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EVALUATING GROWTH AND YIELD POTENTIAL OF SOME BRASSICA (*BRASSICA JUNCEA* L. CZERN.) GENOTYPES UNDER SALINE-SODIC FIELD CONDITIONS

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Abstract

A field trial was conducted to evaluate the growth and yield performance of five genotypes of *Brassica juncea* (Agati Sarheen, Toria selection, Sultan Raya, P-78 and NIFA- Raya) in saline–sodic soils. Genotypes were collected from ARI Tandojam and NIFA Peshawar. Two sets of experiments at non saline and saline-sodic site, were laid out using randomized complete block design (RCBD) and were replicated thrice. Growth and yield parameters (i.e. plant height, number of branches, number of siliqua plant^{-1}, siliqua length, number of grains siliqua^{-1}, grain weight.plant^{-1},100 grain weight and grain yield) were recorded at crop maturity. Salt tolerance in *Brassica* genotypes were assessed on the basses of growth performance under salinity. *Brassica* genotypes exhibited significant variability in salt tolerance due to presence of salt in the growth medium. There was a decrease in growth and yield parameters in all the brassica genotypes. Comparatively, better response was observed by genotype Agati sarheen and P-78. Based on relative reduction (<50%) in different agronomical parameters it was concluded that the genotypes Agati sarheen and P-78 were moderately tolerant and had the potential to perform under saline-sodic environments.

KEYWORDS: *Brassica juncea* genotypes, Saline-sodic environment, Growth and yield performance.

INTRODUCTION

Rape-seed (*Brassica napus* L.) and mustard (*Brassica juncea* L. Czern.) are the second most important sources of oil seed crop in Pakistan, (Tanveer *et al*., 2002). Due to its low inputs and high adaptability to salinity and drought stress, it has been cultivated under both irrigated and non-irrigated areas of Pakistan. It has been reported (Khan *et al.*, 2006) that improved types of *Brassica* varieties have a yield potential of over 2500 kg per hectare which reflects that 2-3 times substantial increase in average yield is possible. In Sindh province, it is mostly cultivated as Zaid Kharif (September) crop on residual moisture of rice on both Northern and Southern rice tracks (Bhatti & Soomro, 1996). The presence of soil salinity on these tracks affects yield considerably.

Brassica is classified as tolerant to salinity (Maas & Hoffman, 1977). Although it has higher threshold values (i.e., 9.0 dS/m), but rate of yield decline above the thresholds was much greater than other crops (Maas, 1990). However the variability in tolerance limits also exists between and within genotypes. The variability in salt tolerance within the genotypes mainly depends on uptake and accumulation of sodium (Na^+) in shoot (Flowers, 2004). It has been reported that plants adopt avoidance mechanism by restricting the higher uptake of Na ions in active parts (i.e., leaves), and accumulate them in roots and stem. The genotypes sensitive to salinity accumulate Na ions more quickly than tolerant cultivars and this ion accumulation leads to leaf death and progressively death of the plant (Munns, 2002). Keeping in view above facts, a field trial was conducted to evaluate the salt tolerance in some locally available Brassica (*Brassica juncea*) genotypes on the bases of their growth and yield performance in saline–sodic soils.

