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Effect of planting time and density of top shoot cuttings in potato production

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ABSTRACT

An investigation was conducted in the experimental field of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur to find out the effect of planting time and 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 spacing (S_1 - 50 X 10 cm, S_2 - 50 X 15 cm and S_3 - 50 X 20 cm) to evaluate the economic benefit. The treatment effects were found significant in most of the characters studied. The plants of early planting (25, November) produced higher foliage coverage (70.94 %), plant height (66.16 cm), number of branches / plant (4.40), number (6.57) and weight (208.90g) of tuber per plant and yield (27.80 t / ha). The higher plant density (closer spacings) increased the foliage coverage (64.77 %), plant height (52.76 cm) and yield (22.73 t / ha) while wider spacings increased the plant vigor (6.00), number of branches / plant (3.58), number of tuber / plant (5.62). The plants grown from early planted top shoot cuttings with closest spacing produced highest foliage coverage (73.73 %), plant height (69.20 cm) and per hectare yield (30.73 t / ha). The plants of early planted top shoot cuttings produced the higher percentage of medium and large tubers irrespective of spacings.

INTRODUCTION

Potato (*Solanum tuberosum*) is the most important tuber crop in the world as well as in Bangladesh. It belongs to the family Solanaceae. It ranks first among the vegetables in terms of area and production and is the third largest food crop in Bangladesh next to rice and wheat. Potato produces more calories and protein per unit of land with minimum time than most of the major food crops (Upadhya, 1995). It is also a world leading vegetable that contains appreciable amount of vitamin B and vitamin C as well as some minerals (Thompson and Kelly, 1957). Potato contributed alone as much as 50 percent of the total annual vegetable production (Anon, 1998). The area, production and average yield of potato in Bangladesh are 3 lakh ha, 4227576 tons and 14.09 t ha^{-1} respectively (Anon, 2007). The average yield is very low compared to some leading potato growing countries, though the soil and climatic conditions of Bangladesh are congenial to the proper growth of the crop. Among the different causes of low yield of potato in our country, lack of practicing improved production technologies are important. Planting time, spacings, propagating materials, seed size, propagation method etc. are some of the important factors, which should be standardized for each agro-climatic zones of the country. Potato cultivation and increase in yield mostly depend on the availability of sufficient quantities of good quality seed potatoes. The total seed potato requirement of the country is about 5.25 lakh tons (Karim, 2006). Out of the total requirement, Banglaesh Agricultural Development Corporation (BADC) is supplying only about 2% that is used by the farmers as the replacement stock (Talukder, 2004). Seed tuber is the most important planting material used in the country. Besides that potato can be grown from several types of propagating materials like sprout cuttings, top-shoot cuttings or stem segments with at least one bud and true potato seeds.

The yield of potato like any other crop is under the control of the environmental factor. So, planting time is an important factor for potato production. There had been a number of attempts in Bangladesh to find out the appropriate time for the planting of seed potato. Fort-nightly plantings from October 25 to December 25, the highest yields were produced by the plantings of

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November 10 and 25 (Ahmad and Quasem, 1967). The best yields were also obtained by the early plantings (Ahmad and Ahmad, 1973). The middle of November is the appropriate time of planting of potato for Bangladesh (Ahmad and Samad, 1976). However, there are some discrepancies in planting time of seed potato and information regarding the planting time of top-shoot cuttings is scanty. Therefore, the present study has been undertaken to evaluate the performance of top-shoot cuttings as planting material in potato production and to find out the optimum planting time of top-shoot cuttings for potato production in Bangladesh.

MATERIALS AND METHODS

Site and season of the experiment

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 (Table 1).

Table 1
Meteorological data during the experimental period (in field) from September 2007 to April 2008.

Month	Temperature (^{0}C)		Relative humidity (%)		Rainfall (mm)	No. of Rainy Days
	Maximum	Minimum	9 am	2 pm		
September	32.1	26.4	80.6	70.5	145.8	11
October	32.1	23.5	77.7	-	393.3	9
November	29.4	19.5	74.6	53.2	63	1
December	26.1	13.8	73.0	51.1	Nill	-
January	24.6	13.4	74.9	54.6	51.4	5
February	25.9	14.6	72.1	50.1	67.8	3
March	28.0	20.5	87.5	77.5	10.4	4
April	28.5	20.5	85.7	77.5	12.5	5

Source: Plant Physiology Division; Meteorological station, BRRI, Joydebpur, Gazipur.

