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Effect of salt stress on photosynthetic components of sugar beet in the greenhouse and field conditions

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ABSTRACT

Chlorophyll content and chlorophyll fluorescence could be used to analyze the efficiency of photosynthesis in plants against environmental stresses, especially salinity and their simple application facilitates stress evaluation. In order to study the response of different photosynthetic characters to salinity stress at different sugar beet growth stages, two separate experiments were designed and conducted. Six sugar beet genotypes were evaluated under two treatments including non-stress (control) and salinity with 16 dsm^{-1} electrical conductivity in the greenhouse and field conditions. Samples were collected at four- and eight-leaf (establishment) stages in the greenhouse and at leaf development (16-leaf) and physiological maturity (40- leaf) stages in the field. Photosystem (II) efficiency, evapotranspiration, stomatal conductance, photosynthesis, respiration, and chlorophyll a and b content were measured at sampling stages. The highest impact of salinity on photosynthetic traits at various growth stages was observed at the second growth stage (8-10 -leaf or establishment stage). Leaf transpiration rate, stomatal conductance, and total chlorophyll content had significant correlation with root and sugar yield. During the early stages of sugar beet growth in the salinity treatment, with reduction in initial fluorescence and without influence on maximum fluorescence, the photosystem (II) efficiency increased but during the establishment stage, reduction in all chlorophyll fluorescence parameters resulted in significant decrease in photosystem (II) efficiency which caused damage to photosynthetic system and reduction in total content of chlorophyll a and b. Salinity tolerance of genotype 7219 was accompanied by a decrease in transpiration and stomatal conductance but genotypes BP Karaj and 7233- p.29*MSC2, displayed tolerance to salinity by transpiration reduction and chlorophyll fluorescence increase. Genotype 452 was susceptible to salinity stress and showed no salinity tolerance mechanism. Finally, it was shown that in addition to genotype, different growth stages are effective on salinity tolerance. In genotype selection, physiological mechanisms of stress tolerance in different growth stages are also important.

Keywords: Chlorophyll fluorescence, genotype, photosynthesis, salinity, stomatal conductance

INTRODUCTION

Salinity is one of the main constraints in agricultural areas which is increasing gradually. Saline lands are distributed all over Iran country especially in central parts (FAO 2000). The average yield reduction in saline area is more than 50% (FAO 2000). The economic loss caused by salinity is estimated to be one billion dollars per year (Qureshi et al. 2007). Environmental stresses such as drought and salinity have direct impact on photosynthesis and respiration rate through reduction in both plant growth and yield. Under environmental stresses, plant photosynthesis character is used as a criterion for resistant line selection (Ashraf et al. 2007). Reduction in photosynthesis depends on type of salinity stress and its intensity, stress occurrence status, and species susceptibility (Robinson et al. 1983). In other hand, photosynthesis is not only involved in the accumulation of structural materials but also it may influence

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Table 1. Sugar beet genotypes characteristics

No.	Genotype	Germity	Characteristics	Genotype background	Reference
1	Bp Karaj	Polygerm	Drought tolerant	Bulk	Sadeghian, 2004
2	7219 p. 69	Polygerm	Drought tolerant	line	Sadeghian, 2004
3	7233 p. 29	Polygerm	Salt tolerant	line	Ebrahimian&Ranji, 2004
4	428 OT,	Monogerm	Rather salt tolerant	line	Ebrahimian&Ranji, 2004
5	9597p.12	Monogerm	Rather salt tolerant	line	Ebrahimian&Ranji, 2004
6	452	Monogerm	Drought sensitive	line	Sadeghian, 2004

