Evaluation of CIP bred clones for expansion of potato production in the coastal areas of Bangladesh

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Abstract: A set of International Potato Center (CIP)-bred potato clones was evaluated for their salt tolerance and productivity in replicated field trials in three coastal districts of Bangladesh, namely, Chittagong, Patuakhali and Satkhira. In each year of experimentation from 2011 to 2015, salinity levels increased progressively during the season and varied with time and place. Evaluation and selection were carried out using GGE biplot analysis and mean yield across the test sites; and the best performing clones were selected for the next year’s trial. Of the original fifteen test clones, two (CIP 301029.18 and CIP 396311.1) were selected for evaluation in the regional yield trial with cvs. Diamant and Asterix as checks. In the regional yield trial, across locations, CIP 301029.18 was the highest (21.8 ton/ha) and CIP 396311.1 (21.3 ton/ha) was the 2nd highest yielder such that CIP 301029.18 produced 64.0% higher yield and CIP 396311.1 produced 32.4% higher yield compare to their corresponding check varieties Diamant and Asterix. Similar ranking was found under farmers’ field conditions. Finally, these 2 clones CIP 301029.18 & CIP 396311.1 were found promising for their good productivity under saline conditions and CIP 396311.1 was released by the National Seed Board in Bangladesh in 2016.

Keywords: CIP bred potato clone, salt tolerance, yield, Bangladesh

1 Introduction

Potato is becoming the number one non-grain crop in the world to ensure food security. It gives an exceptionally high yield with more nutrition per unit area per unit time than any other crop. According to FAOSTAT (2013), total potato production in Bangladesh ranks 7th in the world and it is second only to rice in Bangladesh, where about 8.95 million tons of potato was produced from about 0.46 million hectares of land in 2014 (BBS, 2014).

Soil salinity is a worldwide problem and Bangladesh is no exception. In Bangladesh, salinization is one of the major natural hazards hampering crop production. The total area of Bangladesh is 147570 km². The coastal area covers about 20% of the country and over thirty percent of the net cultivable area. About 52.8 percent of the net cultivable land in the coastal area is affected by varying degrees of soil salinity (Begum et al., 2009) with ranges from 3.63 to 27.67 (dSm⁻¹) (Akhter et al., 2008). Crop productivity is low due to salinity and a lack of saline tolerant varieties and in such conditions potato cultivation is limited as well.

Potato is relatively sensitive to salinity, particularly in the early growth stages (Munira et al., 2015). High salinity reduced the growth and production of potato by affecting physiological processes, ion balance, water status, mineral nutrition, stomatal behavior and photosynthetic
efficiency (Munns, 2002). Such physiological changes result in decreased plant growth (Mensah et al., 2006) and consequently reduced crop yield. Such decrease in growth caused by salt stress has been observed in potato (Farhatullah and Raziuddin, 2002; Shaterian et al., 2005). The reduction in growth following salinity treatment is explained as being due to accumulation of excess amounts of Na⁺ and Cl⁻ which are toxic to plants and adversely affect yield (Munns, 2002).

The present research was undertaken to i) evaluate and select CIP-bred potato clones best suited for the coastal areas in successive clonal generations; and to ii) estimate and validate the yield performance of the selected CIP-bred clones under saline condition in the coastal areas of Bangladesh.

2 Materials and Methods

Evaluation and selection for salinity tolerance was initiated in 2011-12 with 15 CIP–bred clones recommended for subtropical lowland conditions of Bangladesh. The research program was designed to coincide with sequential experimental field trials comprising Preliminary yield trial (PYT), Secondary yield trial (SYT), advanced yield trial (AYT) and regional yield trial (RYT) to select the best suited salinity tolerant potato clones/varieties for the coastal region of Bangladesh. All trials (PYT, SYT, AYT & RYT) were conducted at the same locations of Satkhira (22°44' N Latitude, 89°06' E Longitude), Patuakhali (21°83’ N Latitude, 90°14 E Longitude) and Chittagong (22°18’ N Latitude, 91°49’ E Longitude) from 2011 to 2015 (Plate 1). The country’s most popular potato varieties Diamant and Asterix were used as check varieties in SYT, AYT and RYT, where white and red skinned CIP-bred clones were compared with cv. Diamant and Asterix, respectively. Field trials were conducted following randomized complete block design (RCBD) in replicated plots (3) of 3.0 m x 3.0 m size where plant spacing was 60 cm x 25 cm. The PYT, SYT and AYT were planted in the 3rd to 4th week of November with the exceptions that the 2014-15 RYTs were planted on 1st December (Chittagong and Patuakhali where excessive soil moisture delayed planting) and 9th November (Satkhira). Edaphic information (Quddus, 2009) on experimental sites are represented in Table 1. To validate and compare the experimental trial yield of the 2 CIP clones with the yield in farmer’s field conditions additionally 5 farmers’ field trials were conducted in Chittagong (1) Patuakhali (2) and Satkhira (2).