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

The experiment consisted of two factors including planting time and plant density. Factor -A (Planting times) included P_1 = 25, November, P_2 = 5, December and P_3 = 15, December. Factor- B (Plant density /spacing) included 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).

Preparation of planting material

A small piece of land was ploughed, laddered and leveled until fine tilth. Nitrogen, phosphorous and potassium 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 15, 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.

Design and layout

The experiment having two factors was laid out in randomized complete block design (RCBD) with three replications. The entire experimental field was divided into three blocks, representing three replications. Each of which again divided into ten unit plots. The treatment was assigned randomly to unit plots of each block. Thus, the total number of unit plot was 30. The size of a unit plot was 2.0 m X 2.4 m.

Land preparation and fertilizer application

The experimental field was mechanically ploughed, laddered and leveled until fine tilth. Irrigation channels were prepared around the plots as per design. Full doses of cowdung (10 t / ha), TSP (220 kg /ha), MP (270 kg / ha), Gypsum (120 kg / ha), $ZnSO_4$ (14 kg / ha), Boric acid 6 kg / ha and half doses of urea (175 kg / ha) were applied final land preparation. The rest half doses of urea (175 kg / ha) were applied as top dressing in two splits.

Planting method

Well rooted top shoot cuttings were planted at three different times (25, November, 05, December and 15, December) maintaining assigned spacings as per treatment.

Intercultural operations

Immediately after planting, the plants were protected from scorching sunlight by providing shade for three days. Intercultural operations such as weeding, earthing up etc. were done manually. After spading the soil between the rows, weeds were removed. Earthing up was done 3 times during the growing period. First earthing up at a height of 15-20 cm from the base was done after 35 days of planting, second one after 20 days of first earthing up. Before earthing up, urea was applied. Irrigation was applied four times, first one was two week after planting, second one was just after earthing up, third one was at 55 days and the last one was at 75 days after planting. During land preparation, Miral (0.30 %) was applied to soil for the control of soil insects. A general dose of 0.2 % Asataf (Systemic insecticide) was sprayed at every 15 days and Dithane M-45 @ 2-2.5 kg / ha was sprayed at 10 days interval. The spraying was started at 35 DAP. Ridomil Gold was sprayed @ 2 kg / ha one time after rainfall to prevent Late blight infection.

Harvesting

Crop was harvested after 100 days of planting when the crop was full matured and four –fifths of the plants got dried up. The plants were harvested carefully with the help of spades without any injury.

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.

Rate of plant survivability

This observation was noted at 15 days from planting of cuttings. The numbers of survived cuttings were recorded. Percentage of survivability for unit bed per replication was calculated by using the following formula: Plant survivability

(%) = (Number of survived cuttings / number of cuttings planted per treatment) X 100.

Plant vigor

The plant vigor was calculated on the basis of phenotypic expression of plants by eye estimation using arbitrary 1-10 scale (1 = poor and 10 = vigorous).

Foliage coverage

The area covered by the canopy of plants at 45 and 60 DAP was measured by using eye estimation and expressed into percentage.

Plant height

The height of 5 randomly selected plants from each plot was measured in centimeter from the ground level to the tip of the longest shoot at 45 and 60 days after planting. The average height of the plant was calculated from the total plant height dividing by the number of plants.

Number of branches per plant

At 60 DAP the number of branches per plant was counted from five randomly selected plants and the average was measured from the total number of branches dividing by five.

Number of tubers per plant

All the five plants selected at randomly from each plot were harvested and the number of tubers per plant was calculated from the total number of tubers dividing by five.

Weight of tubers per plant

The weight of tubers per plant was calculated from the average of five randomly selected plants from each plot at harvest. The weight of tubers per plant was calculated by using the following formula: Weight of tubers per plant (g) = Total weight of tubers (g) / Number of plants.

Yield of tubers per plot (kg) and yield (t / ha)

The gross yield of tubers per plot was recorded by taking weight of the harvested tubers from all plants of a unit plot and was converted to yield in ton per hectare by using following formula:

Yield (t / ha) = Tuber yield per plot (kg) / Area of plot (m^2) X 10,000 / 1000.

