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Field performance of some potato varieties under different saline conditions of Bangladesh

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In the rabi season of 2019-2020, an experiment in three distributed replicas at three different locations: Satkhira (AEZ-11), Koyra (AEZ-13) and Bagerhat (AEZ-11) were conducted in the farmer's field of Khulna division to select suitable soil salinity resistant varieties. Fourteen exotic potato varieties (*Solanum tuberosum*) have been characterized under saline stress conditions of the coastal areas of Bangladesh. Tuber skin color BARI Alu-35, 37, 40, 41, 73 and 81 are white to light yellow in color and BARI Alu-36, 72, 78 and 79 were red. The highest emergence (%) at 30 DAP was found in BARI Alu-72 along with highest foliage coverage (%) at 60 DAP. Moreover, BARI Alu-72 produced number of stem hill^{-1}, number of tuber plant^{-1}, weight of tuber plant^{-1}, weight of fresh plant (kg), dry matter tuber and tuber yield. Varietal yields ranged from 20.98 to 29.75 t ha^{-1}. Among the varieties, BARI Alu-72 yielded highest (29.75 t ha^{-1}) followed by BARI Alu-73 (28.01 t ha^{-1}) and BARI Alu-79 (27.66 t ha^{-1}). Since BARI Alu-72 produced comparatively higher yield form other varieties, it could be considered suitable for costal region. If it suits into their cropping pattern, the variety may be a good option for farmers by increasing cropping intensity, benefit financially and meet their nutritional demands.

Key words: Costal area, dry matter, potato, soil salinity, variety, yields performance.

INTRODUCTION

Potato (*Solanum tuberosum* L.) known as *Alu* is an edible tuber yielding plant of the family Solanaceae. The potato plant is an annual herbaceous plant, typically propagated by planting tuber pieces that contain two or three eyes. Potato is popularly known as "The King of Vegetables" (Johora et al., 2017). Potato stands in fourth position among largest food crops in the world after rice, wheat and maize, owing to its good yield potential and high nutritious value. It is a core component of the sustainable global food frame work that provides more food energy on less ground than rice, wheat and maize. Considering the importance, potato stands in second position after rice (Aus, Aman, Boro). Due to its many uses as vegetables and tasty processed products, potato recently became Bangladesh's leading food crop (Saha and Hossain, 2011). More than half of the world's potato supply from developing countries such as Bangladesh and also considered a vital source of nutrition and income

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for number of farmers (Sabur and Gangwar, 2005). It is revealed that total potato production is 96, 55,082 M. Ton from 20.614 Acre of land with (BBS, 2019). Meanwhile, there is a significant gap between the average national potato yields in Bangladesh compared to other potato-growing nations, such as the France, Germany, UK, USA and Netherlands. For example, the yield of potatoes in the UK is roughly 48 MT/ha, two and a half times greater than in Bangladesh (Saha and Hossain, 2011). Using high yielding varieties could be a solution to lessen this yield gap.

One of the most ecological threats to global agriculture is salinity of soils (Zhang et al., 2007). It leads to an imbalance in plant physiological processes and also impact the quality and production of potatoes in mainly semi-arid growing areas (Ahmed et al., 2020). Moreover, salinity produces an unfavorable hydrological condition that restricts the regular development of crops (Amin et al., 2008). In extreme saline environment, a little crops/cultivar can subsist or achieve economic yield (Shrivastava and Kumar, 2015). About 8 million hectares of land (6% of the total land area) and 50% of the world's irrigated land are at risk of salinity (Charfeddine et al., 2019). In Bangladesh, salinity affected area was recorded 83.3 million hectares roughly in 1973, which was raised to 102 million hectares in 2000.The number raised to 105.6 million hectares in 2009 and continues to expand. Salinity has risen in the country around 26% in the last 35 years, extending into non-coastal areas as well (SRDI, 2009). It impacts crops at the critical growth stages based on salinity level which decreases yield and, in extreme cases, overall yield loss (Rasel et al., 2013). Soil salinity is a seasonal problem in Bangladesh that severely spoil crop production especially in rabi season in the saline belt, but it reaches almost neutral condition in Kharif-II and does not immensely hamper production (Khan et al., 2008). The magnitude of the issue of soil salinity in Bangladesh's seaside areas rises with soil desiccation (Haque, 2006).

