Journal of Multidisciplinary Sciences
www.multidisciplines.com

In vitro screening of salt tolerate genotypes based on morphological traits under different salinity levels in onion

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Received: 25 August 2020; Accepted: 16 October 2020; Published online: 22 October 2020

Abstract. The experiment was performed at the tissue culture laboratory of Genetics and Plant Breeding Department, Sher-e-Bangla Agricultural University, Bangladesh, from 2017 to 2018 to screen salt-tolerant onion genotypes based on morphological traits using different concentrations of salt viz. T_0 (0 Mm NaCl), T_1 (50 mM NaCl), T_2 (100 Mm NaCl) and T_3 (150 mM NaCl). Different combinations and concentrations of salt levels on *in vitro* growth performance and plant regeneration were observed. Analysis of variance showed that the highly significant variation among all the genotypes for all nine traits under study expects the number of roots. It was found that treatment T_0 (8.38 cm) produced the highest plant height and treatment T_3 (4.71 cm) produced the lowest plant height (4.71 cm). Treatment T_0 (12.10 g) showed the maximum leaf fresh weight (g) in Nath Royal-1069 (V_6) and the lowest leaf fresh weight (g) in the treatment T3 (2.90 g) in the genotypes of BARI Piaj-1. Moreover, treatment T_2 (13.5 g) showed the maximum bulb yield per plant (g) in Annex N-35 (V_5) and the minimum bulb yield per plant at the treatment T3 (4.0 g) in the genotypes of BARI Piaj-5 (V2). Among the variety, the performance of Annex N-35 (V_5) was better than other onion studied varieties.

Keywords: *Onion, tissue culture, salt stresses, morphology*

Cite this as: Rifat, M.M.H., Huda, K.M.K. & Islam, M.S. (2020). *In vitro* screening of salt tolerate genotypes based on morphological traits under different salinity levels in onion. J. Multidiscip. Sci. 2(2), 41-48.

1. Introduction

Salinity stress involves changes in various physiological and metabolic processes, depending on the severity and duration of the stress, and ultimately inhibits crop production (James et al., 2011; Rahnama et al., 2010; Rozema et al., 2008). Soil salinity is known to repress plant growth in the form of osmotic stress caused by ion toxicity (James et al., 2011; Rahnama et al., 2010). Due to salinity stress, the water absorption capacity of root systems decreases, and water loss from leaves is accelerated due to osmotic stress of high salt accumulation in soil and plants. Therefore, salinity stress is also considered hyperosmotic stress (Munns, 2005). Salinity stress causes various physiological changes, such as interruption of membranes, nutrient imbalance, which impairs the ability to detoxify reactive oxygen species (ROS), differences in the antioxidant enzymes, and decreased photosynthetic activity, and decrease in stomatal aperture (James et al., 2011). Salinity results in a reduction of K^+ and Ca^{2+} content and an increased level of Na^+, Cl^- and SO_4^{2-}, which forms its ionic effects (Mansour et al., 2005; Islam et al., 2018). Reduction in biomass, photosynthetic capacity changes in leaf water potential, and leaf turgor have been reported to have a cumulative effect attributed to salinity stress (Munnas, 2002). It is also clear that soil and environmental factors do influence plant growth under salinity conditions.

The onion is very sensitive to electrical conductivity values as low as 1.2 dSm^{-1} and water stress because of the root system (Koriem et al., 1994; Maas, 1977). It is necessary to screen onion genotypes/varieties for salt tolerance so that improved lines can be developed (Joshi and Sawant, 2011). It was observed that soil-water stress at any growth comparison of salinity and drought stress effects on parameters in the onion stage leads to a reduction in quality characters of onion (Singh and Alderfer, 1966). A comprehensive understanding of plants' physiological responses to salt stress is essential for future plant improvement strategies. Onion is an economically important crop that is cultivated widely in East Asia for its economic value. The molecular and cellular processes underlying the acclimation of onion to abiotic stresses have attracted much interest because the response of this economically important crop to adverse environmental factors is not well understood as in other crop plants (Shinozaki and Yamaguchi-Shinozaki, 2000). Genetic variations and differential responses to salinity stress in plants differing in stress tolerance enable plant biologists to identify physiological mechanisms and incorporate them into suitable species.

