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# Evaluation of Potato Varieties against Salinity Stress in Bangladesh

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Authors SM and MMH (Supervisor) contributed in designing, conducting, statistical analysis and report writing. Authors MZ and JUA were co-supervisors of this work. Author MMI assisted author SM to prepare this manuscript. All authors read and approved the final manuscript.*

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## ABSTRACT

**Aims:** The main aim of this study was to find out the salinity tolerant varieties of potato and to evaluate the growth and yield performance of potato varieties under different salinity level.
**Study Design:** The experiment was laid out in the two factor completely randomized design (CRD) with the three replications.
**Place and Duration of Study:** A pot experiment was conducted at the Horticulture Research field and Horticulture Laboratory of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh during December 2011 to April 2012.
**Methodology:** The possible combination of the ten potato varieties (Diamant, Lady Rosetta, Provento, Felsina, Granola, Asterix, Cardinal, Sagita, Shilbilati and LalPakri) and the four levels of salt (NaCl) ($S_o$= 0.50 dS/m, $S_1$= 3.25 dS/m, $S_2$= 6.95 dS/m and $S_3$= 8.90 dS/m) were considered as the treatment variables. There were 120 earthen pots and the tubers of selected genotypes were

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planted in each pot. After 20 days of planting treatment was applied and irrigated every two days interval. 2 ds/m and 6 ds/m saline water was used to raise 0.5 ds/m and 3.25 ds/m respectively. To reach 6.95 ds/m first fifteen days pots were irrigated at 6 dS/m and then 8 ds/m at 2 days interval. Similarly, pots were irrigated at 6 ds/m (first 7 days) and 8 ds/m (next 7 days) and then 12 ds/m to reach 8.90 ds/m at the same interval to avoid osmotic shock. Finally, the electrical conductivity of the soil against treatment reached and measured by Electrical Conductivity meter. It was taken 30 days to raise the soil salinity up to the treatment. These levels of salinity were maintained up to final harvest. After harvesting some important physiological, and yield contributing attributes such as chlorophyll content, membrane leakage, ion uptake and tuber weight were measured.

**Results:** In respect of leaf chlorophyll content, membrane leakage, per plant tuber weight, and ion uptake were better in Sagita and Felsina. The variety Sagita followed by Felsina had less membrane injury upto 32.14% where as Shilbilati and Lalpakri exhibited upto 69.45% membrane injury at 6.95 dS/m of salinity. At the same time, Sagita gave the highest yield followed by Felsina, Lady Rosetta and Provento.

**Conclusion:** Finally, the present results revealed that variety Sagita and Felsina responded well under salinity stress condition. Lady Rosetta and Provento performed moderately at 6.95 dS/m. The varieties Shilbilati and Lalpakri were salt sensitive among the selected genotypes.

*Keywords: Genotypes; electrical conductivity; chlorophyll content; membrane leakage; ion uptake; tuber weight.*

## 1. INTRODUCTION

Potato is the fourth leading world food crop after rice, wheat and maize because of its great yield potential and high nutritive value. It is a key part of global sustainable food system producing more food energy on less land than rice, wheat and maize. After rice (boro, aman, aus), potato is the second most important crop in Bangladesh. And recently potato has become major food crop in Bangladesh because of its multiple uses as vegetable and delicious processed items [1]. More than half of global potato production is in developing countries like Bangladesh rendering an important source of food and income of millions of farmers [2]. It is revealed that total potato production is 8.4 million MT from 460,000 ha of area with an average yield 18 MT/ha. Meanwhile, there is a wide gap between average national yield of potato in Bangladesh compared to other potato growing countries of the world like Netherlands, UK, France, USA and Germany. Potato yield in UK is about 48 MT/ha, which is more than two and half times higher than that of Bangladesh [1].

