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Performances of tomato cultivars in coastal areas based on GGE biplot analysis

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Abstract

Soil salinity problem is undoubtedly a major cause which limits the crop production in the coastal region of Bangladesh. Hence an experiment was conducted to observe the stability of cultivars at two coastal saline areas namely Benarpota and Kalapara of Bangladesh based on yield and yield related traits. Eight tomato varieties were used and the experiment was laid out in Randomized Complete Block Design with three replicates. The collected data were analyzed statistically using R-Stat program. The stability of the cultivars was done by R Stat biplot analysis. Yield parameters were significantly affected by salinity at both locations. At Kalapara and Benarpota the variety BARI Tomato-7 gave the highest plant height, 120 cm and 114.67cm, respectively. BARI Tomato-4, BARI Tomato-9 and BARI Tomato-11at Benarpota were earlier for harvest days. The highest number of fruits/plant was recorded from BARI Tomato-11while the lowest number was for BARI Tomato-4 at Benarpota which was statistically similar to BARI Tomato-8 at Kalapara. BARI Tomato-7 gave the highest fruit yield (90.0 t/ha) at Benarpota and (84.67 t/ha) at Kalapara which was significantly different from all other varieties and followed by BARI Tomato-14 (82.67 t/ha) and BARI Tomato-8 (80.33 t/ha). The lowest yield was obtained from BARI Tomato-11 at both the locations. Salt tolerant BARI Tomato-7 was the most suitable variety for Benarpota and Kalapara regions. Based on GGE biplot Genotype (G), Environment (E) and Genotype × Environment (G × E) interactions, BARI tomato-7 and BARI tomato-14 obviously ranked first position at Benarpota and kalapara, respectively.

Key words: Tomato, coastal area, salinity, stability

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Introduction

Bangladesh has 3 million hectares of land affected by salinity, mainly in the coastal and south-east districts, with ECe (Electrical Conductivity) values ranging between 4 and 16 dS/m (Zaman and Bakri, 2003). Agricultural land use in these areas is very poor, which is roughly 50% of the country's average (Petersen and Shireen, 2001). Most of the coastal areas are located over medium highlands, where flooding depth ranges from 0.3-0.9 meter. This category of land certainly is suitable for minimum two crops and even sometimes three crops with winter wheat or other winter crops. The existing cropping patterns followed in the coastal areas are mainly Fallow-Fallow-Transplanted Aman rice. In general, soil salinity is believed to be mainly responsible for low land use as well as cropping intensity in these areas (Rahman and Bhattacharya, 2014). The low land used in saline area is mainly problematic due to unfavorable soil salinity in dry season and unavailability of quality irrigation water. In the coastal saline belt with short winter season, timely sowing/planting of rabi (winter) crops is very essential. Purposefully concomitant cropping intensity can be increased in about 0.596 million hectares of very slight (S1) and slightly saline (S2) areas by adopting proper soil and appropriate water management practices with the introduction of salt tolerant crop varieties. Salinity problems resulting from seawater intrusion are more acute and lands are commonly left fallow as crop production is restricted by the presence of salts particularly in the months of March and April (Mondol, 1997). So, selection of crop or a variety of a crop for saline area considered as an important management option to minimize yield loss due to mainly salinity. Apparently salinity is an important determinant for soil capability and it is seen as a "modifier" which put restrictions on possible crop choices (Wilde, 2000).

The vegetable production which supplies 40% of the world's food is threatened by increasing soil salinity (FAO, 2004). Excessive soil salinity reduces productivity of many agricultural crops, especially vegetables that are particularly sensitive throughout the ontogeny of the plant. According to the United States Department of Agriculture (USDA), onions are sensitive to saline soils, while cucumbers, eggplants, peppers, and tomato are moderately tolerant. Vegetable production can help farmers to generate income which eventually alleviate poverty. Tomato growing is labor intensive but is an alternative cash crop for small farmers. At present the primary vegetable production area in Bangladesh is 4,96,824 hectares and 23,817 hectares areas are under tomato cultivation both in winter and summer and the production of tomato is about 1,90,213 tons (FAO, 2010).

