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Evaluation on salinity tolerance of new maize hybrids at early growth and their performance in coastal field

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Abstract The stress of 150 mM NaCl decreased the growth and vigor of maize seedlings. Assessment on tolerance to NaCl stress of maize which elaborating stress tolerance index (STI) resulted in huge variation on tolerance of 20 genotypes to salinity stress. Based on a mean value of STI=0.15 and $\sqrt{\sigma^2}$=0.05, a hybrid was classified tolerant when its STI>0.18. Hybrids of H31, H33, H34, H48, and H50 were considered tolerant, while H16, H18, H19, H22, H25, H32, H42, and H49 were medium tolerant to saline stress. The hybrids exhibited high variation in the field performances, in either vegetative growth or yield components. The hybrids with highest yield in coastal field was H32. However, other hybrids also performed well and had the yield which were not significantly different from H32. They were H17, H19, H29, H31, H33, H34, H48, H50 and H51. All of these salinity tolerant hybrids were prospective to grow in coastal area.

Keywords: Corn, Coastal, Saline, Stress tolerance index

Introduction

Salinity has been shown a potential threat influencing almost 900 million ha of land which nearly accounts for 20% of the total cultivated area and also half of the irrigated land of the world (Butcher *et al.,* 2016). Most of the sodic-saline fields are located on the coastal area and expanding every year due to sea water intrusion. Soil salinization is the most worldwide problem hampering land productivity, especially in the arid and coastal land (Ladeiro, 2012). Globally, salinity influenced land amounted to about 397 million hectares (FAO, 2005 and Munns, 2005). In Indonesia, an archipelago with coastlines of 81,000 km, 13.2 million ha of agricultural land on the coast areas are potentially affected by salinity (Suprianto *et al.*, 2010). The area of saline soils is predicted to increase as the impact of global climate changes.

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High salt content of the coastal land decreases the productivity because most of the plants does not grow well. Salinity, as an abiotic stress, widely limits the crop production severely (Tang *et al.*, 2015). A saline soil is usually the reservoir of a number of soluble salts such as Ca^{2+}, Mg^{2+}, Na^{+} and anions SO_4^{2-}, Cl^{-}, HCO^{3-} and high amounts of K^{+}, $CO3^{2-}$, and NO^{3}. A soil can be termed as saline if its EC is 4 dS/m or more (Sparks, 2003; Sposito, 2008), equivalent to 40 mM NaCl with an osmotic pressure of 0.2 MPa. Salinity is the condition when the EC is sufficient to cause yield reduction of most crops.

Growth and yield reduction in association to salinity is due to osmotic stress followed by ion toxicity (Farooq *et al.*, 2015). High number of ions in the saline soil lowers the flow of water lead to difficulties in water uptake or even loss of intracellular water in plants (Yan *et al.,* 2013). Salinity induces a water deficit as well as ionic toxicity in the plants resulting in alteration in the ionic homeostasis. In addition to the osmotic and toxic effects, salt stress is also manifested as an oxidative stress. Consequently, salt-stress influences different physiological and biochemical processes including photosynthesis, respiration, protein synthesis or lipid metabolism (Acosta-Motos *et al.*, 2015).

Plants undergo a variety of mechanism to grow successfully under salinity stress, such as stomatal regulation, changes in hormonal balance, activation of antioxidant adjustment, maintenance of tissue water contents, and various mechanism of ion toxic exclusion (Farooq *et al.*, 2015). The accumulation of the compatible solutes and the activation of the antioxidant system are the effective measures for plants to enhance the salt resistance (Tang *et al.*, 2015). To cope with salt stress, plants have evolved mainly two types of tolerance mechanisms based on either limiting the entry of salt by the roots, or controlling its concentration and distribution (Hanin *et al.*, 2016). Tolerance mechanism to salt toxicity may also be by mean of accumulation of osmotic adjustment substances and ion-selective absorption and compartmentalization (Liang *et al.*, 2018). Tolerance to Na^{+} and Cl^{-} is an important factor in adaptation to the soil saline (Hariadi *et al.*, 2015).