The United Nations Environment Program estimates that approximately 20% of agricultural land and 50% of cropland in the world is salt-stressed [3]. Six of 14 billion ha of arable land available in the world are located in these areas, and out of this, about one billion ha are affected by excess salt [4]. In Bangladesh, out of 2.85 million hectares of the coastal and offshore areas of which about 833,000 hectares of the arable lands, constitute nearly 52.8 per cent net cultivable saline area dispersed in 64. Upazila of 13 districts are affected by different degrees of salinity. Coastal area in Bangladesh constitutes 20% of the country of which about 53% are affected by different degrees of salinity [5].

Potatoes are relatively sensitive to salinity [6], particularly in the early growth stages [7,8]. High salt contents reduce the growth and production of potato by affecting physiological processes, including modification of ion balance, water status, mineral nutrition, stomatal behavior and photosynthetic efficiency [9]. Salt stress has various effects on plant such as increased respiration rate and ion toxicity, membrane instability resulting from calcium and potassium displacement by sodium membrane permeability [10], and decreased efficiency of photosynthesis [11,12]. The most important process that is affected by salinity is photosynthesis [13].The average yield of potato in Bangladesh is only 18 MT/ha although the yield potential, or achievable yield, has been reported to be as high as 40 MT/ha. It appears that there is scope for increasing the yield of potato by narrowing the yield gap [14].

The southern belt of Bangladesh is affected by salinity in about 0.83 million hectares [15]. Most of the saline areas remain fallow during rabi season. By the expansion of potato cultivation in these areas, part of the food crisis may be mitigated. So, suitable varieties of potato are essential for these regions. Studies on salt

tolerance mechanisms in potato are also rare. Considering the importance and constraints to cultivate potato in saline areas of Bangladesh an investigation will be carried out with the following objectives: to find out the salinity tolerant varieties of potato and to evaluate the growth and yield performance of potato varieties under different salinity level.

## 2. MATERIALS AND METHODS

### 2.1 Experimental Site and Design

A pot experiment was conducted at the Horticulture Research field and Horticulture Laboratory of Bangabandhu Sheikh Mujibur Rahman Agricultural Univeristy, Gazipur, Bangladesh during December 2011 to April 2012. The experiment was laid out in the two factor completely randomized design (CRD) with the three replications.

### 2.2 Treatments

#### 2.2.1 Plant materials

Ten potato varieties (Diamant, Lady Rosetta, Provento, Felsina, Granola, Asterix, Cardinal, Sagita, Shilbilati and Lal Pakri) were considered as the first treatment variables in this study. The tubers of first eight HYV potato genotypes were collected from Tuber Crop Research Center, Bangladesh Agricultural Research Institute, Gazipur and local varieties were collected from Bogra.

#### 2.2.2 Salinity Level (NaCl)

Four levels of salt (NaCl) ($S_o$= 0.50 dS/m, $S_1$= 3.25 dS/m, $S_2$= 6.95 dS/m and $S_3$= 8.90 dS/m) were considered as the second treatment variables in this study. The United States Salinity Laboratory Staff had defined a saline soil as one having electrical conductivity of saturation extract of soil greater than 4 mS $cm^{-1}$ and an exchangeable sodium percentage less than 15% [16].

### 2.3 Cultivation Procedures

There were 120 earthen pots and each contained 10 kg of soil. Recommended doses of manures and fertilizers at the following rates were applied in each pot as basal dose during pot preparation [17]. The tubers of selected genotypes were planted in each pot on December 07, 2011. After 20 days of planting treatment was applied and irrigated every two days interval. 2 ds/m and 6ds/m saline water was used to raise 0.5 ds/m and 3.25 ds/m respectively. To reach 6.95 ds/m first fifteen days pots were irrigated at 6 dS/m and then 8 ds/m at 2 days interval. Similarly, pots were irrigated at 6 ds/m (first 7 days) and 8 ds/m (next 7 days) and then 12 ds/m to reach 8.90 ds/m at the same interval to avoid osmotic shock. Finally, the electrical conductivity of the soil against treatment reached. It was measured by Electrical Conductivity meter. It was taken 30 days to raise the soil salinity up to the treatment. These levels of salinity were maintained up to final harvest. Leaves were collected at early stages of plant (December 27, 2011) just before application of salinity treatment in the pots. At the vegetative growth stage plant height, the number of leaves and fallen leaves were counted. The tubers were harvested on February 28, 2012.