osmotic regulation. It sounds that in resistant plants, in which plant growth and yield is less affected by salinity, photosynthesis is the first parameter affected by stress (Niazi et al. 2004). It should be noted that some parameters such as photosynthesis, stomatal conductance, and water status change on the basis of leaf position on the canopy, and stress progress (Ober et al. 2005). Several studies reported different impact of environmental stresses on chlorophyll content. Shaw et al. (2012) reported 3% decrease in chlorophyll content owing to drought stress occurrence which cannot be used as a criterion for genotype differentiation. Thus chlorophyll fluorescence may be used a better indicator of photosynthesis damage in sugar beet. The measurement of chlorophyll fluorescence and photochemical efficiency of photosystem II (Fv/Fm) is an effective method to determine environmental stress influence on plant (Kovar et al. 2001). In early season drought stress conditions (Mohammadian et al. 2003) and low salinity level (up to 9 dS/m) (Park et al. 2006), the measurement of chlorophyll fluorescence and photosystem II efficiency was shown as an effective methods for studying environmental stresses impacts in sugar beet. In some studies no correlation was found between this parameters and stress resistance (Netondo et al. 2004; Ashraf et al. 2007; Hajiboland et al. 2009). The main objective of this study was to determine the appropriate growth stage for physiological character evaluation in sugar beet genotypes and their differentiation under salinity stress.

MATERIALS AND METHODS

A) Greenhouse experiment

Six sugar beet genotypes (Table 1) were compared in normal and NaCl salinity level (EC=6 ds m^{-1}) in factorial arrangement based on completely randomized design with three replications in the greenhouse (200 µmol m^{-2} s^{-1} PAR; 25 ^{o}C/15 ^{o}C). Seeds were planted in alluvial sands in 6 L pots with 24 holes (one plant per hole). Pots were irrigated with Hoagland nutrient solution for one month and then NaCL was directly added to the pots. Samples were taken from young leaves at 4- and 8-leaf stages and following parameters were measured:

transpiration rate, stomatal conductance, and photosynthesis rate using IRGA equipment (Anonymous 1993). Chlorophyll extraction was performed with 80% acetone using Kumari (2007) method and the optical density of chlorophyll solution was read at 645 nm and 663 nm wave lengths using spectrophotometer (Camspec-M330). Chlorophyll fluorescence variables including initial fluorescence (F_0), maximum fluorescence (F_m) and variable fluorescence ($Fv = F_M-F_0$) were measured using chlorophyll fluorescence meter (PSM mark II plant stress meter) (Öquist and Wass 1988).

Field experiment

Field experiment was conducted at Rudasht Salinity Research Station located at 52^{o} E, 32.5^{o} N, 1450 m above sea level in Isfahan province, Iran. The experimental design was split plot based on randomized complete block design with three replications in 2007-08. Main plots were allocated to normal water and a soil salinity level with EC=16 dS m^{-1} and sub-plots were allocated to six genotypes (Table 1). Row to row and plant to plant distances were 50 and 20 cm, respectively to obtain plant density of 100000 plants per hectare. Before planting, the soil electrical conductivity was 8 dS m^{-1}. Two water treatments including normal water (EC=4 dS m^{-1}) and saline water (EC=12 dS m^{-1}) were used. After two irrigations, at establishment (6-8 leaves) stage, plants were irrigated with saline water. Samples were taken two times from the leaves at development (16-leaf) and maturity (40-leaf) stages and photosynthesis, transpiration, stomatal conductance, and chlorophyll a and b content were measured.

After physiological maturity, root yield (RY), sugar content (SC) (using polarimeter, Wolfgang model), Sodium, potassium (using flame photometer, Kernchen model), and amino nitrogen (by blue-number method using Betalyzer system)

Table 2. Soil properties at 0-30 cm depth

Year	Electrical conductivity	Acidity (total saturation)	Organic carbon (%)	Absorbable sodium (meq g L^{-1})	Absorbable potassium (mg Kg^{-1})	Absorbable phosphorus (mg Kg^{-1})
2007	7.95	7.8	0.47	14	270	18
2008	7.5	7.8	0.47	15	260	17

Table 3. Average quantitative and qualitative characteristics of two water treatments used in the experiment