Salinity problem received very little attention in the past, but due to increased demand for growing more food to feed the booming population of the country it has become imperative to explore the potentials of these lands (Islam *et al.*, 2020). After harvesting Transplanted Aman which is the major crop cultivated in salt affected areas, a vast area of land in these areas remain either fallow or covered by some minor crops at marginal level of production. The production of tomato is being constrained in the coastal areas of Satkhira and Kalapara due to lack of appropriate information of knowledge of suitable varieties, improved technology and upward or lateral movement of saline groundwater during the dry season viz, November-May (Karim *et al*., 1990). Phenotypically stable genotypes are of great importance, because the environmental condition varies from year to year/region to region. Wide adaptation to the particular environment and consistent performance of recommended genotypes is one of the main objectives in variety development. Although a number of varieties have been recommended for the cultivation, the information on the stability is lacking for the agro-climatic conditions. So, there is the necessity to evaluate and to screen the potential genotypes giving consistent performance over years and to select the genotypes on the basis of stability parameters for important yield and maturity attributes (Kalloo, 1998). Lines selected for high yield in high yielding environment have above average environmental sensitivity, while selection for high yield in below average environment results in lines with above average stability (Jinks and Pooni, 1982). The assessment of stability or desirability among genotypes is assumes very important. Identification of stable genotype(s) and desirable environment(s) has been the most important objectives of multi-environment trials. Biometrically, GGE biplot is a methodology for genotype evaluation based on genotype main effect (G) plus genotype-by environment interaction. Estimation of stability performance becomes an important tool to identify consistently high-yielding genotypes (Kang, 1998;

Kadir *et al*., 2007). The genotypes with high yield potential under optimal condition also express their superiority under limiting condition. The purpose of this study was to observe the performance of eight different tomato varieties for growing under saline areas and to identify the most suitable genotypes for that location. Moreover, this study will help the farmers in selecting the suitable variety for growing in salt affected soils in the dry season.

Materials and Methods

A field experiment was conducted from December 2010 to March 2011 at Agricultural research station, Benarpota in Satkhira district and another at farmer's field, Kalapara in Patuakhali district. Eight tomato varieties were used in this study. These wereV_1- BARI Tomato-2, V_2-BARI Tomato-3, V_3-BARI Tomato-4, V_4-BARI Tomato-7, V_5- BARI Tomato-8, V_6-BARI Tomato-9, V_7- BARI Tomato-11 and V_8-BARI Tomato-14, collected from HRC, BARI, Gazipur. Seeds were sown in seed bed and four week-old seedlings were transplanted in the field on 15 December 2010 at Benarpota and 18 December at Kalapara. The unit plot size was 1 m × 3 m. The experiment was laid out in a RCB design with three replications. Recommended doses of fertilizers (250-80-125 kg/ha NPK and 5 t/ha cow dung) were applied. Total amount of cow dung, TSP and 1/3 each of urea and MP were applied at final land preparation. Rest portion of urea and MP were applied in two equal installments at 21 and 35 DAT. Intercultural operations were done properly as and when necessary to obtain optimum plant growth. Data on plant height, branches/plant, fruits/plant, and weight of fruit/plot, weight of fruits, diameter/fruits and yield (ton/ha) were recorded. Leaf chlorophyll content was measured using a hand-held chlorophyll content SPAD meter (CCM-200, Opti-Science, USA). At each evaluation the content was measured 3 times from three leaves at three positions per plant and the average was used for analysis. Plants were harvested during late March 2011 to April 2011 across locations. Soil salinity of the experimental plots was determined by portable soil salinity meter. After every 10 days' field scout portable EC meter was used for soil salinity measurement. The collected data were analyzed statistically by using R-Stat program. The treatment means were compared using DMRT/ LSD at 5% level of probability following Gomez and Gomez (1984). Ranking of the genotypes was done by R Stat GGE biplot program.

