Influences of Weight and Row Width of Tubers from True Potato Seed on Growth and Yield of Potato

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Abstract: Quality tuber seed, higher seed price and improved production practices are the major constraints of potato production in Bangladesh. Varying weight of seedling tuber such as 1-5 g, 6-10 g, 11-20 g and 21-30 g were planted at 10-, 15-, 20-, 25- and 30-cm row width, respectively to investigate the effects of true potato seed (TPS) seedling tubers weight and row width on growth and yield of potato. Dry matter accumulation and tuber yield was significantly influenced by the weight of TPS seedling tubers and row width. The largest weight of TPS seedling tuber (21-30 g) planted at 30-cm row width produced the highest yield (>39 t ha^{-1}) and it was identical with TPS seedling tuber weight of 1-5 g, 6-10 g and 11-20 g planted at 10-, 15 and 20-cm row width, respectively. Leaf dry matter, tuber dry matter and total dry matter had a strong positive correlation on tuber yield. The regression equation predicted that for every 1.0 g leaf dry matter (LDM) accumulation, 2363 g tuber was gained. The smallest weight (1-5 g) of TPS seedling tuber planted at 10- and 15-cm row width is suggested for cultivation practices to minimize production cost that could provide sustainable economic production of potato in Bangladesh.

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1. Introduction

The yield of potato (*Solanum tuberosum* L.) is very low in Bangladesh as compared to potato-growing countries of the world. The area of potato cultivation is increasing rapidly over time due to congenial climatic conditions particularly prolonged winter in the north-west region in Bangladesh. Unfortunately the yield level is not satisfactory yet due to scarcity of quality tuber seeds and its higher cost, improper agronomic practices and rapid dissemination of degenerative diseases (Mahmud et al., 2009). The total requirement of seed potatoes is about 0.38 million tons in Bangladesh. Out of this quantity, only 4-7% of the total requirements are good quality. The rest quantity of seed (93-96 %) is covered by the farmer's seed or ware potatoes which are very poor in quality (Banik, 2005; Mahmud et al., 2009). Replacement of farmer's seed with high quality seed potatoes would make a significant contribution towards an increased yield of potato in Bangladesh (Siddique and Rashid, 2000).

Potato seed tubers account for approximately 12 to 15% of the total operating costs to raise potatoes (Patterson, 2007). In addition to the cost of seed tubers, cost per unit area is determined by weight of tuber seed per piece, in-row spacing and distance between rows (William et al., 2011). Each of these factors can affect not only total tuber yield but also size distribution of the harvested tubers (Wurr, 1974). True potato seed is a promising technology which can minimize seed cost and has shown higher yield potentiality in some countries (Upadhya, 1987; Pallais 1994). There are three alternatives for using TPS to raise potato crop. These are direct seeding, transplanting of TPS seedling in the field and use of TPS to produce seedling tubers in nursery beds or fields which are used as planting materials for raising a ware potato crop for the following year. Out of those methods, ware potato production using TPS has been reported to be advantageous (Rashid et al., 1993). The small tubers derived from TPS progenies have high yield potential regardless of planting method and do not show any genetic variation. The small tubers (1-5 g) obtained from true seeds are useful as seed tubers (Rasul et al., 1997) which has enough scope for producing quality seed potato as well as ware potato using TPS seedling tubers thereby boosting up the potato production in Bangladesh.

Optimum planting density along with size of tubers is one of the most important factors of the production practices of potato cultivation. Numerous studies have been conducted showing the effects of planting a constant seed piece size at differing in-row spacing on yield and quality of potatoes (Arsenault et al., 2001), but no sufficient research work has been carried out to find out the optimum seed size to cultivate potato using TPS seedling tubers specially in Bangladesh. There is a scope to disseminate this new technology in large scale among the potato growers to boost up the potato production. Hence, it is essential to determine an appropriate production package for potato cultivation using TPS seedling tubers. Cognizant of the above facts, a program was designed in order to assess the performance of TPS 1 cultivars as influenced by weight of seedling tuber and row width on growth and yield of potato in the north-west region of Bangladesh.

