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Research Article

EVALUATION OF SOME PROMISING SALT TOLERANT MAIZE LINES IN THE COASTAL REGION OF BANGLADESH

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Abstract

Salinity is a significant barrier that inhibits crop production in salt-affected areas as in the southern region of Bangladesh. Maize (*Zea mays* L.), is the third most major cereal crop that has shown decreased plant growth and production potential under saline conditions. Furthermore, salinity affects both plant growth and production. Hybrid maize has been recently introduced to the cropping systems of southern Bangladesh to enhance cropping intensity and productivity. The experiment was conducted at the Botiaghata, Khulna (AEZ-11) during the *Robi* season of 2022-23 to determine hybrid salt tolerant lines for maximizing maize yield and its utilize thousands of hectares of unproductive land and dikes of shrimp farms. Fifteen advanced lines of hybrid maize were evaluated in the study. The experiment was laid out in randomized compete block design with three replications. The highest grain yield was found in E-34 x BIL-211 was 11.37 t ha^{-1} and which was followed by Pinacle-3 x BIL-211 (9.71 t ha^{-1}) and BIL-79 x Pinacle-16 (9.09 t ha^{-1}). The lowest yield was found from BIL-106 x CML-480 (3.53 t ha^{-1}). It is suggested that E-34 x BIL-211 can be grown in the southwestern coastal region of Bangladesh.

Introduction

Salt stress is a major problem for today's globally focused commercial agriculture (Seleiman *et al.,* 2021a). Aside from soil salinity, one of the main factors affecting the yield of agriculture is using saline water for irrigation, especially in low-lying coastal areas of certain countries (Daliakopoulos *et al.,* 2016). Reduced plant growth due to a decline in relative water potential is one of the negative consequences of salt stress; another is the short and long-term unfavorable impact on soil and water quality (Seleiman *et al.,* 2021b; EL-Sabagh *et al.,* 2019). Water stress and salt stress are related, and even in situations when soil moisture content is not a limiting factor for crop production, both stresses have an impact on plant development and, eventually, the yield of plants (EL-Sabagh *et al.,* 2020). Maize, like other C4 plants, can flourish in both saline and non-saline environments due to its capacity to adapt to stress and its relative tolerance to salinity (Khaliq *et al.,* 2019). The ultimate effect on plant productivity is dependent upon the duration and intensity

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of the stress as well as the growth phase in which the stress arises, even though salinity negatively affects maize development and yield qualities throughout the plant cycle (Billah *et al,* 2017). The early development stage of maize is particularly susceptible to salt stress, compared to other row crops (Ullah *et al.,* 2023). Maize (*Zea mays* L.) is the predominant cereal crop cultivated globally and has significant economic value for the industry. Maize is the second most produced cereal crop in the world, behind wheat. Maize has the top position in Latin America and Africa among developing nations, while it ranks third in Asia, leading to rice and wheat (Biswas *et al.,* 2023). Due to a change in worldwide demand for maize crops, especially in developing countries, the amount demanded is expected to increase from 282 million tons in 1995 to 530 million tons in 2023 (FAOSTAT, 2023). Maize exports have a gross profit per hectare that is 2.4 times greater than that of wheat or rice. According to the Food and Agriculture Organisation (FAO), maize is also more resistant to diseases and insect pests (Masudul *et al.,* 2017). Maize has the position of the third most significant grain crop in Bangladesh (Biswas *et al.,* 2023). It is cultivated in a variety of soil types and environmental conditions (Bagum *et al.,* 2017). The maize cultivation area and production in Bangladesh for the 2021-22 season totaled 4,76,492 acres and 4.26 million MT, respectively (BBS, 2022). The demand for maize in Bangladesh is steadily rising, leading to growth in both production and consumption. However, it is important to note that there exists a substantial gap between the demand and supply of maize (Islam and Hoshain, 2022). The coastal area of Bangladesh comprises 19 districts, including 32% of the land which faces the most significant risk of soil and water salinity. The research conducted by (Salehin *et al.,* 2018) and (Masuda *et al.,* 2021) reveals a significant increase of around 26% in soil salinity within the specified geographical area during 35 years. The observed progressive upward trend has resulted in adverse consequences for soil fertility and maize production (Sikder *et al.,* 2016).