Potatoes, especially in the early growth phases, are relatively sensitive to salinity (Levy, 1992; Nadler and Heuer, 1995; Maas and Hoffman, 1997). Photosynthesis is the most significant mechanism affected by salinity (Ashraf and Shahbaz, 2003; Sayed, 2003; Hayat et al., 2010). Moreover, salt stress enhances respiration rate, ion toxicity, and membrane instability that lead to poor growth of plants (Gupta et al., 2002). By disturbing physiological processes, including ion balance change, water status, stomata actions, mineral nutrition and photosynthetic efficacy, high salt content lowers potato growth and production (Munns, 2002).

Salinity is impacted in around 0.83 million hectares of the southern belt of Bangladesh (BARC, 2018). During rabi season, most of the saline areas stay fallow. A part of food shortage can be mitigated by expanding potato production in these regions. Therefore, salinity tolerant high yielding potato varieties are crucial need for this area. Considering the importance and constraints to cultivate potato in saline areas of Bangladesh, an experiment was carried out with the objective to evaluate potato varieties' growth and yield efficiency of at multiple levels of salinity.

MATERIALS AND METHODS

Farmer's field was chosen to conduct the experiment in the form of three replicas in three different places Satkhira (AEZ-11), Koyra (AEZ-13) and Bagerhat (AEZ-11) of Khulna division in the *rabi* season of 2019-2020. It was a medium highland where soil salinity exist 2.92 to 5.43 dSm^{-1} during the time of planting. Ten varieties were used as experimental materials which 9 varieties viz. BARI Alu-36, BARI Alu-37, BARI Alu-40, BARI Alu-41, BARI Alu-72, BARI Alu-73, BARI Alu-78, BARI Alu-79 and BARI Alu-81 were used in the study. BARI Alu-35 was considered as check. These varieties were collected from Bangladesh Agricultural Research Institute (BARI), Joydepur, Gazipur. The study was constructed with three replications in Randomized Complete Block Design (RCBD). The experimental field was divided in 3 blocks representing 3 replications and each block had 10 individual plots. 3 replications were made in 3 districts. The total numbers of plot were 30. Unit plot size was 2 m × 3 m. Urea, Cowdung, Triple super Phosphate, Muriate of potash, Gypsum and Boron were applied to the plots for potato cultivation at the rate of 350, 10000, 200, 250, 100 and 6 kg ha^{-1}, respectively (BARC, 2018). Total amount of cowdung, triple super phosphate, muriate of potash, gypsum and boron were added as basal dose during the final preparation of land. Remaining urea was applied after sowing 35 DAS (days after sowing). 'A' grade whole tuber of was planted maintaining spacing of 60 cm × 25 cm on December 05, 2019. Weeding was done manually from 15 DAS up to final harvest. Weeding was performed six times to keep the plots clean of weeds. At the time of the finished land preparation, Furadan (Carbofuran) 5 G at 20 kg has been used to control cut warm. After 38 days of planting, a light irrigation was given. Again after 52 and 63 days of planting, secure at 2 g/L water was sprayed to avoid late blight infestation due to vulnerable foggy weather. At a 15-day interval between planting and potato harvest, the soil salinity of the test plots was measured. It started on 05 December, 2019 and ended on 13 March, 2020. Soil samples were also taken before planting and after potato harvesting to assess the nutrient condition of soil in experimental plots. Yield and yield harvesting was done on 13 March 2020. Ten potato plants were randomly picked for data collection from each plot. The outer row plants and the very end of the middle rows have been omitted from data collection. Data on the morphological and yield parameters % emergence at 30 DAP, % foliage coverage at 60 DAP, plant height at 60 DAP, number of stem $hill^{-1}$, number of tuber $plant^{-1}$, weight of tuber $plant^{-1}$, days to maturity, weight of fresh plant (kg), dry matter shoot, dry matter tuber and tuber yield were collected from the selected plants during experimental phase. The data was analyzed using the program R (4.0.2) for variance analysis (Table 1 and Figure 1).

