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# SCREENING SALT-TOLERANT SUGAR BEET GENOTYPES USING STRESS TOLERANCE INDICES

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ABSTRACT

To evaluate the salt-tolerant sugar beet genotypes and identify the tolerating lines, 30 genotypes were selected from Iranian Sugar beet Seed Institute Breeding Program. The experiment took one agricultural year to complete in 2017. A total number of 30 sugar beet genotypes, including five genotypes as Controls, were cultivated subject to two salinity levels of irrigation water, 2dS.m$^{-1}$ and 14dS.m$^{-1}$ respectively, in five replications within the format of complete randomized block design. Upon the establishment of the plants, the number of the plants on the cultivation lines was counted and thinning was carried out. The entire cultivation plots were harvested in technological harvesting time and the roots were counted and weighed and finally sent to Sugar beet Technology Laboratory affiliated with Sugar beet Seed Institute-Iran to be used for pulp determination and eventually undergo qualitative analysis. Some of the important traits measured in the laboratory were: root yield(RY), sugar content(SC), white sugar content(WSC), sugar yield(SY), white sugar yield(WSY), sodium, potassium and nitrogen impurities, molasses sugar(MS), extraction coefficient of sugar(ECS) and alkalinity coefficient(Alc). Data analysis was carried out in SAS and the mean comparisons were carried out using Duncan test in a 5% probability level and the interaction effects were examined by taking advantage of slicing method. The experiment results indicated that salinity has a significant effect on such traits as RY, SY, WSY and SC. There was evidenced a very significant difference between the investigated genotypes in terms of the aforementioned traits. On average, the root yield was found decreased to half subject to salinity. The white sugar yield were obtained equal to 1.31 ton.ha$^{-1}$ and 2.51 ton.ha$^{-1}$ subject to salinity and non-saline condition, respectively; but, the sugar content was significantly increased under saline conditions. A large array of diversity was documented between the examined genotypes and, in between, genotypes S1-930882, OT-110-25-90, DR1-HSF-14-P.35 and S1-940655 had higher RY, SY , WSY and better stress tolerance indices(STI), on average. Genotype S1-930702 can be candidate as one of the best selectable genotypes for its high SY and WSY. Genotypes S1-930708, OT-111-17-90, S1-930770, OT-111-9-90 and S1-940645, as well, had high root yields on average but they were not classified as stress tolerant genotypes for their high yield differences under stress and non-stressed conditions and also for their low Stress Tolerance Index (STI).



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## Introduction

Generally, the reduction in sugar beet yield comes about under saline conditions or for the low genetic potential of the varieties and/or the lack of proper agricultural management processes implemented under such conditions [1, 2]. Under such conditions, inappropriate climate and unfavorable environmental conditions can intensify the effect of salinity stress [3]. Based on the summarizations made by [5], the salt-tolerance threshold in sugar beet is 7dS.m$^{-1}$ and its yield reduction gradient after the threshold point is 6%. But, these values largely differ depending on variety, climate, irrigation management, fertility level and agricultural management methods [4, 5,6]

Generally, the ions existent in water and soil limit the plant's growth in two ways: first of all, the presence of salt in soil solution diminishes the plant's capability for water absorption and this leads to the reduction in growth rates. This aspect of the salinity stress can be traced in the osmotic effects of salinity stress; secondly, if the extra amounts of salt are taken in by

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the plants through transpiration, it will cause cellular damages in the active and photosynthesizing leaves that can bring about more reductions in growth. These aspect of salinity stress can be referring to specific effects of salinity or ionic effects [7, [8, 9, 10]. In sugar beet, as well, the desired result might not be obtained even with its high relative tolerance to salinity stress for such a reason as its sensitivity during early growth stages [5, 11]. The selection of a suitable cultivar that can exhibit relatively higher tolerance during early growth stages along with appropriate agricultural management can help overcoming the problem. During the studies conducted for the identification of salt tolerant resources, a number of salt-tolerant strains were identified but it is still necessary to do further research works in this regard so that more salt tolerant varieties and more commercial cultivars can be found out. Some of these studies deal with morphological traits of the varieties and evaluate such characteristics as greenness of the leaf color, life length of the leaf and vegetative growth of the varieties [12]. In some other studies, as well, the physiologic attributes of the salt-tolerant strains have been explored, including leaf chlorophyll content, number and area of the stomata and sodium to potassium ratio, proline, betaine and osmotic regulators [13, 14]. The results of these studies indicated that the vegetative growth of the tolerant and sensitive plants goes down under salt stress conditions. The chlorophyll content as well as the number and area of the stomata are higher in sensitive strains than in semi-tolerant and tolerant ones and, in the meantime, salinity causes an increase in free sodium and proline in the shoot of the plants but it decreases the potassium amounts and relatively tolerant genotypes accumulate higher amounts of sodium and proline but lower amounts of potassium in comparison to sensitive genotypes. It was found in the experiment conducted by [15] that the relative water content (RWC) of leaf significantly decreases with the increase in salinity and this is similar to the reaction plants develop under drought stress conditions. It was figured out in salt-tolerant genotype identification plan that there are salt-tolerant strains in 7233-P.29 mass so the use of S1 and S2 seeds prepared from them is recommended in the supplementary studies for the selection of salt-tolerant strains [16]. In the meantime, comparison of salt-tolerant line MST*7233-P.29 with the cultivar commonly used in Isfahan Region (IC) and Nemakill made it clear that the aforesaid line outperforms them all [17].

