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Growth and Yield of Different Size-Seedling Tubers Derived from True Potato (*Solanum tuberosum* L.) Seeds as Influenced by Clump Planting

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Abstract

An experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during November 2010 to March 2011. Four levels of seedling tuber size, *viz.* 6-<7 g (S_1), 7-<8 g (S_2), 8-<9 g (S_3) and, 9-≤10 g (S_4) and three levels of seedling tuber, *viz.* 1 hill^{-1} (N_1), 2 hill^{-1} (N_2) and 3 hill^{-1} (N_3) were laid out in a Randomized Complete Block Design with three replications. At harvest, the tallest plant (82.17 cm), highest number of leaves plant^{-1} (83.30), highest LAI (6.23), tubers weight hill^{-1} (128.90 g) and tuber yield ha^{-1} (25.78 t) were found in S_4, while the lowest was in S_1. On the other hand, the tallest plant (74.91 cm), highest number of leaves plant^{-1} (74.45), highest LAI (5.41), tubers weight hill^{-1} (123.95 g) and tuber yield ha^{-1} (24.79 t) were found in N_3, while the lowest was in N_1. The tallest plant (85.09 cm), highest number of leaves plant^{-1} (87.97), highest LAI (6.64), tubers weight hill^{-1} (138.35 g) and tuber yield ha^{-1} (27.67 t) were found in S_4N_3 and the lowest gross tuber yield ha^{-1}(12.83 t) was from S_1N_1. Large seedling tuber with single seedling tuber hill^{-1} performed better.

Keywords: Seedling tuber, clump planting, morphological features, potato yield.

1. Introduction

In Bangladesh, potato (*Solanum tuberosum* L.) is one of the major crops next to rice and wheat and it covers an area of about 403.4 thousand hectares of land yielding 14.74 t ha^{-1} (MOA, 2009). The national average yield of potato in Bangladesh is much lower compared to many potato growing countries of the world like Belgium, the Netherlands, UK, Germany and USA where the average yield ranges between 38.4 to 49.0 t ha^{-1} (FAO, 1999). This low yield of potato in Bangladesh are due to lack of quality seed tuber, environmental limitations, unavailability and uneven distribution of certified seeds and use of indigenous cultivars (Roy *et al*., 2009; Roy *et al*., 2005).Potato production in Bangladesh may be increased by improving cultural practices which are optimization of manure and fertilizer, planting time, spacing and use of optimal size seed tubers which influences the yield of potato (Divis and Barta, 2001). Development of true potato seed (TPS) technology has opened a new era in potato cultivation. TPS progeny may produce 500 to 800 seedling tubers m^{-2} of land when planted at 10 cm × 10 cm spacing (TCRC, 2004). Small seedling tubers (≈10g) are usually neglected In Bangladesh both in terms of ware potato and seed tuber, although the genetical constitution of small seedling tuber is more or less similar to that of standard one (Upadhya *et al*., 2003).

Seedling tubers may be planted together in a hill, which is known as clump planting and could behave equally to single bigger seed tuber. Seedling tuber size and clump planting may be considered as very important factors for the production of potato. In traditional method of potato production, seedling tuber size and plant population per hill have been found to influence the yield and economic return (Hossain, 2004). Considering the importance of size of seedling tubers and clump planting, the present study was undertaken to study the growth and yield performance and develop a feasible standard method for utilization of TPS seedling tubers.

2. Materials and Methods

2.1. Experimental site, soil and climate

The experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during November 2010 to March 2011.Soil of the experimental field was a silty loam in texture under AEZ Madhupur Tract.

2.2. Plating material

TPS seedling tubers of the variety BARI TPS-1 were used in this experiment which is collected from the Tuber Research Centre, Bangladesh Agriculture Research Institute, Gazipur. The variety is a hybrid between female parent MF-II and male parent TPS-67 that was released by the National Seed Board (NSB) during 1997.