In addition to the chemical properties of soil that disrupt plants, stress in plants becomes more complex as in general coastal land has high sand content and low organic matter because of leaching (Xie *et al*., 2017). Consequently, breeding for adaptivity to coastal land is also became more complex because it needs to consider not only the tolerance of the plants to salt toxicity but also the ability of the plants to grow and yield normally on coastal land. Therefore, much of today's research focuses on the effects of saline water and land on crop productivity (Hairmansis *et al*., 2017).

Breeding for an abiotic-stress tolerance usually involves selection for yield under optimum condition consecutively and simultaneously with the selection under stress condition (Herison *et al.,* 2017). Selection under optimum condition is to obtain maximum genetic potential as in such condition the maximum genetic potential of yield is expected to be realized (Herison *et al.,* 2014). Whereas selection under stress condition is to determine the yield stability indicated by the least yield reduction under stress environment (Kim *et al.,* 2015).

The response of plants to salinity varies among the plant species or even among varieties within a species. Maize (*Zea mays* L.) has been reported to be moderately sensitive to salt stress (Farooq *et al*., 2015). The effect of salt stress is more apparent in the seedling phase. Giaveno *et al.* (2007) confirmed genetic variability among hybrids for germination under salt stress and concluded that traits like seedling weight, growth rate, and photochemical efficiency should be used to assay salt tolerant maize hybrids under salt stress. Many researches had been reported to assess tolerance to saline in maize (Farooq *et al.,* 2015); (Collado *et al.,* 2016); (Hoque *et al*., 2015). The objectives of this study were to evaluate salinity tolerance, the growth and yield performance of newly developed maize hybrids in coastal field.

Materials and methods

Twenty newly hybrids of maize generated from the cross breed of irradiated gamma lines with local variety were evaluated for their tolerance to salinity stress. They were named as H16, H17, H18, H19, H20, H22, H24. H25, H29, H31, H32, H33, H34, H39, H42, H46, H48, H49, H50, and H5 (Rustikawati *et al.,* 2012) The study was conducted in 2 experiments to determine the tolerance of new hybrids to salinity and their performance in coastal field.

Assessment of new maize hybrids on NaCl tolerance at seedling stage

This experiment was evaluated the NaCl stressed tolerance at the seedling stage, arranged in a randomize complete block design with 3 replications. Each experimental unit consisted of 10 seedlings. Based on the previous evaluation. the NaCl concentration of 150 mM was sufficient to inhibit seedling growth of hybrids up to 50% of the normal growth. As a control. The hybrids were grown in AB mix nutrient culture without treated with NaCl.

The experiment was carried out in a wick system hydroponic model with twin stacked plastic boxes with the dimension of 50 cm (length) x 30 cm (width) x 15 cm (height). The lower box was the nutrient container, and the upper one was the sand media container. The seedlings were maintained for 4 weeks before harvested. The main variable observed was shoot dry weight (Carpýcý *et al.,* 2009; 2010). For supporting data, some variables were shoot length, number of leaves, root length, plant fresh weight, shoot fresh and dry weight, root fresh and dry weight, the ratio of shoot to root, and percent survival seedling. The relative tolerance of plants to NaCl stress was determined on the stress tolerance index (STI) (Bahari *et al.*, 2013; Collado *et al.*, 2016) as the following formula:

$$STI = \frac{Ypi\ x\ Ysi}{\overline{Yp}^2}$$

where STI, Ypi, Ysi and $\overline{\mathrm{Yp}}^2$ were stressed tolerance index, observed value of the plant grown in normal condition, observed value in stress condition and the total mean in normal condition, respectively.

Determination of hybrid tolerance to NaCl stress was calculated from the average of weighted STI values. Weighting was done on the main variable of shoot dry weight with a score of 2, while other variables with a score of 1. Hybrids considered tolerant when the value of $> \bar{x} + ½\sqrt{σ}^2$, medium tolerant if $\bar{x} - ½\sqrt{σ^2} \leq STI \leq \bar{x} + ½\sqrt{σ}^{2,}$ and sensitive if $STI < \bar{x} - ½\sqrt{σ}^2$.