Maize is particularly vulnerable to salinity stress. Therefore, understanding how maize responds to salt stress, its methods of resistance, and the overall alternatives for managing it will help improve the planning process for maize in saline environments (Elhakem, 2019). Furthermore, salt has an impact on both the growth and reproduction of plants, which may have significant consequences depending on the specific organ being harvested, such as the stem, leaf, root, shoot, fruit, fiber, or grain. Shoot growth is often diminished to a greater extent than root growth. The different effects of various mechanisms on plants depend upon many aspects, such as the specific species, lines, age of the plant, ionic strength and composition of the salinizing solution, and the particular organ under consideration (Masuda *et al.,* 2020). Maize is used in several nations for dietary and nutritional safety (Adnan *et al.,* 2021). Food crop variety, nutritional variance, and food security challenges may be effectively addressed by the implementation of a replacement diet (Pujiasmanto, 2014). Currently, there is an effort to include maize in the coastal cropping pattern, which is mostly alone (Billah *et al.,* 2017). The study focused on a preference to choose rice-maize patterns rather than traditional rice-rice and rice-wheat cropping patterns (Adnan *et al.,* 2020). There is variation in the salt tolerance levels of maize. Hence, it is essential to determine the appropriate lines for the saline region of the south-western coast. The main challenges for determining salinity tolerance in the field are the differences in soil physio-chemical conditions and variations in rainfall. Multiple research has been undertaken to investigate the impact of salt on plant development (Achakzai *et al.,* 2010; Akram *et al.,* 2010; Majeed *et al.,* 2014; Hoque *et al.,* 2015). While previous research has examined maize cultivation (Hajong *et al.,* 2023), the current study aims to provide information about the potential of these maize lines in enhancing productivity and increasing acreage in the southwestern coastal region of the country.

Materials and methods

Experimental setup and design

The experiment was carried out in the experimental field of MLT site, Batiaghata Khulna (AEZ-11) during the *Robi* season of 2022-23. The soil of the experimental field was a clay loam in texture and medium-high elevation. With low organic matter content in the brown ridge and high levels in the dark grey soils, the soil was calcareous brown and dark grey. The High Ganges River Flood Plain (22.8875 ^{0}N latitude and 89.5167 ^{0}E longitude), was the site of the experiment location. Fifteen advanced lines of hybrid maize namely E6 X E5, BMZ-9 x BIL-211, E-34 x BIL-211, 900M-4 x Bill-28, E-5 x E-6, BIL-79 x Pinacle-16, Pinacle-10 x BMZ-9, BIL-106 x CML-480, BIL-18Y x BIL-211, Pinacle-3 x BIL-211, BIL-157 x BIL-28, BIL-216 x

900M-1, 981, and P-3355 were evaluated in the research. The unit plot size was 3m x 2m and the spacing maintained was 60cm x 25cm. Each plot consist of had 40 plants. The experiment was laid out in a Randomized Complete Block Design (RCBD) design with three replications.

Land preparation and fertilization

Before experimentation, the field was thoroughly prepared to provide ideal condition for the development of crops. The soil was tilled three to four times using a power tiller to obtain optimal tilth. Experimental plots were fertilized with 230-48-90-43-3.5-1-5000 kg ha-1of N-P-K-S-Zn-B and cowdung. One third of N and full quqntity of other fertilizer were applied at the time of final land preparation. The remaining quantity of N were applied in two equal splits as top dress at 25-30 days after sowing and 40-45 DAS.

Crop growth and harvest

Seeds were sown on 29 December, 2022. Thinning and weeding were conducted as per necessary, and no unusual occurrences of insect pests or diseases were found. The crop was harvested on 26 April, 2023.