Results and Discussion

***Salinity levels*:** Soil salinity at Benarpota and Kalapara during tomato growing period of the year 2010 and 2011 are shown in Figure 1 and Figure 2. Lowest salinity was recorded at transplanting time and the highest salinity was recorded at harvesting time. At transplanting date, it was 5.2 dS/m and 3.2 dS/m, at harvesting date 13.25 dS/m and 11.25 dS/m at Benarpota and Kalapara respectively. Salinity increased in both the locations after January. Rain water decreased salinity but after ten days' salinity increased again. This studied range corroborated the reports of Naher *et al*., 2011) and Zaman and Bakri (2003).

***Plant height*:** Saline stress leads to changes in growth, morphology and physiology of the plant parts that will in turn change water and ion uptake. Significant difference among the different treatments of tomato plant was observed in case of plant height at Benarpota and Kalapara. Both at Kalapara and Benarpota the variety BARI Tomato-7 gave the tallest plant, 120 cm and 114.67cm, respectively while the second highest from BARI Tomato-14 (Figure 3). The variation of plant height in salinity may be a result of a combination of osmotic and specific ion effects of Cl^- and Na^+. Salinity stress resulted in a clear stunting of plant growth in BARI Tomato-8, thereby showing the lowest plant height. This research was similar to the annual research report of BARI (2007). The reduction of the plant height due to reduction in internodal distance with increased salinity may be a result of a combination of osmotic ion effects of Cl^- and Na^+ (Al-Rwahy, 1989; Zhu, 2001).

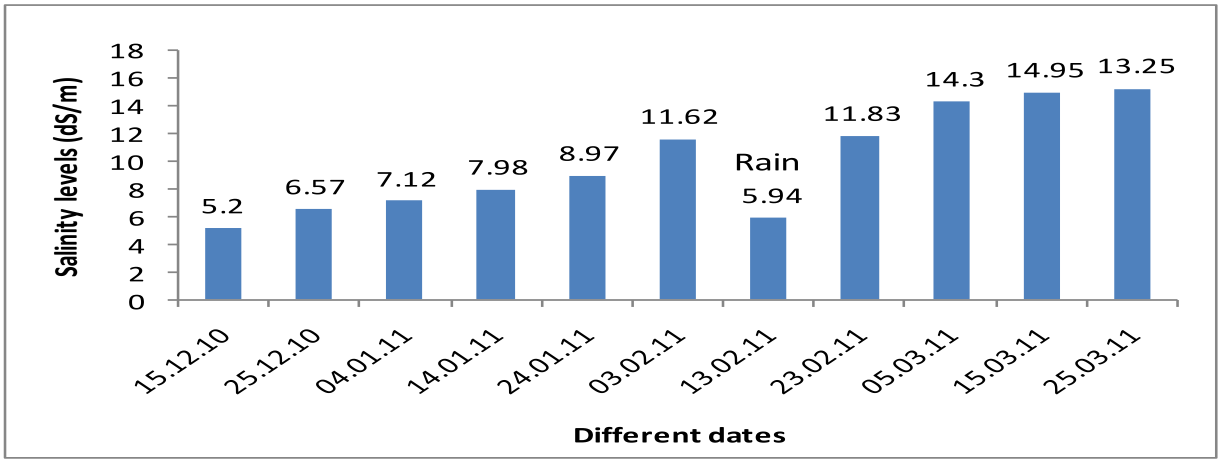

Figure 1. Salinity levels of the soils of different treatments of tomato throughout the growing season at Benarpota.