Performance of growth of new maize hybrids in coastal field

The study was carried out on a coastal field within 200 m apart from the sea shore. The soil structure consists of 80% sand with a pH (H_2O) of 6.8 (medium) and a total N content of 0.24% (medium), P_2O_5 of 3.19 ppm (very low), K_{dd} of 0.7 me $(100g)^{-1}$ (medium). The experiment was arranged in a randomized complete block design with three replications. Each experimental unit was planted for one hybrid sized of 3m x 3m. The seeds were sown singly in the rows with 25 cm apart. Fertilization was done at a rate of 300 kg Urea, 200 kg SP36 and 150 kg KCl per ha. Harvesting was done when the ears were fully dried in the field. The vegetative variables observed were plant height, number of leaves, leaf area, stem diameter and plant fresh weight. Whereas, the generative variables were time to harvest, ear length, ear diameter, number of kernel lines, weight of 100 grain, cob weight per plant, grain weight per plant, grain weight per plot, and estimated grain yield per ha. Data were analyzed statistically with Anova at $α=5\%$, and the means comparison were performed LSD test at $α=5\%$.

Results

Assessment of new maize hybrids on NaCl tolerance at seedling stage

The stress of 150 mM NaCl decreased the growth and vigor of maize seedlings. Data observed in each variable were calculated as the STI values. The STI of shoot length and the number of leaves were generally higher than other variables. This indicated that there was a decrease in the size of those two variables which were smaller than the others. The highest STI calculated from shoot length was 0.40, while the lowest value was 0.17. Whereas, for the number of leaves, the highest STI was 0.62, and the lowest was 0.35. The STI variances of the shoot length and the number of leaves was 0.09 and 0.08, respectively. The variances of STIs for all observed variables ranged from 0.02 to 0.09. The hybrid with the highest STI on shoot length and the number of leaves was H34 (Table 1).

The STI values based on other variables including root length, shoot fresh and dry weight, root fresh and dry weight were below 0.28 (Table 1). These variables found a very large decrease in size between stress and non-stress conditions, so that the STI value was very low. The ranges of STI values on root length was relatively higher (0.11 to 0.28). Meanwhile, on shoot and root variables in both fresh and dry weight was lower STI. The STI value for shoot fresh weight ranged from 0.01 to 0.14, while for shoot dry weight ranged from 0.02 to 0.24. The STI values on root fresh weight and dry weight were slightly higher than on shoot fresh and dry weight. The STI value based on root fresh weight was highly correlated with shoot fresh weight (r=0.88). Likewise, the STI value between shoot root dry weight and root dry weight (r=0.71). The ratio of shoot to root was calculated from dry weight which indicated the concentration of dry matter accumulation in shoots. The STI based on the ratio of shoot to root ranged from 0.04 to 0.22. Of the five variables related to shoot and root, the H34 hybrid consistently had the highest STI.

There was a high consistency of STI values on H34 for all variables. The highest average STI from all variables showed on H34 was 0.28, while the lowest showed on H39 and H51 was 0.09. Based on a mean value of STI=0.15 and a $\sqrt{\sigma^2}$=0.05, the hybrid was tolerant if STI>0.18, medium tolerant 0.13≤STI≤0.18, and sensitive STI<0.13. Based on these criteria, five tested hybrids were classified tolerant to 150 mM NaCl, namely H31, H33. H34. H48, and H50. The H16, H18, H19, H22, H25, H32, H42, and H49 hybrids were medium tolerant to salinity while the other hybrids were sensitive.