MATERIAL AND METHODS

Five genotypes of *Brassica juncea* (Agati Sarheen, Toria selection, Sultan Raya, P-78 and NIFA- Raya) were collected from Agriculture Research Institute (ARI), Tandojam and Nuclear Institute of Food and Agriculture (NIFA), Peshawar. The former four were collected from ARI Tandojam and later one from NIFA Peshawar. Two suitable sites were selected at different locations of NIA experimental farm. Soil samples were collected from 0-30 cm depth. The soil samples were processed for physico-chemical analysis. The details of physio-chemical properties are presented in Table 1. Soil texture (Particle size distribution) was determined by Bouyoucos hydrometer method (Bouyoucos, 1965). Soil salinity (electrical conductivity ECe) was measured through conductivity meter (model: WTW LF-530, Germany) in the saturated soil extract. Soil reaction pH was determined by pH meter (PCSIR LPM 1.4, Karachi). $Na^+$and K^+ in soil: water extract were determined by Flame Photometer (PFP-7, Jenway, England), whereas Ca^{2+} + Mg^{2+} were estimated titermetrically. Carbonates (CO_3^-) and bicarbonates (HCO_3^-), often termed as total alkalinity, were determined by titration with 0.5 N sulphuric acid (H_2SO_4) using phenolphthalein and methyl orange as indicators, respectively. For chlorides (Cl-) determination, the solution of silver nitrate ($AgNO_3$), 0.05 N was used to titrate into a soil extract containing chlorides in the presence of K_2CrO_4 indicator. The soils were categorized as non saline and saline-sodic, according to the values of sodium adsorption ratio (SAR = 48-148). All the analysis was performed by standard methods as reported by Jackson (1958).To maintain the uniformity of soil salinity, sowing was done in small subplots (size = 0.9 m x 1.5 m i.e.1.35 m^2). Three rows of 1.5 meter length were planted in each subplot. The row spacing was 30 cm. The experiment was laid in randomize manner using randomized complete block design (RCBD), with three replicates. Growth and yield parameters (i.e. Plant height, Number of branches, Number of siliqua $plant^{-1}$, siliqua length, Number of grains. $siliqua^{-1}$, Grain weight. $Plant^{-1}$,100 grain weight and Grain yield $plot^{-1}$) were recorded at crop maturity. The data regarding all the growth and yield parameters was analyzed statistically using analysis of variance (ANOVA), Duncan Multiple Range Test (DMRT) and correlations by MSTAT-C computer package (Anon., 1991) to compare the significance among the genotypes.

RESULTS

Effect of salinity on growth performance of *Brassica* genotypes: *Brassica* genotypes exhibited variable response in growth due to soil salinity. Mean of squres from analysis of variance (Table 2), for different growth parameters showed significant effect of salinity on growth performance of all the tested genotypes *Brassica*. There was decrease in plant height under salinity (Table 3). Reduction in plant height was statistically significant with respect to salinity treatment and non significant among the genotypes. The genotype P-78 had maximum plant height under saline condition (142 cm) followed by Toria selection (128cm).

However, the relative decrease was minimum in Toria selection (2.8%). While, maximum decrease in plant height was observed in NIFA raya i.e., 42.2%. Effect of salinity was comparatively less on the branching capacity of *Brassica* genotypes. Almost all the genotypes showed less than 10% reduction in number of branches, except NIFA-raya. On the other hand the effect of salinity was almost nil in P-78 genotype.

The mean values for siliqua number among the genotypes were 431 under non-saline and 355 under saline conditions. Among the individual genotypes maximum number of siliqua under saline conditions were observed in NIFA- raya (i.e. 542 silique $plant^{-1}$). Least decrease under saline condition was observed in Agati sarheen (i.e. 2.68%). On the other hand, maximum reduction in siliqua numbers was observed in Toria selection, where the relative decrease was 56%.

There was also decrease in length of siliqua of all *Brassica* genotypes. The reduction in siliqua length was statistically significant (Table 3) with respect to soil salinity and within the genotypes as well. All the genotypes were showing <50% decrease under salinity. The mean values for siliqua length under non saline and saline-sodic environments were 5.16 and 4.66 cm, respectively. Among the individual genotypes, maximum siliqua lengths under saline condition was recorded in Toria selection (5.08 cm) followed by P-78 (4.95 cm) and Sultan-raya (4.93 cm). It was also observed that though the values of siliqua length under salinity were maximum in Toria selection but the relative decrease was comparatively high (16.86%), whereas least decrease was observed in genotype Durr-e-NIFA (0.74%). Grain formation in *Brassica* genotypes was markedly decreased due to salinity of the soil.

Table 1. Physiochemical properties of experimental sites (Non saline and saline).