Soil salinity monitoring and data collection

The average soil salinity was constantly monitored throughout the growth period of the crops. The EC meter (HANNA: HI 9835) was used to collect measurements at 15-day intervals. The results showed a wide range of soil salinity, suggesting the presence of fluctuating soil conditions and their possible influence on crop development. Data on yield and yield contributing characters such as Plant height (cm), Ear height (cm), Plant stand Plot^{-1}, Plant lodging (%), Days to tasseling, Pistillate formation, Cob length (cm) Grain rows Cob^{-1}, Number of grain Cob^{-1}, 1000 grain weight (g), Harvest index (%) and Yield (t ha^{-1}) were recorded plot wise. The dates of soil salinity data during different growth stages of mentioned entitled were recorded.

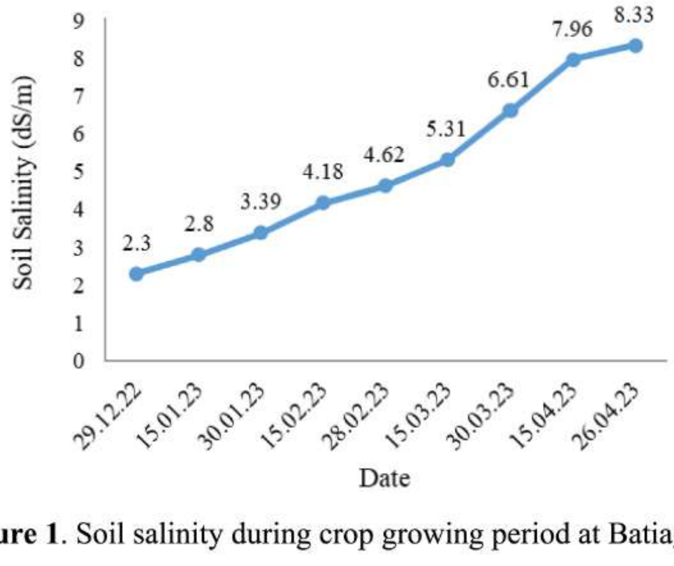

Figure 1. Soil salinity during crop growing period at Batiaghata, Khulna.

$$\textbf{Harvest Index \%} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Statistical analysis

Five plants were taken from each plot for data collection. Collected data were statistically analyzed by Software R (version 4.1.2). The significance of the difference between pairs of mean values was compared by the least significance difference (LSD) test at 5% level of probability.

Table 1. Average rainfall (mm) and temperature (^{0}C) during the experimental period from May 2022 to April 2023 in Batiaghata, Khulna

Month	Weekly rainfall (mm)				Monthly rainfall (mm)	Temperature^{0}C (monthly average)	
	1st week	2nd week	3rd week	4th week		Maximum	Minimum
May-22	34.00	20.0	0.3	116.0	170.3	34.66	27.26
Jun-22	0	2.0	47.0	14.0	63	29.18	28.18
Jul-22	50.0	19.0	20.0	24.0	113	33.80	27.91
Aug-22	51.0	48.0	60.0	10.0	169	33.43	27.71
Sep-22	0.7	149.0	163.0	0.8	313.5	46.15	27.30
Oct-22	50.0	0.2	0.6	17.0	67.8	32.79	25.06
Nov-22	0	0	0	0	0	30.43	19.49
Dec-22	0	0	0	0	0	27.28	16.19
Jan-23	0	0	0	0	0	25.00	14.65
Feb-23	0	0	0	0	0	29.71	18.84
Mar-23	0	0	25	96	121	32.59	21.86
Apr-23	19	0	0	15	34	48.91	25.36

Source: Meteorological Station Khulna.