2. Material and Methods

Site description and experimental design

The study was conducted in the field of Breeder Seed Production Farm of Tuber Crops Research Centre, Bangladesh Agricultural Research Institute (BARI), Debiganj, Panchagarh, (29.1^0 N latitude, 88.5^0 E longitude and at altitude of 39.4 m above the sea level) Bangladesh. The soil is a loam. The soil organic matter was 1.3%, soil bulk density was 1.45 (g cm^{-3}), total N 0.08%, available P was 13.20 (μg g^{-1}), exchangeable K was 0.162 (meq100 g^{-1}). The land was well prepared by tractor driven disc plough followed by laddering. The size of a unit plot was 6.0 m x 5.6 m. Four levels of TPS seedling tuber weight such as 1-5 g (<15 mm), 6-10 g (15-20 mm), 11-20 g (21-30 mm), 21-30 g (31-45 mm) and five levels of row width (10-, 15-, 20-, 25- and 30-cm corresponding to 17, 11, 8, 7 and 6 tuber m^{-2}) were tested. The treatment combinations were arranged in a factorial randomized complete block design with 3 replications. The tested TPS seedling tubers were developed by BARI and certified as TPS-1 cultivar (Razzaque et al*.,* 2000).

Crop management

Well-sprouted tubers were planted in the furrows as per treatment. Nitrogen, P, K, S, Mg, Zn and B was used at the rate of 140, 15, 100, 16, 10, 3 and 1.2 kg ha^{-1}, respectively. The source of N, P, K, S, Mg, Zn and B was urea, triple super phosphate, murate of potash, gypsum, magnesium sulphate, zinc sulphate and boric acid, respectively. Applied fertilizers and planted tubers were covered with soils properly making a ridge. Then two furrows at a depth of 5-6 cm were made 10-12 cm apart from furrow having planted tubers where half of N and all other fertilizers applied. The planting was done on 3rd week of November. Weeding was required once to keep the plots weed free. Irrigations were provided at stolonization (22-23 days after planting (DAP)), tuberization (33-35 DAP) and bulking (55-56 DAP) period, respectively. Earthing up was done once followed by top dressing of remaining N was applied at 30-32 DAP. Preventive measures were taken to control virus and blight diseases applying appropriate insecticides and fungicides. Furadan 5 G at the rate of 15 kg ha^{-1} was applied in furrows (depth 5-6 cm) to control cut worm. Dithane M-45, Acrobat MZ-2 and Tafgard were applied at the rate of 2 kg, 1.5 kg and 1 L, respectively. Dithane M-45 and Acrobat MZ-2 was applied twice while Tafgard was applied four times. Plants were dehaulmed at 105 DAP and tubers were harvested at 7 days after dehaulming.

Data collection and statistical analysis

Dry matter collection was recorded from randomly pre-selected 3 m^{-2} areas per plot during harvesting. Five hills were uprooted at 15-days regular intervals commence from 30 DAP to 105 DAP to determine components of dry matter accumulation. After harvesting plants were separated into leaf, stem and tuber and weighed. Sub samples of each were dried in an oven at 70^0 C for 72 hours for estimation of leaf, stem and tuber dry matter. After dehaulming randomly 5 hills were harvested to record the number of tubers (≥10 mm diameter tuber was considered as tuber) and fresh weight of tuber per hill. Fresh tuber yield was harvested from randomly pre-selected central areas (about $12m^{-2}$) of each plot and converted into tons per hectare (t ha^{-1}).

Mean data was analyzed statistically and was carried out to analysis of variance (ANOVA) using general linear model to evaluate significant differences between means at 95% level of confidence. It was performed using the Statistical Analysis System (SAS 2003). Further statistical validity of the differences among treatment means was estimated using the Duncan's New Multiple Range Test (DMRT) comparison method. Microsoft Office Excel 2007 was used for regression analysis.

