International Journal of Applied Research
Journal HP: www.intjar.com, ISSN: 2411-6610

Combination of planting time and plant density in better potato production

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ARTICLE INFO

Article history

Accepted 10 July 2019
Online release 20 July 2019

Keyword

Planting time
Plant density
Combined effect
Potato production

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ABSTRACT

Plant density and planting time are the most important factors for yield and quality of potato. An investigation was therefore conducted in the experimental field of Horticulture, BSMRAU, Gazipur to find out the combined effect of planting time and plant density of top shoot cuttings in potato production. There were three planting times (P_1 - 25, November, P_2 - 05, December and P_3 - 15 December) and three plant densities (S_1 - 50 X 10 cm, S_2 - 50 X 15 cm and S_3 - 50 X 20 cm) of top shoot cuttings which in combination made nine treatment combinations. Unit plot size was 2.0 m X 2.4 m. The experiment was laid out in two factors randomized complete block design with three replications. It was apparent that combination of planting time of top shoot cuttings had significant effect on plant survivability. The plants of earliest plantings with wider spacings (P_1S_3) showed maximum vigor (8.00). The maximum foliage coverage (73.73 %) was produced by P_1S_1 while it was minimum in P_3S_3 at 60 DAP. Maximum plant height was recorded in P_1S_1 while it was minimum in P_3S_3. Significant variation on number of branches per plant was also observed with highest number of branches in P_1S_3 and lowest number of branches was recorded in P_3S_1. Maximum number of tubers per plant (6.80) was observed in P_1S_3 while the lowest number was found in P_3S_1. The maximum weight of tubers per plant was observed in P_1S_3 and least tuber weight per plant was in P_3S_1. The treatment combination P_1S_1 produced maximum yield (14.77 kg and 30.73 t / ha). The maximum percentage of < 28 mm, 28-45 mm and > 45 mm size tuber was found in P_3S_1, P_3S_3 and P_1S_3 respectively. P_1S_1, P_1S_2, P_1S_3 and P_2S_1 produced higher percentage of medium (>50 %) and large size tubers (> 15 %). Total variable cost was highest in potato production by using seed tuber whereas it was lowest in P_1S_3. Net returns and BCR were highest when potato produced from seed tubers closely followed by P_1S_1.

Introduction

With the increase in Bangladesh's population and decrease in arable land, food security issues have become more prominent. Potato (*Solanum tuberosum* L.) is one of the most important staple food crops in Bangladesh and plays important roles in coping with multiple crop indices, the output of cultivated land, and food security problems (Seyed and Asghar, 2011).

Top-shoot cuttings are routinely used in seed potato production (Hossain, 1993). Early planted top-shoot cuttings produced more tubers per plant with a greater mean tuber weight than from the late planting (Hossain et al., 1998).

Increased yields from potato cultivation mostly depend on the availability of sufficient quantities of good quality seed potatoes and the annual seed potato requirement of the country is about 0.60 million ton (Bangladesh Agriculture Development Corporation, 2012). Out of the total requirement, the Bangladesh Agriculture Development Corporation (BADC) supplied only 18,899 ton (3.16%) in 2010–2011 that was used by the farmers as replacement stock (Bangladesh Agriculture Development Corporation, 2012).

The plant spacing influences the yield of potato. In general, larger seed and closer spacing up to a certain limit increase the yield of tubers per unit area. Yield increased with a decrease in spacing from 25 to 20 cm and in rows of 55 cm apart (Banerjee et al., 1988). It was also reported that plant spacing had no significant effect on the number of main stems per hill, although the number of tubers per hill increases with increase in plant spacing. The yield of tubers per hill increased significantly with increase in plant spacing (Sultana and Siddique, 1991).

In practice, plant density in the potato crop is manipulated through the number and size of the seed tubers planted (Allen and Wurr, 1992). Therefore, many studies have been conducted to establish the optimal combination of seed size and planting distance for a certain environment (Sultana and Siddique, 1991, Negi et al., 1995, Creamer et al., 1999, Hoque, 2001, Bussan et al., 2007).

Increase in plant density is an effective way to improve potato yield, but certain differences exist among high densities and growing seasons (Vasilyev, 2014). Yu et al. (2009) showed that fall potato yield is positively correlated with density. Zhao et al. (2005) found that plant density has a downward parabolic relationship with potato yield, and delayed sowing dates require increased

densities to obtain the maximum yield. However, little is known about the impact of combination of planting density and time on potato production. To address these issues, the present study aimed to investigate the differences between potato crops grown at different densities in combination with planting time.