Fertilizer was applied @ 160-44-132-15 kg/ha of N, P, K and S, respectively. Full amount of P and K and 50% of N were applied as basal and the remaining amount of urea was top dressed at 35 days after planting. Yield and

| Experimental location | Name of the agro ecological region (AEZ) | AEZ covered in the region | Land type, Soil type |
|-----------------------|-----------------------------------------|--------------------------|---------------------|
| Patuakhali and Satkhira | Ganges Tidal Floodplain | AEZ 13 | Medium low, low Heavy silt clays, alkaline |
| Chittagong | Chittagong Coastal Plain & St. Martin’s Coral Island | AEZ 23, 24 | High, medium high, medium low Grey silt loam, Silt clay loam |
yield contributing characteristic data were recorded following CIP protocol (CIP, 2006) and were statistically analyzed using STAR software (Developed by Biometrical Division, IRRI) and GGE bi-plot analysis was performed using R software (Version 3.0.0). Plant height and vigor were recorded at 60 days after planting (DAP). Plant vigor and senescence data were taken on 1-5 scales where for the former, 1 represents very low vigor and 5 very high vigor, while for the later 1 is low (senescent) and 5 is high (green). Salinity levels of the experimental fields were measured at planting and during different crop stages from 2011 to 2015 and in on-farm trials in 2014-15 at different stages of plant growth from planting to harvesting using a portable EC meter (Model. HI9813-5, Hanna Instruments, supplied by-Invent Technologies LTD. House-119, Flat B-1, Road-01, Block-F, Banani, Dhaka-1213, Bangladesh).

3 Results and Discussion

The level of soil salinity was measured in research and farmer’s field trials at different stages of plant growth (Planting to harvesting). Salinity levels varied with time and place and gradually increased in the dry period (December-March) peaking just before the monsoon rains.
(Fig. 1, Fig. 2 and Fig. 3). In the experimental field during 2014-15, comparatively higher salinity was recorded at Patuakhali (Fig. 2) whereas in the farmer’s field higher salinity was recorded at Satkhira (Fig. 3). In these two locations, increased salinity levels were recorded at the tuber maturation to harvesting stage and such raising in salinity levels may be due to higher capillary movement of ground water, low rainfall and higher temperature.

### 3.1 Mean yield performance and selection of CIP clones for RYT

The average yield performance of CIP genotypes at 3 different locations during 2011-12, 2012-13 and 2013-14 are presented in Table 2. In each trial the CIP-bred clones responded differently in the saline soil at three coastal districts. During selection of the best clones in the

![Figure 1](image1.png)

Figure 1: Salinity level of salt tolerance trial during different growth to harvest stages of potatoes at Chittagong, Patuakhali & Satkhira during 2011 to 14 crop seasons

![Figure 2](image2.png)

Figure 2: Salinity level of salt tolerance trial during different growth to harvest stages of potatoes at Chittagong, Patuakhali & Satkhira during 2014-15 crop seasons
Figure 3: Salinity level of salt tolerance trial (farmers’ field trials) during different growth to harvesting stages of potatoes at Chittagong, Patuakhali & Satkhira during 2014-15 crop season

Table 2: Average yield performance of advanced CIP clones and check varieties in PYT, SYT and AYT at 3 locations of Bangladesh during 2011-14