It can be inferred according to the results of the above experiments that there has been a positive trend in introducing the salt-tolerant varieties in Iran and they have been accompanied by useful results. But, in continuing the above experiments, it has to be noted in selecting the proper indices for the nomination of the salt-tolerant genotypes that their relationship with the amount of extractable sugar per every unit area has to be figured out because being characterized by properties like high K/Na and proline is insufficient and these factors can render part of the produced sugar non-extractable and negatively influence the sugar content[18] pinpointed the most appropriate titration method for drought, salinity and normal stress conditions. Another essential point in selecting the salt-tolerant genotypes and lines is their yield stability that has to be evaluated in time and in place. Based on the susceptible stress index (SSI), smaller amount of SSI is indicative of low yield variations of a genotype subject to stress in contrast to that subject to favorable conditions and its higher stability [19]. Based on stress tolerant index (STI), the more stable genotypes feature higher STI values [20]. Also, the selection of more superior genotypes in regard of these indices is based on lower Tol and higher MP [21]. Of course, the necessary condition for the creation of a positive and logical relationship between Tol and MP indices is that the genetic variance should be larger in stressing than in the otherwise environment. The more the Tol index is found smaller, the more it is indicative of the idea that the genotype’s performance is closer in stressed conditions to unstressed conditions and/or the plant is more tolerant to stress. Making the selections based thereon causes the choice of the genotypes that exhibit higher performance but lower performance potential subject to stress. The correlation between MP and Tol is negative in the majority of the modes. Also, selection based on MP brings about performance enhancement in both of the stressed and non-stressed environments. In case that the objective is performance enhancement under stress conditions, selection based on MP can be useful. Of course, it has to be noted that such a selection causes a simultaneous reduction in the mean productivity and performance subject to unstressed conditions. Generally, SSI index and STI index have higher efficiencies in selecting the superior lines for the former’s use of environmental condition’s harshness constant (SI) and the latter’s use of geometric mean.

In analyzing the correlation between sugar yield and stress sensitivity and tolerance, [22] showed that STI index, mean production index (MP) and the geometric mean index (GMP) are the most indices for the identification of salt-tolerant hybrids.

[23] expressed in screening 80 sugar beet genotypes under greenhouse and field conditions in a four-year period of time that a salinity equal to 12dS.m$^{-1}$ is the most appropriate salinity level for the evaluation of the genotypes and the root yield as compared to the other traits is most heavily influenced by the salt stress. They underlined that white sugar yield is the best scale for selecting the salt-tolerant genotypes and that BP MASHAD is the best genetic material that can be employed in breeding projects.

The aim of this study is the screening and selecting of tolerate genotypes of sugar beet based on sugar yield and higher STI.

**Materials and Methods**

In the present study, 30 sugarcane genotypes, including five genotypes as controls, were cultivated subject to two salinity levels of irrigation water, 2dS.m$^{-1}$ and 14dS.m$^{-1}$, in five replications within the format of complete randomized block design. At first, the farm was selected with a uniform salinity and two times irrigation before planting (with 2 and 8dS.m$^{-1}$ water for non-saline and saline plots, respectively) were carried out to instigate more uniform salinity of the soil. Following the tillage operation in fall, the intended land was again prepared in April and cultivation was conducted during 17-19April. The cultivation was carried out in the form of furrow-irrigated raised bed system. The entire plots were irrigated with non-saline water for the first and second times [3]. After the plants were found well-established, the later irrigations were carried out based on the specified treatments. Soil samples were collected in all the experimental plots from various depths:0-30, 30-60 and 60-90 centimeters, before sowing the seeds as well as during the growth season. This was done to determine the amount of salinity the plant is exposed to during the growth season as well as for managing the later irrigations (determination of the amount of leaching fractions). Upon the leaves being found established (8-10 leaf stage), the number of the plants on the cultivation rows was counted following which some thinning was conducted. Diazinon sprays were undertaken seven times for pest extermination. The number of plants was counted after emergence and also following exposing the plants to salinity treatment so that the salt-sensitive and salt-tolerant genotypes can be identified during early vegetative growth stage. The entire cultivation plots were harvest in technological harvest time and small samples were taken from shoots to be subjected to dry weight determination. After the roots were counted, they were sent to the sugar technology laboratory to be weighed and undergo pulp determination and qualitative analysis. The traits evaluated in the laboratory were root yield (RY), sugar content or purity (SC), white sugar content (WSC), sugar yield (SY), white sugar yield (WSY), sodium, potassium and nitrogen impurities, molasses sugar (MS), extraction coefficient of sugar (ECS), alkalinity coefficient (Alc), dry matter percentage of root (DM) and shoot yield. Sugar content was measured based on polarimetry method; harmful nitrogen content was determined based on chromatography using betalyzer device and sodium and potassium impurities were measured based on flame photometry [24, 25]. The dry matter percentage of root was measured through placing an amount of root paste in a 105°C oven and allowing it to reach a constant weight [26]. The amount of molasses sugar was estimated based on the amounts of potassium, sodium and harmful nitrogen. The rest of the parameters and indices were calculated using the following relations:

Equation (1): WSC= SC-(MS+0.6)
Equation (2): SY=SC× RY
Equation (3): WSY=WSC× RY
Equation (4): ECS=(WSC/SC)× 100
Equation (5): Alc=(K+Na)/(α-N)
Equation (6): $$Tol = Y_p - Y_s$$
Equation (7): $$MP = \frac{Y_p + Y_s}{2}$$
Equation (8): $$STI = \frac{Y_p \times Y_s}{\overline{Y}_p^2}$$

Yp: yield in non-saline condition; Ys= yield in stress condition; $\overline{Y_p}$ = mean of the genotypes yield in non-saline condition
Experimental data analyses were conducted using SAS software and performing mean comparisons based on Duncan test in a 5% probability level and the group comparisons were carried out using orthogonal coefficients and the interactions effects were determined using slicing method [27].

## Results

### Soil Salinity:

In this experiment, it was endeavored in line with creating identical plant density to keep the soil salinity low when planting so that a uniform plant density could be preserved in both saline and non-saline conditions. After emerging of the plants, irrigation operation was conducted using 14dS.m$^{-1}$ water salinity to increase the salinity of the soil and it was continued until the salinity value of the soil reached a range between 14-16dS.m$^{-1}$(figure 1). Under such conditions, it could be ascertained that the yield and growth reductions under salinity conditions have been due to the effect of soil salinity not for the lower density of the plants [3].