2.3. Treatments and design of the experiment

The experiment consisted of two factors *viz*., seedling tuber size and clump planting. Clump planting is the technique of planting of more than one tuber hill^{-1}and the plant hill^{-1}counting as single plant. Factor A: Four levels of seedling tuber size, *viz*. 6-<7 g (S_1), 7-<8 g (S_2), 8-<9 g (S_3) and, 9-≤10 g (S_4) and three levels of seedling tuber, *viz*. 1 hill^{-1} (N_1), 2 hill^{-1} (N_2) and 3 hill^{-1} (N_3) were tested in this study. The experiment was laid out in a Randomized Complete Block Design with three replications. The total area of the experimental plot was divided into three equal blocks. Each block was divided into 12 plots and there were 36 unit plots altogether. The size of the each plot was 1 m × 1 m. The distances between rows was 50 cm and between plants was 10 cm.

2.4. Land preparation and application of manure and fertilizers

The field was opened in the 2nd week of November 2010 with a power tiller and left exposed to the sun for a week. The fertilizers were applied at 300, 220, 250, 100, 25, 15 and 10000 kgha^{-1} as urea, TSP, MP, gypsum, Zinc sulphate, boric acid and cowdung, respectively (TCRC, 2004). Fifty percent of urea and full amount of other fertilizers were applied during final land preparation. Moreover, Carbofuran 5G @ 15 kg ha^{-1}was also applied during that time.

2.5. Seed preparation, sowing and intercultural operation

The tubers were graded according to the size and kept under diffuse light conditions to have healthy and good sprouts. Planting was done on November 28, 2010.Intercultural operations like weeding, earthing-up, irrigation were furnished for proper growth and development of the crop. Dithane M-45 was sprayed in two instalment at an interval of 15 days from 50 DAP as preventive measure against late blight disease.

2.6. Harvesting, data collection and statistical analysis

The crop was harvested at 100 DAP when the plants showed 80 to 90% of leaf senescence. Haulm cutting was done before 7 days of harvesting. Ten plants were randomly selected from each unit plot and data on days to emergence, plant height, number of leaves, leaf area index, fresh mass, dry mass, crop growth rate, weight of tuber hill^{-1} and yield of tubers were collected. Leaf area index (LAI) and crop growth rate (CGR) were computed following standard formula as given below:

$$\text{LAI} = \frac{\text{Leaf area}}{\text{Unit land area}}$$

Where,

Unit land area = Spacing of plant to plant and row to row (10 × 50 cm)

$$CGR = \frac{W_2 - W_1}{T_2 - T_1} \text{ g m}^{-2} \text{ day}^{-1}$$

Where,
W_2 and W_1 are the dry mass at time T_2 and T_1, respectively.

Data were analysed with the help of MSTAT-C Program and mean values of all the parameters were adjudged by least significance difference (LSD) at 5% level of probability.

3. Results and Discussion

3.1. Days to first emergence

The emergence was influenced significantly due to seedling tubers size. Seedling tubers (8-<9 g and 9-≤10 g) required less duration (7.56 days), whereas seedling tubers (7-<8 g) required comparatively higher duration (8.67 days) for first emergence but it was statistically similar to 6-<7 g seedling tubers (Table 1).The duration required for first emergence was not influenced significantly by the clump planting (Table 1) and also by the treatment combination of seedling tuber size and clump planting (Table 2).

3.2. Days to 80% emergence

Days to 80% emergence was influenced significantly due to seedling tuber size (Table 1). Seedling tubers (8-<9 g and 9-≤10 g) required less duration (10.78 days), whereas seedling tubers (6-<7 g) required higher duration (12.33 days). The results indicate that duration required for emergence decreased gradually with the increase in tuber size. The early emergence from large seedling tubers was probably due to more reserve food material. This result is in agreement with the findings of Hossain (2004) who reported that emergence was faster in case of larger tubers compared to smaller ones. Emergence of plants was also influenced significantly by the clump planting. Minimum duration (10.92 days) was required in N_3 compared to 1 or 2 seedling tubers hill^{-1} (Table 1).Significant variation was recorded among the treatment combinations. Minimum duration for 80% emergence of plants required in S_4N_3 (Table 2). This result is in agreement with the findings of Hossain (2004) who reported that emergence was faster in case of larger seedling tubers with higher number of seedling tubers hill^{-1}.