Growth performance of new maize hybrids in coastal field

The maize hybrid can grow well on the coastal land which was indicated as a sandy loam with very low P and medium N and K contents. The level of salt was relatively low so that no plants show symptoms of poisoning. Based on the ANOVA at 5% level, the hybrids had a very significant differences observed on all variables, except stem diameter. The LSD test on the means demonstrated the variation among variables. The highest plant height observed on the hybrids H33 and H46, which were 212.37 and 213.10 cm, respectively. In addition, both also have more leaves compared with others. Other hybrids that have the same number of leaves as H46 were H16 and H29. However, the leaf area was not in line with the number of leaves. The hybrids with the highest leaf area were H19, H32 and H48. Stem diameter was an important variable indicating the strength of the plant against wind. For this variable, all hybrids did not differ statistically with the largest on H48. The plant fresh weight was determined by the supporting variables plant height, leaf length, leaf width, leaf area, number of leaves and stem diameter. The hybrid with the highest plant fresh weight was H46. Other hybrids have a plant fresh weight that was not different from H46 were H29, H31, H32. H34, H42, H49, H50, H51. Over all, the hybrids that showed the best vegetative growth were H33 and H46 (Table 2).

The age of the new hybrids tested ranged from 91 to 101.33 days. The earliest harvesting was found on the hybrid H39 (91 days). However, this hybrid did not show a good generative performance compared to the others. Variations in the length and diameter of the ear were not high enough. Long and large diameter of the ear are expected to have more kernels. Of the 20 hybrids, the H19 had the largest ear size (17 cm long, 4.63 cm diameter). In addition, the H32 also have a relatively large ear. A larger diameter of ear was usually followed by a higher number of seed rows. Hybrid H19 had the large diameter followed by a large number of seed rows. With a high weight of 100 grains, H19 also have a high yield per ha (8.96 tons). The hybrid with the highest number of seed rows was H32. With large cobs and medium seed size, H32 had the highest grain weight per plant of 139.07 g with a potential yield in the coastal field of 9.74 tons/ha (Table 3). Estimation of the yield per hectare was made in a population of 70000 plants. Other yield components such as cob weight per plant and grain weight per plot had a very high positive correlation with yield/ha with a correlation coefficient of 91% and 66%, respectively.

The hybrids of H33 and H46 consistently have good performance in the vegetative growth, but not for the generative variables and the yields. The H33 hybrid had a relatively large diameter, ear weight per plant, grain weight per plant, and grain weight per plot, so that the yield was also relatively high (8.88 tons/ha). The H46 hybrid only grew superior vegetatively. However the less superior generatively compared to other hybrids. On the other hand, hybrids H17, H19, H29, H31, H32, H34, H50 and H51 were less superior vegetatively, but the yields were superior and not significantly different from H32. Overall, based on the yield of 9.74 tons/ha, the hybrid H32 showed the highest potential to grow in the coastal field.

Table 1. Calculated stress tolerance index (STI) on all variable of maize hybrids seedlings