RESULTS AND DISCUSSION

Salinity

Upper trend for all three locations was found by analyzing the salinity data (Figure 1). The initial salinity was lowest (2.92 ds/m) in Bagerhat and highest (4.12 ds/m) was in Satkhira. In Koyra, the increase rate was comparatively

Table 1. Monthly average air temperature, average humidity (%) and total rainfall during the experimental period from November 2019 to March 2020 in Satkhira, Koyra and Bagerhat.

District	Month 2019-2020	Monthly average air temperature (°C)		Average humidity (%)	Total rainfall (mm)
		Maximum average	Minimum average		
Satkhira	November	29.76	20.05	80	171.9
	December	25	14.75	87	11.4
	January	24.36	13.39	87	34.4
	February	27.00	14.76	89	2.5
	March	31.95	20.14	91	84.8
Koyra	November	31.5	17.2	81	0.00
	December	27.5	11.6	84	0.00
	January	29	11.3	78	0.00
	February	30.5	10.8	74	2.5
	March	34.5	19.5	71	10.00
Bagerhat	November	32.5	17.4	76	0
	December	28.80	9.6	77	2.4
	January	30.80	10.90	71	0
	February	33.40	12.00	67	10
	March	35.50	14.70	64	41.6

Source: Satkhira, Khulna and Bagerhat Meteorological Station

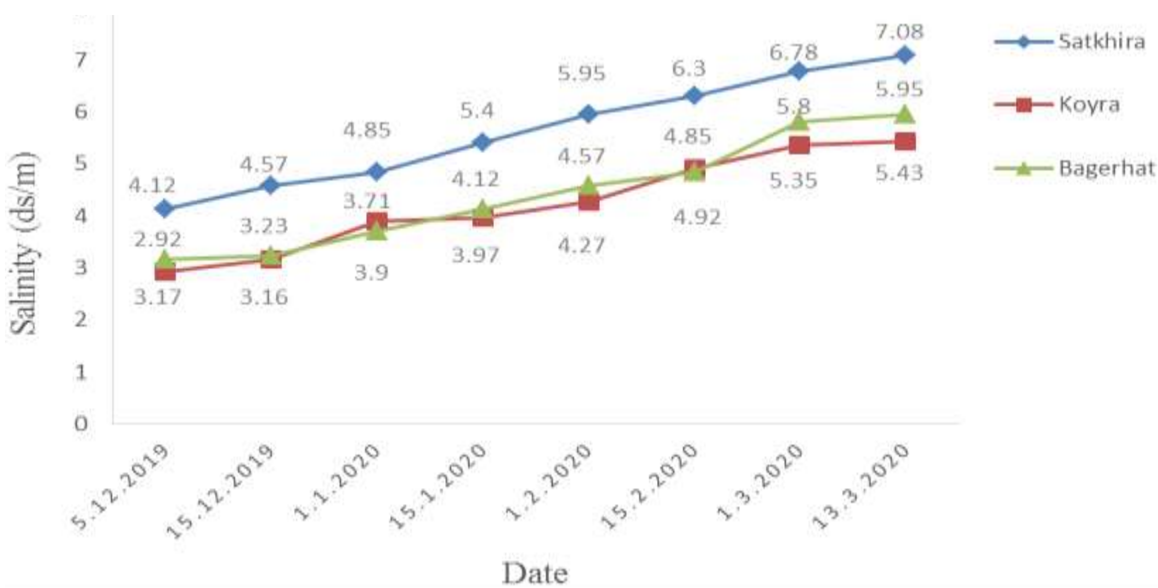

Figure 1. Soil salinity during crop growing period at Satkhira, Koyra and Bagerhat districts.

low compared to Bagerhat and Satkhira. The maximum salinity (7.08 ds/m) was detected in Satkhira, where it was 5.95 ds/m in Bagerhat and 5.43 ds/m in Koyra.