Table 1. Effect of seedling tuber size and clump planting on the emergence of plant and plant height at different days after planting (DAP)

Treatments	Days to 1st emergence	Days to 80% emergence	Plant height (cm)			
			40 DAP	55 DAP	70 DAP	100 DAP
Seedling tuber size						
S_1	8.11 ab	12.33 a	39.14 d	47.12 d	55.49 d	65.99 d
S_2	8.67 a	11.56 ab	44.48 c	51.69 c	60.48 c	69.46 c
S_3	7.56 b	11.11 b	50.47 b	58.38 b	67.23 b	74.37 b
S_4	7.56 b	10.78 b	55.51 a	65.00 a	72.84 a	82.17 a
LSD $_{(0.05)}$	0.81	0.89	1.33	1.57	1.19	0.87
Seedling tuber hill^{-1}						
N_1	8.00	12.00 a	46.07 b	54.23 b	62.78 b	72.10 b
N_2	8.08	11.42 ab	47.17 b	54.89 b	63.06 b	71.98 b
N_3	7.83	10.92 b	48.96 a	57.52 a	66.19 a	74.91 a
LSD $_{(0.05)}$	0.71	0.78	1.15	1.36	1.03	0.76

In a column, means followed by same letter (s) do not differ significantly at 5% level of probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

Table 2. Combined effect of seedling tuber size and clump planting on the emergence of plant and plant height at different days after planting (DAP)

Treatments	Days to 1st emergence	Days to 80% emergence	Plant height (cm)			
			40 DAP	55 DAP	70 DAP	100 DAP
S_1N_1	8.33	13.00 ab	37.87 i	47.00	55.03	66.01 i
S_1N_2	8.00	13.00 ab	38.80 hi	46.27	54.13	64.30 j
S_1N_3	8.00	11.00 c	40.75 gh	48.10	57.32	67.67 h
S_2N_1	9.33	13.33 a	44.40 ef	51.47	59.97	69.35 fg
S_2N_2	8.67	10.67 c	43.00 fg	50.40	59.03	68.66 gh
S_2N_3	8.00	10.67 c	46.03 de	53.20	62.45	70.36 f
S_3N_1	7.33	11.00 c	47.53 d	56.10	65.53	73.20 e
S_3N_2	8.00	10.67 c	50.95 c	57.97	67.25	73.40 e
S_3N_3	7.33	11.67 bc	52.93 bc	61.07	68.90	76.52 d
S_4N_1	7.00	10.67 c	54.47 ab	62.37	70.57	79.85 c
S_4N_2	7.67	11.33 c	55.93 a	64.93	71.83	81.57 b
S_4N_3	8.00	10.33 c	56.13 a	67.70	76.11	85.09 a
$LSD_{(0.05)}$	1.41	1.56	2.30	2.73	2.06	1.51

In a column, means followed by same letter (s) do not differ significantly at 5% level of probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

3.3. Plant height

Plant height was significantly influenced by seedling tuber size at 40, 55, 70 and 100 DAP of potato (Table 1). Increased size of seedling tuber significantly increased the plant height. The tallest plant at 40, 55, 70 and 100 DAP were recorded in S_4. Whereas, the shortest plants were at 40, 55, 70 and 100 in S_1. The plant height was higher in larger seedling tubers because larger seedling tubers had huge stored food material that supported increased vegetative growth of the plants. This result is consistent with several other findings (Garg*et al.*, 2000; Reust, 2002; Hossain, 2004; Tohin, 2010) in potato they reported that plant height of potato increased with increasing seed tuber size.

Plant height was influenced significantly by the clump planting. The tallest plants at 40, 55, 70 and 100 DAP were found in N_3. Whereas, the shortest plants at 40, 55 and 70 DAP were found in N_1, while the shortest plants at 100 DAP were from N_2 and it was statistically similar to N_1. The highest plants grown from 3 seedling tubers hill^{-1} was probably due to more inter-plant competition for sunlight (Table 1). This result is in agreement with the findings of Hossain (2004). The plant height was influenced significantly by the treatment combinations at 40 and 100 DAP (Table 2). The tallest plants at 40 and 100 DAP were recorded in S_4N_3. On the other hand, the shortest plants at 40 DAP were from S_1N_1 and at 100 DAP from S_1N_2.

3.4. Number of leaves per plant

The foliage coverage of plants was influenced significantly at all dates of observations due to seedling tuber size. The highest number of leaves plant^{-1}at all dates of observations was found in S_4, while the lowest number of leaves plant^{-1}was found in S_1. The result revealed that the number of leaves increased gradually with the increase in seedling tuber size (Table 3). This trend of the present results agreed with that of Gulluoglu and Aroglu (2009) and Hossain (2004) in potato. They were reported that leaf number in potato decreased with decreasing tuber weight.