Tuber grade by number (%)

All the tubers from the randomly selected five plants were graded into three groups by number under three grades (< 28 mm, 28-45 mm and > 45 mm) and expressed in percentage. By using the following formula percentage of each grade was calculated. Tuber grade by number (%) = Number of particular grade / Total number of tubers X 100.

Tuber grade by weight (%)

All the tubers were graded into three groups by weight under three grades (< 28 mm, 28-45 mm and > 45 mm) from the randomly selected five plants and expressed in percentage. By using the following formula percentage of each grade was calculated. Tuber grade by weight (%) = Weight of particular grade / Total weight of tubers X 100.

Statistical analysis

To find out the significance of experimental result the collected data on different parameters were analyzed statistically by using MSTAT-C program. The mean for all the treatments were calculated and analysis of variance for each parameter was performed by F-test. The mean separation was done by the DMRT at 5 % level of probability.

RESULTS AND DISCUSSION

Growth characteristics

Plant survivability

The planting time and plant densities of top shoot cuttings had no significant effect on plant survivability (Table 2). The survivability of top shoot cuttings was more than 97 % irrespective of planting time and planting density. The higher percentage of survivability might be the consequence of proper care and management.

Plant Vigor

There were significant variations on plant vigor due to the influence of planting time and plant density of top shoot cuttings (Table 2). Plant vigor decreased with delaying of planting. The highest plant vigor (7.33) was found in the plants produced in earliest planting. Plant vigor increased with the increase of plant spacing. The maximum plant vigor (6.00) was obtained from widest spacings (50 X 20 cm). This may be due to less competition among the plants for light and nutrients in wider spacings compare to closer spacings.

Foliage coverage

Good foliage of a plant indicates its good growth and development. The difference on foliage coverage due to the effect of different planting times was found significant (Table 2). Foliage development increased with the progress in days after planting for all the planting times. At 60 days after planting the maximum foliage coverage (70.94 %) was recorded in early planting (25, November planting) and the minimum foliage coverage (52.00 %) was in late planting (15, December planting). The minimum foliage coverage in case of December, 15 planting because of relatively low temperature prevailing almost from the very beginning of its cropping period.

Distinct effects of different plant densities were also recorded on foliage coverage (Table 2). There was an increase in foliage coverage with reducing plant spacings. The highest foliage coverage (64.77 %) was observed in closest spacing (50 cm X 10 cm), while it was lowest (59.32 %) in widest spacing (50 cm X 20 cm). The highest foliage coverage in closest spacings might be due to the presence of more number of plants in closest spacings compare to wider spacings. The results was in agreement with that of Rashid et al. (1993) and Ranalli et al. (1994) who found higher foliage coverage with closer spacings compared to wider spacings.

Table 2
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_1	98.41	7.33 a	51.26 a	70.94 a
P_2	98.82	5.78 b	42.97 b	63.07 b
P_3	97.59	3.44 c	33.14 c	52.00 c
Level of significance	NS	*	*	*
S_1	98.70	5.11 b	45.13 a	64.77 a
S_2	98.22	5.44 b	42.32 b	61.92 b
S_3	97.90	6.00 a	39.91 c	59.32 c
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.
* = Significance at 5 % level of probability, NS = Non- significant.

Plant height

The results revealed that time of planting had significant effect on plant height at both 45 and 60 DAP (Table 3) plant height increased with the progress of days after planting in all the planting times. The crops of 25, November or early planting (P_1) produced the tallest plant (66.16 cm) followed by 5, December or mid planting (P_2) but shortest plant (41.41 cm) was obtained from 15, December or late planting (P_3) at 60 DAP. In case of 25, November planting, plant got considerable

favorable temperature and clear sunny days which presumably promoted the growth and development of plants resulting tallest plant. On the other hand, plants of 15, December planting availed low temperature during their vegetative phase which resulted shortest plant.

The response of different plant densities to plant height was significant at both 45 and 60 DAP (Table 3). The plant height increased with the increased of days after planting in all planting densities. The highest plant height (58.28 cm) was observed from the plants having higher plant density in closer spacing (S_1 = 96 plants / m^2 or 50 cm X 10 cm spacing), while the shortest plant (51.73 cm) was obtained from the lowest plant density in wider spacing (S_2 = 48 plants / m^2 or 50 cm X 20 cm) at 60 DAP. The maximum plant height at the closest spacing might be due to the irradiation effect on dense plant population.