Sample number	Electrical conductivity (dS m^{-1})	Acidity	Bicarbonate	Cl	Sulphate	Total anions	Calcium and magnesium	Sodium	Total cations
1	4.2	7.1	4	34	13.8	51.8	22	30.8	52.8
2	12.1	7.5	5.2	94	37.3	136.5	34	103.5	137.5

Table 4. Mean comparison of yield (fresh weight) and root weight of six sugar beet genotypes under non-stress and stress conditions

	4 leaf stage	Establishment		Development		Harvest	
	Aerial parts yield (g plant)	Aerial parts yield (g plant)	Root yield (g plant)	Aerial parts yield (t ha^{-1})	Root yield (t ha^{-1})	Aerial parts yield (t ha^{-1})	Aerial parts yield (t ha^{-1})
Control	4.37 a	9.72 a	1.04 a	23.86 a	20.86 a	6.23	33.4 a
EC = 16 dS m^{-1}	2.90 b	8.09 b	0.81 b	15.98 b	16.23 b	6.67	26.56 b
S_e	0.3	0.56	0.07	1.26	0.37	0.65	0.69
BP Karaj	4.15	12.13 a	1.17 a	27.47 a	20.30	7.36	34.13
7219 P.69	4.28	9.67 ab	1.04 ab	23.05 ab	17.45	7.13	28.88
7233 P.29	4.12	9.47 ab	0.97 ab	27.63 a	22.08	6.94	32.98
428oT	2.53	7.74 b	0.71 b	11.47 c	18.80	7.09	29.77
9597 p12	3.58	6.87 b	0.67 b	17.75 bc	16.35	5.21	27.55
452 OT	3.15	7.52 b	0.98 ab	12.15 c	15.75	4.96	26.57
S_e	0.56	1.05	0.13	3.03	2.14	0.75	2.36

Means with the same letter are not significantly different at p<0.05

were measured. Other traits such as sugar yield, white sugar yield, and alkalinity coefficient were measured based on equation 1 to 5. Molasses sugar content was estimated using Reinfeld equation (Abdollahian Noghabi et al. 2005).

$$\text{Alkalinity coefficient (\%)} = \frac{K + Na}{\text{aminoN}} \quad (1)$$

$$\text{Molasses sugar content (MS\%)} = 0.343(Na+k) + 0.094(\alpha\text{-amino N}) - 0.31 \quad (2)$$

$$\text{White sugar content (W.S.C)} = (\text{S.C.} - \text{MS})\% \quad (3)$$

$$\text{Extraction coefficient of sugar} = \text{W.S.C./S.C.} \quad (4)$$

$$\text{White sugar yield (WSY)} = \text{W.S.C.} \times \text{root yield} \quad (5)$$

Since in this study, sampling was carried out according to sugar beet growth stages and different statistical models were used for greenhouse and field conditions, therefore combined analysis was not used. For each environment, data analysis was performed using MSTATC software (MSTATC 1986) and mean comparison was done using Duncan multiple range test.

RESULTS AND DISCUSSION

A) Greenhouse experiment

1- 4-leaf stage

At this stage, salt stress significantly reduced aerial parts yield (Table 4). Photosynthetic properties such as transpiration, stomatal conductance, net photosynthesis, and total chlorophyll content were not influenced by salinity but chlorophyll fluorescence parameters including photosystem II(Fv/Fm) efficiency and variable fluorescence (F_v) were significantly increased (p<0.01). The initial fluorescence of the control treatment was higher than others. In other words, salt stress decreased the initial fluorescence in plant and irrespective of non significant effect on maximum fluorescence, photochemical efficiency of photosystem II (Fv/Fm) and variable fluorescence (F_v) were significantly increased (P<0.01). By increasing the photochemical efficiency of photosystem II (Fv/Fm) and variable fluorescence (Fv), sugar beet rebuffed the chlorophyll fluorescence and thus this extra energy did not damage the leaf photosynthesis apparatus and chlorophyll content. Similarly, Park et al. (2006) reported reduction in