Clump planting significantly influenced the number of leaves plant^{-1}. The maximum number of leaves plant^{-1}at all dates of observation was recorded in N_3. On the other hand, the minimum number of leaves plant^{-1}at all dates of observations was found inN_1. The results indicated that the number of leaves plant^{-1}were directly proportional to the clump planting (Table 3). This result is in agreement with the findings of Hossain (2004). There were significant variations among the treatment combinations of seedling tubers size and clump planting. The highest number of leaves plant^{-1}at all dates of observations were found in S_4N_1 whereas, the lowest number of leaves plant^{-1} at 40 DAP was from S_1N_2. At 55 and 70 DAP, the lowest number of leaves plant^{-1} were recorded from 6-<7 g seedling tuber size with 1 and 2 seedling tubers hill^{-1}, respectively while at100 DAP, the lowest number of leaves plant^{-1} was found in S_1N_2 (Table 4). This result is in agreement with that of Hossain (2004).

3.5. Leaf area index

The effect of seedling tuber size on leaf area index (LAI) was significant at 40, 55, 70 and 100 DAP (Table 3). LAI increased with increasing tuber size. The highest LAI was recorded in 9-≤10 g seedling tuber at all dates of observations. The lowest LAI was recorded in 6-<7 g seedling tuber at 40, 55, 70 and 100 DAP were recorded in 6-<7 g seedling tuber (Table 5). This result is supported by Verma *et al.,* (2007) in potato.

The LAI was significantly influenced by clump planting at 40, 55, 70 and 100 DAP (Table 3). LAI increased with increasing number of seedling tuber hill^{-1}. The highest LAI was recorded in N_3while the lowest was recorded in N_1.The interaction effect of seedling tuber size and clump planting was significant on LAI at 70 and 100 DAP except at 40 and 55 DAP (Table 4). The highest LAI was recorded in S_4N_3 at 70 and 100 DAP.

3.6. Fresh mass production per plant

Fresh mass production plant^{-1} showed significant variations due to seedling tuber size. The highest fresh mass plant^{-1} at 40, 55, 70 and 100 DAP were recorded in S_4. The lowest fresh mass plant^{-1} at all dates of observations was recorded in S_1 (Table 5).

Table 3. Effect of seedling tuber size and clump planting on the number of leaves hill^{-1}and leaf area index at different days after planting

Treatments	Number of leaves hill^{-1}				Leaf area index			
	40 DAP	55 DAP	70 DAP	100 DAP	40 DAP	55 DAP	70 DAP	100 DAP
Seedling tuber size								
S_1	28.12 d	36.32 d	50.26 d	62.84 d	2.42 d	2.72 d	3.77 d	4.30 d
S_2	35.10 c	44.58 c	56.43 c	68.29 c	2.89 c	3.15 c	4.07 c	4.54 c
S_3	41.40 b	49.09 b	61.74 b	74.48 b	3.61 b	4.00 b	4.97 b	5.45 b
S_4	46.87 a	55.68 a	69.11 a	83.30 a	4.16 a	4.8 a	5.85 a	6.23 a
$LSD_{(0.05)}$	1.52	1.67	1.32	1.19	0.11	0.50	0.22	0.23
Seedling tuber hill^{-1}								
N_1	36.56 b	43.56 c	57.54 c	70.61 b	3.10 c	3.32 b	4.43 b	4.97 b
N_2	37.62 b	46.69 b	59.20 b	71.63 b	3.21 b	3.61 ab	4.62 b	5.00 b
N_3	39.44 a	49.00 a	61.41 a	74.45 a	3.49 a	3.99 a	4.93 a	5.41 a
$LSD_{(0.05)}$	1.32	1.45	1.14	1.03	0.09	0.43	0.19	0.20

In a column, means followed by same letter (s) do not differ significantly at 5% level of probability,S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

Table 4. Combined effect of seedling tuber size and clump planting on the number of leaves hill^{-1}and leaf area index at different days after planting