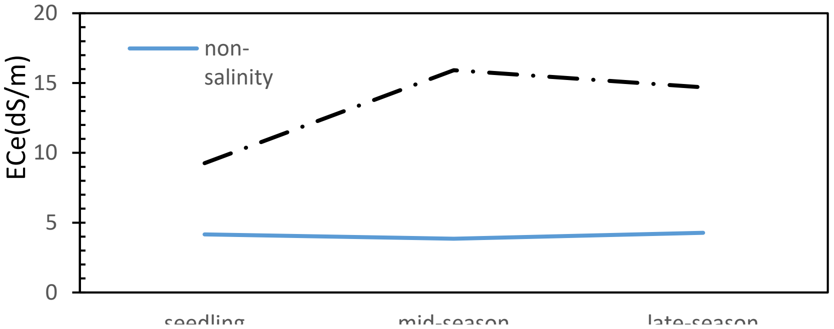


**Fig. 1.** Soil salinity diagram during growth season in saline and non-saline conditions

**Root Yield**

Based on the obtained results, the effect of salinity treatment on root yield was found statistically significant in a 5% probability level. The genotype effect and the interaction effect of salinity×genotype were also found statistically significant in a 1% probability level (table 1). Root yield in saline and non-saline conditions were 22.78 ton.ha$^{-1}$ and 11.55ton.ha$^{-1}$, respectively (table 2). It means that a reduction by 49.3% was evidenced in sugar beet root yield subject to salt stress. Based on the threshold of salinity tolerance of sugar beet, the foresaid reduction in yield is obtained in salinity rates almost equal to 15.3dS.m$^{-1}$ [5].

Among of the studied genotypes, very evident differences were scored in terms of root yield, white sugar yield, sugar yield, white sugar content, extraction coefficient of sugar, sugar content, molasses sugar, alkalinity coefficient and harmful sodium, potassium and nitrogen impurities.

The highest root yield, 28.16ton.ha$^{-1}$, was obtained in the genotype S1-930708 (no.8) and there was not found any significant difference between the foresaid genotype and the following ones in this regard: S1-930882 (no.24), DRI-HSF-14-P.35 (no.29), OT-110-25-90 (no.3), OT-111-17-90 (no.6), S1-940655 (no.17), S1-930770 (no.21), S1-930702 (No.7), OT-111-9-90 (no.4) and S1-940645 (no.13) (Table 3). The group comparisons, as well, indicate that the genotype numbers 8, 24, 3 and 6 significantly differ from the controls group mean values in a 1% level and that genotype numbers 17, 21, 7 and 4 significantly differ from the controls group mean values in a 5% level but their difference was not found statistically significant as compared to the genotype no.29 as best control genotype (table 4).

**Table 1.** Analysis of variance

| S.O.V | df | Means of Squares | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Root Yield | Sugar Yield | White Sugar Yield | Sugar Content | White Sugar Content | Extraction Coefficient of Sugar | Molasses Sugar | Alkalinity Coefficient | Na | K | N |
| Rep. | 2 | 278.42 | 7.39 | 3.43 | 3.16 | 3.95 | 23.20 | 0.15 | 6.71 | 0.22 | 1.04 | 11.86 |
| Salinity(a) | 1 | 5291.80 $^{*}$ | 95.35 $^{*}$ | 59.73 $^{*}$ | 47.86 $^{**}$ | 2.16 $^{ns}$ | 1575.59 $^{*}$ | 70.40 $^{**}$ | 0.40 $^{ns}$ | 321.07 $^{**}$ | 17.32 $^{ns}$ | 75.95 $^{*}$ |
| Error(a) | 2 | 79.62 | 2.29 | 1.26 | 0.04 | 0.76 | 25.39 | 0.48 | 1.15 | 2.62 | 2.47 | 1.79 |
| Genotype(b) | 27 | 169.12 $^{**}$ | 3.22 $^{**}$ | 1.70 $^{**}$ | 6.63 $^{**}$ | 11.76 $^{**}$ | 119.39 $^{**}$ | 1.27 $^{**}$ | 1.44 $^{**}$ | 6.69 $^{**}$ | 2.56 $^{**}$ | 1.07 $^{**}$ |
| a×b | 27 | 104.60 $^{**}$ | 2.02 $^{**}$ | 1.04 $^{**}$ | 1.51 $^{*}$ | 1.99 $^{*}$ | 18.77 $^{*}$ | 0.27 $^{ns}$ | 0.32 $^{ns}$ | 1.23 $^{**}$ | 0.43 $^{ns}$ | 0.41 $^{ns}$ |
| Error(b) | 108 | 44.27 | 1.00 | 0.53 | 0.87 | 1.17 | 11.76 | 0.18 | 0.35 | 0.64 | 0.44 | 0.54 |
| CV% | | 38.76 | 37.71 | 38.45 | 5.90 | 9.62 | 4.86 | 10.53 | 18.94 | 13.79 | 11.50 | 19.10 |

**Table 2.** Means of measured characteristics in saline and non-saline conditions.

| Treatment | Means of | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Root Yield(ton.ha$^{-1}$) | Sugar Yield(ton.ha$^{-1}$) | White Sugar Yield(ton.ha$^{-1}$) | Sugar Content(%) | White Sugar Content(%) | Extraction Coefficient of Sugar(%) | Molasses Sugar(% in beet) | Alkalinity Coefficient | Na | K | N |
| Salinity | 22.78 a | 3.41 a | 2.51 a | 15.35 b | 11.37 a | 73.69 a | 3.37 b | 3.19 a | 4.42 b | 5.45 b | 3.18 b |
| Non-salinity | 11.55 b | 1.91 b | 1.31 b | 16.41 a | 11.15 a | 67.57 b | 4.67 a | 3.09 a | 7.19 a | 6.09 a | 4.53 a |

The same word in each column aren't significant at 5% level of probability.