Table 3
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_1	59.50 a	66.16 a	4.40 a
P_2	51.91b	59.91 b	3.49 b
P_3	37.30 c	41.41 c	2.3 c
Level of significance	*	*	*
S_1	52.76 a	58.28 a	3.24 c
S_2	49.41 b	54.47 b	3.37 b
S_3	46.54 c	51.73 c	3.58a
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.

Number of branches

Planting time had significant effect on number of branches per plant. Number of branches decreased with delaying of planting (Table 3). The highest number of branches per plant (4.40) was obtained from 25, November planting (P_1) while 15, December planting (P_2) produced lesser number of branches per plant (2.30). November planting had a congenial environment in terms of temperature and sunny days which might influence the vegetative growth as well as emergence of higher number of branches per plant.

The number of branches per plant increased significantly with decreasing plant density (increasing spacings). The maximum number of branches per plant (3.58) was recorded from widest spacings (S_3) while the minimum number of branches per plant (3.24) was obtained from closest spacings (S_1). There was tendency of producing higher number of branches per plant at lower plant density with wider spacing may be due to availability of nutrient elements and more space for growth and development.

Yield Performance

Number of tubers per plant

Time of planting significantly influenced the number of tubers per plant (Table 4). Number of tubers / plant decreased with delaying of planting. The highest number of tubers (6.57) was produced by the plants planted on 25, November (P_1). The late planting December, 15 (P_3) produced significantly lowest number of tuber (3.82). The seasonal variation is an important determinate of the number of tubers. The top shoot cuttings planted at 25, November experienced optimal conditions for growth and tuber production for longer periods than the successive cuttings resulting higher number of tuber per plant at 25, November planting.

The plant density had significant effect on the number of tubers per plant (Table 4). The maximum number of tubers per plant (5.62) was found with wider spacing (S_3) and minimum number (5.04) with closer spacing (S_1). It was observed that the number of tubers per plant gradually increased with increasing spacings. The increase in number of tubers per plant in wider spacings was probably due to less inter-plant competition for space, light, water and nutrient whereas in closest spacings there was an intense competition for nutrition and space which restricted plant growth and tuber formation. The present findings were in agreement with the findings of Sultana and Siddique (1991) and

Hossain (1995) who reported that the number of tubers per plant increased significantly at wider spacings.

Weight of tubers per plant

The influence of different planting time on tuber weight per plant was found significant (Table 4). It was recorded that early planting increased the tubers weight per plant. The highest weight of tubers per plant (208.90 g) obtained from November, 25 planting (P_1) followed by December, 5 planting (P_2). December, 15 planting (P_3) produced the lowest tubers weight per plant (92.59 g).The crop of 25, November grew under more favorable conditions than subsequent crops. Moreover, potato tuberization had occurred by 30-40 days after planting. The crop planted at 15, December tuberized around 25, January, when the environment was not suitable for tuberization because of relatively high temperature (20-25^{0}C). As a result, tuber size was largest for the crop of 25, November and least for the crop of 15, December.

Weight of tubers per plant increased significantly with increase in plant spacings (Table 4). The highest weight of tubers / plant (196.92 g) was obtained from widest spacings whereas minimum tuber weight per plant (115.36 g) was found from closest spacings. Hossain (1995) reported that weight of tubers / plant increased significantly at wider spacings which corroborate the present findings.

Yield of tubers per plot

The yield of tubers per plot decreased significantly with delaying of planting (Table 4). The maximum yield of tubers per plot (13.36 kg) was obtained from the earliest planting and the minimum (5.93 kg) from late planting. The highest tuber yield per plot in earliest planting might be due to higher number and weight of tubers per plant produced by the plants of early planting.

The influence of plant density on tuber yield per plot was found significant (Table 4). Tuber yield per plot increased with increase in spacings. The maximum tuber yield per plot (10.92 kg) was observed in closest spacings. The lowest yield per plot (9.23 kg) was found in widest spacings. The highest yield per plot with closest spacings might be due to accommodating number plants per plot in closest spacings. Hossain (1995) reported that weight of tubers per square meter increased at closer spacings which corroborate the present findings.