| Clone/TCRC code | Average tuber yield (ton/ha) |
|-----------------|-------------------------------|
| CIP-101 (301024.14) | PYT (2011-12) | SYT (2012-13) | AYT (2013-14) | RYT (2014-15) |
| CIP-102 (301029.18) | 14.89 | 21.97 | 19.84 | 21.85 |
| CIP 104 (301055.53) | 11.87 | - | - | - |
| CIP 108 (376181.5) | 15.12 | - | - | - |
| CIP-111 (380583.8) | 11.94 | 21.37 | 17.84 | - |
| CIP-112 (380606.6) | 16.10 | 25.33 | 18.29 | - |
| CIP-117 (386292.3) | 14.25 | 17.41 | - | - |
| CIP-119 (392797.22) | 17.00 | 17.80 | - | - |
| CIP-129 (393536.13) | 14.32 | - | - | - |
| CIP-130 (393617.1) | 19.56 | 22.53 | 16.33 | - |
| CIP 134 (395183.7) | 16.41 | - | - | - |
| CIP 137 (395193.6) | 14.20 | - | - | - |
| CIP-139 (396311.1) | 15.56 | 27.81 | 22.71 | 21.27 |
| Diamant | 14.21 | 15.64 | 15.62 | 13.32 |
| Asterix | - | 16.35 | 15.85 | 16.07 |
| LSD at 0.05 | 6.64 | 4.28 | 2.91 |
| CV (%) | 12.34 | 8.13 | 9.70 |

** Level of significance

** = Significant at 0.01 level of probability
preliminary yield trial (PYT) the mean yield performance over three locations, tuber shape, size, color of the skin and overall appearance were considered, and 8 clones (CIP-101, CIP-102, CIP-111, CIP-112, CIP-117, CIP-126, CIP-130 and CIP-139) were selected for secondary yield trial (SYT) in the 2012-13 crop season.

GGE bi-plot analysis was used during 2012-13 to support the selection of the best suited CIP clones for 2013-14 in 3 different saline environments. The polygon of a biplot is the best way to visualize the interaction patterns between genotypes and environment (Yan and Kang, 2003). The “Which won where /What” pattern of biplot display showed that CIP-139 was the best suited genotype at Satkhira and Chittagong, CIP-112 at Patuakhali and CIP-102 at Chittagong (Fig. 4). Considering mean yield and stability performance from the biplot analysis (Fig. 4 and 5) 5 clones viz., CIP-102, CIP-111, CIP-112, CIP-130 and CIP-139 were selected for inclusion in the AYT at the same locations in 2013-14. In the advanced yield trial (AYT) during 2013-14, CIP-139 was the mean highest yielder and CIP-102 was the 2nd highest yielder (Table 3). The “Which won where /What” pattern of biplot display showed that CIP-139 was the best suited genotype at Satkhira and Chittagong and CIP-102 at Patuakhali. Considering the

![Figure 4: Polygon view of GE interaction for CIP potato clones over 3 locations during 2012-13 (Ctg=Chittagong, Pat=Patuakhali and Sat=Satkhira)](image)

![Figure 5: Ranking the test environments relative to the highest yielding genotypes at 3 locations during 2012-13 (Ctg=Chittagong, Pat=Patuakhali and Sat=Satkhira)](image)

| Clone/ Variety | Plant height (cm) at 60 DAP | Plant vigor at 60 DAP (1-5 Scale) |
|---------------|----------------------------|----------------------------------|
|               | Chittagong | Patuakhali | Satkhira | Mean | Chittagong | Patuakhali | Satkhira | Mean |
| CIP-102 (301029.18) | 41.73      | 32.06      | 56.60    | 43.46 | 4.33      | 4.83      | 5.00     | 4.72 |
| CIP-139 (396311.1) | 26.23      | 30.46      | 50.60    | 35.76 | 4.00      | 4.50      | 5.00     | 4.50 |
| Diamant       | 31.50      | 28.26      | 39.20    | 32.99 | 3.67      | 3.83      | 4.47     | 3.99 |
| Asterix       | 42.66      | 42.80      | 45.00    | 43.49 | 3.67      | 4.17      | 4.17     | 4.00 |
| CV (%)        | 9.70       |            |          |       | 7.14      |          |          |      |
| LSD at 0.05   | 6.47       |            |          |       | 0.30      |          |          |      |
| Level of significance |                   |          |          |       |           |          |          |      |
| Genotype (G)  | **         |            |          |       | **        |          |          |      |
| Location (L)  | **         |            |          |       | **        |          |          |      |
| G x L         | **         |            |          |       | NS        |          |          |      |

** = Significant at 0.01 level of probability; NS=Not Significant; Plant vigor (1=low vigor and 5=very high vigor)
mean yield and stability performance of bi-plot display (Fig. 6 and 7) 2 clones viz., CIP-102 and CIP-139 were selected for inclusion in the regional yield trial (RYT) at the same locations in 2014-15.