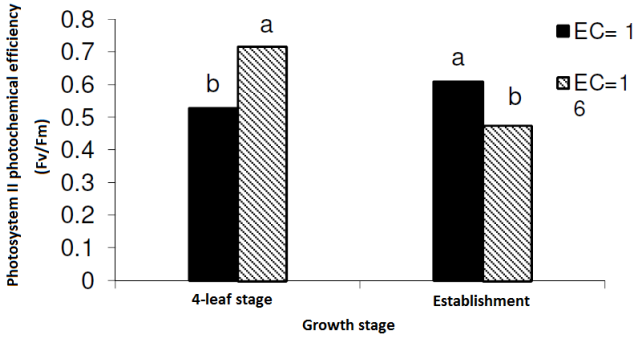

Figure 1. Mean comparison of photosystem II (Fv/Fm) efficiency and variable fluorescence (F_v) under control and salinity level at 4-leaf and establishment stages in the greenhouse

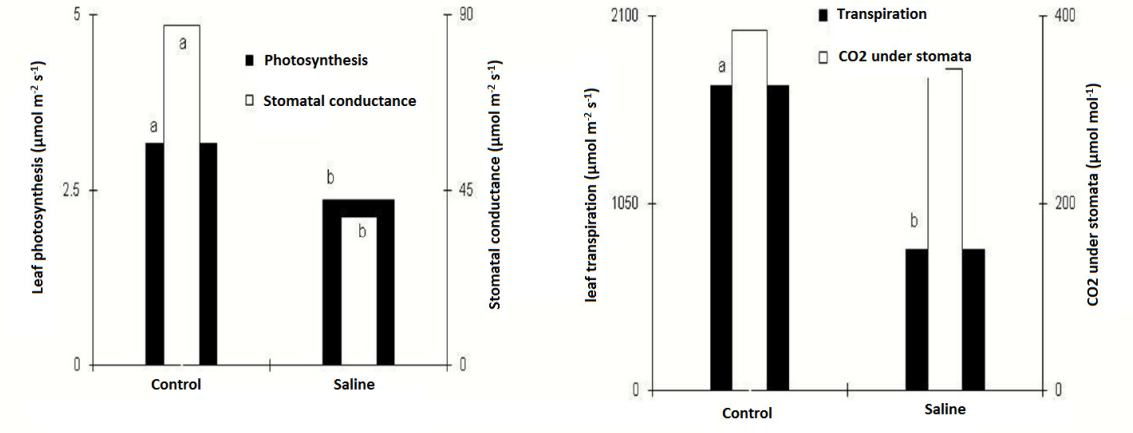

Figure 2. Mean comparison of photosynthesis rate, stomatal conductance (µmol m^{-2} s^{-1}) (left side), transpiration (µmol m^{-2} s^{-1}), and CO_2 under stomata (µmol mol^{-1}) (right side) at establishment stage in the greenhouse

photosystem II (Fv/Fm) efficiency under EC=9 dS m^{-1} at 4-leaf stage in sugar beet.

2) 8-10 leaf stage (establishment)

At this stage, salinity decreased both root and aerial parts yield (Table 4). It also significantly decreased transpiration and stomatal conductance ($p<0.01$), photosynthesis rate ($p<0.05$), chlorophyll b content ($p<0.05$), variable fluorescence ($p<0.01$), and maximum fluorescence ($p<0.05$). Salt stress had greater impact on physiological traits at this stage than other stages. Compared with establishment stage, salt stress could not affect biochemical and physiological reactions at 4-leaf stage. Some studies reported no significant effect of stress on plant physiological traits up to 35 days (Niazi et al. 2004) and even up to 50 days (Delfine et al. 1999) after planting. Salinity caused stomatal closure and reduction in stomatal conductance and transpiration (Figure 2) which is a natural mechanism in plants to deal with salinity effect (Anonymous 2000). However, the rate of photosynthesis and stomatal conductance was low which might be due to the plant growth. Transpiration and stomatal conductance had a significant negative correlation with leaf sodium content which indicated that with increase in salinity, leaf sodium content increased followed by stomatal closure and decrease in gas exchange. A significant positive correlation between stomatal conductance and leaf chlorophyll content indicated that low chlorophyll content restricted stomatal exchange capacity (Matsumoto et al. 2005).