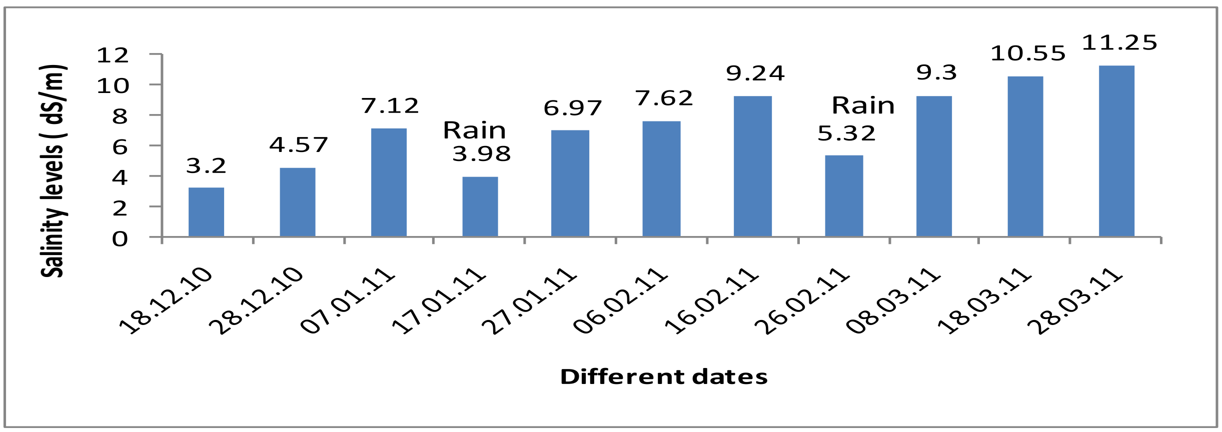

Figure 2. Salinity levels of the soils of different treatments of tomato throughout the growing season at Kalapara.

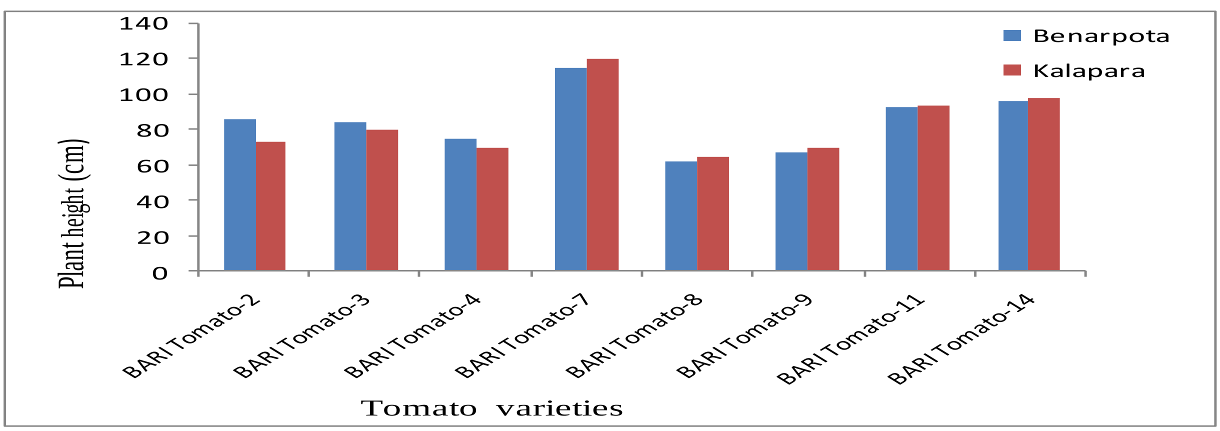

Figure 3. Plant height of tomato varieties grown under studied saline areas (Benarpota and Kalapara)

***Branches/plant*:** The results presented in Table 1 indicated that there were no significant differences in respect of branches/plant between varieties. At Kalapara BARI Tomato-4 but at Benarpota, BARI Tomato-9 contained the highest number of branches/plant. At both the locations BARI Tomato-8 showed the lowest number of branches per plant. Similar results were also reported by Cuartero and Munoz (1999).

***Days to flowering and days to harvest*:** Days to flowering varied significantly among the varieties. At Kalapara, BARI Tomato-2, BARI Tomato-3, BARI Tomato-4 and BARI Tomato-14 and at Benarpota BARI Tomato-4 showed statistically identical for days to flowering. BARI Tomato-9 showed early days to flowering at both the locations. During time of flowering soil salinity at Benarpota was about 11.62 dS/m (Table 1). Cuartero and Munoz 1999; Cruz and Cuartero, 1990; reported the same results in case of tomato. They reported that due to salinity increase flowering date become earlier. Highest date of harvest of BARI Tomato-2 (104) and BARI Tomato-3(105) at Kalapara were statistically same. BARI Tomato-4, BARI Tomato-9 and BARI Tomato-11at Benarpota found early (91 days) days. BARI Tomato-2 and BARI Tomato-3 showed late harvest days at both the locations (Table 1). This result corroborated with the result of BARI Annual research report (2007). This report was also similar to other studies (Adams and Ho, 1989) and Vanleperen, 1996).