Emergence (%) at 30 DAP

Significant difference was noted between the varieties in emergence percentage. BARI Alu-72 recorded the highest emergence (82.35%), which was statistically similar to BARI Alu-73 (78.04%), BARI Alu-79 (78.27%) and BARI Alu-81 (79.02%). A previous study (Anonymous, 1987) reveals that the emergence rate ranged from 82 to 93% among six Dutch varieties, which was closely linked to the results (Figure 2). Alom et al. (2003) found out significant variation among fifteen

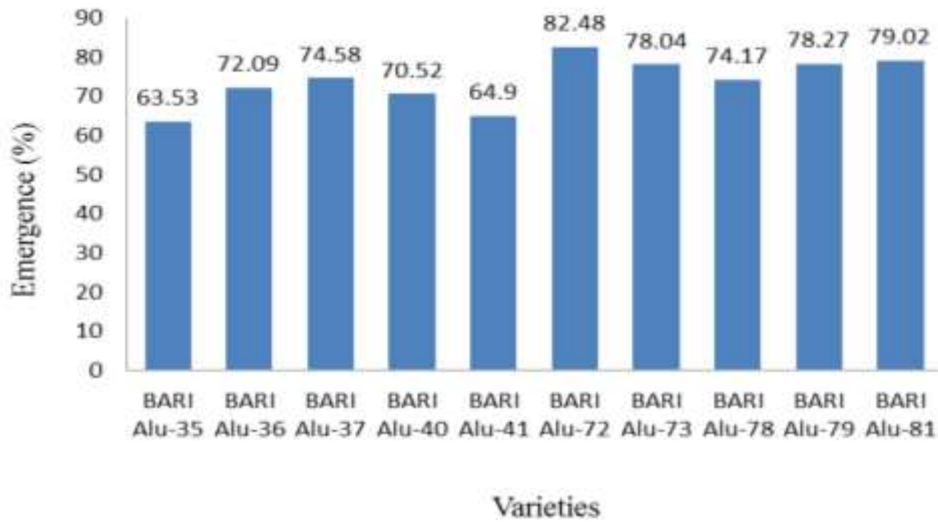

Figure 2. Variations in emergence percentage at 30 DAP of different potato varieties.

varieties of potato ranges from 91 to 63% where highest emergence was Cardinal (91%), Hera (90%), Diamont (89%) and Mondial (88%) and lowest Granola (63%). The emergence could vary due to varietal genetic potentiality, tuber seed quality or degree of salinity. Response of potato to salinity varies with the crop stages and it becomes severe when salinity imposed during planting because it retards the emergence of potato plants (Levy 1992). Salt stress retards the germination and delayed the emergence of potato tubers (Levy, 1992; Jefferies, 1996). Moreover, high salinity responsible for rot of the seed tubers and this might be one of the major causes of sufficient emergence under saline condition (Ghosh et al., 2001).

Foliage (%) coverage at 60 DAP

Coverage of the foliage at 60 DAP (Days after planting) of the varieties differed significantly (Table 3). The foliage coverage (86.33) was maximum in the plant of BARI Alu-72 and the lowest foliage coverage (66.90) was found from the plant BARI Alu-35 which was statistically similar BARI Alu-36 (70.01). Alom et al. (2003) observed significant variation among fifteen varieties of potato ranges from 1125 to 415.46 cm^2 where maximum canopy was Ailsa (1125.22 cm^2) and lowest Multa (445.12 cm^2). Difference in nitrogen use efficiency could be a reason for variations in the foliage coverage. Difference in nitrogen use efficiency could be a reason for variations in the foliage coverage. Salinity is an osmotic stress and it causes physiological drought which hampers the cell expansion of the plants (Hsiao and Xu, 2000). Plants reduce the leaf area, that is, foliage area to cope up with the drought condition by reducing transpiration rate (Negrão et al., 2017).

