant density and RDF levels on economics of potato cultivation

Treatment	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C Ratio
T_{1}- 40cm×20cm @100%RDF	99643.00	182445.70	82802.70	0.83
T_{2}- 40cm×20cm @50%RDF	92494.00	193085.83	100591.83	1.09
T_{3}- 40cm×20cm @25%RDF	88919.00	96792.91	7873.91	0.09
T_{4}- 30cm×15cm @100%RDF	128443.00	171248.34	42805.34	0.33
T_{5}- 30cm×15cm @50%RDF	121294.00	195921.12	74627.12	0.62
T_{6}- 30cm×15cm @25%RDF	117719.00	75954.74	-41764.26	-0.35
T_{7}- 20cm×10cm @100%RDF	208443.00	110218.04	-98224.96	-0.47
T_{8}- 20cm×10cm @50%RDF	201294.00	92163.29	-109130.71	-0.54
T_{9}- 20×10cm @25%RDF	197719.00	49294.37	-148424.63	-0.75

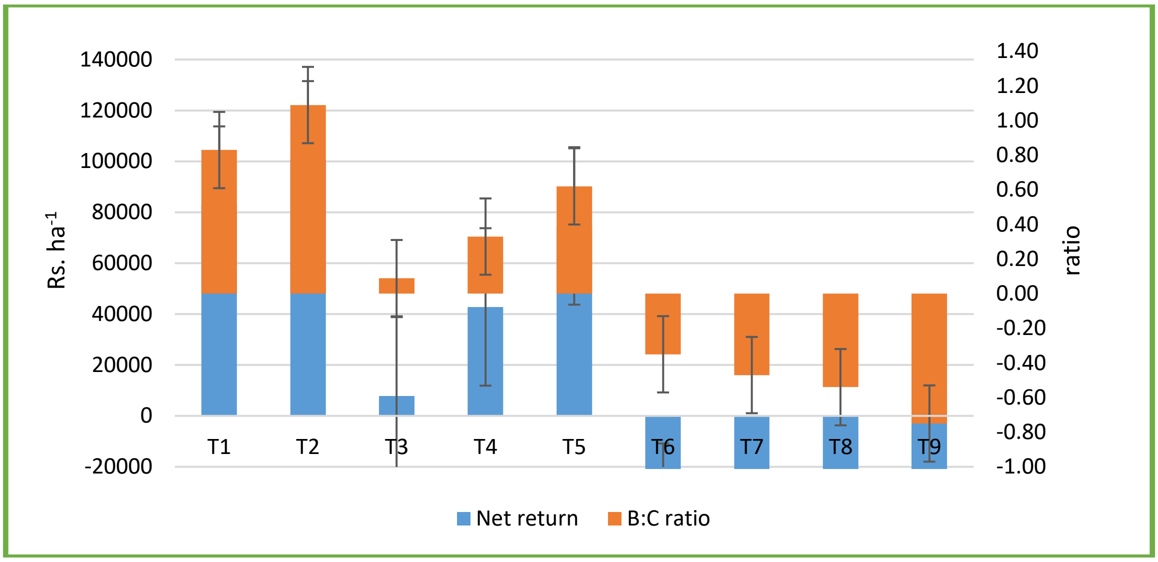

Fig. 2. Treatment wise net return and B:C ratio of potato cultivation

3.3 Economics of Potato Cultivation

The treatment-wise data on the economics of potato production are displayed in Table 3. With T3 (40cm×20cm @25%RDF) had the lowest cultivation costs (Rs. 88919.00 ha^{-1}), followed by T2 (Rs. 92494.00 ha^{-1}) with 40cm×20cm spacing and 50%RDF level, and T7 (20cm×10cm @100%RDF) had the highest (Fig. 1). This happened due to variance in input cost among treatments. Potato tubers and seed tubers were sold @ Rs.400/q and Rs. 1200/q, respectively. Consequently, high gross return (Rs. 195921.12 ha^{-1}) was worked out from T5 (30cm×15cm @50%RDF) followed by T2 (Rs. 193085.83 ha^{-1}) with spacing of 40cm×20cm and 50%RDF level (Fig. 1). With T2 (40cm×20cm @50%RDF), the highest net return (Rs. 100591.83 ha^{-1}) and B: C ratio (1.09) were attained (Fig. 2). Akinpelu et al. (2011) found that growing potatoes in Nepal with NPK 15:15:15 fertilizer applied at a rate of 200 kg ha^{-1} is profitable, with a gross return of NR 230,100.00 ha^{-1} and a benefit cost ratio of 1.40.

4. CONCLUSION

Based on the results, treatment T2, which involved spacing 40cm×20cm and applying fertilizer at a 50% RDF level, could be deemed the most profitable for producing seed tuber production. As a result, our research showed that agronomical techniques including increasing planting density and using a suitable amount of NPK fertilizer might be helpful in boosting seed tuber output, which would assist in reducing production costs.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

We all author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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