### 2.4 Physiological Parameters Determined at Different Salinity Levels in Potato Varieties

#### 2.4.1 Membrane leakage

Samples were washed with three changes of distilled water to remove solutes from leaf surfaces and damaged areas. Leaf discs were placed in a Pyrex test tube (15 × 25 mm) into 15 ml solution of a given concentration (0.5 dS/m, 3.25 dS/m, 6.95 dS/m and 8.90 dS/m) NaCl salinity tests. Samples were incubated at 10ºC for 24 hours, after which media were drained and samples washed with five changes of distilled water. Samples were incubated with 15 ml of distilled water and kept at 10ºC for 24 hours in the dark. Tubes were then brought to 25ºC and the electrical conductivity (EC) of the incubation medium was read using a conductivity meter after a vigorous mixing of the tube's contents by hand. Following the initial reading, samples were autoclaved at 121ºC temperature and 15 PSI pressure for 15 minutes to kill leaf tissues, brought to 25ºC and a final reading was obtained.

Calculation of the percentage injury of was performed as follows:

$$\% \text{ Injury} = 1- [1- (T_1/T_2)/ 1- (C_1/C_2)] \times 100$$

Where T and C refer to the EC values of stress treated and control tubes and 1 and 2 refer to the initial and final EC, respectively [18].

#### 2.4.2 Chlorophyll content

The chlorophylls of the mature leaves were estimated by the following method of [19] with some modification. Fresh plant material (1g) was roughly homogenised in morter by keeping the temperature at 2ºC in dark condition and extraction was carried out using 90% acetone, with addition of a pinch of magnesium carbonate to protect and stabilize the chlorophylls. This extract was filtered through Whatman No.1 filter paper under suction using funnel. The residue was washed thoroughly 2-3 times with 90% acetone, collecting all the washings in the same filtrate and final volume of the filtrate was made to 100 ml with 90% acetone. Absorbance of chlorophyll 'a' and 'b' was recorded using double beam spectrophotometer (Model 200-20, Hitachi, Japan), at 663 and 645 nm using 90% acetone as blank. Following formulae were used to determine the chlorophylls content.

Chlorophyll 'a' = X = [12.7 x A663 - 2.69 x A645] x V/ (1000 x W)

Chlorophyll 'b' = Y = [22.9 x A645 - 4.68 x A663] x V/ (1000 x W)

Total chlorophyll (a + b) =Z= [8.02xA663+ 20.20 x A645] x V/ (1000 x W)

#### 2.4.3 Ion uptake

Oven dried grinding 0.5 g sample was taken into 50 ml conical flask and 5 ml $HNO_3$+ $HClO_4$ was added into it. After that, it was transferred into digestion chamber for 2.5 hours. Then it was cool down. Again, 20 ml distilled water was added and heated with digestion chamber at 280ºC for 30 minutes. The solution was then transferred into 100 ml volumetric flask with filter paper and made the volume 100 ml (stock solution). 5 ml extract solution in addition with 20 ml distilled water was taken into 50 ml volumetric flask. At last, 1 ml $LnCl_2$ was added and the volume was made 50 ml with distilled water. Finally, reading of $Na^+$ and $K^+$ was taken by atomic absorption spectrophotometer by the following equation [20]:

$$\% \text{ Ion} = \{(S-B) \times CF \times DF\}/10000$$

Where, S= Absorbance value of the sample, B= Blank value, CF= Concentration factor and DF= Dilution factor.