Plant height at 60 DAP

The height of the plants varies considerably between varieties (Table 3). The tallest (64.53) plant was observed in BARI Allu-41 variety. Statistically it was similar with BARI Alu-78 (62.50 cm), BARI Alu-40 (62.12 cm) and BARI Alu-36 (61.57 cm) and the shortest was BARI Alu-79 (55.27 cm), BARI Alu-81 (55.27 cm) and BARI Alu-37(55.83 cm). A significant higher height (53.9 cm) of the variety Lal Pakir was recorded by Islam et al. (1996). In different studies, plant height differences of the same variety may have been attributed to planting materials. Alom et al. (2003) reported that plant height varied from 44.91 to 31.42 cm where height was Binella (44.91 cm) and lowest was Chamak (31.42 cm). Plant height depends on the genetic constitution and proper growth of the plant. Plant height, leaf area and fresh weight accumulation were decreasing depending on increased salinity (Heuer and Nadler, 1995). Salinity inhibits the process of cell division and cell expansion and that is why the plant growth as well as plant height of the potato plants is retarded (Gao et al., 2014; Mezanur-Rahman et al., 2016).

Number of stems hill^{-1}

Wide variation was noticed among the varieties for number of stems per hill (Table 3). BARI Alu-722 had the largest number of stems per hill (6.26) followed by BARI Alu-41(5.51) and BARI Alu-40 (5.60). The lowest number of stems hil^{-1} was BARI Alu-35 (3.13). Parallel finding was detected in another study. Studies (Anonymous, 1987) indicated that the stem hill^{-1} number varied from 4.50 (Cardinal) to 1.5 (Charlotte) in various varieties. Alom et al. (2003) found out significant variation among fifteen

Table 2. Morphological characteristics of different varieties of potatoes.

Variety	Growth habit	Tuber shape	Skin colour
BARI Alu-35	Spready	Oval	Light yellow
BARI Alu-36	Spready	Oval	Red
BARI Alu-37	Spready	Oval	Light yellow
BARI Alu-40	Spready	Round	Light yellow
BARI Alu-41	Spready	Round	Red
BARI Alu-72	Spready	Round	Red
BARI Alu-73	Spready	Oval	Light yellow
BARI Alu-78	Spready	Round	Red
BARI Alu-79	Spready	Oval	Red
BARI Alu-81	Spready	Oval	Light yellow

Table 3. Effects of varieties on yield and yield contributing characters of potato.

Variety	% Foliage coverage at 60 DAP	Plant height at 60 DAP	No. of stem hill^{-1}	No. of tuber plant^{-1}	Weight of tuber plant^{-1} (g)	Days to maturity	Weight of fresh plant (kg)	Dry matter (%)		Tuber yield (t ha^{-1})
								Shoot	Tuber	
BARI Alu-35	66.90^{d}	59.41^{bc}	3.13^{e}	6.28	410.99^{f}	90^{a}	0.80^{e}	21.40^{c}	14.67^{e}	20.98^{f}
BARI Alu-36	70.01^{d}	61.57^{ab}	3.76^{de}	7.15	446.67^{ef}	86^{cd}	1.70^{c}	16.43^{ef}	16.10^{e}	21.17^{f}
BARI Alu-37	80.23^{bc}	55.89^{c}	4.90^{bc}	6.39	524.87^{bc}	88^{bc}	0.67^{e}	26.10^{a}	18.13^{d}	23.68^{e}
BARI Alu-40	77.46^{c}	62.12^{ab}	5.60^{ab}	7.37	549.44^{abc}	86^{cd}	2.53^{ab}	18.03^{d}	19.06^{cd}	26.74^{c}
BARI Alu-41	77.84^{c}	64.53^{a}	5.81^{a}	8.34	530.28^{bc}	90^{ab}	2.86^{a}	18.96^{d}	20.90^{b}	27.37^{c}
BARI Alu-72	86.33^{a}	58.73^{bc}	6.26^{a}	9.70	583.20^{a}	90^{ab}	2.80^{a}	18.76^{d}	23.73^{a}	29.75^{a}
BARI Alu-73	80.16^{bc}	58.53^{bc}	4.50^{cd}	8.85	549.61^{abc}	85^{d}	2.26^{b}	23.23^{b}	21.73^{b}	28.81^{ab}
BARI Alu-78	79.53^{bc}	62.50^{ab}	5.00^{bc}	9.11	474.90^{de}	88^{abc}	1.20^{d}	15.83^{f}	18.06	25.00^{d}
BARI Alu-79	82.27^{b}	55.27^{c}	4.62^{c}	8.41	556.71^{ab}	87^{cd}	2.63^{ab}	16.13^{f}	18.23^{d}	27.66^{bc}
BARI Alu-81	78.47^{c}	55.27^{c}	4.93^{bc}	9.24	502.57^{cd}	90^{ab}	2.50^{ab}	17.96^{de}	20.26^{bc}	27.12^{c}
$LSD_{0.05}$	2.63	4.61	0.79	NS	49.29	2.50	0.34	1.55	1.71	1.24
CV%	3.52	4.53	955	139.71	5.60	1.65	11.19	4.62	5.18	2.81