Due to changing climatic condition crop needs to be developed to face the adverse climatic effects. High salinity is one of our country's main abiotic stresses due to billions of dollars' losses every year from crop damage. *Allium* sp. is significant in our country, and the medicinal value is very high as raw in a salad or used in cooked food or sauce, confectionary, or bakery food. Onion serves as an antioxidant in the human body. By producing *Allium*, it will be possible to fulfill the nutritional and economic demands of Bangladesh. To meet the demand of yield, tolerance to abiotic and biotic stresses, and other qualities of *Allium* sp. through *in vitro* culture or genetic engineering, establishing an *in vitro* protocol for plant regeneration is essential. It is essential to bring Bangladesh's saline-prone areas under cultivation by developing salt-tolerant crops to feed Bangladesh's increasing population. Salt tolerant *Allium* varieties could be distributed to the farmers for cultivation. This will be included in their cropping pattern and crop rotation. In this way, it will contribute to the development of sustainable technology.

If we enhance onion productivity by developing salinity tolerant onion cultivars, it will reduce imports and save foreign currency. The study was undertaken to identify the salt-tolerant onion genotypes that may sustain a reasonable yield on salt-affected soils.

2. Materials and methods

2.1. Experimental site and materials

The experiment was conducted at the tissue culture laboratory of Sher-e-Bangla Agricultural University, Dhaka-1207, from April 2017 to April 2018. Seeds of *Allium* genotypes were collected from the plant genetic resource center, Bangladesh Agricultural Research Institute, Gazipur, and other sources.

2.2. Sterilization

Seeds were surface-sterilized with 70% ethanol and 10% NaOCl solution for 6 min and then in distilled water for 30 min. and then rinsed three times at 5 minutes each with autoclaved distilled water.

2.3. Germination of seedlings

The seeds were sown on the surface of hormone-free sterilized new MS nutrient media (Murashige and Skoog, 1962) containing 3% sucrose, 0.8% agar, and pH adjusted to 5.8 before autoclaving. All processes were done under aseptic conditions in the laminar airflow cabinet.

2.4. Salt stress treatments

Salt treatments were achieved via the gradual addition of NaCl to fresh MS medium. The four levels of salts were: 0 mM 50 mM, 100 mM and 150 mM NaCl. The seeds were incubated under 16 h photoperiod at 25±2 °C in a growth chamber until three weeks.

2.5. Salt induction and growth

Seeds were placed into new MS media, including control and salt stress. These seedlings were cultured on MS nutrient medium for growth and development. Seedlings were subculture every three weeks onto the freshly prepared MS medium. Biomass changing was recorded at the end of each six-week culture period till the 3rd subculture. Salt stress conditions were realized in 0 mM, 50 mM, 100 mM, and 150 mM NaCl to the MS medium.

2.6. Regeneration

Survival seedlings were transferred to a regeneration medium composed of the same basal medium supplemented with 0.01 mg/L 6-benzylaminopurine and 0.001 mg/L a-naphthaleneacetic acids. Survival representative seedlings were transferred to a rooting media.

2.7. Rooting

If the salt-stressed *Allium* seedling was beginning to rise, they were transferred to rooting media supplemented either with naphthalene acetic acid 0.1 and 0.2 mg/L, and the number of shoots produced roots was recorded. All media was containing 3% sucrose with pH adjusted at 5.76 and were solidified. After six weeks, survival seedlings were transferred in rooting media.

2.8. Data collection and statistical analysis

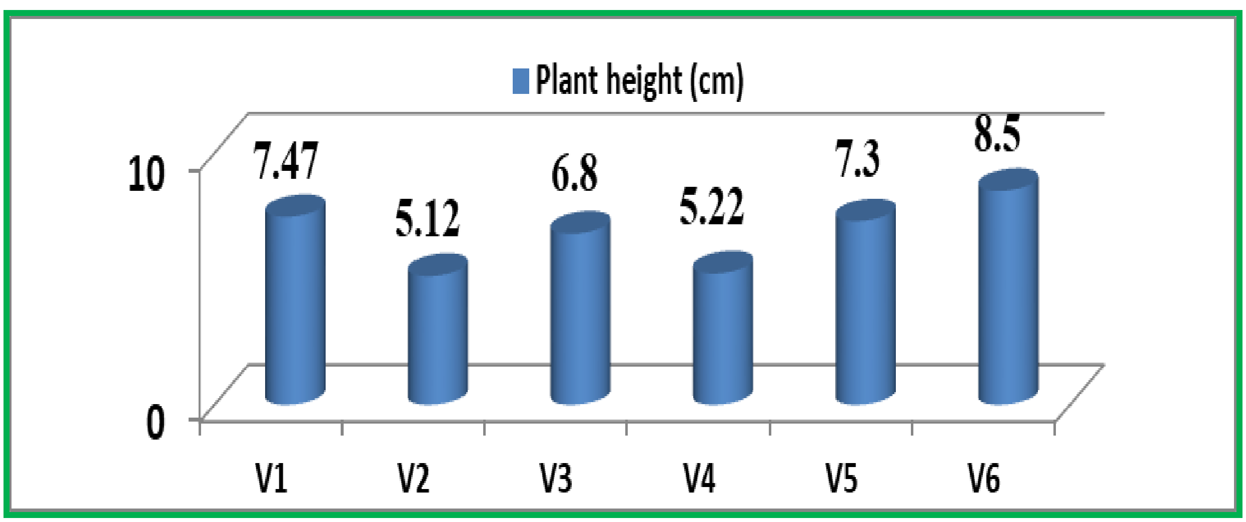
Plant height, root length, shoot length, root fresh weight, shoot fresh weight, survival percentages, root dry weight, shoot dry weight, and no root and bulb weight were collected under control and stress conditions. The experiments were conducted randomized with three replications. Tissue culture responsiveness and variation were analyzed statistically by the analyzing variance and Turkey test at a 1% probability level.