##### *2.4.3.1 Sodium/Potassium ratio ($Na^+/K^+$)*

The $Na^+/K^+$ in each genotype at control and saline conditions were calculated as follows:

$$Na^+/K^+ = \frac{\text{Percent } Na^+}{\text{Percent } K^+}$$

#### 2.4.4 Tuber yield of potato as affected by salinity

Tuber weight was weighted in gram. Per plant tuber yield was calculated after harvest.

### 2.5 Data Analysis

The collected data from the experiment were analyzed by using statistical package programme MSTAT-C to illustrate the statistical significance of the experimental results developed by Gomez and Gomez [21]. The means differences were compared by Dancan's Multiple Range Test (DMRT) at 1% level of significance.

## 3. RESULTS AND DISCUSSION

### 3.1 Effects of Salinity Levels on the Physiological Parameters of Potato Varieties

#### 3.1.1 Membrane leakage

With increasing salinity levels the percent injury was found to increase significantly (Fig. 1). The highest injury (73.78%) was found in Shilbilati and the lowest was in Sagita (59.23%) at the highest level of salinity (8.90 dS/m). A significant variation was found among the genotypes. The highest percentage of injury (69.45%) was noticed in Shilbilati followed by Lalpakri (64.57%) and the lowest (30.15%) of that was in Sagita followed by Felsina (32.14%) and Lady Rosetta (44.76%) at 6.95 dS/m. With the increased salinity levels the membrane leakage percentage gradually increased. At 3.25 dS/m Felsina, Sagita, Lady Rosetta and Provento showed better performance. On the other hand, Granola, Asterix, Diamant, Cardinal, Lalpakri and Shilbilati acted as salinity sensitive variety. Similar results were obtained by Lutts et al. [22] and Kaya et al. [23] who reported that high salt concentration increased the membrane permeability of sensitive rice varieties and strawberry plants, respectively. Under salinity stress plant membranes are subject to changes often associated with increases in permeability and

loss of integrity [24]. Therefore, the ability of a cell membrane to control the rate of ion movement in and out of cells is used as a test of damage to a great range of tissue. However, electrolyte leakage was observed in all of the cultivars in the study despite the fact that membrane injury increased in a condition of high soil salinity.

### 3.1.2 Chlorophyll content

Leaf chlorophyll was significantly reduced in stressed plant. Felsina recorded the maximum total chlorophyll content followed by Sagita. Significantly the lowest total chlorophyll content was recorded in Shilbilati followed by Lalpakri (Fig. 2). Diamant, Granola and Asterix varieties showed moderate performance. The higher values of chlorophyll attributed to an increased photosynthetic rate, more dry matter production and higher productivity [25] and could be a reason for higher yield of salt tolerant genotypes under salt stress [26]. The reduction in chlorophyll contents under stress environments was observed in potato varieties by Ashraf et al. [27] and Khan et al. [25] who reported severe reduction in salt sensitive genotypes.

From the present investigation, it was clear that the chlorophyll content in the leaves of potato is increased at lower levels of salinity. Such an increase in the chlorophyll content might be due to the osmotic adjustment mechanism developed by the plants while a decrease at higher levels might be associated with disruption in cellular functions and damage to photosynthetic electron transport chain due to accumulated ions. The present results on chlorophyll content were in agreement of the report of Khan et al. [25] and Harinasut et al. [26]. They reported that chlorophyll content were the maximum in salt tolerant genotypes compared to salt sensitive varieties in potato.

### 3.1.3 $Na^+/K^+$ in roots and leaves

The $Na^+/K^+$ content in roots and leaves were significantly affected by salinity treatments (Table 1). $Na^+/K^+$ content in roots and leaves were highest (1.89 and 1.57 respectively) at highest salinity level (8.90 dS/m) in Shilbilati and the lowest (0.21 and 0.14 respectively) was at control in Sagita and Felsina. $K^+$ content in leaves decreased with increasing salinity levels. At control, Shilbilati scored 0.24 and 0.61 respectively whereas at 8.90 dS/m it was 1.89 and 1.57 respectively. It is clear that there was marked increase of $Na^+/K^+$ ratio with the increase of salinity level. On the other hand, in case of 3.25 dS/m the ratio was comparatively lower than that of 6.95 dS/m.