Materials and Methods

Experiment site

The field experiment was conducted at the Horticultural Research Farm, BSMRAU, Gazipur during winter season of 2007-08. The location of the experimental site is at the center of Madhupur Tract (24.09 ^{0} N latitude and 90.26 ^{0} longitudes) at 8.5 m above the sea level (Anon., 1998).

Soil

The soil of the experimental field was silty clay of Shallow Red Brown Terrace type under Salna Series of Modhupur Tract in Agro ecological zone (AEZ) 28. The soil containing a pH of 6.4 (Anon., 1998; Haider et al., 1991).

Climate

The experimental site is situated in a sub-tropical climate zone and characterized by no rainfall during December to March and plenty during the rest of the year. Mean weekly data on relative humidity, rainfall and maximum and minimum temperature during the study period were noted from the meteorological station of BSMRAU from September 2007 to April 2008 as reported by Yasmin et al. (2019).

Planting material

Top shoot cuttings of standard potato variety Diamant was used in the experiment. The seed was collected from the Tuber Crop Research Center (TCRC).

Treatments of the experiment

Combination of planting time (P_1 = 25, November; P_2 = 5, December; P_3 = 15, December) and plant density /spacing S_1 = (96 plants /m^2 or 50 cm X 10 cm); S_2 = (64 plants / m^2 or 50 cm X 15 cm) and S_3 = (48 plants / m^2 or 50 cm X 20 cm) resulted in nine treatment combinations (P_1S_1, P_1S_2, P_1S_3, P_2S_1, P_2S_2, P_2S_3, P_3S_1, P_3S_2, P_3S_3). The control was whole tuber with 60 cm X 25 cm spacing.

Preparation of planting material

The land was properly ploughed and fertilizer were applied @ cowdung 10 tons / ha, urea 350 kg / ha, TSP 220 kg / ha and MP 270 kg / ha. Full dose of TSP and Mp and 1/3 rd urea were applied at final land preparation and rest 2/3 rd urea were applied in two splits at 10 days interval from emergence for better vegetative growth. Well sprouted seed tubers of Diamant variety were planted at 25, October to produce top shoot cuttings. When the plants reached at 20-25 cm height first top shoot cuttings were taken and planted them after treating with hormone (15 ppm IBA and 10 ppm IAA) in a well prepared seed bed containing sand and well rotten cowdung at the ratio of 1: 1 at 10, November 2007 for rooting. Another two top shoot cuttings were taken at 20, November and 30, November and planted them in well prepared seed bed for rooting. Thus, rooted top shoot cuttings were prepared for planting at 25, November, 05 December and 15, December.

Economic analysis

Partial economic analysis was done in order to find out the benefits of using different treatments compare to control. For this purpose cost for seed sowing, cuttings of top shoot, fertilizer / pesticide application, harvesting costs etc. were recorded in per hectare. Partial analysis was done by calculating non-material (labour) and material cost (Seed, fertilizer etc.) for computing the cost of production. The price of the potato tubers was determined on market price basis. Benefit cost ratio was calculated by using the following formula: Benefit cost ratio = Net returns (tk / ha) / Total variable cost (tk / ha).

Design and layout, land preparation, intercultural operations and harvesting were performed according to the method described by Yasmin et al. (2019).

Data collection

Data on different morphological, physiological and tuber characters were recorded on the following parameters from the sample plants of each plot during the course of experiment. The sampling was done randomly. The plants in the outer row were excluded during randomization. Five plants were randomly selected from each plot to record the data on rate of plant, survivability (%), plant vigor, plant height (cm), foliage coverage (%), number of branches per plant, number of tubers per plant, weight of tubers per plant, yield of tubers (kg / plot and tons / ha), tuber grade by number (%), tuber grade by weight (%) and economic analysis: BCR calculation according to the method applied by Yasmin et al. (2019).

Results and Discussion

Growth Characteristics

Plant survivability

The interaction effects were found insignificant on plant survivability (Table 1). The higher percentage of survivability might be the consequence of proper care and management.

Plant Vigor

Plant vigor varied significantly due to the interaction effect of planting time and densities of top shoot cuttings (Table 1). The plants of earliest plantings with wider spacings (P_1S_3) showed maximum vigor (8.00) which was statistically similar with P_1S_2 (7.33) followed by P_1S_1 (6.67), P_2S_3 (6.33). The lowest vigor (3.33) was obtained from P_3S_1 and P_3S_2.