Table 1. Agronomic performances of Tomato varieties at Benarpota and Kalapara during *rabi* season of 2010-2011.

Tomato Varieties	Plant height		Branches/Plant		Days to flowering		Days to harvest	
	Benarpota	Kalapara	Benarpota	Kalapara	Benarpota	Kalapara	Benarpota	Kalapara
BARI Tomato-2	85.67f	73.00i	4.00	4.33	50.00c	53.67a	101.67b	104.00a
BARI Tomato-3	83.67f	79.67g	4.00	4.33	51.67bc	54.00a	102.00b	105.00a
BARI Tomato-4	75.00h	69.67j	4.33	5.00	53.00a	54.67a	91.33h	94.67f
BARI Tomato-7	114.67b	120.00a	4.00	4.33	50.00c	52.67b	94.33f	96.33e
BARI Tomato-8	62.00m	64.33l	3.67	3.33	51.67bc	53.00a	99.00c	97.00d
BARI Tomato-9	67.00k	69.33j	5.00	4.67	46.67d	50.67c	91.33h	99.33c
BARITomato-11	92.67e	93.00e	4.00	4.33	52.00b	52.00b	91.67h	90.33i
BARITomato-14	96.00d	97.60c	4.67	4.33	51.67bc	53.67a	94.67f	93.00g
CV (%)	1.18		8.81		2.06		0.84	

*Means in the column with same letter indicate no difference at Duncan's Multiple Range Test at $P < 0.05$.

***Leaf chlorophyll contents*:** Chlorophyll contents changed significantly among the cultivars at different growth stages. At vegetative stage BARI Tomato-7 showed the highest chlorophyll content (48.7 SPAD units) at Benerpota and BARI Tomato-9 showed the lowest chlorophyll content (41.55 SPAD units) at Kalapara. Tomato cultivars had highest chlorophyll content in flowering stage, 56.90 and 54.05 SPAD units at Benatpota and Kalapara respectively. At maturity stage the chlorophyll content was the lowest at both the regions (Table 2).

It can be observed that the highest salinization induced a significant decrease in the total chlorophyll content. These results are in agreement with (Khavarinejad and Mostofi, 1998); Adams (1988) and Satti and Al-Yahyi (1995) for tomato. Generally, chlorophyll contents were reduced markedly at high salinity concentration treatments especially with aged plants. It might be due to the reason that the total chlorophyll and the proportion of its components depended on the biological process and development stages of the plant and also on the type and concentration of the salt. Ahmed *et al.,* (1978) and Hajer *et al.,* (1993) also obtained similar findings in case of tomato plant. Reduction in chlorophyll concentrations is probably due to the inhibitory effect of the accumulated ions of various salts on the biosynthesis of the different chlorophyll fractions. NaCl stress decreased total chlorophyll content of the plant by increasing the activity of the chlorophyll degrading enzyme: cholorophyllase (Rao and Rao, 1981), inducing the destruction of the chloroplast structure and the instability of pigment protein complexes (Sing and Dubey, 1995).

Table 2. Leaf chlorophyll content of eight tomato varieties at vegetative, flowering and maturity stages at 5% level of significance.