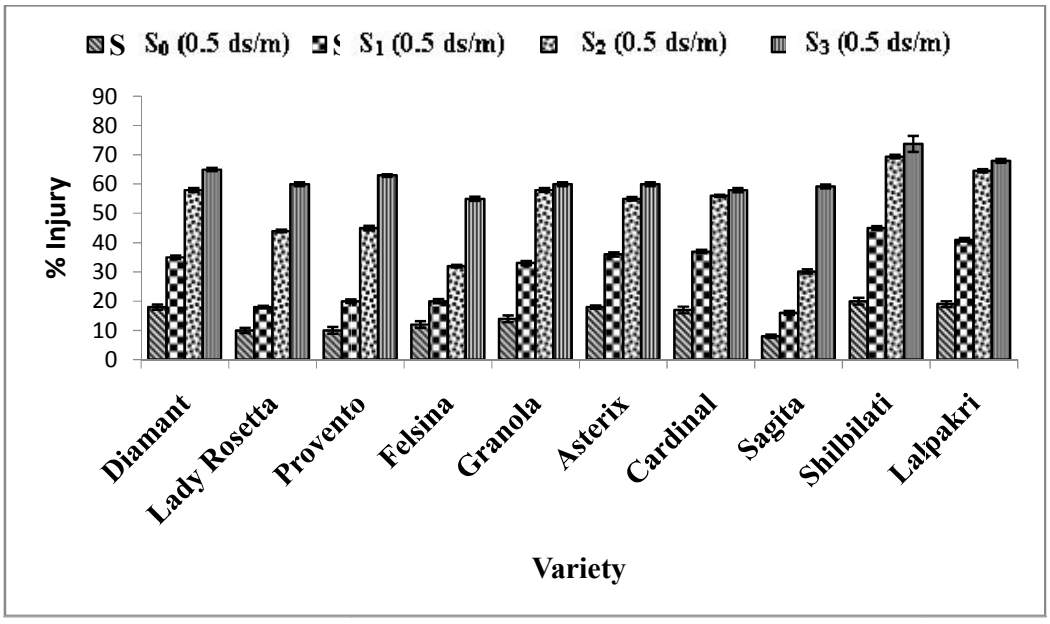


**Fig. 1. Effect of salinity on membrane leakage (%) of potato varieties**

**Table 1. Na+/K+ in root and leaves of potato varieties at different levels of Salinity**

| Treatment | $Na^+/K^+$ ratio | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Root | | | | Leaf | | | |
| Salinity / Variety | 0.5 dS/m | 3.25 dS/m | 6.95 dS/m | 8.90 dS/m | 0.5 dS/m | 3.25 dS/m | 6.95 dS/m | 8.90 dS/m |
| Diamant | 0.37 opq | 1.23 ghi | 1.52 cde | 1.56 b-e | 0.31 qr | 1.24 b-h | 1.28 b-h | 1.26 b-h |
| Lady Rosetta | 0.30 opq | 0.76 n | 1.09 h-l | 1.17 hij | 0.21 qr | 0.80 mno | 0.95 j-n | 0.97 i-n |
| Provento | 0.453 op | 1.10 h-l | 1.18 hij | 1.26 ghi | 0.24 qr | 0.75 no | 1.09 f-l | 1.18 d-k |
| Felsina | 0.29 opq | 0.81 mn | 0.94 k-n | 1.04 ijkl | 0.14 r | 0.70 no | 0.92 k-n | 0.89 lmn |
| Granola | 0.41 opq | 1.10 h-l | 1.30 fgh | 1.41efg | 0.23 qr | 1.08 g-l | 1.16 e-k | 1.22 c-i |
| Asterix | 0.42 opq | 0.94 k-n | 1.41 efg | 1.49 def | 0.23 qr | 1.21 d-j | 1.23 b-i | 1.34 a-g |
| Cardinal | 0.50 o | 1.23 ghi | 1.50 def | 1.74 ab | 0.31 qr | 1.05 hm | 1.39 a-e | 1.48 abc |
| Sagita | 0.21 q | 0.79 mn | 0.90 lmn | 0.98 j-m | 0.19 qr | 0.71 no | 0.88 lmn | 0.93 k-n |
| Shilbilati | 0.24 pq | 1.26 gh | 1.71 abc | 1.89 a | 0.61 op | 1.43 a-e | 1.50 ab | 1.57 a |
| Lalpakri | 0.39 opq | 1.16 hijk | 1.54 b-e | 1.66 bcd | 0.42 pq | 1.31 a-h | 1.35 a-f | 1.45 a-d |