Foliage coverage

The interaction effects of planting time and plant density on foliage coverage was found significant and it increased with the progress in days after planting (Table 1). Foliage coverage varied ranging from 49.57 % to 73.73 % at 60 days after planting. The maximum foliage coverage (73.73 %) was produced by P_1S_1 (early planting with closest spacing) followed by P_1S_2 (70.87 %), P_1S_3 (68.23 %) and P_2S_1 (65.43 %) while it was minimum (49.57 %) in P_3S_3 at 60 DAP.

Table 1: Interaction effects of planting time and plant density of top shoot cuttings on plant survivability, plant vigor and foliage coverage of potato

Treatment	Plant survivability (%)	Plant vigor (1- 10)	Foliage coverage (%)	
			45 DAP	60 DAP
P_1S_1	98.93	6.67 bc	53.67 a	73.73 a
P_1S_2	98.40	7.33 ab	51.70 b	70.87 b
P_1S_3	97.90	8.00 a	48.40 c	68.23 c
P_2S_1	98.93	5.33 e	45.30 d	65.43 d
P_2S_2	98.93	5.67 de	42.90 e	63.60 e
P_2S_3	98.60	6.33 cd	40.70 f	60.17 f
P_3S_1	98.23	3.33 f	36.43 g	55.13 g
P_3S_2	97.33	3.33 f	32.36 h	51.30 h
P_3S_3	97.20	3.67 f	30.63 i	49.57 i
Level of significance	NS	*	*	*
CV (%)	1.43	9.23	1.69	1.25

Means bearing same letter in a column do not differ significantly at 5 % level of probability.

Table 2: Interaction effects of planting time and plant density of top shoot cuttings on plant height and number of branches per plant

Treatment	Plant height (cm)		Number of branches / plant
	45 DAP	60 DAP	
P_1S_1	62.83 a	69.20 a	4.27 b
P_1S_2	60.00 b	66.33 b	4.33 b
P_1S_3	55.67 c	62.93 c	4.60 a
P_2S_1	54.80 c	59.77 d	3.27 e
P_2S_2	51.67 d	56.60 e	3.50 d
P_2S_3	49.27 e	54.37 f	3.70 c
P_3S_1	40.63 f	45.87 g	2.20 g
P_3S_2	36.57 g	40.47 h	2.27 g
P_3S_3	34.70 h	37.90 i	2.43 f
Level of significance	*	*	*
CV %	1.04	1.03	2.34

Means bearing same letter in a column do not differ significantly at 5 % level of probability.

Plant height

A significant interaction between planting time and plant density was found in respect of plant height at 45 and 60 DAP which has been presented in Table 2. During the period of plant growth maximum plant height (69.20cm) was recorded in the plants of P_1S_1 followed by P_1S_2 (66.33 cm), P_1S_3 (62.93 cm) and P_2S_1 (59.77 cm) while it was minimum (37.90 cm) in P_3S_3 at 60 DAP. The variation in plant height due to the influence of different treatment combinations may be the consequences of the variation of temperature and light.

Number of branches

Significant variation on number of branches per plant was observed due to the interaction effect of planting time and planting density (Table 2). The highest number of branches (4.60) was found in P_1S_3 (25, November planting with 50 X 20 cm spacings) at 60 DAP. The second highest number of branches per plant (4.33) produced by P_1S_2 (25, November planting with 50 X 15 cm spacings) which was statistically similar to P_1S_1 (25, November with 50 X 10 cm spacings). The lower number of branches (2.20) was recorded in P_3S_1 (15, December planting with 50 X 10 cm spacings) which was statistically similar to P_3S_2 (15, December with 50 X 15 cm spacings)

Yield Performance

Number of tubers per plant

Different treatment combinations showed significant effect on number of tuber per plant (Table 3). The maximum number of tubers per plant (6.80) was observed in the treatment P_1S_3 (25, November planting with 50 X 20 cm spacing) which was statistically similar to the P_1S_2 (6.70) followed by P_1S_1 (6.20) and P_2S_3 (6.10) while the lowest number of tubers per plant was found in P_3S_1 (3.63). The number of tubers per plant is a vertical character, which was largely governed by the number of stems per plant. It was found that plants of earlier planting with widest spacings produced maximum branches which helped to produced more number of tubers per plant.