3. Results and Discussion

Dry matter accumulation

Treatment combination had significant influence on leaf, stem, tuber and total dry matter accumulation. The highest LDM (126 g m^{-2}) was obtained from the largest weight (21-30 g) of TPS seedling tubers when planted at 25-cm followed by 15-, 20- and 30-cm row width and seedling tuber weight of 11-20 g planted at 10-, 15- and 20-cm row width and 6-10 g TPS seedling tuber weight planted at 10- and 15-cm row width and 1-5 g seedling tuber weight planted at 10-cm row width. On the contrary, the lowest LDM yield (73 g m^{-2}) was recorded from 1-5 g seedling tuber weight planted at the widest row width (30-cm). The TPS seedling tuber weight of 11-20 g planted at 10-, 15- and 20-cm row spacing produced higher LDM and thereafter decreased with each incremental increase of row width (Table 1). The smaller TPS seedling tuber size (6-10 g) planted at closer row width (10- and 15-cm) also produced better LDM and thereafter decreased significantly at each incremental increase of row width. The smallest weight of (1-5 g) TPS seedling tuber planted at 10-cm row width produced also relatively higher LDM and decreased at each incremental increase of row width. The highest LDM was obtained due to larger tubers and it was possibly

Table 1. Leaf dry matter accumulation as influenced by TPS seedling tuber weight and row width

Tuber	Row spacing (cm)				
wt. (g)	10	15	20	25	30
1-5	118 a	105 bc	97 cd	86 e	73 f
6-10	120 a	124 a	107 b	91 cd	82 e
11-20	119 a	120 a	122 a	115 b	102 b
21-30	113 b	119 ab	122 a	126 a	116 a

Means followed by the same letters are not significantly different at P≤ 0.05 using DMRT

due to more accumulation of carbohydrates and produced more photosynthetic organ than the smaller tubers. Closer row width produced comparatively higher LDM than that of wider row width in case of smaller TPS seedling tuber weight. The higher LDM was obtained at the closer row width and it might be due to more number of plants present per unit area. Regardless of seedling tuber weight and row width LDM was increased up to 75 DAP and thereafter declined up to end of the growing season (data not shown). In all cases declining rate of LDM was probably due to leaf senescence and translocation of minerals from source to sink. Leaf dry matter yield increased with each incremental increase in TPS seedling tuber weight. These results corroborated the findings of Basu (1986), Midmore (1988) and Singh et al., (1997b). The results revealed that row width of 10, 15, 20 and 25-cm was better corresponding to 1-5 g, 6-10 g, 11-20 g and 21-30 g TPS seedling tuber weight, respectively to obtain more LDM.

The highest SDM was recorded by the largest weight (21-30 g) of TPS seedling tuber planted at 10-cm row width followed by 11-20 g TPS seedling tuber weight at 10-cm row width (Table 2). On the contrary, the smallest TPS seedling tuber weight (1-5 g) planted at the widest row width (30-cm) produced minimum SDM (20 g m^{-2}) which was identical with same weight of TPS seedling tuber planted at 25-cm row width and 6-10 g seedling tuber weight planted at 30-cm row width. These results are consistent with findings of Singh et al., (1997b) and Nandekar (2005).

Table 2. Stem dry matter accumulation as influenced by TPS seedling tuber weight and row width

Tuber	Row spacing (cm)				
wt. (g)	10	15	20	25	30
1-5	51.3 c	38 f	29 h	24 ijk	20 k
6-10	53 bc	41 ef	32 gh	26 ij	22 jk
11-20	57 ab	46 d	39 ef	33 g	28 hi
21-30	60 a	50 cd	41 de	36 fg	32 gh

Means followed by the same letters are not significantly different at P≤ 0.05 using DMRT