Hybrids	Shoot length	Number of leaves	Root length	Shoot fresh weight	Shoot dry weight	Root fresh weight	Root dry weight	Shoot to root ratio	Percent survival	Average STI	Salinity tolerance
H16	0.33	0.41	0.27	0.04	0.09	0.14	0.10	0.13	0.04	0.17	Medium tolerant
H17	0.22	0.35	0.16	0.03	0.06	0.05	0.05	0.07	0.07	0.11	Sensitive
H18	0.37	0.40	0.29	0.04	0.08	0.11	0.08	0.15	0.06	0.17	Medium tolerant
H19	0.31	0.55	0.15	0.03	0.06	0.07	0.06	0.17	0.04	0.15	Medium tolerant
H20	0.17	0.40	0.17	0.02	0.04	0.07	0.07	0.04	0.04	0.11	Sensitive
H22	0.29	0.44	0.20	0.02	0.06	0.08	0.05	0.17	0.06	0.14	Medium tolerant
H24	0.18	0.43	0.14	0.02	0.06	0.10	0.09	0.04	0.04	0.11	Sensitive
H25	0.26	0.52	0.18	0.02	0.04	0.06	0.05	0.11	0.05	0.13	Medium tolerant
H29	0.18	0.40	0.13	0.01	0.03	0.08	0.06	0.05	0.03	0.10	Sensitive
H31	0.42	0.52	0.23	0.07	0.13	0.12	0.10	0.15	0.06	0.19	Tolerant
H32	0.36	0.52	0.22	0.07	0.13	0.14	0.10	0.08	0.08	0.18	Medium tolerant
H33	0.40	0.50	0.27	0.05	0.12	0.15	0.12	0.10	0.06	0.19	Tolerant
H34	0.38	0.62	0.28	0.14	0.24	0.27	0.26	0.22	0.05	0.28	Tolerant
H39	0.17	0.39	0.11	0.01	0.03	0.03	0.04	0.04	0.08	0.09	Sensitive
H42	0.29	0.59	0.19	0.05	0.09	0.16	0.13	0.05	0.05	0.17	Medium tolerant
H46	0.18	0.41	0.12	0.03	0.05	0.08	0.22	0.06	0.03	0.12	Sensitive
H48	0.35	0.60	0.22	0.07	0.11	0.11	0.06	0.18	0.10	0.19	Tolerant
H49	0.25	0.47	0.18	0.05	0.10	0.12	0.11	0.09	0.06	0.15	Medium tolerant
H50	0.36	0.60	0.26	0.09	0.17	0.25	0.19	0.19	0.06	0.24	Tolerant
H51	0.18	0.40	0.18	0.01	0.02	0.04	0.02	0.07	0.06	0.09	Sensitive
σ^2	0.09	0.08	0.05	0.03	0.05	0.05	0.05	0.05	0.02		
Mean ±SE	0.28 ± 0.004	0.48 ± 0.004	0.20 ± 0.003	0.05 ± 0.002	0.04 ± 0.002	0.11 ± 0.002	0.09 ± 0.002	0.10 ± 0.002	0.11 ± 0.001		

Table 2. Vegetative growth of maize hybrids grown in coastal field

Hybrids	Plant height (cm)	Number of leaves	Leaf area (cm^2)	Stem diameter (mm)	Plant fresh weight (g)
H16	190.33 b	13.3 ab	488.00 a-e	17.47 a	1193.33 def
H17	182.90 bc	12.3 b-e	501.00 a-e	15.57 a	1050.00 f
H18	168.90 c-f	11.7 c-f	456.33 cde	15.27 a	1239.67 c-f
H19	183.63 bc	12.3 b-e	562.33 a	17.20 a	1493.33 a-f
H20	181.27 bc	12.7 a-d	541.33 abc	16.03 a	1096.67 ef
H22	146.57 g	11.0 ef	447.33 de	14.73 a	1253.33 c-f
H24	146.47 g	10.7 f	353.33 f	15.77 a	1186.67 def
H25	159.73 fg	11.7 c-f	427.67 ef	15.90 a	1046.67 f
H29	179.63 bcd	13.7 ab	556.67 ab	15.90 a	1543.33 a-e
H31	178.87 b-e	11.0 ef	558.67 ab	16.70 a	1598.33 a-d
H32	189.67 b	11.3 def	568.00 a	16.83 a	1696.00 abc
H33	212.37 a	13.0 abc	559.00 ab	17.13 a	1750.33 ab
H34	167.43 c-f	11.3 def	530.33 a-d	17.27 a	1455.00 a-f
H39	162.60 d-g	10.3 f	470.67 b-e	16.40 a	1378.33 b-f
H42	162.60 d-g	11.0 ef	498.00 a-e	16.17 a	1849.00 ab
H46	213.10 a	14.0 a	546.33 ab	17.47 a	1929.67 a
H48	176.43 b-f	10.3 f	572.00 a	17.90 a	1418.33 b-f
H49	161.17 efg	11.0 ef	498.67 a-e	16.70 a	1552.67 a-e
H50	189.53 b	12.3 b-e	559.33 ab	15.80 a	1570.67 a-e
H51	183.77 bc	12.3 b-e	529.33 a-d	15.77 a	1382.67 b-f
LSD0.05	18.44	1.54	89.12	2.23	484.45