**Table 3.** Comparison of genotypes in measured characteristics

| Genotype Num. | Pedigree | Means of measured characteristics | | | | |
|---|---|---|---|---|---|---|
| | | Root Yield (ton.ha$^{-1}$) | Sugar Yield (ton.ha$^{-1}$) | White Sugar Yield (ton.ha$^{-1}$) | Sugar Content (%) | White Sugar Content (%) |
| 8 | S1-930708 | 28.16 a | 3.87 ab | 2.65 abc | 14.66 jk | 9.79 ij |
| 24 | S1-930882 | 26.79 ab | 3.92 a | 2.73 ab | 14.77 ijk | 10.32 g-j |
| 29 | DR1-HSF-14-P.35 | 23.74 abc | 3.18 a-e | 1.91 a-h | 13.67 k | 8.12 k |
| 3 | OT-110-25-90 | 23.68 abc | 3.77 abc | 2.79 a | 15.99 c-i | 11.75 c-g |
| 6 | OT-111-17-90 | 22.68 a-d | 3.24 a-e | 2.27 a-f | 14.71 ijk | 10.05 hij |
| 17 | S1-940655 | 21.70 a-d | 3.57 abc | 2.70 ab | 16.53 a-f | 12.32 b-e |
| 21 | S1-930770 | 21.36 a-d | 3.11 a-f | 2.14 a-f | 14.85 ijk | 10.05 hij |
| 7 | S1-930702 | 21.29 a-d | 3.37 a-d | 2.51 a-d | 16.46 b-g | 12.05 b-f |
| 4 | OT-111-9-90 | 19.39 a-e | 3.05 a-g | 2.18 a-f | 15.70 d-j | 11.03 e-i |
| 13 | S1-940645 | 19.16 a-e | 3.08 a-g | 2.33 a-e | 16.46 b-g | 12.57 a-d |
| 14 | S1-940650 | 18.25 b-f | 2.74 a-h | 2.01 a-h | 14.94 ij | 10.54 g-j |
| 5 | OT-111-29-90 | 17.95 b-f | 2.63 a-h | 1.72 b-h | 14.92 ij | 9.45 ij |
| 2 | 8001-S1-18 | 17.61 c-g | 2.96 a-g | 2.24 a-f | 16.98 abc | 12.79 a-d |
| 16 | S1-940654 | 16.95 c-h | 2.49 b-h | 1.70 b-h | 14.97 ij | 10.03 hij |
| 1 | 8001-S1-1 | 16.83 c-h | 2.90 a-g | 2.25 a-f | 17.22 abc | 13.17 abc |
| 23 | S1-930792 | 16.44 c-h | 2.54 a-h | 1.77 a-h | 15.50 e-j | 10.45 g-j |
| 22 | S1-930772 | 16.40 c-h | 2.52 a-h | 1.84 a-h | 15.70 d-j | 11.39 d-h |
| 9 | S1-940615 | 15.61 c-h | 2.37 c-h | 1.72 b-h | 15.27 f-j | 10.47 g-j |
| 15 | S1-940653 | 15.35 c-h | 2.55 a-h | 1.89 a-h | 16.65 a-e | 12.19 b-e |
| 27 | 7233-P.29 | 15.09 c-h | 2.63 a-h | 2.03 a-g | 17.56 ab | 13.50 ab |
| 19 | S1-940665 | 14.20 d-h | 2.36 c-h | 1.64 c-h | 16.98 abc | 11.71 c-g |
| 28 | 191 | 11.67 e-h | 2.03 d-h | 1.57 d-h | 17.76 a | 13.84 a |
| 11 | S1-940622 | 11.61 e-h | 1.77 fgh | 1.25 fgh | 15.22 g-j | 10.19 hij |
| 25 | S1-930962 | 11.42 e-h | 1.67 gh | 1.10 gh | 15.11 hij | 9.88 ij |
| 30 | Ghazale | 10.94 e-h | 1.89 e-h | 1.43 e-h | 17.32 ab | 13.12 abc |
| 10 | S1-940619 | 9.62 fgh | 1.50 h | 1.07 gh | 15.61 d-j | 10.75 f-j |
| 18 | S1-940656 | 8.65 gh | 1.41 h | 1.04 gh | 16.28 b-h | 11.38 d-h |
| 26 | 8001-bulk | 8.06 h | 1.37 h | 0.99 h | 16.88 a-d | 12.37 b-d |

The same word(s) in each column aren't significant at 5% level of probability.

**Table 4.** Comparison root yield of genotypes vs controls and genotype29 with orthogonal coefficient.

| Genotype Num. | Pedigree | Comparison of genotype # | | Root Yield(ton.ha-1) of | | |
|---|---|---|---|---|---|---|
| | | vs Controls | vs Genotype29 | Genotype | Controls | Genotype 29 |
| 1 | 8001-S1-1 | 42.75 ns | 143.59 * | 16.83 | 13.90 | 23.74 |
| 2 | 8001-S1-18 | 68.60 ns | 113.04 ns | 17.61 | 13.90 | 23.74 |
| 3 | OT-110-25-90 | 478.47 ** | 0.01 ns | 23.68 | 13.90 | 23.74 |
| 4 | OT-111-9-90 | 150.83 * | 56.77 ns | 19.39 | 13.90 | 23.74 |
| 5 | OT-111-29-90 | 81.77 ns | 100.86 ns | 17.95 | 13.90 | 23.74 |
| 6 | OT-111-17-90 | 385.06 ** | 3.41 ns | 22.68 | 13.90 | 23.74 |
| 7 | S1-930702 | 273.11 * | 18.03 ns | 21.29 | 13.90 | 23.74 |
| 8 | S1-930708 | 1015.88 * | 58.39 ns | 28.16 | 13.90 | 23.74 |
| 9 | S1-940615 | 14.52 ns | 198.70 * | 15.61 | 13.90 | 23.74 |
| 10 | S1-940619 | 91.71 ns | 598.55 ** | 9.62 | 13.90 | 23.74 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 11 | S1-940622 | 26.28 ns | 441.77 ** | 11.61 | 13.90 | 23.74 |
| 13 | S1-940645 | 138.37 ns | 62.97 ns | 19.16 | 13.90 | 23.74 |
| 14 | S1-940650 | 94.64 ns | 90.47 ns | 18.25 | 13.90 | 23.74 |
| 15 | S1-940653 | 10.52 ns | 211.26 * | 15.35 | 13.90 | 23.74 |
| 16 | S1-940954 | 46.33 ns | 138.65 ns | 16.95 | 13.90 | 23.74 |
| 17 | S1-940655 | 304.38 * | 12.48 ns | 21.70 | 13.90 | 23.74 |
| 18 | S1-940656 | 138.13 ns | 683.88 ** | 8.65 | 13.90 | 23.74 |
| 19 | S1-940665 | 0.44 ns | 273.32 * | 14.20 | 13.90 | 23.74 |
| 21 | S1-930770 | 278.31 * | 17.02 ns | 21.36 | 13.90 | 23.74 |
| 22 | S1-930772 | 31.14 ns | 161.92 * | 16.40 | 13.90 | 23.74 |
| 23 | S1-930792 | 32.32 ns | 159.87 * | 16.44 | 13.90 | 23.74 |
| 24 | S1-930882 | 830.85 ** | 27.88 ns | 26.79 | 13.90 | 23.74 |
| 25 | S1-930962 | 30.73 ns | 455.47 ** | 11.42 | 13.90 | 23.74 |