Treatments	Number of leaves plant^{-1}				Leaf area index			
	40 DAP	55 DAP	70 DAP	100 DAP	40 DAP	55 DAP	70 DAP	100 DAP
S_1N_1	28.20 g	34.77 g	51.80 fg	63.30 h	2.32	2.21	3.89 efg	4.45 e
S_1N_2	27.07 g	35.20 g	49.23 h	61.90 h	2.35	2.59	3.61 g	4.04 f
S_1N_3	29.10 g	39.00 f	49.73 gh	63.33 h	2.60	3.06	3.82 fg	4.40 ef
S_2N_1	32.73 f	40.97 f	53.77 f	67.03 g	2.81	3.04	3.89 efg	4.48 e
S_2N_2	34.83 f	45.20 e	56.40 e	67.67 g	2.82	3.12	4.06 ef	4.44 ef
S_2N_3	37.73 e	47.57 de	59.13 d	70.17 f	3.06	3.29	4.24 e	4.69 e
S_3N_1	40.50 d	46.70 e	58.38 de	73.07 e	3.35	3.62	4.63 d	5.14 d
S_3N_2	42.93 cd	50.90 c	62.93 c	74.03 e	3.58	3.98	4.93 d	5.31 d
S_3N_3	40.77 d	49.67 cd	63.90 c	76.33 d	3.91	4.39	5.35 c	5.90 bc
S_4N_1	44.80 bc	51.80 c	66.23 b	79.03 c	3.94	4.41	5.32 c	5.81 c
S_4N_2	45.63 b	55.47 b	68.23 b	82.90 b	4.11	4.75	5.89 b	6.22 b
S_4N_3	50.17 a	59.77 a	72.87 a	87.97 a	4.41	5.25	6.33 a	6.64 a
LSD $_{(0.05)}$	2.64	2.90	2.28	2.07	0.19	0.87	0.39	0.41

In a column, means followed by same letter (s) do not differ significantly at 5% level of probability,S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

Table 5. Effect of seedling tuber size and clump planting on the fresh and dry mass production plant^{-1}at different days after planting (DAP)

Treatments	Fresh mass production (g plant^{-1})				Dry mass production (g plant^{-1})			
	40 DAP	55 DAP	70 DAP	100 DAP	40 DAP	55 DAP	70 DAP	100 DAP
Seedling tuber size								
S_1	46.22 d	98.78 d	157.5 d	233.2 d	9.911 d	20.71 d	32.71 d	49.74 d
S_2	97.62 c	132.2 c	190.0 c	264.4 c	19.32 c	27.60 c	38.77 c	55.29 c
S_3	135.9 b	190.6 b	242.8 b	314.9 b	24.65 b	36.23 b	46.40 b	63.50 b
S_4	212.5 a	268.3 a	337.5 a	456.0 a	39.19 a	49.55 a	66.17 a	90.23 a
LSD $_{(0.05)}$	4.12	5.32	4.91	8.08	1.61	1.83	2.61	2.82
Seedling tuber hill^{-1}								
N_1	103.9 c	151.8 c	211.5 c	284.9 c	19.52 c	29.73 c	41.41 c	58.79 c
N_2	120.6 b	168.8 b	226.1 b	308.4 b	22.72 b	32.65 b	45.43 b	63.65 b
N_3	144.8 a	196.9 a	258.3 a	358.0 a	27.55 a	38.18 a	51.20 a	71.63 a
LSD$_{(0.05)}$	3.63	4.61	4.25	6.99	1.39	1.59	2.26	2.44

In a column, means followed by same letter (s) do not differ significantly at 5% level of probability,S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

Table 6. Combined effect of seedling tuber size and clump planting on the fresh and dry mass production plant^{-1} at different days after planting (DAP)