The SDM yield increased with each incremental increase in TPS seedling tubers. The larger seedling tuber weight at closer row width always produced higher SDM yields than that of smaller TPS seedling tuber weight at wider row width. Maximum tuber dry matter (TuDM) was produced by the largest weight (21-30 g) of TPS seedling tuber planted at 20, 25 and 30-cm row width followed by 11-20 g TPS seedling tuber weight planted at 20 and 25-cm row width and 6-10 g TPS seedling tuber weight planted at 10 and 15-cm row width and the smallest weight (1-5 g) of TPS seedling tuber planted at 10-cm row width. Tuber dry matter increased significantly with each incremental increase in seedling tuber size at wider row width. Higher TuDM yield was possibly due to larger tuber weight (6-10 g and 11-20 g) planted at closer row width produced higher number of plants and more tubers per hill per unit area. The largest TPS seedling tuber weight planted at the widest row width produced higher TuDM. The smallest weight (1-5 g) of TPS seedling tuber planted at 10-cm row width produced maximum TuDM (984 g m^{-2}) while with same weight of TPS seedling tuber planted at 30-cm row width produced minimum TuDM yield which was at par with 20 and 25-cm row width (Table 3).

Table 3. Tuber dry matter yield as influenced by TPS seedling tuber weight and row width

Tuber	Row spacing (cm)				
wt. (g)	10	15	20	25	30
1-5	984 b	874 c	717 d	690 de	607 e
6-10	990 b	1064 ab	975 b	878 c	769 d
11-20	968 bc	983 b	999 b	984 b	982 b
21-30	962 bc	969 bc	987 b	997 b	1108 a

Means followed by the same letters are not significantly different at P≤ 0.05 using DMRT

Nandekar (2005) also reported that higher dry shoot yield was obtained by higher planting density resulted in higher tuber yield. Tuber dry matter yield increased by smaller weight of TPS seedling tuber with closer row width and it was possibly due to higher accumulation of LDM and SDM. The results revealed that the largest weight (21-30 g) of TPS seedling tuber planted at 20, 25 and 30-cm row width performed better. On the contrary 11-20 g seedling tuber size planted at 20 and 25-cm row width grew well compared with other row width. The smaller TPS seedling tuber weight (6-10 g) planted at 10 and 15-cm row width produced higher TuDM than that of other row width. The smallest weight (1-5 g) of TPS seedling tuber planted at the closest row spacing (10-cm) obtained appreciable

TuDM yield (983.7 g m^{-2}) compared with the other row width.

Total dry matter is an additive effect of LDM, SDM and TuDM. Maximum TDM was obtained by the largest weight (21-30 g) of TPS seedling tuber planted at 30 cm row width followed by 20-cm row width with same weight of TPS seedling tuber weight. These results were identical to 1-5 g, 6-10 g and 11-20 g TPS seedling tuber weight planted at 10-cm and 10, 15 and 25-cm row width, respectively (Table 4). The lowest TDM was recorded from 1-5 g seedling tuber weight planted at 30-cm row width which was identical to 25- cm row width. The smallest weight (1-5 g) of TPS seedling tuber planted at 10-cm row width produced appreciably higher TDM (1151.9 g m^{-2}) and thereafter yield decreased significantly with each incremental increase of row width. Similarly 6-10 g seedling tuber weight planted at 10 and 15-cm row width recorded higher TDM compared to 25 and 30-cm row width.

Table 4. Total dry matter (kg m^{-2}) accumulation as influenced by TPS seedling tuber weight and row weidth

Tuber	Row spacing (cm)				
wt. (g)	10	15	20	25	30
1-5	1.15 b	1.02 c	0.84 de	0.80 e	0.70 f
6-10	1.16 b	1.23 a	1.11 b	0.99 c	0.87 d
11-20	1.14 b	1.15 b	1.13 b	1.16 b	1.11 b
21-30	1.14 b	1.14 b	1.15 b	1.16 b	1.26 a

Means followed by the same letters are not significantly different at P≤ 0.05 using DMRT

Smaller tuber weight at closer row width had a significant role to produce higher TDM while larger weight of TPS seedling tuber with wider row width did well to accumulate TDM. These findings are in agreement with the findings of Singh et al., (1997b); Midmore (1988); Basu (1986); Santoso and Blamely (1985). The results revealed that the combinations of 1-5 g TPS seedling tuber weight planted at 10-cm row width, 6-10 g TPS seedling tuber weight planted at 10 and 15-cm row width, 11-20 g TPS seedling tuber weight planted at 25-cm row width and the largest weight (21-30 g) of TPS seedling tuber planted at 25 and 30-cm row width produced higher TDM.