Remarks: numbers in the same column followed by the same letters were non-significant difference based on LDS at α=5%

Table 3. Generative growth and yield of maize hybrids grown in coastal field

Hybrids	Time to harvest (days)	Ear length (cm)	Ear diameter (mm)	Number of kernel lines	Weight of 100 grain (g)	Cob weight per plant (g)	Grain weight per plant (g)	Grain weight per plot (g)	Yield per ha (ton)
H16	100.00 abc	19.27 a	39.57 hij	11.87 e-h	37.67 a	1090 ij	75.9 g	616 i	5.32 g
H17	98.00 b-f	17.33 b	42.60 def	12.53 c-f	28.53 def	1536 fgh	123.1 a-d	1274 g	8.62 a-d
H18	95.33 e-i	15.97 b-e	41.07 e-i	13.40 a-d	28.27 def	1289 ghi	90.0 efg	893 ghi	6.30 efg
H19	96.67 d-h	17.00 bc	46.30 a	13.47 a-d	34.07 b	1678 d-g	128.1 ab	1124 ghi	8.96 ab
H20	97.33 c-g	17.40 ab	41.93 d-h	12.40 def	29.80 cd	1488 f-i	105.8 b-f	1000 ghi	7.41 b-f
H22	98.33 a-e	16.20 b-e	39.93 ghi	11.87 e-h	27.50 ef	1149 hij	92.1 efg	868 ghi	6.45 efg
H24	94.33 g-ij	15.17 c-h	41.10 e-i	13.60 abc	25.00 g	866 j	81.8 fg	746 hi	5.73 fg
H25	94.00 h-k	13.50 ghi	37.03 j	11.80 fgh	26.67 fg	831 j	78.9 fg	638 i	5.52 fg
H29	98.33 a-e	16.80 bcd	40.63 f-i	11.20 gh	30.03 cd	1630 efg	128.5 ab	1236 gh	8.99 ab
H31	92.00 jk	13.33 hi	45.97 ab	13.00 b-e	29.47 cde	2342 ab	127.3 ab	3234 ab	8.91 ab
H32	92.67 ijk	15.50 b-f	45.53 abc	14.17 a	29.73 cde	2250 ab	139.1 a	3075 abc	9.74 a
H33	92.67 ijk	13.77 f-i	45.70 ab	13.00 b-e	30.33 cd	2172 abc	126.8 abc	2974 abc	8.88 abc
H34	92.33 ijk	15.27 c-g	43.60 b-e	11.83 fgh	31.03 c	2567 a	124.8 abc	3358 a	8.74 abc
H39	91.00 k	13.33 hi	41.63 d-i	13.83 ab	30.93 c	1377 ghi	95.6 d-g	2032 f	6.69 d-g
H42	92.00 jk	13.03 i	43.57 b-e	13.67 abc	29.60 cde	1416 f-i	100.7 b-g	2185 ef	7.05 b-g
H46	100.67 ab	15.40 c-g	43.07 c-f	11.50 fgh	30.40 cd	1476 f-i	100.1 b-g	2290 def	7.00 b-g
H48	95.33 e-i	16.33 b-e	42.63 def	11.83 fgh	29.40 cde	2084 bcd	121.6 a-d	2731 bcd	8.51 a-d
H49	95.00 f-j	14.53 e-i	39.27 ij	11.67 fgh	29.80 cd	1545 fgh	98.2 c-g	2144 ef	6.87 c-g
H50	98.67 a-d	14.97 d-h	42.50 d-g	10.83 h	30.23 cd	1807 c-f	114.9 a-e	2318 def	8.04 a-e
H51	101.33 a	14.03 f-i	44.10 a-d	12.17 efg	30.47 cd	1994 b-e	114.9 a-e	2587 cde	8.04 a-e
LSD0.05	3.31	1.91	2.57	1.14	2.28	420.47	28.63	509.76	2.01

Remarks: means in the same column followed by the same letters were non-significant difference based on LDS at α=5%

Discussion

The evaluation of new maize hybrid was carried out to see its development potential in coastal land influenced by salinity. To ensure that the selected hybrids may be a source of saline tolerant genes, the study was conducted simultaneously both in controlled conditions and the production potential in saline fields. Under controlled conditions with NaCl treatment, it can be seen that hybrids genetically show tolerant or sensitive performance. The development of salinity tolerant crops is essential for increasing productivity on saline soils (Hoang *et al.*, 2016). Some agricultural crops are able to tolerate land with high salt stress (Ma'ruf, 2017).