Results and discussion

Plant height (cm)

Plant height is a crucial morphological characteristic that highly predicts the presence of growth resources. Significant variation in mature plant height (cm) across the different lines are presented in Table 2. Plant height of hybrid maize lines ranged from 105.33 cm to 182.33 cm. The tallest plant was observed in E6 x E5 (182.33 cm) which was statistically similar to BIL-157 x BIL-28 (182.10 cm), BIL-18Y x BIL-211 (181.77 cm), 900M-4 x Bill-28 (180.77 cm) and E-34 x BIL-211 (180.66 cm) and the smallest in BIL-106 x CML-480 (105.33 cm). These results are in accordance with the results of Ali *et al.* (2020) who also reported difference of plant height in various hybrids ranges from 166.01 to 200.70 cm.

Plant stand plot^{-1}

Plant stand is an important parameter for determining seed quality, replanting decisions, identify problems, agricultural operations, estimate potential yield loss and the yield. Significant difference in Plant stand plot^{-1} among the different maize lines are presented Table 2. Plant stand plot^{-1} ranged from 36.00 to 40.00. The highest crop stand plot^{-1} was found BMZ-9 x BIL-211 (40.00) and 900M-4 x Bill-28 (40.00) which were statistically similar with BHM-16 (Check) (39.67), P-3355 (39.67), BIL-79 x Pinacle-16 (39.67), BIL-216 x 900M-1 (39.00), E-34 x BIL-211(38.67) and E-6 x E-5 (38.67) and the lowest number of plant stand plot^{-1} was found BIL-106 x CML-480 (35.00) followed by E-5 x E-6 (35.00) Table 2. Ali *et al.* 2020 reported significant variation among eleven cultivars and those more or less similar in comparison with this finding whose ranged between 39.00 to 42.00 plants/six-meter square plot.

Plant lodging (%)

Stalk strength is a particularly important and quantifiable indicator of maize. Plant lodging, which may result from mechanical instability of the plant structure, external factors like wind or both, can cause the physical collapse of the plant canopy. Plant lodging of hybrid maize lines ranged from 0.00% to 12.50% where maximum plant lodging was recorded BIL-106 x CML-480 (12.50%) which was statistically similar to E-5 x E-6 (10.00%) and BIL-18Y x BIL-211 (9.16%) and minimum was BMZ-9 x BIL-211 (0.00%) statistically similar by 900M-4 x Bill-28, BIL-79 x Pinacle-16, BHM-16 (Check), P-3355, BIL-216 x 900M-1, Pinacle-3 x BIL-211, E-34 x BIL-211 and E-6 x E-5 in Table 2. Few previous research on lodging of maize cultivars was found Zhao *et al.* (2015) was 8 to 12%, Chang *et al.* (2016) was 5 to 16%, Ma *et al.* (2014) was 5 to 60% and Chen *et al.* (2012) was 2 to 7 % all were more or less similar with my result.

Ear height (cm)

Ear height is phenotypic parameter that reveal important agronomic traits in maize which directly affect lodging resistance and ultimately relate to maize yield. Significant difference in ear height (cm) among the different lines were found (Table 2). The ear height ranged from 43.66 cm to 97.44 cm. The maximum ear height was recorded in 981 (97.44 cm) followed by BMZ-9 x BIL-211 (95.44 cm), Pinacle-3 x BIL-211 (90.22 cm) and minimum in BIL-106 x CML-480 (43.66 cm). Ratul *et al.* (2017) revealed significant difference among 15 genotypes for this trait. The mean value ear height of fourteen genotypes were 48.53cm.

Days to tasseling

Significant variation in days to tasseling among the different hybrid maize lines was found (Table 2). Tassel formation ranged from 66 to 69 where longest duration taken in the line P-3355 (69) and the shortest duration taken in E5 x E 6 (66) which was followed by Pinacle-10 x BMZ-9 (66.33), Pinacle-3 x BIL-211 (66.33) and BIL-106 x CML-480 (66.67). Ratu *et al.,* (2017) observed highly significant variation (52.67 to 59) among 15 genotypes in days to tasseling. Toungos *et al.* (2019) observed significant difference (57 to 63) in days to tasseling.