With increase in salinity, the total chlorophyll content, and chlorophyll a and b content decreased (Figure 3) which showed that chlorophyll degradation at this stage resulted in stomatal closure and free radicals generation. Reduction in chlorophyll fluorescence and photosystem II efficiency results in chlorophyll degradation following serious damages to the plant growth. The effect of this phenomenon is shown in total chlorophyll content of susceptible variety 9597. Compared with other genotypes, variety 9597 had the lowest total chlorophyll content and dry weight (9.5%).

Unlike first stage in which higher initial fluorescence was observed in control treatment, in this stage, stress decreased significantly all

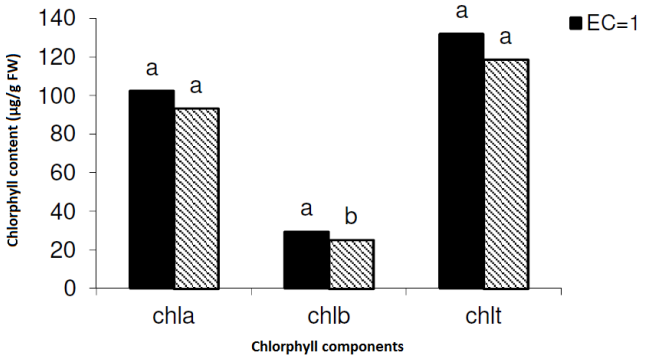

Figure 3. Mean comparison of total chlorophyll content and chlorophyll a and b content (Microgram per gram fresh weight)

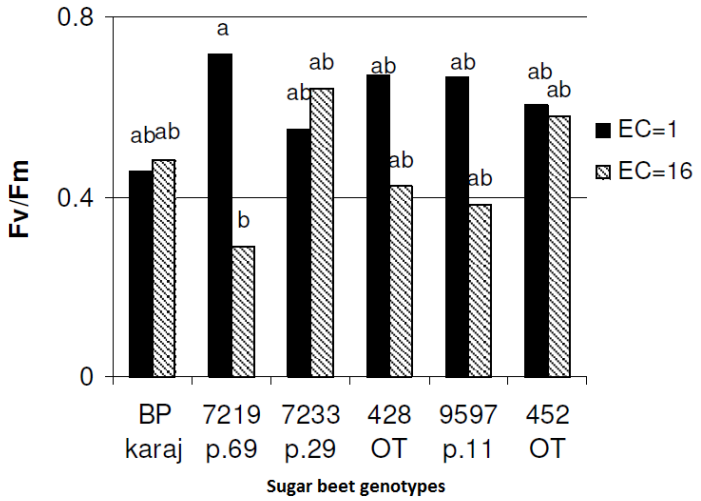

Figure 4. Mean comparison of photochemical efficiency (Fv/Fm) variation in sugar beet genotypes under normal and stress conditions at 8-10 leaf stage in the greenhouse

fluorescence parameters. Although the initial fluorescence reduction was not significant but the maximum fluorescence and its variations had significant reduction which resulted in the reduction of photosystem II efficiency (Figure 1). Among genotypes, BP Karaj and 7233 p.29 had increased photochemical efficiency (Fv/Fm) of PS II (Figure 4). In plants, absorbed energy is converted into photochemical reaction, fluorescence and heat. Therefore, plants which convert absorbed energy into heat or fluorescence have more tolerance to stress. As it shown in Figure 4, since photosystem II efficiency decreased dramatically in genotype 7219 p.69, therefore this parameter could not be used for stress tolerance.