varieties of potato ranges from 4.95 to 2.19. Branching capacity of varieties may differ due to their own genetic potentiality and capacity to use nitrogen properly at vegetative stage. Under saline condition, plants uptake excess amount of Na instead of K and Ca. The NA content of leaves, stem and tubers increased with increase of salinity. However, sodium accumulation is preferentially higher in stem which might be a cause of lower stem per hill though this phenomenon also varied with the branching capacity of the varieties (Ghosh et al., 2001).

Number of tubers plant^{-1}

Varietal difference existed with respect to the number of tubers plant^{-1}. Non-significant variation found among ten varieties (Table 3). Maximum number of tuber plant^{-1} was found in the variety BARI Alu-72 (9.70) and the lowest was BARI Alu-35 (6.28). Tesfaye et al. (2012) found significant variation among the cultivars for tuber number plant^{-1} where highest number of tubers plant^{-1} (10.93) was recorded from Chala cultivar and lowest (6.7) in Badsha cultivar. Salinity tolerant capacity of varieties varied widely which could be a cause for difference in tuber number plant^{-1}. Salinity reduces the vegetative growth of the potato plants which ultimately reduce the photosynthetic area. Reduction of photosynthesis as well as growth of the plant reduces the tuber number per plant (Islam et al., 2018).

Tuber color and shape

In their shape, flesh and skin color, the tubers of many potato varieties under study showed great diversity (Table 2). BARI Alu-40, BARI Alu-41, BARI Alu-72 and BARI Alu-78 were round while BARI Alu-35, BARI Alu-36, BARI Alu-37, BARI Alu-73, BARI Alu-79 and BARI Alu-81 produced oval shape tuber.

The skin red color observed BARI Alu-36, BARI Alu-41, BARI Alu-72, BARI Alu-78 and BARI Alu-79, other

Figure 3. Different potato varieties during study period.

varieties were yellow in color. Akter et al. (1994) and Alom et al. (2003) found out different colors and shape in different varieties of potatoes (Table 2 and Figure 3).

Days to maturity

The varieties showed no substantial difference between the days needed for maturity. The minimum time of maturity (85 days) was required for the variety BARI Alu-73, whereas 90 days for maturity were reported for the variety BARI Alu-35, followed by BARI Alu-40 (90 days), BARI Alu-41 (90 days) and BARI Alu-81 (90 days). BARI Alu-73 was identified as the earliest bulking variety in this experiment and 88 to 90 days were required for most cases (Table 2). Alom et al. (2003) reported that days to maturity varied from 75 to 94 days where least period days to maturity was Heera (75 days) and maximum days to maturity KufriSindhuri (94 days). Alom et al. (2003) reported that days to maturity ranged from 75 to 94 days, with Heera having the least days to mature (75 days) and KufriSindhuri having the most days to maturity (94 days).

Varietal diversity and environmental variables such as temperature could change the time of maturity from variety to variety. Zhang et al. (2005) opined that, enhancement of salinity level delayed tuberization by 5 to 10 days (20 and 40 mmol NaCl) or inhibited completely (80 mmol NaCl) in addition to reduce in tuber yields.