Tomato Variety	Chlorophyll content (SPAD unit)					
	Vegetative Stage		Flowering Stage		Maturity stage	
	Benarpota	Kalapara	Benarpota	kalapara	Benarpota	Kalapara
BARI Tomato-2	46.85ab	47.07ab	54.80b	52.75b	43.75b	44.85b
BARI Tomato-3	41.45d	41.62d	45.75de	47.55d	43.50b	43.50bc
BARI Tomato-4	43.70cd	44.4bcd	48.60d	49.40c	41.50c	42.70c
BARI Tomato-7	48.70a	49.05a	56.90a	54.05a	46.73a	47.65a
BARI Tomato-8	46.25bc	45.83bc	52.05bc	51.65bc	35.95e	37.80e
BARI Tomato-9	42.20cd	41.55d	47.05e	46.65e	43.75b	44.75b
BARI Tomato-11	44.50c	44.5bcd	50.60c	50.50cd	40.50d	41.10d
BARI Tomato-14	44.90c	45.85bc	54.05b	53.35b	43.05b	42.85c
CV (%)		3.37	1.42		1.71	

***Cluster/plant*:** There were no significant differences among the varieties in case of cluster/plant. BARI Tomato-11 gave the highest number of cluster/plant. BARI Tomato-4 gave the lowest number of cluster/plant at both the locations (Table 3). The variety BARI Tomato-11 was the cherry type, so its number of cluster per plant was highest. This is consistent with the hypothesis of Cuartero and Fernandez-Munoz (1999) that stress restricts the number of flowers per truss. The number of cluster/plant was reduced both with high salinity and with long salinisation periods. So this characteristic seems to show little response to salinity up to 8 dS/m ECe (Van leperen, 1996).

***Fruits/plant*:** The highest number of fruits/plant was recorded from BARI Tomato-11which was statistically different from other varieties. The lowest number was recorded from BARI Tomato-4 at Benarpota which was statistically similar to BARI Tomato-8 at Kalapara. But, BARI Tomato-2, BARI Tomato-3 and BARI Tomato-8 and BARI Tomato-14 showed the same number of fruits/plant (Table 3). Results of this study are in conformity with the studies of Adams and Ho (1989) and Vanleperen (1996) who observed that the number of harvested fruits per plant decreased due to salinity. The decrease of fruit number in the present study at Benarpota may be due to the effect of high EC value during the growing period. The reduction in fruit number observed in the study appeared to be related to a reduction in the average number of flowers per cluster and per plant. The differences in fruit number and size were larger with increasing duration of the harvesting period. Grunberg *et al.* (1995) reported that fruit set could be decreased because of low number of pollen grains/flower in plants under salt stress; extra flower production would be inhibited (Saito and Ito, 1974).

Weight of fruit per plant**:** The results represent that there was a significant difference among the weight of fruits per plant. BARI Tomato-7 gave the highest fruit weight at Benarpota. BARI Tomato-8 at Benarpota and BARI Tomato-7 gave the same fruit weight (Table 3). BARI Tomato-11 gave the lowest fruit weight at both the locations. The mean fruit weight of Benarpota was less than Kalapara due to high salinity.

Fruit diameter**:** The highest fruit diameter was noted from BARI Tomato-14 at Kalapara and second from BARI Tomato-7 at Benarpota. The lowest fruit diameter was found in BARI Tomato-11 which was cherry type tomato at both the locations. At Kalapara BARI Tomato-7 and BARI Tomato-3 but at Benarpota, BARI Tomato-8 produced statistically same fruit diameter (Table 3).

Table 3. Yield and yield contributing characters of Tomato varieties at Benarpota and Kalapara during *rabi* season of 2010- 2011.