3. Results and discussion

The analyses of variance of different onion genotypes for morpho-physiogenic traits are shown in Table 1. Analysis of variance indicated that the highly significant difference among genotypes for all nine traits under study viz., plant height (cm), root length (cm), fresh root weight (g), root dry weight (mg), leaf length (cm), fresh leaf weight (g), dry leaf weight (mg) and bulb yield per plant (g) expect the number of roots. These results suggest that variation among the genotypes for all these traits expects some roots. It was found that better performance in control and performances decreased with the increase of salinity level in *Brassica campestris* genotypes (Akhter et al., 2012). The data were subjected to biometrical analysis, and the results obtained are presented below under the following headings:

3.1. Plant height

Significant differences were recorded for plant height among varieties, treatments, and their interactions (Table 1). However, the plant height decreases to increase the salt concentrations gradually was observed, and it depends upon the variety and concentration of the salinity level used and combinations of variety and salinity levels (Table 2). The maximum plant height was found in the genotypes V6 (8.5 cm) in Nath Royal- 1069, and the minimum plant height was found in the genotypes of V2 (5.12 cm) in BARI Piaj-5 (Figure 1). Genotypes V2 (5.12 cm) and V4 (5.22 cm) showed more or more minor similar trends, and V3 (6.8 cm) and V5 (7.3 cm) observed moderate plant height. These results indicated that the genotypes V6 (8.5 cm) in Nath Royal- 1069 showed better plant height performance among all the genotypes studied.



Genotypes

Figure 1. Effect of different genotypes of onion on plant height. Note: V1 = BARI Piaj-1, V2 = BARI Piaj-5, V3 = Taherpuri, V4 = Faridpuri, V5 = Annex N-53 and V6 = Nath Royal-1069.

Table 1. Analysis of variance for different characters in onion genotype				
Characters	Mean sum of square			
	Factor A (Salt level) df = 3	Factor B (Variety) df = 5	AB Variety × Salt level df = 15	Error df = 48
PH (cm)	43.01**	21.26**	0.93**	0.010
RL (cm)	2.25**	2.45**	0.12**	0.012
RFW (g)	2.09**	6.79**	0.30**	0.011
RDW (mg)	1753.77**	1130.86**	1.39**	0.010
LL (cm)	22.40**	10.94**	1.27**	0.012
LFW (g)	55.84**	16.87**	1.66**	0.011
LDW (mg)	2186.52**	546.87**	38.49**	0.013
NR	0.00	6.80**	0.00	0.417
BYP (g)	67.54**	34.80**	1.12**	0.011

**= Significant at 1% level of probability, * = Significant at 5% level of probability.
PH (cm): Plant Height, RL (cm): Root Length, RFW (g): Root Fresh Weight, RDW (mg): Root Dry Weight, LL (cm): Leaf Length, LFW (g): Leaf Fresh Weight, LDW (mg): Leaf Dry Weight, NR: No. of Roots and BYP (g): Bulb Yield per Plant.