But, if the genotypes are screened based on stress tolerance index (STI) subject to saline and non-saline conditions, amongst the genotypes that possess high root yield, on average, the followings can be selected S1-930882 (no.24), OT-110-25-90 (no.3), DRI-HSF-14-P.35 (no.29) and S1-940655 (no.17) (figure 2). The STI values obtained for these genotypes were 1.37, 1.03, 1.00 and 0.85, respectively, which are above average value of the stress tolerance index range in the studied genotypes.
Based on the fig. 2, the genotypes that are located in the right-hand upper quarter feature higher STI values hence higher yields. There is no genotype is seen in this part but the closest genotypes to this region are the genotypes S1-930882 (no.24), OT-110-25-90 (no.3), DRI-HSF-14-P.35 (no.29) and S1-940655 (no.17). The genotype S1-930702 (no.7), as well, has been selected due to its high content of SY and WSY(figures 3 and 4). These genotypes, as well, have lower differences in stress and unstressed conditions (lower Tol); moreover, they also have higher mean productivity (high MP). Genotypes S1-930770 (no.21) and OT-111-17-90 (no.6), as well, are situated in an acceptable place in fig.2, so they can be subjected to supplementary experiments so as to avoid omitting the good genotypes.
The highest root yield, as was made clear in the experiment, pertained to S1-930708 (no.8) and it was found having a low STI and high Tol for its low yield under stress conditions, so it is not useful for the salinity stress conditions.

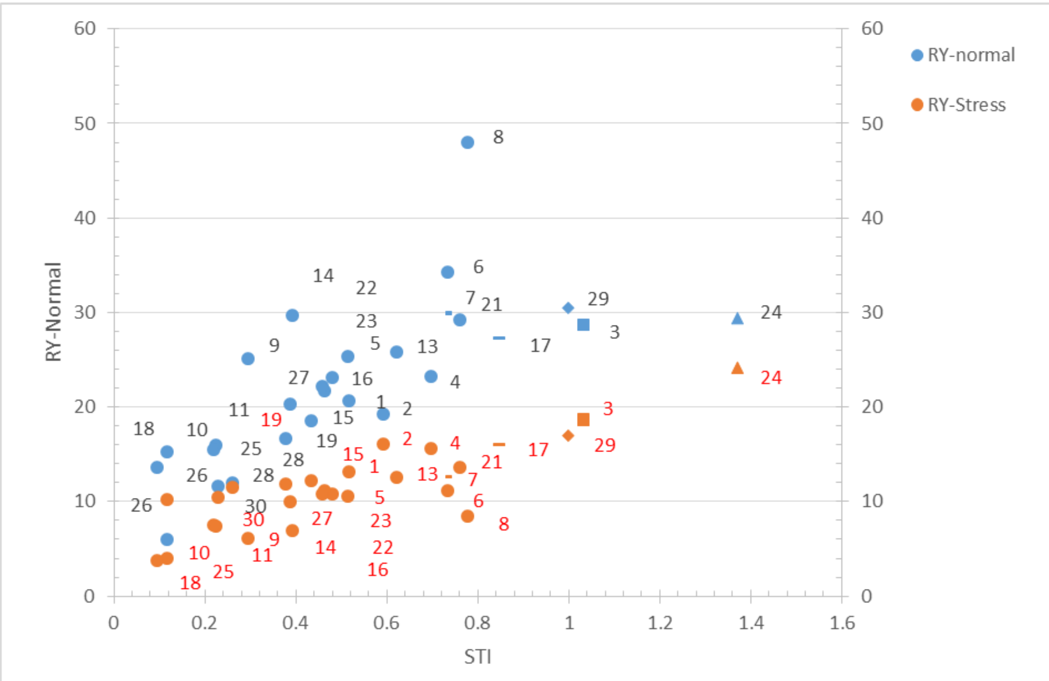


**Fig2.** Bi-Plot diagram of stress tolerance index and root yield in saline(yellow) and non-saline(blue) condition. Selected genotypes: S1-930882(Num.24) Δ , OT-110-25-90(Num.3) □ , DR1-HSF-14-P.35(Num.29) ◊ , S1-940655(Num.17) — , S1-930702(Num. 7) ⁻ .

**Sugar Yield**

The effect of salinity treatment on sugar yield was found statistically significant in a 5% probability level. The genotype effect and the interaction effect of salinity×genotype were also found statistically significant in a 1% probability level (table 1). Sugar yield in non-saline was 3.41 $ton.ha^{-1}$ and it decreased 44% in saline condition with 1.91 $ton.ha^{-1}$ (table 2).

The highest sugar yield, 3.92$ton.ha^{-1}$, was obtained in the genotype S1-930882 (no.24) and there wasn't found any significant difference between the foresaid genotype and 17 genotypes based on table 3. The group comparisons, as well, indicate that the genotype numbers 24, 8, 3 and 17 significantly differ from the controls group mean values in a 1% level and that genotype numbers 7, 6, 21, 13 and 4 significantly differ from the controls group mean values in a 5% level (table 5).