The new hybrid under study has varying levels of tolerance to high NaCl stress under a controlled condition. Most of the plants were curl, necrosis and even died due to NaCl of 150 mM. There was a significant decrease in growth under stress conditions compared to control. According to Kholová *et al.* (2009), salinity stress reduces relative water content, chlorophyll and carotenoid content, membrane stability index, potassium and calcium content, and increases the content of superoxide radicals (O_2^-), hydrogen peroxide (H_2O_2), thiobarbituric acid reactive substances, proline, glycinebetain, total dissolved sugar, and sodium, as well as the ratio of Na^+/K^+ dan Na^+/Ca_2^+. The excess of sodium ions interferes with potassium absorption (Shahzad *et al.*, 2012). Impaired potassium absorption causes stomatal undulation disorders so that corn will lose a lot of water until it results in necrosis of leaf tips (Sümer *et al.*, 2004).

The decrease in growth under NaCl stress conditions was used to determine the tolerance level of hybrids. The relative tolerance of hybrids can be estimated using the stress tolerance index (STI) (Bahari *et al.*, 2013; Collado *et al.*, 2016). The STI values indicate the ability of plants to survive under stressful conditions. The selected genotypes by STI are the ones having high observed value in both stressed and non-stressed conditions. If there is no decrease in the value of the observed variables in the stress condition compared to that of the average measurement over all hybrids under study in non-stress condition, then the STI value will be equal to 1 or higher. This may ensure that the decrease in yield was caused due to the influence of salinity. In the controlled conditions, maize was moderately sensitive to salt stress (Farooq *et al.*, 2015). Salt content of more than 250 mM NaCl on maize caused plant wilting, necrosis and inhibition in growth (Menezes-Benavente *et al.*, 2004). Even in this study, the stress of 150 mM NaCl for 30 days caused maize seedlings to be necrosis at the tips of the leaves and wilt to death. In plants that were still alive, there was a significant decrease in seedling size for all observed variables compared to that in normal conditions. The greater decrease was found in shoot and root variables in both fresh and dry weight. In both of these traits, a lower STI value was obtained. These two variables are relatively more sensitive to salinity stress. Some researchers also used shoot fresh weight or shoot dry weight (Hoque *et al.,* 2015; Carpýcý *et al.,* 2010) as a variable for observing NaCl stress in maize. Akram *et al*. (2007) used the dry weight of corn starch to determine tolerance for maize, while Hosseini *et al*. (2012) studied on rice.

In addition, NaCl stress decreases the fresh and dry weight of root. The STI value of root fresh weight was highly correlated with shoot fresh weight (r=0.88). Root growth was severely disturbed by the presence of NaCl stress. The root variable is appropriate for selecting tolerance to salinity. The ratio of shoot to root dry weight which indicated the concentration of plant dry matter accumulation in shoots. Plants that did not experience stress was a marked increase in the shoot/root ratio. On the other hand, in sensitive plants, salinity reduced shoot growth by suppressing leaf initiation and expansion, as well as internode growth, and by accelerating leaf abscission so that the shoot/root value becomes smaller (Akram *et al*., 2007; Qu *et al*., 2012).