In the case of treatments, significant differences were found among the treatments (Table 1). Treatment T_0 (8.38 cm) produced the highest length of shoot, and treatment T_3 produced the lowest length of shoots (4.71 cm) (Table 3). It was also observed that increasing salt concentration decreases plant height. A high level of NaCl has been shown to restrict onion growth, which decreases bulb yield (Malik et al., 1978). The interaction effect of genotypes and salinity showed that treatment T_1 (10 cm) showed the highest number of plant height in Nath Royal- 1069 (V_6) and the lowest number of plant height in the treatment T_3 (3.70 cm) in the genotypes of Faridpuri (V4) (Table 4). Significant variation was found for these onions (Azoom et al., 2014; Santra et al., 2017).

3.2. Root length

Root length was significant among varieties, treatments, and their interactions (Table 1). The highest root length was found in the genotypes V2 (2.58 cm) in BARI Piaj-5, and the lowest root length was recorded in the genotypes of V5 (1.40 cm) in Annex N-53 (Table 2). Genotypes V3 and V4 showed 2.15 cm and 2.25 cm, respectively, which observed moderate root length. These results indicated that the genotypes V2 (2.58 cm) in BARI piaj-5 showed better root length performance among the rest of the genotypes.

In the case of treatments, significant differences had been found among the treatments (Table 1). Treatment T_0 (2.32 cm) produced the highest length of root, and treatment T_3 produced the lowest length of root (1.48 cm) (Table 3). It was observed that increasing the salt concentration decrease the root length except for a little increasing trend in the treatments of T_2. The interaction effect of genotypes and salinity showed that treatment T_2 (2.9 cm) showed the highest root length in BARI Piaj-5 (V2) and the lowest root length in the treatment T_3 (1.0 cm) in the genotypes of Annex N-53 (V5) (Table 4). Previous studies in onion also found significant variation for these traits (Azoom et al., 2014; Santra et al., 2017).

3.3. Root fresh weight

It was revealed significant differences in fresh root weight (g) among varieties, treatments, and their interactions (Table 1). However, the fresh root weight (g) decreases gradually to increase the salt concentrations was observed, and it depends upon the variety and concentration of the salinity level used and combinations of variety and salinity levels (Table 2). The maximum root fresh weight (g) was found in the genotypes V2 (3.45 g) in BARI Piaj-5, and the minimum root fresh weight (g) was found in the genotypes of V6 (1.47 g) in Nath Royal- 1069 (Table 2). Genotypes V1 (2.57 g) and V3 (2.5 g) showed similar root fresh weight (g). These results indicated that the genotypes V2 (3.45 g) in BARI Piaj-5 showed better fresh root weight (g) among all the genotypes studied.

Table 2. Effect of different varieties of onion genotypes on growth attributes									
Varieties	PH (cm)	RL (cm)	RFW (g)	RDW (mg)	LL (cm)	LFW (g)	LDW (mg)	NR	BYP (g)
V1	7.47b	1.50cd	2.57b	44.78c	6.40c	7.32d	87.28c	5.00a	7.09d
V2	5.12d	2.58a	3.45a	58.55a	4.65e	7.12e	77.40f	4.00ab	6.50e
V3	6.80c	2.15b	2.50b	48.92b	6.10d	8.47b	85.60d	4.00ab	9.45b
V4	5.22d	2.25b	1.80c	40.42d	6.42c	7.90c	81.65e	5.00a	8.00c
V5	7.30b	1.40d	1.60cd	34.30e	7.12b	8.61b	90.88b	3.00b	11.00a
V6	8.50a	1.77c	1.47d	32.55f	7.35a	10.40a	96.55a	4.00ab	9.69b
THSD 0.05	0.056	0.063	0.055	0.164	0.164	0.164	0.057	0.372	0.054

THSD **0.05 =** Tukey's Honestly Significant Difference Test at alpha 0.05. A column with a similar letter (s) is statistically identical, and those with the dissimilar letter(s) differ significantly as per the 0.01 level of probability. PH (cm): Plant Height, RL (cm): Root Length, RFW (g): Root Fresh Weight, RDW (mg): Root Dry Weight, LL (cm): Leaf Length, LFW (g): Leaf Fresh Weight, LDW (mg): Leaf Dry Weight, NR: No. of Roots and BYP (g): Bulb Yield per Plant. V1 = BARI Piaj-1, V2 = BARI Piaj-5, V3 = Taherpuri, V4 = Faridpuri, V5 = Annex N-53, V6 = Nath Royal- 1069.