Weight of tuber plant^{-1}

Weight of tuber plant^{-1} of the varieties varied markedly (Table 3). Weight of tuber plant^{-1} ranges from 583.20 to 410.99. The maximum weight of tuber plant^{-1} was found from BARI Alu-72 (583.20 g) which was statistically similar BARI Alu-79 (556.71 g) and the minimum tuber weight plant^{-1} was BARI Alu-35 (410.99 g). The observations of this experiment support the results of Akassa et al (2014), who reported that the weight of tuber plant^{-1} ranged from 425.7 to 683.3 g. Healthy tuber formation requires better vegetative growth which can differ by the saline tolerance capacity of the varieties. Moreover, genetic potentiality may also be responsible for different types of tuber formation. Salinity hampered the plant growth and development by lowering osmotic potential of soil solution, toxicity of salt and imbalance of nutrient uptake (Ashraf and Shahbaz, 2003). These factors hinder the physiological mechanism like photosynthesis, assimilate partitioning and retard the proper growth and development (Munns and James, 2003; Tester and Davenport, 2003).

Weight of fresh plant

Fresh plants weight varied significantly among the varieties (Table 3). The highest fresh plant weight (2.86 kg) was detected in BARI Alu-41 which was tracked by BARI Alu-72 (2.80 kg). The lowest fresh plant weight was detected in BARI Alu-37 (0.67 kg) which was followed by BARI Alu-35 (0.80 kg). Alom et al. (2003) observed significant variation among fifteen varieties, whereas highest weight was Petronese (2.90 kg) and the lowest was Heera (0.80 kg), malta (0.50kg), Granola (0.50 kg) and Cleopetra (0.50 kg). Plant itself reduces foliage coverage and biomass production to tolerate salinity. Plant did not take enough water from saline soil to maintain its growth and transpiration rate due to imbalance of the water potential of saline soil (Dahal et al., 2019). To tackle the wilting and oxidative burst, plants reduce morphological growth to minimize the transpiration rate as well as to protect the oxidative burning of the physical structures (Nishida et al., 2009).

Tuber yield (t ha^{-1})

In the case of tuber yield, different varieties display marked variation (Table 3). BARI Alu-72 yielded (29.75 t ha^{-1}) maximum which was closely related to BARI Alu-73 (28.81 t ha^{-1}) and BARI Alu-79 (27.66 t ha^{-1}). Minimum yield was recorded from BARI Alu-35 (20.98 t ha^{-1}), which was statistically parallel to BARI Alu-36 (21.17 t ha^{-1}). The yield of most of the varieties was within the range of 25 to 27 t ha^{-1}. Akter et al. (1994) also found similar type of result. The performance of Petronese, KufriSindhuri and Cardinal was statistically comparable (Iqbal et al., 1982), which is consistent with those observations. Significant volumes of leaves and stems led to the maximum yield, which allows to deposit larger photosynthesis amounts and eventually maximizes yield. However, a positive relationship was also found between tuber production and the number of stems per hill (Davies, 1969; Siddique et al., 1987). Tuber yield depends on the intensity of salinity level and tolerance potential of the potato varieties (Dahal et al., 2019). However, salinity reduces the photosynthesis by reducing rubisco enzyme activity, CO_2 uptake, stomatal conductance and nutrients uptake of the plants (Odemis and Caliskan, 2014; Akhtar et al., 2015). Changing of photosynthetic capacity and assimilates partioning influence the potato tuber yield (Dwelle et al., 1981). Salinity increases the carbohydrate, starch and nonstructural carbohydrate content in leaves and increases carbohydrate content in leaves and decreases tuber dry matter production which suggest that salinity inhibits the carbohydrate translocation to the tuber (Ghosh et al., 2001; Dahal et al., 2019).

Conclusion

Crop production in coastal saline zones especially during the Rabi season (dry season), is very poor due to the increase in soil salinity. It can be inferred that the results of various yield parameters of potato varieties BARI Alu-72 have a bright prospect of growing in the coastal region of Bangladesh under saline stress conditions. For higher yields and economic returns from potatoes, farmers in coastal saline areas may grow BARI Alu-72. It can also be suggested to grow BARI Alu-73 and BARI Alu-79 along with BARI Alu-72 for their high yield capacity. As BARI Alu-72 is red in color, it might possibly contain a high number of phytonutrients with antioxidant activity. Carotenoids, flavonids, caffeic acid, etc., which exhibit action against free radicals are among these essential health-promoting compounds.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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