Varieties	Cluster/plant (no)		Fruits/cluster (no)		Fruits/ Plant (no)		Wt. of fruits/ plant (kg)		Diameter/ Fruits (cm)		Yield (ton/ha)	
	Benar	**Kalap**	**Benar**	**Kalap**	**Benar**	**Kalap**	**Benar**	**Kalap**	**Benar**	**Kalap**	**Benar**	**Kalap**
BARI Tomato-2	9.0	9.66	4.67e	4.0e	32.0f	33.67e	1.55e	1.50e	13.67e	12.0f	60.0g	62.0f
BARI Tomato-3	10.0	9.33	4.0e	5.67d	32.0f	34.33e	1.55e	1.67d	13.00e	15.0c	61.67g	68.33d
BARI Tomato-4	8.33	8.67	3.33f	4.67e	22.67j	24.67i	0.87g	0.77g	8.00i	9.0h	28.67i	29.0h
BARI Tomato-7	9.00	9.67	6.33c	5.0bc	36.0 d	30.0g	2.37a	1.96b	17.00b	15.8c	90.0a	84.67c
BARI Tomato-8	9.33	9.0	4.67e	3.00f	27.0h	24.33i	1.97b	1.70cd	15.00c	13.0e	80.33c	68.0d
BARI Tomato-9	9.0	9.67	5.0d	5.67d	32.0f	34.0e	1.0f	1.53de	10.00g	14.6d	56.0h	60.0g
BARITomato-11	12.0	11.0	13.67a	12.0b	210 b	212.33a	0.57h	0.46h	6.67j	6.0j	6.67j	5.67k
BARITomato-14	9.67	10.67	4.0e	5.67d	32.0d	37.0c	1.50c	1.80bc	14.00d	18.0a	66.67e	82.67c
CV (%)	6.89		11.16		3.75		7.18		1.05		7.81	

***Benar = Benarpota, Kalap = Kalapara,** *Means in the column with same letter indicate no difference at Duncan's Multiple Range Test at $P < 0.05$.

Yield (ton/ha)**:** BARI Tomato-7 gave the highest fruit yield (90.0 t/ha) at Benarpota and (84.67 t/ha) at Kalapara which was significantly different from all the other varieties and followed by BARI Tomato-14 (82.0 t/ha) and BARI Tomato-8 (80.33 t/ha). The lowest yield was obtained from BARI Tomato-11 at both the locations (Table 3). At Benarpota and Kalapara the yield was 6.67 t/ha and 5.67 t/ha respectively due to its very small fruit size. But BARI Tomato-4 was inferior to all the other varieties. The yield of some varieties was less typically due to higher amount of salt depositions in the rhizosphere. However, BARI Tomato-14 was the second tallest but the fruits production in this variety was low, may be due to its higher value for green matter under high salinity at Benarpota. This result was similar to Annual research report of BARI (2007) and BARI and ICBA (2007) in the saline areas of Bangladesh. Generally, the incorporation of salinity stress and weakness to tolerate salinity could lead to higher loss of plant production in some varieties (Daoud *et al*., 2001). If the results of two locations are compared then it is clear that among the eight varieties, BARI Tomato-7 gave the highest plant height, individual fruit weight, fruit weight/plant, fruit diameter, and yield/ha, so it was the best variety among the all at Benarpota and Kalapara. Benarpota has higher salinity than Kalapara during the growing period. The salinity was lower at Kalapara due to rain at growing period. This may be a reason for higher total tomato production at Kalapara than Benarpota region.

***GGE biplot analysis*:** For cultivar evaluation genotype (G) and genotype × environment (GE) is an important indicator for considering meaningful selection decisions. In GGE Biplot techniques, the horizontal axis (PC1) indicated the main effects of genotype while the vertical axis (PC2) showed the interaction of genotypes and environment which is the basic criterion for genotype stability (Yan, 2002). The performance of tomato genotypes was presented in the biplot based on fruit yield data of two locations (Figure 4).