| Level of Significance | ** | | | | ** | | | |
| CV % | 8.64 | | | | 11.74 | | | |

** *indicates significant at 1% level and Values with different letters are significantly different; Values with same letters are not significantly different*

Potato grown under high salinity (8.90 dS/m) accumulated the maximum amounts of $Na^+$ in their leaves and roots. So, the growth of these plants was affected due to high concentration of $Na^+$ and low ratios of $K^+$ [28,29].

### 3.2 Effects of Salinity Levels on the Tuber Yield of Potato Varieties

The effect of salt stress on the tuber yield plant$^{-1}$ was statistically significant (Table 2). The highest yield plant$^{-1}$ (363.3 g) was recorded in Sagita at control condition and the lowest yield (19.00 g) was recorded in Shilbilati at 8.90 dS/m level of soil salinity. At 3.25 dS/m, the highest tuber yield plant$^{-1}$ (290.0 g) was in Sagita and the lowest (56.67 g) was in Shilbilati. Tuber yield decreased with increasing salt level. At 8.90 dS/m, there was a marked reduction in tuber yield. It was found that Sagita showed the maximum yield (121.7 g) followed by Felsina (118.3 g), Lady Rosetta (101.7 g), Provento (81.67 g), Granola (61.67 g, Asterix (50.33 g) and Diamant (50.00 g) at 8.90 dS/m. The lowest yield was recorded in Shilbilati (19.00 g) followed by Cardinal (38.33 g) and Lalpakri (42.33 g) at 8.90 dS/m.