Although the chlorophyll fluorescence may indicate salt stress effect through restriction in energy transfer or light absorption (Dadkhan and Moghtaderi 2008) but at establishment stage, photosystem II was incapable of converting the extra energy which resulted in damage to photosynthetic system especially destruction or reduction in chlorophyll content. Salt stress impact on photosystem II efficiency depends on species (Netondo et al. 2004) and salinity level so that in low salinity level (5.5 dS m^{-1}) in sugar beet (Hajiboland et al. 2009) and up to 20 dS m^{-1} in sorghum (Netondo et al. 2004) this criterion cannot be used as an appropriate index for resistant cultivar selection. At early season (8-10 leaf stage), drought stress had no impact on the initial fluorescence of some genotypes but it decreased photosystem II efficiency together with other parameters (Mohammadian et al. 2003). These results showed that in addition to genotype and salinity level, plant growth stage had also significant effect on chlorophyll fluorescence.

B) Field experiment

1) 16-leaf stage (leaf development)

At this stage, salt stress decreased all parameters but only for photosynthesis rate, the variation was significant ($p<0.05$). Irrespective of reduction

Table 5. Average transpiration (µmol m^{-2} s^{-1}) and total chlorophyll content (micrograms per gram of fresh weight) of sugar beet genotypes under control and salt stress conditions in the field

Environment	Genotype	Growth period							
		4 leaf		Establishment		Leaf development		Maturity	
		Leaf transpiration (µmol m^{-2} s^{-1})	Total Chlorophyll (µg g^{-2} FW)	Leaf transpiration (µmol m^{-2} s^{-1})	Total Chlorophyll (µg g^{-2} FW)	Leaf transpiration (µmol m^{-2} s^{-1})	Total Chlorophyll (µg g^{-2} FW)	Leaf transpiration (µmol m^{-2} s^{-1})	Total Chlorophyll (µg g^{-2} FW)
Control	BP karaj	267	90.4	1470	148.8	1723 cde	91.62	2503	91.72 a
	7219 p.69	357	93.4	1940	133.66	3677 ab	105.02	2077	66.52 b
	7233 p.29	477	72.46	1807	121.66	3300 ab	110.96	2263	56.16 b
	428 QT	307	93.14	2047	137.14	1420 de	75.14	2193	99.12 a
	9597p.11	190	91.66	1877	122.6	1010 e	117.3	2177	66.86 b
	452 QT	343	102.8	1093	128.6	1393 de	92.64	2390	52.22 b
Salt stress	BP karaj	117	100.8	577	136.54	4507 a	73.42	2087	47.3 b
	7219 p.69	237	73	423	111.6	410 e	68.72	2073	55.72 b
	7233 p.29	173	90.6	960	118.06	1440 de	62.12	2173	51.16 b
	428 QT	443	89	833	103.74	1360 de	102.96	2643	52.48 b
	9597p.11	340	96.66	543	107.4	2407 bcd	100.44	2497	46.88 b
	452 QT	273	86.34	1387	135.26	2863 bc	93.08	1587	57.64 b
Standard error		150	13.24	360	13.82	420	14.09	360	7.750

in stomatal conductance and CO_2 under stomata, photosynthesis rate increased under salt stress condition which indicates that the plant utilized efficiently the CO_2 under stomata to increase photosynthesis under stress condition. The effect of genotype on stomatal conductance was significant ($p<0.05$). Plant evapotranspiration, photosynthesis, and CO_2 under stomata were significantly affected by salt × genotype interaction and genotype 7219 p.69 had the maximum and minimum evapotranspiration under normal and salt stress conditions, respectively (Table 5).

Transpiration and stomatal reduction and as a consequence stomatal closure and chlorophyll reduction began from establishment stage (Figures 2 and 3) and progressed to development stage (Table 5). In most plants, salt stress reduced photosynthesis rate and chlorophyll content but the rate and reason was different. In an experiment on spinach, salt stress induced 10% decrease in photosynthesis rate and 70% decrease in stomatal conductance (Robinson et al. 1983). Some studies reported two-thirds reduction in photosynthesis and three times increase in respiration because of significant stomatal resistance. Under salinity stress, stomatal resistance increases in order to maintain a positive water balance inside plant (Geisler et al. 2009). In a study by Norman and Ulrich (1973), increase in sodium and reduction in potassium rate resulted in stomata and mesophyll resistance and 23% reduction in photosynthesis. The effect of salt on photosynthesis is due to non stomatal factors such as chlorophyll and mesophyll conductance (Anonymous 1998; Harley et al. 1992). Thus, plant species have different relative control of stomata and mesophyll conductance by salt.