Weight of tubers per plant

The interaction effect of planting time and plant density on weight of tubers per plant was found significant (Table 3). It varied from 72.23 g to 269.87 g. The maximum weight of tubers per plant (269.87 g) was observed in P_1S_3 (25, November with 50 X20 cm spacing) followed by P_2S_3 (206.07 g), P_1S_2 (200.63 g) and P_1S_1 (156.20 g) while it was minimum (72.23 g) in P_3S_1. Late planting with closest spacings produced least tuber weight per plant may be due unfavorable condition in growing period which reduced the accumulation of reserve food material among in the densely populated plants.

Yield of tubers per plot

The tuber yield per plot varied significantly due to the influence of planting time and plant density (Table 3). The treatment combination P_1S_1 (25, November planting with 50 X 10 cm spacing) produced maximum yield per plot (14.77 kg) followed by P_1S_3 (12.67 kg), $P1S_2$ (12.63 kg), P_2S_1 (11.17 kg) and P_2S_2 (9.70 kg) while it was minimum (5.30 kg) in P_3S_3.

Yield (t / ha)

Significant variation in per hectare yield (t / ha) was observed due to the influence of planting time and plant density (Table 3). The highest per hectare yield (30.73 tons) was produced by P_1S_1 (25, November planting with 50 X 10 cm spacings) followed by P_1S_3 (26.37 t / ha), P_1S_2 (26.30 t /ha) and P_2S_1 (23.23 t /ha) while it was minimum (11.00 t /ha) in P_3S_3.

Tuber grade by number (%)

It was apparent that interaction effects of planting time and plant densities on tuber grades by number have significant effects (Table 4). The maximum percentages (57.63 %) of small tubers (< 28 mm) was found in P_3S_1 (late planting with 50 X 10 cm spacing)) and the minimum (40.40 %) was in P_1S_3 (early planting with minimum plant density). The highest percentage (47.83 %) of medium size tubers (28-45 mm) was found in P_3S_3 (late planting with 50 X 20 cm spacing) and the lowest 40.33 % was in P_1S_1 (early planting with maximum plant density) which was statistically similar with P_1S_2 (42.40 %), P_1S_3 (42.63 %) and P_3S_1 (42.37 %). The highest percentage (16.97 %) bigger tuber (> 45 mm) was found in P_1S_3 which was statistically similar with P_1S_1 (16.33 %) and P_1S_2 (16.33 %) while P_3S_1, P_3S_2 and P_3S_3 did not produced any tuber of > 45 mm size tuber.

Table 3: Interaction effects of planting time and plant density of top shoot cuttings on number and weight of tubers per plant, yield per plot, yield per plot and yield (t / ha)

Treatment	No. of tuber per plant	Wt. of tubers per plant(g)	Yield (kg / plot)	Yield (t / ha)
P_1S_1	6.20 b	156.20 d	14.77 a	30.73 a
P_1S_2	6.70 a	200.63 c	12.63 b	26.30 b
P_1S_3	6.80 a	269.87 a	12.67 b	26.37 b
P_2S_1	5.00 d	117.63 e	11.17 c	23.23 c
P_2S_2	5.73 c	153.20 d	9.70 d	20.20 d
P_2S_3	6.10 b	206.07 b	9.73 d	20.27 d
P_3S_1	3.63 f	72.23 g	6.83 e	14.23 e
P_3S_2	3.87 ef	90.70 f	5.67 f	11.80 f
P_3S_3	3.97 e	114.83 e	5.30 g	11.00 g
Level of significance	*	*	*	*
CV (%)	2.60	1.14	1.65	1.69

Means bearing same letter in a column do not differ significantly at 5 % level of probability.

Table 4: Interaction effects of planting time and plant density of top shoot cuttings on tuber grade by number (%)

Treatment	Tuber grade by number (%)		
	< 28 mm	28-45 mm	> 45 mm
P_1S_1	43.00 e f	40.33 c	16.33 a
P_1S_2	41.27 f g	42.40 c	16.33 a
P_1S_3	40.40 g	42.63 c	16.97 a
P_2S_1	48.00 c	45.33 b	6.67 c
P_2S_2	46.00 d	46.33 a b	7.67 b c
P_2S_3	44.37 d e	47.03 a b	8.60 b
P_3S_1	57.63 a	42.37 c	0.00 d
P_3S_2	53.73 b	46.27 a b	0.00 d
P_3S_3	52.17 b	47.83 a	0.00 d
Level of significance	*	*	*
CV %	2.23	2.87	10.86

Means bearing same letter in a column do not differ significantly at 5 % level of probability.