Pistillate formation

A comparison of the several hybrid maize lines reveals a significant difference in Pistillate formation (Table 2). Pistillate formation ranged from (72 to 74 DAS) where longest duration taken line BIL-79 x Pinacle-16 (74 DAS), E-34 x BIL-211 (74 DAS), BMZ-9 x BIL-211 (74 DAS), BIL-18Y x BIL-211 (74 DAS), BIL-216 x 900M-1 (74 DAS) and 981 (74 DAS) and shortest duration taken BIL-106 x CML-480 (72 DAS). These results were supported by Khan *et al.* (2017).

Table 2. Agronomic performance of different line of maize in 2022-23

Lines	Plant height (cm)	Plant stand plot^{-1}	Plant lodging (%)	Ear height (cm)	Days to Tasseling	Pistillate formation (DAS)
E-6 x E-5	182.33 a	38.67 a	3.33 c	73.88 bcd	66.00 e	73 ab
BMZ-9 x BIL-211	179.22 a	40.00 a	0.00 c	95.44 ab	66.67 cd	74 a
E-34 x BIL-211	180.66 a	38.67 a	3.33 c	83.77 abc	67.00 c	74 a
900M-4 x Bill-28	180.77 a	40.00 a	0.00 c	69.77 cd	68.00 b	73 ab
E-5 x E-6	179.33 a	36.00 c	10.00 a	89.33 abc	66.00 e	73 ab
BIL-79 x Pinacle-16	172.10 ab	39.67 a	0.83 c	56.16 de	67.00 c	74 a
Pinacle-10 x BMZ-9	176.33 ab	38.33 ab	4.16 bc	88.21 abc	66.33 de	73 ab
BIL-106 x CML-480	105.33 c	35.00 c	12.50 a	43.66 e	66.67 cd	72 b
BIL-18Y x BIL-211	181.77 a	36.33 bc	9.16 a	85.65 abc	67.67 b	74 a
Pinacle-3 x BIL-211	180.77 a	39.00 bc	2.50 c	90.22 abc	66.33 de	73 ab
BIL-157 x BIL-28	182.10 a	38.33 ab	4.16 bc	73.88 bcd	68.00 b	73 ab
BIL-216 x 900M-1	168.10 ab	39.00 a	2.50 c	80.55 abc	68.00 b	74 a
981	179.77 a	38.33 ab	4.16 bc	97.44 a	68.00 b	74 a
P-3355	177.99 a	39.67 a	0.83 c	79.44 abc	69.00 a	73 ab
BHM-16 (Check)	148.99 b	39.67 a	0.83 c	70.67 cd	68.00 b	74 a
LSD0.05	28.84	2.34	5.02	22.48	0.57	1.49
CV%	10.04	3.61	60.24	17.11	0.50	1.21

Cob length (cm)

Significant variation in cob length (cm) among the hybrid maize lines are presented in Table 3. Cob length ranged from 15.10 cm to 20.68 cm. The highest length was observed in E-34 x BIL-211 (20.68 cm) which was statistically similar to BIL-79 x Pinacle-16 (19.64 cm), Pinacle-3 x BIL-211 (19.16 cm) and the lowest in 981 (15.10 cm). The results of the study showed parallelism with those of Eren *et al.* (2016) in terms of cob length ranged 24.3 to18.6 cm. Mtyobile (2021) found significant variation ranged from 15.33 to 20.00 cm and are in line with the present findings.

Grain rows Cob^{-1}

The number of rows cob^{-1} is a genetically controlled factor but environmental and nutritional level may also influence the number of rows cob^{-1}. The more number of rows per cob results in more grain yield. The maize line in Grain rows Cob^{-1} showed significant difference from one another (Table 3). Grain rows Cob^{-1} ranged from 14.00 to 20.55. The higher Grain rows Cob^{-1} was observed in E-34 x BIL-211 (20.55 cm) followed by BIL-79 x Pinacle-16 (19.02) and the lowest was found in BIL-106 x CML-480 (14.00). These results are in agreement with Tahir *et al.* (2008), Jahangirlou *et al.* (2021) and Namo and Kyenpiya (2012).