S.#	Soil properties	Non saline	Saline
1.	Soil texture	Silty clay loam (Site–I)	Silty clay loam (Site–II)
2.	Soil ECe (dSm^{-1})	1.2 – 3.42	12.2 – 20.7
3.	Soil pH	7.90 – 8.10	7.70 – 8.00
4.	Na (meq L^{-1})	10.87 – 34.78	217 – 674
5.	K (meq L^{-1})	2.45 – 2.82	1.03 – 1.79
6.	Ca + Mg (meq^{-1})	10.0 – 22.0	41.0 – 41.5
7.	Sodium adsorption ratio (SAR)	4.85 – 15.45	47.93 – 147.96
8.	Salinity class	Non-saline	Saline–Sodic

Table 2. Mean squares from analysis of variance (ANOVA) of growth parameters under saline-sodic field conditions.

Source	Degree of freedom	Plant height	No. of branches	No. of siliqua	Siliqua length
Salinity	1	16226.2**	1.776*	43831^{NS}	1.900**
Genotypes	4	926.1^{NS}	0.2028^{NS}	10907*	2.3429**
Salinity x genotype	4	1327.7^{NS}	0.2455^{NS}	4859^{NS}	0.1954^{NS}
Error	18	770.8	0.27041	29772	0.2154

** = Significant @ 1% prob., * = Significant @ 5% prob., NS= Non-significant

Table 3. Effect of salinity on growth parameters of different *Brassica* genotypes.

Genotypes	Non saline		Saline		Mean
	Plant height (cm)				
NIFA- Raya	191	a	110.3 (42.24)	a	150.7 A
Sultan Raya	157	ab	118.1 (24.78)	a	137.3 A
Toria selection	132	b	128.3 (2.80)	a	130.4 A
Agati Sarheen	184	a	115.2 (37.39)	a	149.4 A
P-78	183	a	141.8 (22.51)	a	162.3 A
Mean	169.4	A	122.74	B	
LSD (0.05)			47.60		
	Number of branches plant^{-1}				
NIFA-Raya	8.0	a	7.0 (12.50)	b	7.5 A
Sultan Raya	8.0	a	7.3 (8.75)	ab	7.6 A
Toria selection	7.7	a	7.6 (1.30)	ab	7.6 A
Agati Sarheen	8.0	a	7.4 (7.50)	ab	7.7 A
P-78	8.0	a	8.0 (0.00)	a	8.0 A
Mean	7.94		7.46		
LSD (0.05)			0.8913		
	Number of siliqua plant^{-1}				
NIFA-Raya	605	a	542 (10.41)	a	573.4 A
Sultan Raya	449	ab	330 (26.50)	ab	389.5 AB
Toria selection	268	b	118 (55.97)	b	193.3 B
Agati Sarheen	410	ab	399 (2.68)	ab	404.7 AB
P-78	425	ab	386 (9.18)	ab	405.7 AB
Mean	431.4	A	355	A	-----
LSD (0.05)			296.0		
	Siliqua length (cm)				
NIFA-Raya	4.03	c	4.00 (0.74)	b	4.02 C
Sultan Raya	5.54	ab	4.93 (11.10)	a	5.25 AB
Toria selection	6.11	a	5.08 (16.86)	a	5.59 A
Agati Sarheen	4.76	bc	4.35 (8.61)	ab	4.55 BC
P-78	5.39	ab	4.95 (8.16)	a	5.17 AB
Mean	5.16	A	4.66	B	
LSD (0.05)			0.7954		

- Values in the parenthesis are relative decrease (%) over control
- Values having the same letters do not differ significantly at 5.0% probability according to Duncan Multiple Range Test (DMRT)

Effect of salinity on yield components of *Brassica* genotypes: Analysis of variance for data of different yield parameters (Table 4) of *Brassica* genotypes also showed significant effects of salinity. All the tested genotypes showed a decreasing trend in number of siliqua plant^{-1}. Under saline conditions, maximum numbers of grains siliqua^{-1} were observed in Toria selection i.e., 18.0 and minimum grains were observed in NIFA raya (i.e., 12.0). The data with respect to relative decrease showed least reduction in Sultan raya and P-78 (7.14%). The relative reduction in Agati sarheen was observed bit higher (i.e., 14.29%). However, all the genotypes have <50% reduction under salinity.