Tuber yield

Tuber number of tuber per unit area and tuber yield was influenced significantly by the treatments. The highest number of tuber per unit area was obtained by 21-30 g seedling tuber weight planted at 10-cm row width (Table 5). Minimum number of tuber per unit area was recorded by 1-5 g and 6-10 g TPS seedling tuber weight planted at 30-cm row width. Number of tubers per unit area decreased with each incremental increase of row width regardless of TPS seedling tuber weight. On the contrary number of tubers per hill decreased at closer row width regardless of seedling tuber size (data not shown). An inverse relationship was observed between tuber numbers per hill per unit area. Tuber number is a function of stem population (Cho and Iritani, 1983; Islam et al., 1997) but is also influenced by cultivars and several other factors, which Control vegetative growth. The higher number of tuber

Table 5. Number of tuber per square meter as influenced by TPS seedling tuber weight and row width

Tuber	Row spacing (cm)				
wt. (g)	10	15	20	25	30
1-5	206 d	142 gh	113 j	95 k	79 m
6-10	221 c	152 f	124 i	102 j	87 l
11-20	233 b	161 e	132 i	109 j	92 k
21-30	247 a	169 e	132 hi	112 j	94 k

Means followed by the same letters are not significantly different at P≤ 0.05 using DMRT

Per hill produced from larger size of tuber and it was possibly due to higher number of stem per hill and translocation of minerals from source to sink. These results are in agreement with the findings of Adhikari (2005) and Batra et al., (1992). They reported that tuber number per plant increased with increase in seedling tuber size which also indicates that the number of main stems per plant has positive bearing on number of tubers per plant. The results corroborate with the findings of Wiersema (1984) and Kadian et al., (1988). Similar relationship was also observed by Engels et al., (1993a). Thus, it is clear that larger seedling tuber size (11-30 g) planted at a closer row width (10-cm) can produce higher number of tuber per unit area.

Maximum tuber yield was produced by 21-30 g seedling tubers planted at 30-cm row width followed by 11-20 g seedling tuber size planted at 20-cm row spacing, 6-10 g seedling tuber size planted at 15-cm row width and 1-5 g seedling tuber size planted at 10-cm row spacing, respectively (Table 6). The lowest tuber yield was obtained by the smallest size (1-5 g) of TPS seedling tuber planted at the widest (30-cm) row width. It was also noted that 21-30 g seedling tubers planted at 10-cm width produced lower yield compared with other row width while by the use of same size of TPS seedling tuber produced higher yield with each incremental increase of row width. Tuber yield increased significantly with decrease in row spacing in case of 1-5 g and 6-10 g seedling tuber sizes. An inverse relationship was observed between the largest and smallest seedling tuber size corresponding to widest and closest row width, respectively. Tuber yield decreased as row spacing increased, which is in agreement with previous studies (Arsenault et al., 2001; Love and Thomson, 1999) The higher yields obtained from larger seedling tubers was probably due to the combined effects of better vegetative growth resulting in assimilation of more carbohydrates and also more number of tubers per unit area. The tuber yield (38.8 t ha^{-1}) obtained by the smallest weight of (1-5 g) TPS seedling tubers planted at 10-cm row width was about 8% and 31% higher than that of 15- and 30-cm row width, respectively.