Figure 2. Pictorial view of different maize lines during the study period.

Number of grain Cob^{-1}

Grain yield is directly related to number of grains per cob. The greater number of grains per cob results in more grain yield. A comparison of the several maize lines shows a significant variation in number of grain Cob^{-1} (Fig 3). Number of grain Cob^{-1} ranged from 407 to 732.76. The higher number of grain cob^{-1} found in E-34 x BIL-211 (732.76) statistically similar to BIL-79 x Pinacle-16 (674.02), Pinacle-3 x BIL-211 (632.14) and the lowest observed in BIL-106 x CML-480 (407). These results were in line with Tahir *et al.* (2008) (436 to 648), Jahangirlou1 *et al.* (2021) (560 to 768), Namo and Kyenpiya *et al.* (2011) (253 to 428).

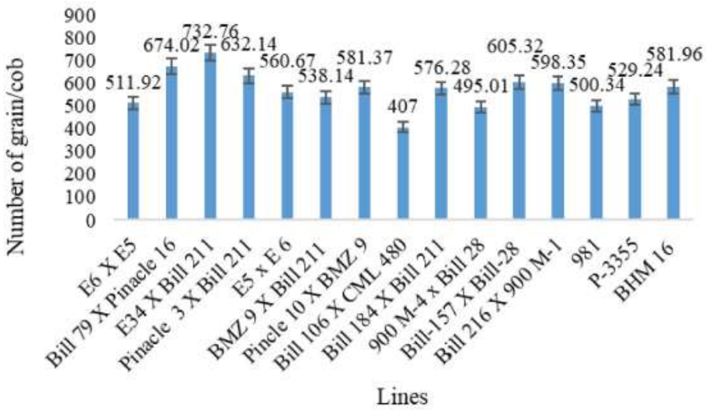

Figure 3. Variation in number of grain clob^{-1} of different maize lines. Vertical bar represents lsd at 5% level of significance

1000 grain weight (g)

There was a significant difference in 1000 grain weight (g) among the maize lines.1000 grain weight (g) ranged from 266.25 (g) to 353.23. The highest 1000 grain weight (g) was produced in E-34 x BIL-211 (353.23 g) followed by Pinacle-3 x BIL-211 (330.00 g) and BIL-157 x BIL-28 (320.00 g) and the lowest was BIL-106 x CML-480 (266.25 g). This was due to the fact that 1000-grain weight is a genetically controlled factor. The more or less similar results were also reported by Tahir *et al.* (2008). Ali *et al.* (2020) found significant variation among 11 cultivars (235 to 363.5g).

Table 3. Yield and yield contributing parameters of different line of hybrid maize in 2022-23

Lines	Cob length (cm)	Grain rows Cob^{-1}	1000 grain weight (g)	Harvest index (%)
E-6 x E-5	16.44 c	16.65 de	288.31 de	34.15 de
BMZ-9 x BIL-211	17.88 bc	16.62 cde	292.00 cd	35.44 cde
E-34 x BIL-211	20.68 a	20.55 a	353.33 a	46.14 a
900M-4 x Bill-28	15.75 cd	15.35 de	272.43 de	33.14 de
E-5 x E-6	18.41 bc	16.00 de	296.71 cd	36.72 cde
BIL-79 x Pinacle-16	19.64 ab	19.02 ab	346. a	45.03 ab
Pinacle-10 x BMZ-9	18.32 bc	18.00 bc	302.03 cd	37.50 cd
BIL-106 x CML-480	13.22 e	14.00 e	266.25 e	31.11 e
BIL-18Y x BIL-211	17.02	16.00 de	300.00 cd	37.00 cd
Pinacle-3 x BIL-211	19.16 ab	18.10 bc	330.00 ab	42.61 abc
BIL-157 x BIL-28	18.44 bc	18.00 bc	320.00 bc	39.82 bcd
BIL-216 x 900M-1	18.05 bc	16.05 de	310.33 cd	38.06 cd
981	15.10 cd	16.10 de	283.34 de	34.00 de
P-3355	17.55 bc	16.00 de	290.21 de	35.02 de
BHM-16 (Check)	18.24 bc	17.00 cd	300.10 cd	37.12 cd
LSD0.05	1.81	1.93	2.362	0.53
CV%	16.44	0.09	4.71	7.4