Grain weight plant^{-1} in *Brassica* genotypes also decreased significantly due to soil salinity. Maximum grain wt. plant^{-1} under salinity was observed in Sultan raya i.e. 14.40 g plant^{-1}, followed by P-78 and Agati sarheen. However, the differences among these three genotypes were statistically at par. The genotype Agati sarheen though had less grain wt plant^{-1} than Sultan raya and P-78 but the relative reduction was minimum (15.38%).The relative reduction in Sultan raya and P-78 was 21.31 and 28.71%, respectively. On the other hand, the genotypes NIFA-raya and Toria selection, showed higher reduction than the other tested genotypes i.e. 75.57 % in NIFA-raya and 70.69 % in Toria selection.

The effect of salt stress was less in case of 100 grain weight. Almost all the genotypes exhibited < 50% reduction in 100 grain weight. The mean decrease under salinity was 25.6%. The data regarding the individual genotypes showed maximum 100 grain weight in Sultan raya (0.45 g) followed by P-78 (0.34 g) and Agati sarheen (0.33 g). It was observed that though the genotype Sultan raya had higher values for 100 grain weight under both growing environments (i.e., 0.71 under non saline and 0.45 g under saline condition) but the relative decrease was bit higher as compared to other tested genotypes (i.e., 36.60%). On the other hand the relative reduction in Agati Sarheen was minimum i.e. 10.31% dec.

Decrease in different growth and yield components significantly affected grain yield. The mean values for the grain yield were recorded as 5756 & 2844 Kg hac^{-1}, under non saline and saline condition, respectively. Among the individual genotypes the only genotypes showing < 50% reduction was P-78 (i.e., 16.04% relative decrease). The genotype Agati Sarheen was on the margin with 49.35% decrease under salinity. On the other hand, significantly higher reduction in grain yield under salinity was observed in NIFA-raya, Sultan-raya and Toria selection i.e., 70, 59 and 56% relative decrease, respectively (Table 5).

Table 4. Mean squares from analysis of variance (ANOVA) of yield parameters under saline-sodic field conditions.

Source	Degree of freedom	No. of grains siliqua $^{-1}$	Grain wt. siliqua $^{-1}$	Grain wt. Plant $^{-1}$	Grain yield	100 grain wt.
Salinity	1	17.48**	0.099**	262.85**	515354**	0.060**
Genotypes	4	40.089**	0.089**	113.80**	45542 ^{NS}	0.057**
Salinity x genotype	4	0.485 ^{NS}	0.011 ^{NS}	15.13 ^{NS}	30134 ^{NS}	0.003
Error	18	1.959	0.0054	13.35	20886	0.002

** = Significant @1% prob., * = Significant @ 5% prob., NS= Non-significant

Table 5. Effect of salinity on yield components of different *Brassica* genotypes.

Genotypes	Non saline		Saline		Mean
	Number of grains siliqua^{-1}				
NIFA-Raya	13	b	12 (7.69)	b	12.32 B
Sultan Raya	14	b	13 (7.14)	b	13.13 B
Toria selection	20	a	18 (10.00)	a	18.80 A
Agati Sarheen	14	b	12 (14.29)	b	13.33 B
P-78	14	b	13 (7.14)	b	13.80 B
Mean	15		13.6		
LSD (0.05)			2.402		
	Grain wt. plant^{-1} (g)				
NIFA-Raya	13.1	bc	3.2 (75.57)	b	8.17 B
Sultan Raya	18.3	ab	14.4 (21.31)	a	16.33 A
Toria selection	11.6	c	3.4 (70.69)	b	7.52 B
Agati Sarheen	13.0	bc	11.0 (15.38)	a	11.98 AB
P-78	19.5	a	13.9 (28.72)	a	16.73 A
Mean	15.1		9.18		
LSD (0.05)			6.267		
	100 grain weight (g)				
NIFA-Raya	0.31	b	0.26 (16.13)	b	0.286 B
Sultan Raya	0.71	a	0.45 (36.60)	a	0.580 A
Toria selection	0.34	b	0.22 (35.29)	b	0.282 B
Agati Sarheen	0.37	b	0.33 (10.31)	ab	0.352 B
P-78	0.44	b	0.34 (22.73)	ab	0.392 B
Mean	0.43		0.32		
LSD (0.05)			0.1329		
	Grain yield (Kg/ hac.)				
NIFA-Raya	7611	a	2256 (70.36)	b	4933 A
Sultan Raya	5144	ab	2100 (59.18)	b	3622 A
Toria selection	4733	b	2078 (56.10)	b	3406 A
Agati Sarheen	5111	ab	2589 (49.35)	ab	3850 A
P-78	6167	ab	5178 (16.04)	a	5672 A
Mean	5756		2844		
LSD (0.05)			2479		