Hybrid tolerance level information is very useful to determine the hybrid suitable to grow in coastal area. The H34 hybrid was able to overcome the negative effect of Na^+ ions so that the STI value was consistently high for all variables. Many previous works demonstrated that tolerance to abiotic stress is controlled by genetic factors (Bahari *et al*., 2013; Hariadi *et al*., 2015; Hoque *et al*., 2015). Genotype factor varies in response to stress conditions at seedling stage, vegetative and generative growth. Differences among genotypes more clearly visible at suboptimum environment. This phenomenon verified that there is a genetic variation among genotypes to cope with stress condition. Genetic variation in abiotic stress tolerance is usually related with allelic variation, gene duplication and/or gene neo-functionalization (Mickelbart *et al.,* 2015).

Salinity is used to describe the presence of increased levels of salts such as sodium chloride, magnesium sulfate, calcium sulfate and bicarbonate in soil and water (Hoang *et al.,* 2014). In coastal areas the increase in NaCl levels occurs due to tides or sea water intrusion. In addition, the two main human activities that accelerate land salinity are irrigation and extensive vegetation clearance which causes saline groundwater to flow into the sea (Hoang *et al*., 2016). The research location is very closed to the sea shore so the influence of sea water is huge. The average EC value at three points of soil samples collected around the experimental area was more than 4.0 dS/m. In addition to the effect of NaCl levels exceeding the threshold, the research area with high sand content was also poor in phosphorus nutrients. Although the N and K content were classified as medium, fertilization was carried out at the recommended rate to evaluate the potential yield of the new hybrids in the coastal field.

Saline tolerant hybrids based on nutrient culture selection do not necessarily have superior performance in saline soils. Previous work reported that salinity tolerance is controlled by two-three major genes (Wang *et al.*, 2010) with non-additive type gene action (Aslam *et al.*, 2015). Meanwhile, the yield is controlled quantitatively by polygenes (Hallauer *et al.*, 2010). The influence of the environment is very complex, although the influence of salinity is more dominant. The physical, chemical and biological properties of the soil play an important role in contributing to soil fertility. In this study, the criteria for the coastal field used as experimental land were sandy loam type with very low P, medium N and K medium nutrient content. Sandy loam soil has the characteristics of low water holding capacity, so that nutrients are easily washed off. To supply the three main macronutrients for plant growth, it is compulsory to add N, P and K fertilizers at planting time (Rustikawati *et al.*, 2020).

With EC 5.84 dS/m, the salt concentration in the soil is considerably high that interfere with plant growth (Ali, 2011). In these conditions, plants have difficulty to absorb water because they compete with salts in the soil. In addition, plants must also overcome ion poisoning, nutritional disturbances and poor soil physical conditions to survive so that productivity is reduced (Shrivastava *et al.,* 2015). The hybrids of H33 and H46 consistently had good vegetative growth performance, and their yield were also comparably high. The highest yield of the new hybrid evaluated in this study was 9.74 tons/ha owned by H32. Therefore, it showed the highest potential to grow in the coastal area. Other hybrids that also performed well and had the yield which were not significantly different from H32 were H17, H19, H29, H31, H33, H34, H48, H50 and H51.

Assessment of tolerance in very early stage of growth will be useful if it can represent tolerance at further vegetative or generative stage in the field as this approach may shortcut the selection cycle in the development of adaptive varieties. Moreover, it is noticeable that there is a huge gap between artificial challenging for an abiotic stress in the greenhouse and in a suboptimal field. The former is a single and highly controlled factor stress, and the latter is more complex environment-related stress. Therefore, any early growth selection methods for stress tolerance which represents the tolerance in the field is valuable for breeders to select tolerant genotypes more easily. The work of Meeks *et al.* (2013) showed the evidence that selected maize genotypes for drought tolerance at seedling stage were tolerance in the less watered field.

Due to the spatial and temporal variability in salinity within most agricultural systems, a stable cultivar must have stress tolerance mechanisms which prevent excessive yield reductions in stress environments. The grain yield and yield stability under environmental stress remain a major selection criteria for stress tolerance in many breeding programs (Mitra, 2001). Hybrids H31, H33. H34. H48, and H50 were the most tolerant to salinity stress. Those hybrids also revealed high yield and prospective to grow in coastal area.

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