Table 6. Tuber yield (t ha^{-1}) as influenced by TPS seedling tuber weight and row width

Tuber wt. (g)	Row spacing (cm) 10	15	20	25	30
1-5	38.8 a	35.9 de	31.0 f	28.2 g	26.7 h
6-10	37.5 bc	38.9 a	35.1e	31.9 f	28.7 g
11-20	36.8 bcd	36.8 bcd	38.9 a	35.9 d	31.2 f
21-30	36.1 d	36.3 d	36.4 c	37.8 b	39.9 a

Means followed by the same letters are not significantly different at P≤ 0.05 using DMRT

In case of TPS seedling tuber size (6-10 g) planted at 15-cm row width produced maximum tuber yield (38.9 t ha^{-1}) which was at par with yields recorded from 10-cm but differed from 20, 25 and 30-cm row width. The tuber yield obtained by 6-10 g seedling tuber weight planted at 15-cm row width was about 11-26% higher than that of 20, 25 and 30-cm row width. Similarly tuber yield obtained by 11-20 g seedling tuber weight planted at 20-cm row width was about 20% higher than that of 30-cm row spacing. The seedling tuber size of 21-30 g planted at 30-cm row width produced 39.9 t/ha and it was 10-39% higher than the other counterpart. This result revealed that larger TPS seedling tuber weight with wider row width and smaller seedling weight with closer row width performed better to obtain higher yield. The results are in agreement with findings of Deka et al., (1996a) and Islam et al., (1997). Considering tuber yield the TPS seedling tuber weight of 1-5 g, 6-10 g, 11-20 g and 21-30 g planted at row width of 10, 15, 20 and 30-cm, respectively is suggested for higher production of potato.

Correlation analysis

Tuber yield is positively correlated between TDM (r=0.92), LDM (r=0.94), SDM (r=0.70), TuDM (r=0.90) and number of tuber (r=0.54). The regression equation predicted that for every 1.0 g TDM accumulation, 238 g tuber was gained. On the contrary for every 1.0 g LDM accumulation, 2363 g tuber was gained. The slopes of regression equation indicated that for every 1.0 g SDM accumulation, only 228 g tuber was gained (Table 7). This positive correlation suggests that different seedling tuber size planted at varying row spacing has strong relation to increase the biomass of plants which has the capacity to produce higher tuber yield. Tuber yield was positively correlated to plant biomass due to the increased plant tissue to accumulate more nutrients from soil. Higher biomass indicates that plants were bigger, healthy and might possess higher photosynthesis rate so that more carbohydrate accumulation and nutrient uptake took place. Despite the positive correlation between tuber yield and SDM yield in plants, the correlation between tuber yield and SDM was a bit weak in this study. However, LDM contributes to the vigorous growth of plants. As a result, the higher biomass of plants produced higher yield.

Table 7. Regression equation, correlation coefficient (r) and coefficients of determination (R^2) of different parameters

Regression equation	r	R^2
$Y_1 = 0.0238x_1 + 9.4568$	0.92**	0.85
$Y_2 = 0.2363x_2 + 9.2497$	0.94**	0.88
$Y_3 = 0.0228x_3 + 26.341$	0.70*	0.48
$Y_4 = 0.0269x_4 + 10.054$	0.90**	0.81
$Y_5 = 0.0408x_5 + 29.221$	0.54*	0.53

Y_1, Y_2, Y_3, Y_4 and Y_5 = Tuber yield, x_1 = Total dry matter; x_2 = leaf dry matter, x_3 = stem dry matter; x_4= tuber dry matter, x_5 = number of tuber per square meter

*significant at 0.05 level of probability and ** significant at 0.01 level of probability

Conclusions

The larger seedling tuber size planted at wider row width and smaller TPS seedling tuber weight planted at closer row spacing was better to produce higher tuber yield. The effects of varying TPS seedling tuber size planted at different row width on economic return will depend on the cost of TPS seedling tuber and the price for harvested potatoes when sold. The tuber yield data appears that TPS seedling tuber weighing approximately 21-30 g planted at 30-cm row width, 11-20 g planted at 20-cm row width, 6-11 g planted at 15-cm row width and 1-5 g planted at 10-cm row width produced satisfactory yield and quality of TPS-1 cultivars in this study. Considering yield and expected economic returns, the smallest weight of (1-5 g) TPS seedling tuber with 10 and 15-cm row width obtained profitable yield compared with other combinations.

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