- Values in the parenthesis are relative decrease (%) over control
- Values having the same letters do not differ significantly at 5.0% probability according to Duncan Multiple Range Test (DMRT)

Table 6. Categorization of *Brassica juncea* genotypes on the basis of <50% decrease in different growth variables.

Genotypes	Plant height	No. of branches plant^{-1}	No. of siliqua plant^{-1}	Siliqua length (cm)	No. of grains siliqua^{-1}	Grain wt plant^{-1}	Grain yield plot^{-1}	100 grain wt.	Variables < 50% red
NIFA-Raya	+	+	+	+	+	-	-	+	6 (MS)
Sultan Raya	+	+	+	+	+	+	-	+	7 (MT)
Toria selection	+	+	-	+	+	-	-	+	5 (S)
Agati Sarheen	+	+	+	+	+	+	+	+	8 (T)
P-78	+	+	+	+	+	+	+	+	8 (T)

T = Tolerant, MT = Medium tolerant, MS = Medium sensitive and Sensitive = (S)

The growth performance of *Brassica* genotypes are summarized in Table 6 on the basis of <50% reduction in different agronomical parameters. It was observed that among the tested genotypes, P-78 and Agati sarheen showed <50% decrease in all the growth parameters. Therefore the genotypes P-78 and Agati sarheen can be categorized as tolerant to saline-sodic environments. On the other hand, the genotypes NIFA raya & Toria selection showed >50% relative decrease in two to three variables, showing sensitivity to saline-sodic environments, especially in case of grain yield and hence were categorized as sensitive to medium sensitive.

DISCUSSION

Salt tolerance is a complex phenomenon. The studies conducted to explore the growth and yield potential of *Brassica* genotypes under natural saline field conditions showed a wide variability among the genotypes. It is assumed that plant growth is ultimately the direct result of massive and rapid expansion of the young cells produced by meristematic division (Neumann, 1997). The growth performance recorded at the time of crop harvest showed that only those genotypes had better response that have the genetic potential for salt tolerance at early seedling stage as was observed in our earlier studies (Shirazi *et al.*, 2011). Among the genotypes tested P-78 and Agati sarheen showed better performance under saline field conditions. The differences among *Brassica* varieties in plant height might be due to the differences in genetic background (Sana *et al.*, 2003). Munns *et al.* (1995) suggest that any varietal diversity in plant growth responses to salinity appears slowly and is caused by genotypic differences in rates of salt accumulation. The accumulations of excessive salts limit the cell wall elasticity and also modify the metabolic activities of the cell (Kingsbury and Epstein., 1984). In addition secondary cells appear sooner and cell wall becomes rigid, as a consequence the turger pressure efficiency in cell enlargement decreases. Reduction in plant height with increasing salinity, have also been observed by Ashraf *et al.* (1999) and Akhtar *et al.* (2002) in *Brassica* species.

Effect of salinity was comparatively less on the branching capacity of *Brassica* genotypes. There was a decrease in the branching volume (diameter) but decrease in number of branches was less. Almost all the genotypes were showing less than 10% reduction in number of branches, except NIFA-raya, where the decrease in number of branches was bit higher. The decrease in the branching volume might be due to reduction in stomatal conductance and carbon assimilation rate, as reported by Brugnoli and Lauteri (1991) in cotton. According to them increasing salinity decreased the stomatal conductance and carbon assimilation rate and thus stem diameter.