**Table 5.** Comparison sugar yield of genotypes vs controls and genotype29 with orthogonal coefficient.

| Genotype Num. | Pedigree | Comparison of genotype # | | Sugar Yield($ton.ha^{-1}$) | | |
|---|---|---|---|---|---|---|
| | | vs Controls | vs Genotype29 | Genotype | Controls | Genotype 29 |
| 1 | 8001-S1-1 | 2.32 ns | 0.24 ns | 2.90 | 2.22 | 3.18 |
| 2 | 8001-S1-18 | 2.77 ns | 0.14 ns | 2.96 | 2.22 | 3.18 |
| 3 | OT-110-25-90 | 12.03 ** | 1.04 ns | 3.77 | 2.22 | 3.18 |
| 4 | OT-111-9-90 | 3.45 * | 0.05 ns | 3.05 | 2.22 | 3.18 |
| 5 | OT-111-29-90 | 0.86 ns | 0.90 ns | 2.63 | 2.22 | 3.18 |
| 6 | OT-111-17-90 | 5.21 * | 0.01 ns | 3.24 | 2.22 | 3.18 |
| 7 | S1-930702 | 6.62 * | 0.11 ns | 3.37 | 2.22 | 3.18 |
| 8 | S1-930708 | 13.63 ** | 1.42 ns | 3.87 | 2.22 | 3.18 |
| 9 | S1-940615 | 0.12 ns | 1.97 ns | 3.37 | 2.22 | 3.18 |
| 10 | S1-940619 | 2.57 ns | 8.47 ** | 1.50 | 2.22 | 3.18 |
| 11 | S1-940622 | 1.02 ns | 6.00 * | 1.77 | 2.22 | 3.18 |
| 13 | S1-940645 | 3.67 * | 0.03 ns | 3.08 | 2.22 | 3.18 |
| 14 | S1-940650 | 1.37 ns | 0.58 ns | 2.74 | 2.22 | 3.18 |
| 15 | S1-940653 | 0.55 ns | 1.20 ns | 2.55 | 2.22 | 3.18 |
| 16 | S1-940954 | 0.37 ns | 1.43 ns | 2.49 | 2.22 | 3.18 |
| 17 | S1-940655 | 9.09 ** | 0.44 ns | 3.57 | 2.22 | 3.18 |
| 18 | S1-940656 | 3.24 ns | 9.37 ** | 1.41 | 2.22 | 3.18 |
| 19 | S1-940665 | 0.09 ns | 2.04 ns | 3.36 | 2.22 | 3.18 |
| 21 | S1-930770 | 4.00 * | 1.01 ns | 3.11 | 2.22 | 3.18 |
| 22 | S1-930772 | 0.44 ns | 1.33 ns | 2.52 | 2.22 | 3.18 |
| 23 | S1-930792 | 0.51 ns | 1.24 ns | 2.54 | 2.22 | 3.18 |
| 24 | S1-930882 | 14.50 ** | 1.64 ns | 3.92 | 2.22 | 3.18 |
| 25 | S1-930962 | 1.49 ns | 6.82 * | 1.67 | 2.22 | 3.18 |

Based on the fig. 3, some of the genotypes are located in the right-hand upper quarter (9 genotypes), and five of them have a higher STI including: S1-930882 (no.24), OT-110-25-90 (no.3), DRI-HSF-14-P.35 (no.29), S1-940655 (no.17) and S1-930702(no,7).

The genotype S1-930708 (no.8) despite of high sugar yield in non-saline condition, it isn't appropriate in saline condition due to low sugar yield in salinity stress condition. Based on fig. (3), the genotypes of 6, 21, 13, 1, 2 and 4 have a relatively high sugar yield in non-saline condition but low sugar yields in saline condition and low STI.

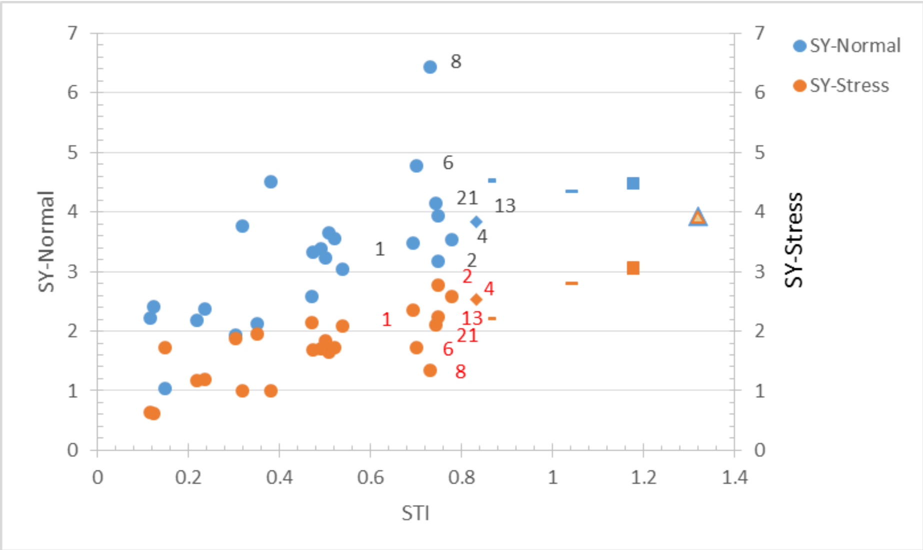


**Fig.3.** Bi-Plot diagram of stress tolerance index and sugar yield in saline(yellow) and non-saline(blue) condition. Selected genotypes: S1-930882(Num.24) ∆ , OT-110-25-90(Num.3) □ , DR1-HSF-14-P.35(Num.29) ◊ , S1-940655(Num.17) — , S1-930702(Num. 7) ⁻ .

**White Sugar Yield:**

The effect of salinity treatment on white sugar yield was found statistically significant in a 5% probability level. The genotype effect and the interaction effect of salinity×genotype were also found statistically significant in a 1% probability level (table 1). White sugar yield in non-saline was 2.51 ton.ha$^{-1}$ and it decreased 47.8% in saline condition with 1.31 ton.ha$^{-1}$ (table 2).

The highest sugar yield, 2.79ton.ha$^{-1}$, was obtained in the genotype OT-110-25-90(no.3) and there was not found any significant difference between the foresaid genotype and 16 genotypes based on table 3, and the last genotype(no. 23) in this group produced 1.77 ton.ha$^{-1}$. The group comparisons, as well, indicate that the genotype numbers 3, 7, 8, 3, 17 and 24 significantly differ from the controls group mean values in a 1% level and that genotype numbers 1, 2, 4, 6 and 13 significantly differ from the controls group mean values in a 5% level (table 6). The most important point in this table is the white sugar yield in genotype no.29 (as best control) which produced 1.91ton.ha$^{-1}$ and some of the genotypes (3, 8, 17 and 24) are significantly better than no.29 at 5% probability level.