2) Physiological maturity

At maturity stage, chlorophyll content influenced by salt × genotype interaction ($p<0.05$) (Table 5) and irrespective of stomatal closure, CO_2 increased under stomata which indicates increase in respiration, storage materials burning , and sugar storage reduction. With increase in salinity stress, chlorophyll content and transpiration rate decreased in most genotypes except genotype 425 (Table 5). In genotype 425, no transpiration reduction was recorded up to maturity which resulted in higher susceptibility and yield reduction (Table 4). Finally, at maturity, with increase in CO_2, chlorophyll content decreased which made plants using stored sugar for survive and as a consequence white sugar yield decreased in susceptible genotypes (Table 6). Transpiration rate, stomatal conductivity, and total chlorophyll content had high correlation with plant dry weight (in three growing stages) and root yield, aerial parts and white sugar content at harvest (Table 7). A significant and positive correlation between transpiration and stomatal conductance with aerial parts and root yield showed that longer stomata opening resulted in high photoassimilate and yield.

In some experiments, salt stress led to the reduction in chlorophyll a and b content, net photosynthesis, stomatal conductance, and transpiration in the range of 75-94% (Netondo et al. 2004). In more extreme stress conditions, other factors such as osmotic stress occurrence on chloroplast thylakoid can affect chlorophyll degrad-

Table 6. Mean comparison of sugar content, sugar yield, white sugar yield, extraction coefficient of sugar, molasses, amino nitrogen, sodium, and potassium content of sugar beet genotypes at maturity stage in the field experiment

	Sugar content (%)	Sugar yield (t ha^{-1})	White sugar yield (t ha^{-1})	Extraction coefficient of sugar (%)	Molasses (%)	Amino nitrogen (meq $100g^{-1}$ pulp)	Sodium (meq $100g^{-1}$ pulp)	Potassium (meq $100g^{-1}$ pulp)
BP Karaj	20.40 ab	7.14 a	6.08 a	82.21 ab	2.41 ce	2.18 cd	1.66 b	5.67 bd
7219 P.69	20.42 ab	6.24 ac	5.38 ac	85.95 a	2.49 e	2.03 d	1.92 b	4.79 e
7233 P.29	21.05 a	6.73 ab	5.80 ab	86.25 a	2.93 de	2.67 bc	1.72 b	5.24 de
9597 p12	19.62 ac	5.74 c	4.60 c	83.95 ab	2.60 bc	2.61 ac	1.99 b	5.77 bc
428oT	19.88 ac	5.69 bc	4.79 bc	83.93 ab	2.58 bc	1.93 d	2.21 ab	5.69 bd
452 OT	18.80 c	5.27 c	4.33 c	81.09 c	2.87 a	2.42 ad	2.68 a	6.24 a
LSD 5%	1.25	1.12	0.97	2.08	0.23	0.45	0.52	0.43

Means with the same letter are not significantly different at p<0.05

Table 7. Correlation between traits

	CHLA	CHLB	TCHL	RY	TY	SC	SY	WSY	TRANS	STC	Pn	CO2
CHLA	1											
CHLB	0.63**	1										
TCHL	0.75**	0.88**	1									
RY	0.31*	0.22	0.32*	1								
TY	0.29*	0.09	0.16	0.52**	1							
SC	-0.06	-0.10	0.01	0.20	-0.11	1						
SY	0.27*	0.18	0.29*	0.96**	0.44**	0.45**	1					
WSY	0.26	0.18	0.30*	0.94**	0.41**	0.52**	0.99**	1				
TRANS	0.15	0.16	0.06	0.35**	0.35*	-0.12	0.29*	0.27*	1			
STC	0.15	0.08	0.07	0.27*	0.32*	-0.11	0.22	0.20	0.86**	1		
Pn	0.28*	0.19	0.27*	0.03	-0.01	-0.03	0.02	0.03	0.11	0.07	1	
CO2	-0.18	-0.11	-0.22	-0.08	0.08	-0.11	-0.10	-0.11	0.39**	0.45**	-0.49**	1