The effect of salinity on siliqua formation was significant. Sana *et al.* (2003) reported that, number of siliqua in plant is critical component to determine yield. Similarly, time of flowering is also critical. Salinity stress decreases growth period and consequently, plants decrease the siliqua number to survive. Reduction in siliqua number might be associated with the increase of ABA and pollen death as already been reported by Lin *et al.* (2004). Zadeh and Naeini, (2007), reported that the reduction in number of flowers primordia could probably be related to effects of salinity stress on generative meristem at the beginning of flowering phase, resulting in reduced number of flowers. Following the flower decrease there was a fall in the number of silique at the phase of fruiting. Sinaki *et al.* (2007) also concluded flowering stage as one of the important reason for the reduction of siliqua in *Brassica* due to the induction of salinity stress. Effect of salinity was also evident on pod length of *Brassica* species. There was a significant decrease in siliqua length in *Brassica* genotypes. However, the relative reduction in all the genotypes was within the economic limits (i.e., < 50%).

Grain formation in *Brassica* genotypes was also reduced due to soil salinity. Baybordi (2010) reported that one of the reasons for decrease in grain number is the reduction in siliqua length. The correlation studies (Table 7) among the growth parameters showed that grain yield has significantly positive relations with plant height, number of branches and grain wt. plant^{-1}. Engqvist and Beker (1993) have the opinion that, seed weight and numbers of silique are more important component for the selection of high yielding genotypes. Mir *et al.* (2010), observed positive correlations between siliqua plant^{-1}, grain siliqua^{-1} and grain weight plant^{-1} with grain yield. Sakr *et al.* (2007) also have the opinion that among the yield components, numbers of seeds are major growth parameter. Grain weight plant^{-1} in *Brassica* genotypes decreased significantly due to salinity of the soil. This decrease in grain weight might be due to prevention of assimilate transported to the seeds and decrease in growth during grain filling stage. Munns *et al.* (2006) also observed many disorders in reproductive stages when barley plants were exposed to salinity stress. Reduction in grain weight plant^{-1} also resulted in decreased grain yield. Maximum grain yield was observed in genotype P-78 (5178 kg hac $^{-1}$) followed by Agati sarheen (2589 kg.hac^{-1}). The relationship between grain weight plant- and grain yield were found positively significant (r = 0.51). According to Flowers *et al.* (1991), poor grain yield under saline environment was due to salt induced shrinkage and even complete damage of chloroplast, decrease in photosynthates in the phloem and water deficiency in the growing region. Similar are the opinion of Ashraf *et al.* (1999) that reduction in grain yield may be due to decreasing assimilates production associated with decreased plant size and yield. Our findings are in agreement, where the correlations between plant height, number of branches with grain yield were found significantly positive (r = 0.66, 0.45, respectively). Based on relative reduction (< 50% decrease) in different agronomical parameters it was concluded that the genotypes Agati sarheen and P-78 are tolerant and have the potential to perform better under saline-sodic environments.

Table 7. Correlation studies (n = 30) among different growth and yield components in *Brassica* genotypes.

Parameters	Grain wt. plant^{-1}	100 grain wt.	Grain yield	No. of branches	No. of grain	No. of siliqua	Plant height
100 grain wt.	0.47**						
Grain yield	0.51**	0.11 NS					
No. of branches	0.58 **	0.05 NS	0.45 **				
No. of grain	-0.12 NS	-0.13 NS	0.08 NS	0.04 NS			
No. of Siliqua	0.19 NS	0.21 NS	0.20 NS	0.04 NS	-0.50*		
Plant height	0.47**	0.13 NS	0.66**	0.43*	0.00	0.21 NS	
Siliqua length	0.27 NS	0.42*	0.05 NS	0.17 NS	0.59 **	-0.24 NS	0.03 NS

** = Significant @ 1% prob., * = Significant @ 5% prob., NS= Non-significant

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