**Table 6.** Comparison white sugar yield of genotypes vs controls and genotype29 with orthogonal coefficient.

| Genotype Num. | Pedigree | Comparison of genotype # | | Sugar Yield(ton.ha$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | | vs Controls | vs Genotype29 | Genotype | Controls | Genotype 29 |
| 1 | 8001-S1-1 | 2.21 * | 0.34 ns | 2.25 | 1.59 | 1.91 |
| 2 | 8001-S1-18 | 2.13 * | 0.32 ns | 2.24 | 1.59 | 1.91 |
| 3 | OT-110-25-90 | 7.24 ** | 2.30 * | 2.79 | 1.59 | 1.91 |
| 4 | OT-111-9-90 | 1.75 * | 0.21 ns | 2.18 | 1.59 | 1.91 |
| 5 | OT-111-29-90 | 0.09 ns | 0.11 ns | 1.72 | 1.59 | 1.91 |
| 6 | OT-111-17-90 | 2.30 * | 0.37 ns | 2.27 | 1.59 | 1.91 |
| 7 | S1-930702 | 4.25 ** | 1.06 ns | 2.51 | 1.59 | 1.91 |
| 8 | S1-930708 | 5.82 ** | 1.69 * | 2.66 | 1.59 | 1.91 |
| 9 | S1-940615 | 0.08 ns | 1.12 ns | 1.72 | 1.59 | 1.91 |
| 10 | S1-940619 | 1.31 ns | 2.11 * | 1.07 | 1.59 | 1.91 |
| 11 | S1-940622 | 0.57 ns | 1.33 ns | 1.25 | 1.59 | 1.91 |
| 13 | S1-940645 | 2.80 * | 0.53 ns | 2.33 | 1.59 | 1.91 |
| 14 | S1-940650 | 0.92 ns | 0.03 ns | 2.01 | 1.59 | 1.91 |
| 15 | S1-940653 | 0.46 ns | 0.002 ns | 1.89 | 1.59 | 1.91 |
| 16 | S1-940954 | 0.06 ns | 0.14 ns | 1.70 | 1.59 | 1.91 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 17 | S1-940655 | 6.18 ** | 1.84 * | 2.70 | 1.59 | 1.91 |
| 18 | S1-940656 | 1.51 ns | 2.31 * | 1.04 | 1.59 | 1.91 |
| 19 | S1-940665 | 0.01 ns | 0.23 ns | 1.64 | 1.59 | 1.91 |
| 21 | S1-930770 | 1.54 ns | 0.16 ns | 2.14 | 1.59 | 1.91 |
| 22 | S1-930772 | 0.34 ns | 0.01 ns | 1.84 | 1.59 | 1.91 |
| 23 | S1-930792 | 0.17 ns | 0.06 ns | 1.77 | 1.59 | 1.91 |
| 24 | S1-930882 | 6.62 ** | 2.03 * | 2.73 | 1.59 | 1.91 |
| 25 | S1-930962 | 1.18 ns | 1.99 * | 1.10 | 1.59 | 1.91 |

In fig.4 illustrated the bi-plot of STI and white sugar yields in saline and non-saline conditions. Based on this figure, eight of the genotypes are located in the right-hand upper quarter and only four of them (24, 3, 17 and 7) have a high STI. The genotype no. 29 had a good place in fig. 2 and 3 but it placed in right-hand lower quarter in fig.4 which it isn't good situation. There are some genotypes like no. 1, 2, 4 and 13 which have a relatively high WSY and high STI. Also, theses genotypes have a good situation in fig. 3, so they can be subjected to supplementary experiments.

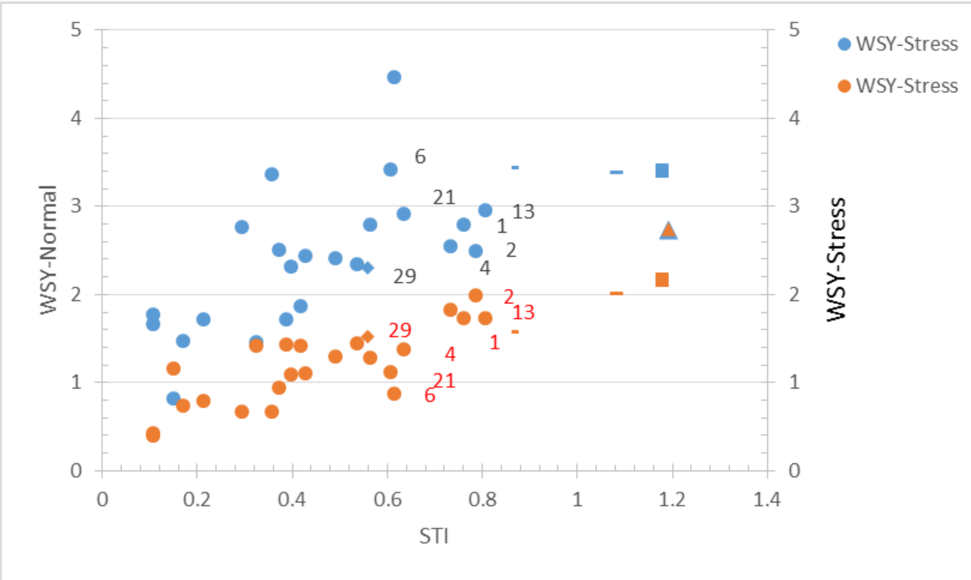


**Fig.4.** Bi-Plot diagram of stress tolerance index and white sugar yield in saline(yellow) and non-saline(blue) condition. Selected genotypes: S1-930882(Num.24) ∆ , OT-110-25-90(Num.3) □ , DR1-HSF-14-P.35(Num.29) ◊ , S1-940655(Num.17) — , S1-930702(Num. 7) ⁻ .

**Discussions**

Generally, the root yield was found reduced by 49.3% in salinity stress condition in comparison to the non-saline condition in the present experiment. [5] introduced $C_{50}$ parameter (50% reduction in sugar beet root yield) subject to a salinity rate of 15.3dS.m$^{-1}$. The salinity rate of the saturated soil extract during the growth season (except for early growth season) was in a range between 14.7dS.m$^{-1}$ and 15.9dS.m$^{-1}$ in this experiment (fig.1). In the early growth season, as well, it was necessary to lower the soil salinity due to the sugar beet's sensitivity to salinity during emergence stage [28, 11, 4] and in order to create proper plant density per every unit area. This is required for separating the salinity stress effect from the lower density of the plants [3].

[29] performed experiments on two species of sugar beet (Beta vulgaris SSP. Martima and Beta vulgaris SSP. Vulgaris) and expressed that salt tolerance of these two beets depends on their abilities to accomplish osmotic adjustment by regulating their ions and water uptake from the growth media. The mechanisms used by these two beets to prevent ionic toxicity, as well, included surrounding the sodium and chloride ions in shoots vacuoles and synthesizing compatible solutes in the cell cytoplasm. They also asserted that the reason for the long-lasting survival subject to salinity stress and preservation of leaf turgescence in these two species come about as a result of reducing the stomatal conductivity and transpiration participates in maintaining the level of leaf turgescence. Also, the high level of photosynthesis in both of these species is indicative of the idea that the reduction in growth under salinity stress conditions occurs not for the reduction in photosynthesis level but the ionic toxicity.