Yield

Significant difference was seen among the lines of maize in respect of maize yield. Yield ranged from 3.55 to 10.29 t ha^{-1}. The highest grain yield was produced in E-34 x BIL-211 (11.37 t ha^{-1}) followed by Pinacle-3 x BIL-211 (9.71 t ha-1) and BIL-79 x Pinacle-16 (9.09 t ha^{-1}) and the lowest was BIL-106 x CML-480 (3.53 t ha^{-1}). Factors like cob length, grain row clob^{-1}, number of grain cob^{-1}, and 1000-grain weight etc. directly affect the yield. These results are in partial agreement with Gul *et al.* (2020) (12.35 to 15.50 t ha^{-1}). Maryam *et al.* (2017) found grain yield ranged from 7.19 to 11.57 t ha^{-1} among 8 cultivars. Ali *et al.* (2020) obtained 6.92 to 5.90 t ha^{-1} among 11 cultivars.

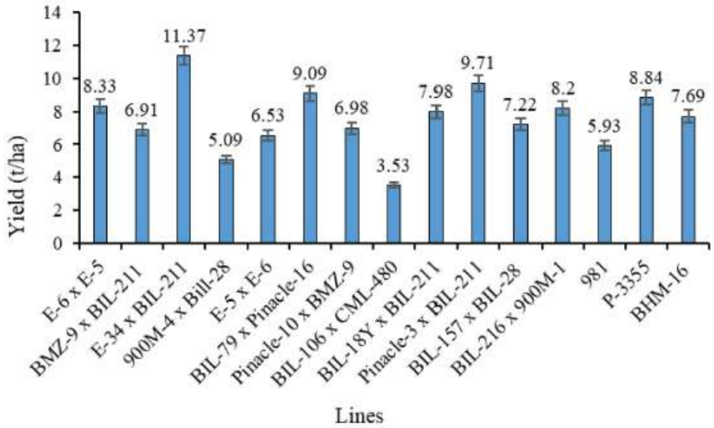

Figure 4. Variation in yield (t ha^{-1}) of different maize lines. Vertical bar represents LSD at 5% level of significance.

Harvest index (%)

Significant variation in Harvest index (%) among the hybrid maize lines are presented in Table 3. Harvest index (%) ranged from 31.11% to 46.14%. The highest Harvest index (%) was found in E-34 x BIL-211 (46.14%) followed by BIL-79 x Pinacle-16 (45.03%) and Pinacle-3 x BIL-211 (42.61%) and the lowest was BIL-106 x CML-480 (31.11%). Armen *et al.* (2007) and Nazir *et al.* (2010) reported fit more or less similar of harvest index in maize and wheat respectively.

Conclusion

All of the yield-contributing characteristics among the fifteen evaluated maize lines showed significant variation in the present study. Number of grain Cob^{-1}, 1000 grain weight (g) was much greater and lower Plant lodging (%) for E-34 x BIL-211 than other hybrid lines. Notably, E-34 x BIL-21showed greater seed yield by having more pistillate formation. The line E-34 x BIL-211 performed better in terms of growth and yield, according to salinity stress condition, and showed higher Harvest index (%). So, it can be suggested for cultivation in the Khulna region during the Robi season under salinity prone area. Pinacle-3 x BIL-211, E-5 x E-6 and P-3355 are also encouraging lines for saline fallow conditions according to their yield performance.

Conflict of interest

All authors declare that they have no conflict of interest.

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