Yield (t / ha)

Per hectare yield also decreased significantly with delaying in planting (Table 4). The crop of early planting produced highest yield (27.80 t / ha) while the crop of late planting produced minimum yield (12.34 t ha). Ahmed and Rashid (1980) reported that the planting of November 20 produced the highest yield which agreed the present findings.

Per hectare yield increased with decrease in spacings (Table 4). The highest yield (22.73 t / ha) was obtained from closest spacings while it was minimum (19.21 t / ha) in widest spacings. Ranalli et al. (1994) reported higher yield at close spacing compared to wide spacings which agreed the present findings. Foliage coverage increased with increase in plant density and thus foliage coverage duration also increased with closest spacing. Since foliage duration was found to be related to total tuber yield (Bremner and Radley, 1996), therefore the total tuber yield increased with closest spacing in the present study.

Tuber grade by number (%)

Percentage of tubers of all grades significantly varied with different planting times of top shoot cuttings (Table 5). The plant of earliest plantings (25, November) produced the maximum percentage (16.54 %) of bigger tuber (> 45 mm size) with higher proportion (41.79 %) of seed size tuber while the late planting produced maximum proportion (54.51 %) of small size tuber (< 28 mm).

The significant variation on grading by number was observed due to the influence of plant densities (Table 5). Percentage of < 28 mm size tuber increased with increasing plant densities. But percentage of 28-45 mm tuber size increased with decreased plant densities. The percentage of < 28

mm size tuber was highest with closest spacings may be due to the presence of many plants as well as many tubers per unit area which got minimum space and food materials for enlargement.

Table 4
Effects of planting time and plant density of top shoot cuttings on number and weight of tubers per plant and yield of tubers per plant, yield /plot and yield (t/ha)

Treatment	No. of tuber per plant	Wt. of tubers per plant (g)	Yield (kg / plot)	Yield (t / ha)
P_1	6.57 a	208.90 a	13.36 a	27.80 a
P_2	5.71 b	158.97 b	10.20 b	21.23 b
P_3	3.82 c	92.59 c	5.93 c	12.34 c
Level of significance	*	*	*	*
S_1	5.04 c	115.36 c	10.92 a	22.73 a
S_2	5.43 b	148.18 b	9.33 b	19.43 b
S_3	5.62 a	196.92 a	9.23 b	19.21 b
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 5
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_1	41.56 c	41.79 b	16.54 a
P_2	46.12 b	46.23 a	7.64 b
P_3	54.51 a	45.49 a	0.00 c
Level of significance	*	*	*
S_1	49.54 a	42.68 b	7.7 a
S_2	47.00 b	45.00 a	8.00 a
S_3	45.64 c	45.83 a	8.52 a
Level of significance	*	*	NS
CV %	2.23	2.87	10.86

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

Tuber grade by weight (%)

Different grades of tubers by weight significantly influenced by the different date of plantings (Table 6). The higher value of percentage of tubers (42.79 %) of < 28 mm was found in P_3 (15, December or late planting) and it was lowest (20.11 %) in P_1 (25, November or early plating). The maximum percentage (57.17 %) of medium size (28-45 mm) was found in P_3 which was statistically same as P_2 (5, December or mid planting) and the highest percentage (28.47 %) large tuber (>45 mm) was observed in P_1.

The influence of plant density on tuber grade by weight was found significant (Table 6). The tubers of < 28 mm, 28-45 mm and > 45 mm size grade varied from 28.09 to 31.38 %, 54.50 to 55.94 % and 14.12 to 15.92 % respectively.

Table 6
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_1	20.11 c	51.76 b	28.47 a
P_2	26.08 b	56.79 a	17.13 b
P_3	42.79 a	57.17 a	0.00c
Level of significance	*	*	*
S_1	31.38 a	54.50 b	14.12 b
S_2	29.51 b	55.27 a b	15.56 a
S_3	28.09 c	55.94 a	15.92 a
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.

CONCLUSION

The plants of early planted top shoot cuttings performed best in respect of plant vigor, foliage coverage, plant height, number of branches per plant, number and weight of tubers per plant and Yield (t/ha). Foliage coverage, plant height, yield per (t / ha) were maximum in the plants grown from top shoot cuttings with closest spacings while number of branches per plant, number and weight of tubers per plant were highest with widest spacings. Therefore it is recommended that earlier planting with closer plant density should be maintained for obtaining better yield and Cuttings should be taken one time from each plant.

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