In the case of treatments, significant differences were found among the treatments (Table 1). Treatment T_0 (2.60 g) produced the highest root fresh weight (g), and treatment T_3 produced the lowest root fresh weight (g) (1.81 g) (Table 3). It was also observed that increasing salt concentration decreases the fresh root weight (g). The interaction effect of genotypes and salinity showed that treatment T_2 (3.9 g) showed the highest root fresh weight (g) in BARI Piaj-5 (V_2) and the lowest root fresh weight (g) found of the treatment T3 (1.20 g) in the genotypes of Nath Royal- 1069 (V6) (Table 4). The combined effect also showed that similar letter (s) is statistically identical in genotypes, and those having a dissimilar letter(s) differ significantly in genotypes. Previous studies in onion also found significant variation for these traits (Azoom et al., 2014; Santra et al., 2017).

3.3. Root dry weight (mg)

Significant variations were observed for root dry weight (mg) among varieties, treatments, and interactions (Table 1). The highest root dry weight (58.55 mg) was found in the genotypes V2 (58.55 mg) in BARI Piaj-5, and the lowest root dry weight (mg) was recorded in the genotypes of V6 (32.55 mg) in Nath Royal- 1069 (Table 2). These results indicated that the genotypes V2 (58.55 mg) in BARI piaj-5 showed better root dry weight among the rest of the genotypes.

In the case of treatments, Treatment T_0 (49.27 mg) produced the highest root dry weight, and treatment T_3 produced the lowest root dry weight (28.52 mg) (Table 3). It was also observed that increasing the salt concentration decrease the root dry weight except for a little increasing trend in the treatments of T_2. The interaction effect of genotypes and salinity showed that treatment T_0 (65.50 mg) showed the highest root dry weight in BARI Piaj-5 (V2) and the lowest root dry weight in the treatment T_3 (18.20 mg) in the genotypes of Nath Royal- 1069 (V6) (Table 4). The combined effect also showed that similar letter (s) is statistically identical genotypes, and those having dissimilar letter(s) differ significantly in genotypes. Similar trends were found in *Brassica campestris* (Akhter et al., 2012). Previous studies in onion also found significant variation for these traits (Azoom et al., 2014; Santra et al., 2017).

Table 3. Effect of different salinity levels on growth-related attributes of onion genotype									
Salt Level	PH (cm)	RL (cm)	RFW (g)	RDW (mg)	LL (cm)	LFW (g)	LDW (mg)	NR	BYP (g)
T_0	8.38a	2.32a	2.60a	49.27a	7.40a	9.86a	95.68a	4.16	10.59a
T_1	7.31b	1.91b	2.11b	46.95c	6.76b	8.93b	91.10b	4.16	9.67b
T_2	6.53c	2.08b	2.40a	48.28b	6.41c	8.64c	88.87c	4.16	8.06c
T_3	4.71d	1.48c	1.81c	28.52d	4.78d	5.78d	70.58d	4.16	6.18d
THSD 0.05	0.055	0.179	0.052	0.164	0.054	0.164	0.164	0.372	0.056

THSD **0.05 =** Tukey's Honestly Significant Difference Test at alpha 0.05. A column with a similar letter (s) is statistically identical, and those with a dissimilar letter(s) differ significantly as per the 0.01 level of probability. Four salinity levels viz. T_0: 0 mM NaCl, T_1: 50 mM NaCl, T_2: 100 mM NaCl, T_3: 150 mM NaCl. PH (cm): Plant Height, RL (cm): Root Length, RFW (g): Root Fresh Weight, RDW (mg): Root Dry Weight, LL (cm): Leaf Length, LFW (g): Leaf Fresh Weight, LDW (mg): Leaf Dry Weight, NR: No. of Roots and BYP (g): Bulb Yield per Plant.

3.4. Leaf length

It was found that leaf length significantly influences varieties, treatments, and interactions (Table 1). The highest leaf length was found in the genotypes V6 (7.35 cm) in Nath Royal- 1069, and the lowest leaf length was recorded in the genotypes of V2 (4.65 cm) in BARI Piaj-5 (Table 2). Genotypes V1, V3, and V4 showed 6.4 cm, 6.1 cm, and 6.42 cm, respectively, which observed moderate leaf length. These results indicated that the genotypes V6 (7.35 cm) in Nath Royal- 1069 showed better performance for leaf length among the rest of the genotypes.