3.2 Plant canopy and yield performance of CIP clones in RYT

On average, plants of all tested clones/varieties were taller at Satkhira where planting was earlier than at the other two locations and plants were on average smaller at Patuakhali where planting was late, corresponding to the increase in salinity levels with time. At the same time, plant vigor ranged from 3.67 to 5.00. CIP-102 and CIP-139 produced more vigorous plants at all locations than check varieties Diamant and Asterix (Table 3). The plant vigor score indicated that CIP-102 and CIP-139 have the capability to thrive under saline conditions.

Salinity effect was evidenced as more rapid advance of senescence. Senescence started at 60 days after planting and gradually increased with plant age but differed among clones (Fig. 8). At tuber-bulking stage the check varieties Diamant and Asterix showed higher senescence than CIP-102 and CIP-139. At 81 days after planting, the highest senescence was found in Asterix and Diamant. CIP clones CIP-102 (3.00) and CIP-139 (2.88) showed comparatively less senescence. At 88 days, CIP clones CIP-102 and CIP-139 were found green at all locations due to salinity tolerance while Diamant and Asterix were completely dried up (Fig. 8).

Significant variation was found in yield at all locations and the yield ranged from 10.38 to 37.53 ton/ha (Table 4). At Satkhira, CIP-102 produced the highest yield (37.53 ton/ha) followed by CIP-139 (31.04 ton/ha) and Asterix (27.70 ton/ha). At Chittagong, the highest yield was found in CIP-102 (16.71 ton/ha) followed by CIP-139 (16.37 ton/ha) and Asterix (13.75 ton/ha). Diamant (10.38 ton/ha) was the lowest yielder at Chittagong. CIP-139 produced the highest yield (16.40 ton/ha) followed by CIP-102 (11.32 ton/ha) and Diamant (10.67 ton/ha). At Satkhira, higher tuber yield were produced by the CIP clones and check varieties due to low level of salinity in the growing period, on the other hand at Patuakhali lower tuber yields were produced due to higher level of salinity. Considering all locations, the highest mean tuber yield was observed in CIP-102 (21.85 ton/ha) with CIP 139 (21.27 ton/ha) being the 2nd highest yielder. CIP-102 produced 64.03% higher yield and CIP-139 produced 32.35% higher yield compare to their corresponding check varieties Diamant and Asterix, respectively.

3.3 Farmers’ field performance

Among the 5 farmers’ field trials, tuber yield ranged from 9.06 to 33.83 ton/ha, where the highest was found in CIP-102 at Chittagong and the lowest was in Asterix at Satkhira (Table 5). Considering the mean yields under farmers’ field conditions, CIP-102 (25.79 ton/ha) was the highest yielder and produced 22.86% higher yield
Figure 8: Mean senescence score of 2 CIP promising clones at 60 to 88 days during 2014-15 crop seasons

Table 4: Tuber yield of 2 CIP promising potato clones and in check varieties at 3 saline locations in Bangladesh at harvest (90 DAP) during 2014-15 crop season

| Clone/Variety | Chittagong | Patuakhali | Satkhira | Mean ± SE |
|---------------|------------|------------|----------|-----------|
| CIP-102 (301029.18) | 16.71 | 11.32 | 37.53 | 21.85 ± 7.99 |
| CIP-139 (396311.1) | 16.37 | 16.40 | 31.04 | 21.27 ± 4.89 |
| Diamant | 10.38 | 10.67 | 18.92 | 13.32 ± 2.80 |
| Asterix | 13.75 | 6.75 | 27.70 | 16.07 ± 6.16 |

CV (%) 13.30

LSD at 0.05 4.13

Level of significance
Genotype (G) **
Location (L) **
G x L **

Table 5: Yield performance of 2 CIP promising potato clones and in check varieties at farmers’ fields at Chittagong (1), Patuakhali (2) and Satkhira (2) in Bangladesh during 2014-15 crop season

| Clone | Chittagong | Patuakhali (Farmer-1) | Patuakhali (Farmer-2) | Satkhira (Farmer-1) | Satkhira (Farmer-2) | Mean ± SE |
|-------|------------|-----------------------|-----------------------|---------------------|---------------------|-----------|
| CIP-102 (301029.18) | 33.83 | 29.06 | 36.75 | 26.17 | 25.79 ± 3.01 |
| CIP-139 (396311.1) | 27.11 | 19.11 | 23.22 | 15.92 | 23.99 ± 2.05 |
| Diamant | 19.39 | 27.78 | 21.28 | 20.99 ± 2.49 |
| Asterix | 23.44 | 20.87 | 9.82 | 9.06 | 17.24 ± 4.15 |