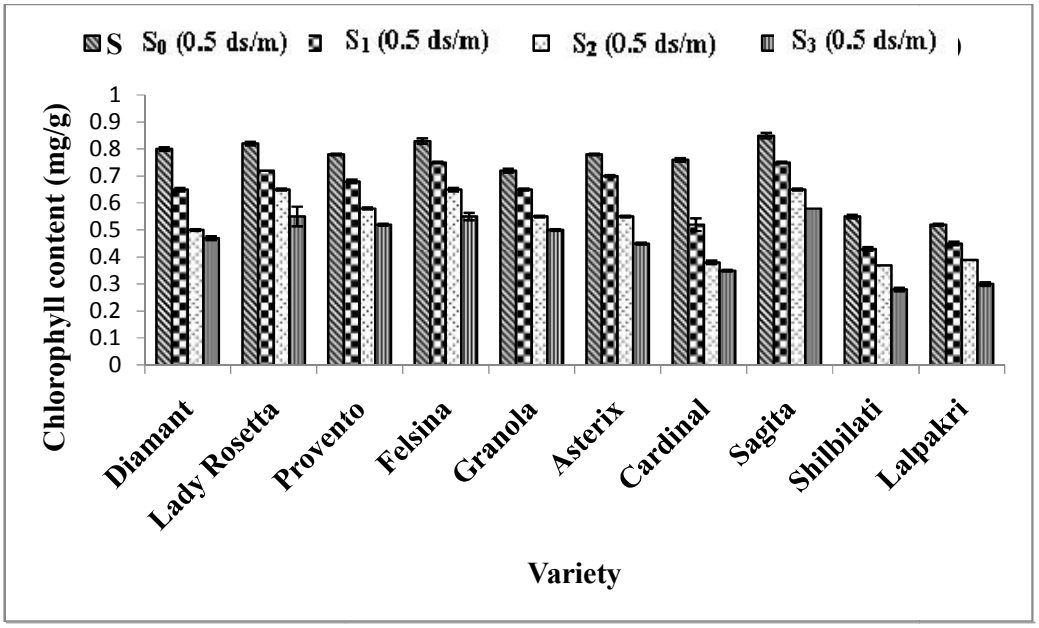


**Fig. 2. Effect of salinity on total chlorophyll content in potato varieties**

**Table 2. Salinity effect on tuber weight (g) of potato varieties at different levels of Salinity**

| Treatment | Tuber weight (g) | | | |
|---|---|---|---|---|
| Salinity / Variety | 0.5 dS/m | 3.25 dS/m | 6.95 dS/m | 8.90 dS/m |
| Diamant | 293.3 ef | 144.7 lm | 93.33 pqr | 50.00 tuvw |
| Lady Rosetta | 310.0 cd | 222.7 h | 150.3 klm | 101.7 pq |
| Provento | 345.0 b | 205.0 i | 106.7 op | 81.67 r |
| Felsina | 320.0 c | 260.0 g | 198.3 l | 118.3 no |
| Granola | 303.3 de | 165.0 j | 103.3 pq | 61.67 st |
| Asterix | 315.0 cd | 156.7 jkl | 91.67 qr | 50.33 tuvw |
| Cardinal | 263.3 g | 91.33 qr | 64.67 s | 38.33 w |
| Sagita | 363.3 a | 290.0 f | 210.0 hi | 121.7 n |
| Shilbilati | 141.7 m | 56.67 stu | 43.33 uvw | 19.00 x |
| Lalpakri | 160.0 jk | 65.00 s | 52.67 stuv | 42.33 vw |
| Level of significance | ** | | | |
| CV (%) | 3.92 | | | |

*** Indicates significant at 1% level and Values with different letter(s) indicate significant differences by Duncan's Multiple Range Test at 1%*

We found that variety Sagita and Felsina showed around 40% yield reduction at 6.95 dS/m whereas, Lady Rosetta 52% and Provento 58% reduction showed. On the other hand, Shilbilati reduced 70% and Lalpakri 67% respectively at 6.95 dS/m. At 8.90 dS/m, all the selected ten genotypes showed above 60% yield reduction.

Increasing salinity can also significantly reduce the total and average yield of different potato cultivars, and the presence of 50 mM NaCl can result in a 50% reduction in the yield of saline sensitive potato plants [30]. The 50% reduction in tuber yield of the genotypes under salt stress in relation to the normal yield has been considered as critical limit for the selection/rejection of the genotypes [31].

## 4. CONCLUSION

The highest membrane injury was found in Shilbilati and the lowest was in Sagita at the highest level of salinity. It was found that Sagita showed the maximum yield followed by Felsina, Lady Rosetta and Provento. The next position scored by Granola then Asterix, Diamant and the lowest was recorded in Shilbilati followed by Cardinal and Lalpakri at 8.90 dS/m. Regarding all the parameters Sagita, and Felsina showed better performance. Performance of Lady Rosetta and Provento is also satisfactory. On the other hand the lowest performance was recorded in Shilbilati followed by Lalpakri, Cardinal, Diamant, Asterix and Granola among the selected genotypes. The better performed varieties may be recommended for the saline prone areas in Bangladesh.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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