Total chlorophyll (TChl), chlorophyll a (Chla), chlorophyll b (Chlb), leaf transpiration (Trans), Stomatal conductance (Stc), photosynthesis (Pn), root yield (RY), sugar content (SC), sugar yield (SY), and white sugar yield (WSY) at maturity.

**,* significant at 1% and %5 probability level, respectively.

ation (Santos 2004). However some studies reported increase in chlorophyll content under salt stress. For example, Dadkhan and Moghtaderi (2008) reported increase in chlorophyll a and b and total chlorophyll content after 8 weeks of salt stress induction, irrespective of decrease in photosynthesis. They concluded that stress had adverse effect on salinity so that with increase in salinity, leaf area decreased compared with leaf dry weight (leaf thickness increased). This was also observed in this study. A thickened leaf has more cells in a specified area with increased chlorophyll content. In some plants, the addition of some elements such as silicon (Moussa 2006) or Homobrassinolide (Hayat et al. 2007) is recommended to decrease salt stress impact and increases chlorophyll and photosynthesis reaction.

Genotype BP Karaj had the highest aerial and root yield at establishment (Table 4) and also white sugar yield at maturity stage (Table 6). Genotypes 7219 p.69 and 7233 p.29 were classified in one group in terms of aerial and root production at establishment and white sugar yield at maturity stage (Tables 4 and 6). Under stress condition, resistant genotype 7219 p.69 closed its stomata and decreased transpiration less than other genotypes. However, in genotypes BP Karaj (except development stage) and 7233 p.29, in addition to reduction in transpiration and stomatal conductance, photosystem II efficiency increased (Table 5, Figure 4). Therefore, these two genotypes used stomatal closure and increase in photosystem II efficiency as proper mechanisms to deal with salt stress. In all growth stages, genotype 452 had the lowest aerial and root yield (Tables 4 and 6). The chlorophyll and transpiration rate of this genotype was not decreased until final stage. Thus this genotype susceptibility to salt stress is related to the lack of using physiological mechanisms.

The highest salinity effect, in terms of photosynthetic traits, was observed at the second growth stage (8-10 leaf stage or establishment). Salinity induced significant reduction in photosystem II efficiency through decreasing all chlorophyll fluorescence parameters. In other words, reduction in chlorophyll fluorescence parameters indicated stress progress in the plant. Thus, in contrast to 4-leaf stage, sugar beet was incapable in controlling extra energy converted by chlorophyll fluorescence which damaged plant photosynthesis structure so that increase in salinity level resulted in chlorophyll degradation and reduction, stomata closure, and consequently reduction in evapotranspiration at establishment stage. This

study showed that chlorophyll fluorescence response to salt stress may change in sugar beet according to plant growth stage. Transpiration, stomatal conductance and total chlorophyll content had high correlation with root yield, aerial parts and white sugar content at maturity which can be used in resistant genotype selection at establishment stage. Increase in chlorophyll fluorescence and reduction in transpiration were observed in genotypes BP Karaj and 7233 p.29. However in genotype 7219 p69, only transpiration reduction was observed. Unlike most genotypes, chlorophyll content and transpiration reduction were not observed in genotype 452 which had the lowest yield.

It is recommended to select genotypes which apply more physiological mechanisms to cope with stress. Also based on different growth stages, different parameters may be used for resistant genotypes selection but high correlation between transpiration rate, stomatal conductance, and total chlorophyll content with root and sugar yield suggested them as appropriate characters for genotype selection before harvest.

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