In the case of treatments, significant differences had been found among the treatments (Table 1). Treatment T_0 (7.4 cm) produced the highest length of leaf, and treatment T_2 produced the lowest length of leaf (6.41 cm) (Table 3). It was also observed that increasing the salt concentration decrease the leaf length except for a little increasing trend in the treatments of T_3. The interaction effect of genotypes and salinity showed that treatment T_0 (8.7 cm) showed the highest leaf length in Nath Royal- 1069 (V2) and the lowest leaf length in the treatment T_3 (2.7 cm) in the genotypes of BARI Piaj-5 (V2) (Table 4). The combined effect also showed that similar letter (s) is statistically identical genotypes, and those having dissimilar letter(s) differ significantly in genotypes. Previous studies in onion also found significant variation for these traits (Azoom et al., 2014; Santra et al., 2017).

3.5. Leaf fresh weight

Highly significant differences were recorded for fresh leaf weight (g) among varieties, treatments, and interactions (Table 1). However, the fresh leaf weight (g) decreases gradually to increase the salt concentrations was observed, and it depends upon the variety and concentration of the salinity level used and combinations of variety and salinity levels (Table 2). The entire leaf fresh weight (g) was found in the genotypes V6 (10.40 g) in Nath Royal- 1069, and the minimum leaf fresh weight (g) was found in the genotypes of V2 (7.12 g) in BARI Piaj-5 (Table 2). These results indicated that the genotypes V6 (10.40 g) in Nath Royal- 1069 showed better performance for fresh leaf weight (g) among all the genotypes studied.

Table 4. The combined effect of onion genotypes and saline level effects on different characters

Variety	PH (cm)	RL cm)	RFW (g)	RDW (mg)	LL (cm)	LFW (g)	LDW (mg)	NR	BYP (g)
ToV1	8.90c	1.80hij	3.50bc	50.50g	7.60cd	9.50ef	98.60f	5.00	9.36g
ToV2	6.40j	2.83ab	3.80ab	65.50a	5.40k	8.30ij	84.40l	4.00	8.60h
ToV3	8.50d	2.50bcde	2.90d	54.50d	7.80c	9.80de	92.50g	4.00	11.80c
ToV4	7.30g	2.70abc	2.20gh	46.30j	6.60gh	9.30f	90.50h	5.00	9.600fg
ToV5	9.30b	1.90ghi	1.50jkl	40.20n	8.30b	10.20c	105.3a	3.00	13.50a
ToV6	9.90a	2.20efg	1.70ij	38.60p	8.70a	12.10a	102.8c	4.00	10.70e
T1V1	8.00e	1.50jkl	2.50efg	48.70i	7.30de	8.80gh	89.30i	5.00	7.20j
T1V2	5.60k	2.40cde	3.30c	62.80c	5.00l	7.60lm	81.50n	4.00	7.80i
T1V3	7.20gh	2.00fgh	2.40fg	53.00f	6.80fg	8.80gh	89.30i	4.00	10.60e
T1V4	5.30kl	2.30def	1.90hi	44.30l	6.30hi	8.70gh	85.50k	5.00	8.90h
T1V5	7.80ef	1.50jkl	1.30kl	37.20r	7.50cd	9.60ef	99.40e	3.00	12.50b
T1V6	10.00a	1.80hij	1.30kl	35.70s	7.70c	10.10cd	101.6d	4.00	11.06d
T2V1	7.50fg	1.60ijk	2.70def	49.70h	6.90fg	8.10jk	90.70h	5.00	6.20l
T2V2	4.60m	2.90a	3.90a	63.80b	5.50k	7.30m	78.40o	4.00	5.80mn
T2V3	6.80i	2.20efg	2.50efg	54.00e	5.40k	8.50hi	87.70j	4.00	8.70h
T2V4	4.60m	2.60abcd	1.70ij	45.30k	6.90fg	7.90kl	82.30m	5.00	7.50ij
T2V5	6.90hi	1.20lmn	1.90hi	39.20o	6.80fg	8.96g	90.50h	3.00	10.40e
T2V6	8.80cd	2.00fgh	1.70ij	37.70q	7.00ef	11.10b	103.6b	4.00	9.80f
T3V1	5.50kl	1.30klmn	1.60ijk	30.20u	3.80n	2.90q	70.50q	5.00	5.60n
T3V2	3.90n	2.20efg	2.80de	42.10m	2.70o	5.30p	65.30s	4.00	4.00o
T3V3	4.70m	1.90ghi	2.20gh	34.20t	4.40m	6.80n	72.90p	4.00	6.70k
T3V4	3.70n	1.40klm	1.40jkl	25.80v	5.90j	5.70o	68.30r	5.00	6.00lm
T3V5	5.20l	1.00n	1.70ij	20.60w	5.90j	5.70o	68.30r	3.00	7.60i
T3V6	5.30kl	1.10mn	1.20l	18.20x	6.00ij	8.30ij	78.20o	4.00	7.20j
THSD 0.05	0.058	0.062	0.053	0.054	0.052	0.056	0.053	0.372	0.057