Treatments	Fresh mass production (g plant^{-1})				Dry mass production (g plant^{-1})			
	40 DAP	55 DAP	70 DAP	100 DAP	40 DAP	55 DAP	70 DAP	100 DAP
S_1N_1	33.17 j	85.73 j	150.80 j	220.30 i	6.96	17.66 h	30.82 i	47.71 g
S_1N_2	49.33 i	107.10 i	163.90 i	245.30 gh	10.44	22.31 g	33.47 hi	50.59 fg
S_1N_3	56.17 i	103.50 i	157.80 ij	234.00 hi	12.33	22.16 g	33.85 hi	50.91 fg
S_2N_1	78.83 h	121.30 h	182.20 h	248.50 fg	15.62	25.57 f	35.71 gh	52.49 efg
S_2N_2	94.67 g	127.90 h	182.10 h	259.40 f	19.36	26.40 f	38.56 fg	55.19 def
S_2N_3	119.40 ef	147.50 g	205.70 g	285.40 e	22.97	30.82 e	42.05 ef	58.17 d
S_3N_1	114.20 f	162.50 f	217.10 f	282.70 e	20.92	32.25 de	40.92 ef	56.50 de
S_3N_2	126.50 e	185.10 e	229.80 e	290.20 e	23.41	35.13 d	45.29 e	59.17 d
S_3N_3	167.20 d	224.20 d	281.60 d	371.70 d	29.61	41.31 c	52.99 d	74.82 c
S_4N_1	189.30 c	237.60 c	295.70 c	388.20 c	34.58	43.43 c	58.18 c	78.45 c
S_4N_2	211.90 b	255.10 b	328.50 b	438.70 b	37.68	46.77 b	64.40 b	89.65 b
S_4N_3	236.30 a	312.30 a	388.10 a	541.00 a	45.30	58.44 a	75.92 a	102.60 a
LSD $_{(0.05)}$	7.25	9.22	8.51	13.99	2.79	3.17	4.52	4.89

In a column, means followed by same letter (s) do not differ significantly at 5% level of probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

Total fresh mass plant^{-1} increased with increasing seedling tuber size. Fresh mass production plant^{-1} was influenced significantly by clump planting. The highest fresh mass plant^{-1} at 40, 55, 70 and 100 DAP were recorded in N_3. The lowest fresh mass plant^{-1} at all dates of observations was recorded in N_1 (Table 5).

Total fresh mass plant^{-1} increased with increasing number of seedling tuber hill^{-1} that increased the number of stem plant^{-1}.There was significant variation among the treatment combinations of seedling tubers size and clump planting. The highest fresh mass plant^{-1} at all dates of observations was recorded in S_4N_3while the lowest fresh mass plant^{-1} was recorded in S_1N_1 (Table 6).

3.7. Dry mass production per plant

Dry mass production plant^{-1} showed significant variation due to the seedling tuber size. The highest dry mass plant^{-1} at 40, 55, 70 and 100 DAP were recorded in S_4. The lowest dry mass plant^{-1} at all dates of observations was recorded in S_1 (Table 5). Total dry mass was higher in larger tubers because larger seedling tuber had huge stored food material than smaller ones and that promoted increased vegetative growth of the plants. This result is consistent with those of other workers (Reust, 2002; Tohin, 2010) in potato.

Total dry mass plant^{-1} was influenced significantly at all dates of observations due to the clump planting. Maximum dry mass plant^{-1} at all dates of observations was recorded in N_3while the minimum in N_1 (Table 5). There was significant variation among the treatment combinations of seedling tubers size and clump planting. The highest dry mass plant^{-1}at all dates of observations was recorded in S_4N_3 (Table 6).

Table 7. Effect of seedling tuber size and clump planting on dry mass production, crop growth rate, tubers weight and gross yield of potato)

Treatments	Dry mass production (g m^{-2})				Crop growth rate (g m^{-2} d^{-1})			Tubers weight (g $hill^{-1}$)	Gross yield (t ha^{-1})
	40 DAP	55 DAP	70 DAP	100 DAP	40-55 DAP	55-70 DAP	70-100 DAP		
Seedling tuber size									
S_1	198.2 d	414.2 d	654.3 d	994.8 d	14.40 a	16.00 b	11.35 b	85.85 d	17.17 d
S_2	386.3 c	551.9 c	775.5 c	1106 c	11.04 b	14.90 b	11.01 b	100.30 c	20.06 c
S_3	492.9 b	724.6 b	928.0 b	1270 b	15.44 a	13.57 b	11.40 b	120.00 b	24.00 b
S_4	783.7 a	990.9 a	1323 a	1805 a	13.81 a	22.16 a	16.04 a	128.90 a	25.78 a
$LSD_{(0.05)}$	32.22	36.66	52.21	56.43	1.911	4.305	2.220	8.52	1.70
Seedling tuber $hill^{-1}$									
N_1	390.4 c	594.5 c	828.2 c	1176 c	13.61 a	15.58 a	11.59 b	98.55 b	19.71 b
N_2	454.4 b	653.1 b	908.7 b	1273 b	13.24 a	17.04 a	12.14ab	103.75 b	20.75 b
N_3	551.1 a	763.7 a	1024 a	1433 a	14.17 a	17.36 a	13.62 a	123.95 a	24.79 a
$LSD_{(0.05)}$	27.91	31.75	45.21	48.87	1.655	3.728	1.923	7.38	1.48