LSD at 0.05 2.28

CV (%) 6.22

Level of significance
Genotype (G) **
Location (L) **
G x L **

** = Significant at 0.01 level of probability

Senescence 1-5 scale, 5=0-20%; 4=21-40%; 3= 41-60%; 2= 61-80% and 1= 81-100% senescence

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** = Significant at 0.01 level of probability
compared to its check variety Diamant (20.99 ton/ha) (Table 5). Again, CIP-139 was the 2nd highest yielder (23.99 ton/ha) and produced 39.15% higher yield compare to its check variety Asterix (17.24 ton/ha) (Table 5). In the farmer’s field at Satkhira, yield was comparatively lower than Chittagong and Patuakhali due to a higher salinity level at the tuber maturation to harvesting stage.

4 Conclusions

Through GGE biplot analysis, CIP-139 was found to be the best suited genotype at Satkhira and Chittagong, and CIP-102 was best at Patuakhali. Among the clones/varieties studied in the regional yield trial CIP 102 (CIP 301029.18) was the mean highest yielder and CIP-139 (CIP 396311.1) was the 2nd highest yielder. In the farmers’ field trials, CIP-102 and CIP-139 produced higher yield than Asterix and Diamant. Considering yield and stability, the CIP clones; CIP-139 (CIP 396311.1) and CIP-102 (301029.18) were designated as saline tolerant potato clones and were proposed for release as saline tolerant potato variety(s).

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References

Akhter, S., Hossain, M.J., Begum, F., Bhuiyajn, M.K.R., Rashid, M., Response of Some Potato Cultivars to NaCl Salinity in pot culture. Eco-friendly Agriculture Journal, 2008, 1(4), 180-184
BBS, Year book of agricultural statistics of Bangladesh, Bangladesh Bureau of Statistics (BBS), Ministry of planning, Government of the People’s Republic of Bangladesh, 2014
Begum, F., Malek, M.A., Aziz, M.A., Evaluation of Cowpea genotypes against salinity under laboratory condition. Annual Research Report, Agronomy Division, Bangladesh Agricultural Research Institute. 2009, p. 63
FAOSTAT, Production Year Book. Food and Agriculture Organization of the United Nations, Rome, Italy, 2013
Farhatullah, M., Raziuddin, R., In vitro Effect of Salt on the Vigor of Potato (Solanum tuberosum L.) Plantlets. Biotechnology, 2002, 1, 73-77
International Potato Center (CIP), Procedures for standard evaluation trials of advanced potato clones. An International Cooperators’ Guide, 2006
Mahmood, L. A., Nawaz, S., Aslam, M., Screening of rice (Oryza sativa L.) genotypes against salinity. International Journal of Agriculture & Biology, 2000, 2, 147-150
Mensah, J. K., Akomeah, P. A., Ikhajiagbe, B., Ekpekurede, E.O., Effect of salinity on germination, growth and yield of five groundnut genotypes. African Journal of Biotechnology, 2006, 5, 1973-1979
Munira, S., Hossain, M.M., Zakaria, M., Ahmed, J.U., Islam, M.M., Evaluation of Potato Varieties against Salinity Stress in Bangladesh. International Journal of Plant & Soil Science, 2015, 6(2), 73-81
Munns, R, Comparative physiology of salt and water stress. Plant Cell Environment, 2002, 25, 239-250
Quddus, M.A., Crop production growth in different agro-ecological zones of Bangladesh. J. Bangladesh Agril. Univ., 7(2), 351–360, 2009
Rahman, M.H., Islam, R., Hossain, M., Haider, S.A., Differential response of potato under sodium chloride stress conditions in vitro. Journal of Bio-Sci., 2007, 16, 79-83
Shaterian, J., Waterer, D., De Jong, H., Tanino, K.K., Differential Stress Responses to NaCl Salt Application in Early- and Late-maturing Diploid Potato (Solanum sp.) Clones. Environmental and Experimental Botany, 2005, 54, 202–212
Yan, W., Kang, M.S., GGE biplot analysis: A Graphical Tools for Breeder, Geneticists and Agronomists. 1st Ed., CRC Press LLC., Boca Roton, Florida, 2003
Yan, W., Rajakan, I., Biplot analysis of the test sites and trait relations of soybean in Ontario. Crop Science, 2002, 42, 11-20
Yan, W., Tinkler, N.A, Biplot analysis of multi environment trial data: Principles and applications. Canadian Journal of Plant Science, 2006, 86, 623-645