THSD **0.05 =** Tukey's Honestly Significant Difference Test at alpha 0.05. In a column, having a similar letter (s) are statistically identical, and those having a dissimilar letter(s) differ significantly as per 0.01 level of probability. PH (cm): Plant Height, RL (cm): Root Length, RFW (g): Root Fresh Weight, RDW (mg): Root Dry Weight, LL (cm): Leaf Length, LFW (g): Leaf Fresh Weight, LDW (mg): Leaf Dry Weight, NR: No. of Roots and BYP (g): Bulb Yield per Plant.

In the case of treatments, significant differences had been found among the treatments (Table 1). Treatment T_0 (9.86 g) produced the highest leaf fresh weight (g), and treatment T_3 produced the lowest leaf fresh weight (5.78 g) (Table 3). It was also observed that increasing salt concentration decreases the fresh leaf weight (g). The interaction effect of genotypes and salinity showed that treatment T_0 (12.10 g) showed the highest leaf fresh weight (g) in Nath Royal- 1069 (V_6) and the lowest leaf fresh weight (g) in the treatment T_3 (2.90 g) of the genotypes of BARI Piaj-1 (V2) (Table 4). Similar trends were found in *Brassica campestris* (Akhter et al., 2012).

3.6. Leaf dry weight

Salinity significantly affects dry leaf weight (mg) among varieties, treatments, and interactions (Table 1). However, the leaf dry weight (mg) decreases gradually to increase the salt concentrations was observed, and it depends upon the variety and concentration of the salinity level used and combinations of variety and salinity levels (Table 2). The highest leaf dry weight (mg) was found in the genotypes V6 (96.55 mg) in Nath Royal- 1069, and the minimum leaf dry weight (mg) was found in the genotypes of V2 (77.40 mg) in BARI Piaj-5 (Figure 2). These results indicated that the genotypes V6 (96.55 mg) in Nath Royal-1069 showed better performance for dry leaf weight (mg) among all the genotypes studied. In the case of treatments, significant differences had been found among the treatments (Table 1). Treatment T_0 (95.68 mg) produced the highest leaf dry weight (mg), and treatment T_3 produced the lowest leaf dry weight (70.58 mg) (Table 3). It was also observed that increasing salt concentration decreases dry leaf weight (mg). The interaction effect of genotypes and salinity showed that treatment T_0 (105.3 mg) showed the highest leaf dry weight (mg) in Annex (V_5) and the lowest leaf dry weight (mg) in the treatment T_3 (65.30 mg) of the genotypes of BARI Piaj-1 (V2) (Table 4). Similar trends were found in *Brassica camprestris* (Akhter et al., 2012).