In a column, means followed by same letter (s) do not differ significantly at 5% level of probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber $hill^{-1}$, N_2= 2 seedling tubers $hill^{-1}$ and N_3= 3 seedling tubers $hill^{-1}$

3.8. Total dry mass production of plant per m^2

There was a significant variation in total dry mass (TDM) production of plant m^{-2} at 40, 55, 70 and 100 DAP due to seedling tuber size (Table 7). Dry mass m^{-2} increased with increasing seedling tuber size. The highest TDM m^{-2} was recorded in S_4. In contrast, the seedling tuber size of 6-<7 g had the lowest TDM m^{-2} at all growth stages. Similar results were reported by Tohin (2010).

The effect of clump planting significantly influenced on TDM production (Table 7). Total TDM production m^{-2} increased with increasing number of seedling tubers $hill^{-1}$. The highest TDM m^{-2} at 40, 55, 70 and 100 DAP was recorded in N_3 and the lowest TDM m^{-2} was recorded in N_1.

The interaction effect of seedling tuber size and clump planting had significant effect on TDM m^{-2} at 55, 70 and 100 DAP (Table 8). The highest TDM m^{-2} was recorded in $S_4N_3$and the lowest TDM m^{-2} was recorded in S_1N_1 except at 100 DAP while it was minimum in S_2N_2.

3.9. Crop growth rate

Crop growth rate (CGR) was significantly influenced by seedling tuber size (Table 7). CGR increased with increasing seedling tuber size. At 55-70 DAP, CGR was higher in S_3 followed by the S_4 with same rank. The lowest CGR both at 40-55 and 70-100 DAP was recorded in S_2. The CGR was higher in larger seedling tuber which might be due to increased TDM $plant^{-1}$. Similar results were reported by other workers (Divis and Barta, 2001 and Tohin, 2010) in potato. They reported that larger tuber produced higher number of stems $plant^{-1}$, highest crop growth rate and yield compared to small ones. The effect of clump planting on CGR was not influenced significantly (Table 7). The interaction effect of seedling tuber size and clump planting on CGR was significant at 40-55 DAP (Table 8). The highest CGR was recorded in S_4N_3 and the lowest in S_2N_2.

Table 8. Combined effect of seedling tuber size and clump planting on dry mass production,crop growth rate, tubers weight and gross yield of potato

Treatments	Dry mass production (g m^{-2})				Crop growth rate (g m^{-2} d^{-1})			Tubers weight (g $hill^{-1}$)	Gross yield (t ha^{-1})
	40 DAP	55 DAP	70 DAP	100 DAP	40-55 DAP	55-70 DAP	70-100 DAP		
S_1N_1	139.10	353.10 h	616.40 i	1176.00 bc	14.27 abc	17.55	11.26	64.15 f	12.83f
S_1N_2	208.90	446.30 g	669.50 hi	1273.00 b	15.83 ab	14.88	11.41	71.65 f	14.33f
S_1N_3	246.70	443.30 g	677.00 hi	1433.00 a	13.11 bcd	15.58	11.37	121.65bc	24.33bc
S_2N_1	312.50	511.30 f	714.30 gh	1016.00 e	13.26 bcd	13.53	11.19	103.35 de	20.67de
S_2N_2	387.20	528.00 f	771.30 fg	1012.00 e	9.39 e	16.22	11.08	90.00 e	18.00e
S_2N_3	459.30	616.40 e	840.90 ef	1018.00 e	10.47 de	14.97	10.75	107.50 cd	21.50cd
S_3N_1	418.40	644.90 de	818.40 ef	1050.00 de	15.10 abc	11.57	10.39	98.35 de	19.67 de
S_3N_2	468.10	702.60 d	905.90 e	1104.00 c-e	15.63 ab	13.55	9.26	133.35 ab	26.67ab
S_3N_3	592.30	826.20 c	1060.00 d	1163.00 c	15.59 ab	15.58	14.55	128.35 ab	25.67ab
S_4N_1	691.50	868.60 c	1164.00 c	1130.00 cd	11.80 cde	19.67	13.51	128.35 ab	25.67ab
S_4N_2	753.50	935.50 b	1288.00 b	1183.00 bc	12.13 cde	23.51	16.83	120.00 bc	24.00bc
S_4N_3	906.10	1169.00 a	1518.00 a	1496.00 a	17.51 a	23.31	17.79	138.35 a	27.67a
$LSD_{(0.05)}$	55.81	63.49	90.42	97.73	3.31	7.46	3.85	14.75	2.95