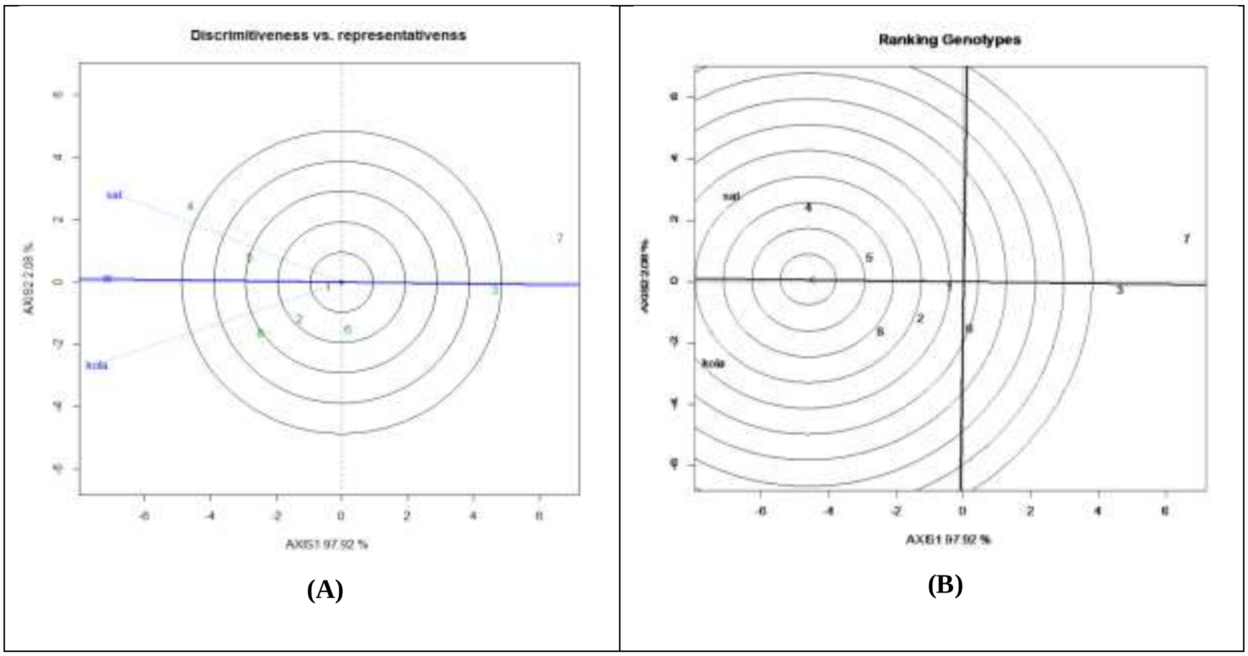

Figure 4. GGE biplot based on yield data showing ideal variety for (A) discriminating and representativeness and (B) the ranking of genotypes among environments. **1-**BARI tomato-2**, 2-**BARI tomato-3, 3-BARI tomato-4, 4-BARI tomato-7, 5-BARI tomato-8, 6-BARI tomato-9, 7-BARI tomato-11, and 8-BARI tomato-14.

Discriminating ability was an important measure of a test environment. Another equally important measure of a test environment was to be representative of all other environments. Yan (2001) presented an idea of comparison of genotypes with an “ideal” genotype. The centers of the concentric circles are the place where an “ideal” genotype is located (Figure 4. A). An ideal genotype is one that is highly differentiating of the genotypes and is representative of all other environments (Yan and Kang, 2003; Fan *et al.,* 2007). Therefore, BARI tomato-2 (1) was the most desirable as it lay closer to the “ideal” i.e. center of the concentric circles, followed by BARI tomato-3 (2), BARI tomato 14(8) and BARI tomato-8 (5). BARI tomato-9 (6) was also found near to centre but undesirable. Ranking genotypes (B) helps to identify the best genotypes for each environment. Considering the yield stability BARI tomato-7 showed the highest performances and BARI tomato-8 ranked the second position. Yan *et al.*, (2000) reported genotype-by-environment interaction as a measure of desirability with respect to discriminating ability and representativeness of test environments. Based on GGE biplot (Genotype (G), Environment (E) and Genotype × Environment (G × E) interaction, BARI tomato-7 and BARI tomato-14 ranked the first position at Benarpota and kalapara, respectively. So, these two varieties can be used for commercial cultivation over the locations. Considering the yield stability over the location (Environment) most stable genotype was BARI tomato-2.

Conclusion

Tomato is a moderately salt tolerant vegetable and the most economical and useful vegetable. The salt tolerant tomato varieties now have become very potential to help generate farmers' income within a much shortened possible period. This will increase the agricultural production which is the backbone of economy in developing countries. Herein of afterwards it can also be concluded that BARI Tomato-7 is the most suitable variety for these two regions.

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