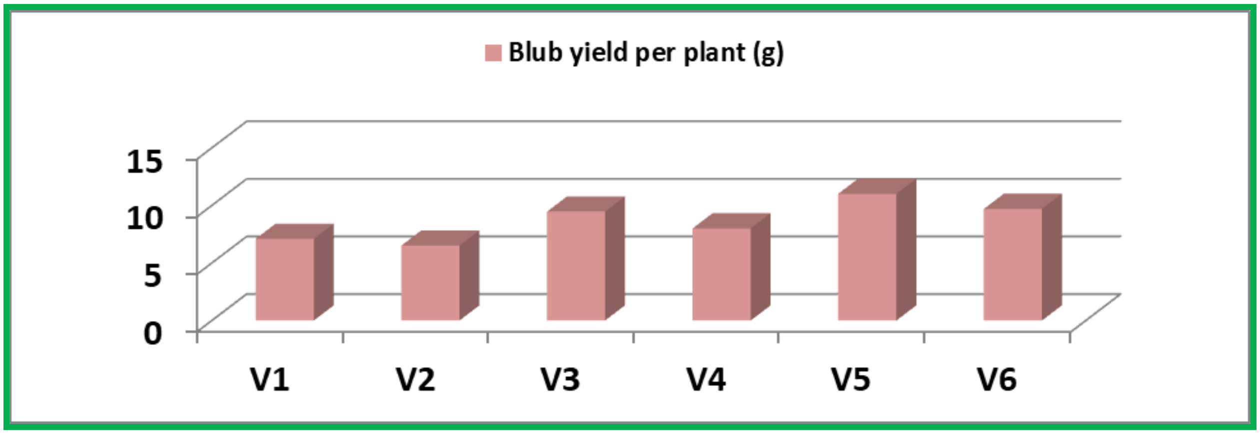
3.7. Number of roots

It was observed that there is a little significant difference in the number of roots among varieties, but not the treatments and their interactions (Table 1). The maximum number of roots was found in the genotypes V1 (5.0) and V4 (5.0) in BARI Piaj-1 and Faridpuri, respectively, and the minimum number of roots was found in the genotypes of V2 (4.0), V3 (4.0), and V6 (4.0) in BARI Piaj-5, Taherpuri, and Nath Royal- 1069 (Table 2) respectively. These results indicated that the genotypes V1 (5.0) and V4 (5.0) in BARI Piaj-1 and Faridpuri showed better performance for the number of roots among all the genotypes studied. In the case of treatments, significant differences had been found among the treatments (Table 1). All the treatments produced a similar number of roots (Table 3). The interaction effect of genotypes and salinity showed that all treatment and all the genotypes more or less produced a similar number of roots (Table 4).

3.8. Bulb yield per plant

Significant differences were recorded for bulb yield per plant (g) among varieties, treatments, and interactions (Table 1). However, bulb yield per plant (g) decreases gradually to increase the salt concentrations was observed (Table 2). The maximum bulb yield per plant (g) was found in the genotypes V5 (11.0 g) in Annex N-35, and the minimum bulb yield per plant (g) was found in the genotypes of V2 (6.50 g) in BARI Piaj-5 (Figure 2). These results indicated that the genotypes V5 (11.0 g) in Annex N-35 showed better performance for bulb yield per plant (g) among all the genotypes.

In the case of treatments, significant differences had been found among the treatments (Table 1). Treatment T_0 (10.59 g) produced the highest bulb yield per plant (g), and treatment T_3 produced the lowest bulb yield per plant (g) (6.18 g) (Table 3). It was also observed that increasing the salt concentration decrease the bulb yield per plant (g). Salinity affects almost every aspect of plants' physiology and biochemistry and significantly reduces yield (Khan et al., 2008). The interaction effect of genotypes and salinity showed that treatment T_2 (13.5 g) showed the highest bulb yield per plant (g) in Annex N-35 (V_5) and the lowest number of bulb yield per plant (g) in the treatment T_3 (4.0 g) in the genotypes of BARI Piaj-5 (V2) (Table 4). A high level of NaCl has been shown to restrict onion growth, which decreases bulb yield (Malik et al., 1978). The growth hamper due to a high level of NaCl was found in microgreens also, and it happened due to osmotic stress that causes water deficit thus, reducing the uptake of water; consequence, causing growth reduction (Islam et al., 2019).



Genotypes

Figure 2. Effect of different varieties of onion on bulb yield per plant (g). V1 = BARI Piaj-1, V2 = BARI Piaj-5, V3 = Taherpuri, V4 = Faridpuri, V5 = Annex N-53, V6 = Nath Royal- 1069.

4. Conclusion

Analysis of variance indicated that the highly significant difference among genotypes for all nine traits under study. These results suggest that variation among the genotypes for all these traits expects some number of roots. Treatment T_1 (10 cm) showed the highest number of plant height in Nath Royal- 1069 (V_6) and the lowest number of plant height in the treatment T3 (3.70 cm) in the genotypes of Faridpuri (V4). Treatment T_0 (12.10 g) showed the highest number of fresh leaf weight (g) in Nath Royal- 1069 (V_6) and the lowest number of leaf fresh weight (g) in the treatment T_3 (2.90 g) in the genotypes of BARI Piaj-1. Treatment T_0 (8.7 cm) showed the highest number of leaf lengths in Nath Royal- 1069 (V2) and the lowest number of leaf lengths in the treatment T_3 (2.7 cm) in the genotypes of BARI Piaj-5 (V2). Treatment T_2 (13.5 g) showed the highest bulb yield per plant (g) in Annex N-35 (V_5) and the lowest number of bulb yields per plant (g) in the treatment T_3 (4.0 g) in the genotypes of BARI Piaj-5 (V2). Among the variety, the performance of Annex N-35 (V_5) was better than other onion varieties. This genotype may be helpful for moderate salt tolerant onion genotypes and for further *in vitro* breeding programs.

Acknowledgment

The University Grants Commission of Bangladesh supported the research work. We would like to special thanks to UGC for sanctioning this fund for our tissue culture work.

Conflicts of interest. There are no conflicts of interest.

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