The sugar yield and white sugar yield are functions of root yield [18] and they are highly correlated as evidenced in table (7). The reduction in sugar yield and white sugar yield under saline condition relative to non-saline conditions were 44.0% and 47.8%, respectively. Sugar content and the white sugar content, as root yield, are amongst the traits influenced on SY and

WSY. Sugar content was 1.06% higher under salinity than non-saline condition and this is probably due to the smaller tubers under salinity condition. Although the sugar content was higher under salinity condition, the white sugar content was almost identical for both of the conditions because sodium, potassium and harmful nitrogen impurities were higher under salinity than non-saline condition. Considering the fact that molasses sugar is calculated based on the amounts of the abovementioned elements [30], it was also found in a higher level under salinity than non-saline condition.

According to the extant differences between sugar beet genotypes in terms of salt tolerance and based on stress tolerance index (STI), several genotypes can be selected from among the studied genotypes using Bi-plot diagram (figures 2 to 4). These include genotype numbers 24, 3, 29 and 17. It has to be noted that these genotypes might not eventually lead to the introducing of a tolerant variety and they may only be applied as genotypes possessing the salt tolerance trait in plant breeding programs.

Based on table (7), the traits that showed high and positive correlation with white sugar content are root yield, wet and dry weight yield of the shoots, sugar yield and extraction coefficient of sugar. [31] findings on correlation coefficients are consistent with the results of the current study. The traits that were found negatively and significantly correlated with the white sugar content are the percentages of such elements as sodium, potassium and nitrogen, alkalinity coefficient, molasses sugar and sugar content. [11] expressed that the increase in salinity causes reduction in the plant's dry weight in the form of a quadratic function.

[32] performed an experiment on ten sugar beet genotypes to evaluate their salt tolerance. It was made clear in their study that $Na^+$ content of the leaves and roots is increased in all of the genotypes subject to salinity. Such an increase in $Na^+$ was higher in the leaves than in the roots. On the other hand, $K^+$ content of the leaves and roots was found decreased which was lower in roots than in leaves. Generally, inorganic solutes (sodium and potassium) were found in higher amounts in leaves than in roots. In this genotype evaluation study, Kawimera was introduced as the most salt-tolerant and Tigris was pinpointed as the most sensitive

**Table 7.** Correlation Coefficient in measured characteristics.

| | RY | Shoot Y. | Dry Shoot Y. | SY | WSY | SC | WSC | ECS | MS | Alc | Na | K | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RY | 1 | | | | | | | | | | | | |
| Shoot Y. | 0.87 ** | 1 | | | | | | | | | | | |
| Dry Shoot Y. | 0.78 ** | 0.94 ** | 1 | | | | | | | | | | |
| SY | 0.98 ** | 0.87 ** | 0.81 ** | 1 | | | | | | | | | |
| WSY | 0.96 ** | 0.85 ** | 0.78 ** | 0.99 ** | 1 | | | | | | | | |
| SC | -0.42 ** | -0.32 ** | -0.19 * | -0.27 ** | -0.20 * | 1 | | | | | | | |
| WSC | -0.12 ns | -0.06 ns | -0.008 ns | 0.02 ns | 0.13 ns | 0.86 ** | 1 | | | | | | |
| ECS | 0.23 ** | 0.24 ** | -0.21 ** | 0.33 ** | 0.44 ** | 0.46 ** | 0.84 ** | 1 | | | | | |
| MS | -0.46 ** | -0.43 ** | -0.33 ** | -0.49 ** | -0.58 ** | -0.02 ns | -0.53 ** | -0.89 ** | 1 | | | | |
| Alc | -0.15 * | -0.24 ** | -0.33 ** | -0.23 ** | -0.25 ** | -0.39 ** | -0.47 ** | -0.42 ** | 0.27 ** | 1 | | | |
| Na | -0.43 ** | -0.44 ** | -0.35 ** | -0.47 ** | -0.54 ** | -0.0005 ns | -0.48 ** | -0.82 ** | 0.93 ** | 0.31 ** | 1 | | |
| K | -0.31 ** | -0.24 ** | -0.20 ** | -0.35 ** | -0.41 ** | -0.16 * | -0.48 ** | -0.68 ** | 0.69 ** | 0.31 ** | 0.40 ** | 1 | |
| N | -0.23 ** | -0.14 * | -0.01 ns | -0.19 * | -0.23 ** | 0.34 ** | 0.02 ns | 0.30 ** | 0.52 ** | -0.63 ** | 0.43 ** | 0.23 ** | 1 |

**Conclusion**

Based on the present experiment's results, salt stress significantly influences the root yield and white sugar yield. The studied genotypes, as well, showed different reactions to salt stress. Based thereon, there are acceptable genotypes to be introduced to the farmers for cultivation under salinity conditions. But, further research in this regard can provide them with more comprehensive results. The genotypes selected in the first place in this experiment were S1-930882 (no.24), OT-110-25-90 (no.3), DRI-HSF-14-P.35 (no.29) and S1-940655 (no.17). Another group was selected so as to prevent elimination of good genotypes that might occur due to experimental mistakes and undergone further research. This second genotype group encompassed S1-930702 (no.7), 8001-S1-1 (no.1), 8001-S1-18 (no.2), OT-111-9-90 (no.4) and S1-940645 (no.13). The genotype S1-930708 (no.8) is possibly appropriate for low salinity conditions that were documented with a high potential in these regions. Thus, the foresaid genotype can be subjected to supplementary studies to be used in regions inflicted with low degrees of salinity problem. In the third priority, two other genotypes, named S1-930770 (no.21) and OT-111-17-90 (no.6) were also selected due to their intermediate root yield and sugar content. Generally, the screening of the genotypes under real and high salt stress conditions provides the researcher with the ability to attain valuable results regarding the selection of salt-tolerant genotypes. The supplementary experiments can be utilized to take more effective steps towards introducing more salt-tolerant varieties.

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