In a column, means followed by same letter (s) do not differ significantly at 5% level of probability,S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber $hill^{-1}$, N_2= 2 seedling tubers $hill^{-1}$ and N_3= 3 seedling tubers $hill^{-1}$

3.10. Tuber weight per hill

The effect of seedling tuber size on tuber weight $hill^{-1}$ was significant (Table 7). Tuber weight $hill^{-1}$ increased with increasing seedling tuber size. The highest tuber weight $hill^{-1}$ was recorded in S_4 where as, the lowest tuber weight $hill^{-1}$ was recorded in S_1. The lesser tuber weight in smaller sized seed tuber might be due to fewer tubers $hill^{-1}$ and smaller weight tuber. This result is supported by several workers (Verma*et al.*, 2007; Gulluoglu and Aroglu, 2009; Tohin, 2010) who reported that tuber yield decreased with decreasing seed tuber weight.

There was a significant variation in tuber weight $hill^{-1}$ due to clump planting (Table 7). Tuber weight decreased with decreasing number of seedling tubers $hill^{-1}$ is the highest tuber weight $hill^{-1}$being recorded in N_3. The interaction effect of seedling tuber size and clump planting on tuber weight $hill^{-1}$ was significant (Table 8). The highest tuber weight $hill^{-1}$ was recorded in $S_4N_3$and it was statistically similar to S_3N_2, S_3N_3 and S_4N_1. The lowest tuber weight $hill^{-1}$ was recorded in S_1N_1which was statistically similar to S_1N_2.

3.11. Gross yield of tuber

The gross tuber yield was significantly influenced by seedling tuber size (Table 7). Gross tuber yield increased with increasing seedling tuber size. The highest gross tuber yield was recorded in S_4. In contrast, the lowest gross tuber yield was recorded in S_1. The gross tuber yield was lower in smaller seedling tuber size because of producing minimum tuber weight $hill^{-1}$. The yield of total tuber also increased gradually with increasing seedling tuber size. This result is supported by many workers (Shingrup *et al.*, 2003; Hossain, 2004; Sonawane and Dhoble, 2004; Verma *et al.*, 2007; Gulluoglu and Aroglu, 2009; Tohin, 2010).

The clump planting also significantly influenced the gross tuber yield in potato (Table 7). The

gross tuber yield increased with increasing seedling tubers hill^{-1}. The highest gross tuber yield was in $N_3$and the lowest tuber yield was in N_1. The higher tuber yield is always associated with higher plant population. The results are in agreement with the earlier findings of Hossain (2004). Nankar (1990) by planting one, two and three seedling tubers hill^{-1} in inter cropping system; found that 3 seedling tubers hill^{-1} gave the highest yield. Significant variation was found in the treatment combinations of seedling tuber size with clump planting (Table 8). Gross yield of tuber increased with increasing seedling tuber hill^{-1}with the increasing seedling tuber size. The highest gross tuber yield was recorded in S_4N_3 and the lowest yield was recorded in S_1N_1which was similar to S_1N_2. This result is in agreement with the earlier findings of Hossain (2004).

4. Conclusions

The morphological features such as days to first and 80% emergence, plant height, number of leaves plant^{-1}, leaf area index (LAI), fresh mass production plant^{-1}, total dry mass (TDM) plant^{-1},TDM m^{-2}and crop growth rate (CGR)were significantly influenced by seedling tuber size and clump planting. Tuber weight hill^{-1} and gross tuber yield were influenced significantly by seedling tuber size and clump planting. Use of True Potato Seed seedling tuber with single number of tuber hill^{-1} was found feasible for potato production.

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