Table 5: Interaction effects of planting time and plant density of top shoot cuttings on tuber grade by weight (%).

Treatment	Tuber grade by weight (%)		
	< 28 mm	28-45 mm	> 45 mm
P_1S_1	22.33 d	50.97 b	26.70 b
P_1S_2	19.67 e	51.90 b	29.43 a
P_1S_3	18.33 e	52.40b	29.27 a
P_2S_1	28.40 b	55.93 a	15.67 e
P_2S_2	26.03 b c	56.73 a	17.23 d
P_2S_3	23.80 c d	57.70 a	18.50 c
P_3S_1	43.40 a	56.60 a	0.00 f
P_3S_2	42.83 a	57.17 a	0.00 f
P_3S_3	42.13 a	57.73 a	0.00 f
Level of significance	*	*	*
CV %	4.66	2.24	4.34

Means bearing same letter in a column do not differ significantly at 5 % level of probability.

Table 6: Partial budget analysis of potato for different treatment combinations of top shoot cuttings and control treatment (whole tuber with 60 X 25 cm)*

Treatment	Total material cost (Tk/ha)	Total non - material cost (Tk/ha)	Total variable cost (Tk/ha)	Yield (t/ha)	Gross returns (Tk/ha)	Net returns (Tk/ha)	BCR
P_1S_1	56720.00	38040.00	94760.00	30.73	368760.00	274000.00	2.89
P_1S_2	56700.00	37560.00	94260.00	26.30	315600.00	221340.00	2.35
P_1S_3	56670.00	37200.00	93870.00	26.37	316440.00	222570.00	2.37
P_2S_1	58220.00	38040.00	96260.00	23.23	278760.00	182500.00	1.90
P_2S_2	58200.00	37560.00	95760.00	20.20	242400.00	146640.00	1.53
P_2S_3	58170.00	37200.00	95370.00	20.27	243240.00	147870.00	1.55
P_3S_1	59720.00	38040.00	97760.00	14.23	170760.00	73000.00	0.75
P_3S_2	59700.00	37560.00	97260.00	11.80	141600.00	44340.00	0.46
P_3S_3	59670.00	37200.00	96870.00	11.00	132000.00	35130.00	0.36
Control	105020.00	28320.00	133340.00	42.00	525000.00	391660.00	2.94

Sale price of potato (top shoot cuttings) = 12.00 Tk / kg
Sale price of potato (form control or whole tuber) = 12.50 Tk / kg.

Tuber grade by weight (%)

The percentage of tuber grade by weight varied significantly due to the influence of planting time and plant density (Table 5). The maximum percentage of tubers of < 28 mm, 28-45 mm and > 45 mm grades were 42.83 % in P_3S_2, 57.73 % in P_3S_3 and 29.43 % in P_1S_2 respectively. It was found that P_1S_1, P_1S_2, P_1S_3 and P_2S_1, produced higher percentage of medium and large size tubers (> 50% and > 15 % respectively).

Economic analysis

In case of top shoot cuttings higher labor involvement required compared to whole tuber. Total variable cost was highest (1,33,340 Tk) in potato production by using seed tuber whereas it was lowest (93,870 Tk) in P_1S_3. Gross return was

highest (5,25,000 Tk) when potato produced from seed tubers while it was lowest (1,32,000 Tk) in P_3S_3. Net returns and BCR were highest (3,91,660 Tk and 2.94 respectively) when potato produced from seed tubers closely followed by the method of producing potato from top shoot cuttings with closer spacings (50 X 10 cm) planted at 25, November (Table 6).Hoque et al., (2001) calculated the highest net benefit (Tk. 78150) and BCR (2.92) from spacing of 40 cm X 15 cm with higher gross return Tk. 118800 and lower variable cost Tk. 40650.

Conclusion

Early planting of top shoot cuttings with closet spacings performed better for good foliage coverage, plant height and per hectare yield whereas late planting of top shoot cuttings with widest spacings performed inferior. The crop grown from early planted top shoot cuttings produced higher percentage of medium (28-45 mm) and bigger size (>45 mm) tubers in all spacings (> 50% and >15% respectively). Net returns and BCR were highest (3,91,600 Tk and 2.94 respectively) in potato produced from seed tubers (whole tuber) with 60 X 25 cm spacings which were very close and comparable to growing potato from early planted top shoot cuttings with closet spacings.

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