Journal of Animal & Plant Sciences, 33(5): 2023, Page: 1204-1213
ISSN (print): 1018-7081; ISSN (online): 2309-8694
https://doi.org/10.36899/JAPS.2023.5.0713

EVALUATION AND SELECTION OF SALINITY TOLERANT LINES IN BRASSICA NAPUS USING CORRELATION AND PATH COEFFICIENT ANALYSIS

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ABSTRACT

Genetic variation and varied response of genotypes with erraticsalt tolerance enable us to recognize and utilize the underlying physiological and biochemical mechanisms in development of salinity tolerant cultivars. In the present studies, ten lines viz., B-56, BLBN, G-96, R-3, RBJ-8007, ZMR-1, ZMR-2, ZNR-1, ZMM-5, and 23627, and six testers i.e., Faisal, Shiralee, Laclone, Long, Legend, and ZMR-3 were collected and crossed in a line by tester fashion. The resultant F_1 crosses and their parental genotypes were assessed at maturity phase in a pot experiment under factorial structured CRD. Recorded data on morphological traits were analyzed to assess the genetic variability in breeding material, association among traits, and their direct and subsidiary effects on seed and oil yield. Analysis of variance showed the presence of significant genetic variability within and among the salinity treatments. Parental genotypes were found significantly different for Na+/K+ ratio, proline contents, osmotic potential, primary branches, and oil contents under all treatments. Entries and parents vs. crosses differed significantly for most of the traits indicating that breeding material possesses genetic variability which may be exploited in future breeding program for effective upgradation of yield and salinity tolerance. Correlation and path analysis exposed that silique per plant, seeds per silique, oil content, thousand seeds weight, and days to 50% maturity might be used as criteria of selection for development of salinity tolerant types with higher yield. Morphological traits showed significant association with yield per plant under salt stress conditions. These associations can be useful in sorting salt tolerant and sensitive high yielding genotypes. Accumulation of proline and Na^+/K^+ ratio may also be chosen as selection criteria for targeting salinity tolerance in the future breeding program. Screening of salt tolerant lines and subsequent development of salinity tolerant cultivars may be helpful in inclusion of salt effected area's under Brassica cultivation thereby increasing the local production of edible oil in Pakistan.

Key words: salinity, correlation, path coefficient, genetic variability, morphological, proline, Na^+/K^+

Published first online June 20, 2023 Published final September 30, 2023

INTRODUCTION

Salinity stress falls under the primary factors restraining the development and production of food crops. Agricultural production in terrestrial areas of the world has largely been affected by elevated level of soil salinity (Zhang and Hodson, 2001). Sodium chloride is the most prevailing element causing salinity. Salinity causes the reduction in growth of plants in two phases. Growth reduction occurs within minutes during initial phase, where excessive salts limit the uptake of water and slower the growth rate due to osmotic effects of salinity.

Salts accumulate in leaves during second phase of growth reduction which may takes days, weeks and even months. It causes salt toxicity which leads to leaves' death ultimately by reducing the total photosynthetic leaf area (Munns, 2005). Accumulation of sodium may cause disturbance in normal metabolic pathways where low Na^+ (Sodium ion) and high K^+ (Potassium ion) and or Ca^{+2} (Calcium ion) are essential for optimum function (Marschner, 1995).

Genetic variability and correlation among the yield related traits decides the fate of crop development program (Khan *et al*., 2006; Tariq *et al*., 2020). Estimation of genetic variability for high yield and salinity tolerance may help in development of lines with high adaptability and yield under normal and stress conditions. Seed yield is polygenic trait which is affected by several other yield contributing attributes. It is therefore necessary for the plant breeders to find the association of various yield attributes. Correlation is imperative to determine the degree of association among the yield contributing characters (Wright, 1921). Therefore, it is essential to study correlation among the traits in order to develop a suitable selection criterion based on the association of different traits with yield per plant. Hence, path coefficient analysis was introduced for the comprehensive determination of impact caused by the different variables on resultant one

Brassica napus is a very important oilseed crop of Pakistan as it possesses major share in the present edible oil production of Pakistan. Present conditions with elevated imports of edible oil to overcome the gap between local production and consumption has diverted the attention of government as well as scientists to enhance the local production of brassica.Past studies indicated that seed yield of brassica may be improved indirectly through improving the siliquae per plant, seeds per silique, and reducing the days to 50% floweringand days to 50% maturity (Rameeh 2011; Zare 2011; Ejaz-ul-Hassan *et al*., 2014). The present research work was programmed with the objective of generating information on genetic mechanisms controlling salinity tolerance, finding the association among various yield attributes, and traits associated with salinity tolerance and finding the direct as well as indirect effects of various traits on crop productivity under varying salt stress conditions. The information generated through this study may help in continuous genetic improvement for development of salinity tolerant cultivars.

MATERIALS AND METHODS

The studied experiments were carried out at the green house of department of Plant Breeding and Genetics, University of Agriculture Faisalabad. Sixteen *Brassica napus* lines were collected from the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad. Ten lines (G-96, ZM-M-5, 23627, ZMR-10, RBJ-8007, ZNR-1, ZMR-2, B-56, BLBN, and R-3) and six testers (Long, Laclone, Legend, Faisal, Shiralee, and ZMR-5) of *Brassica napus* L. were used as male and female parents, respectively to make crosses in a line by tester mating design through controlled pollination. Seeds of parental genotypes and their crosses were collected, cleaned and kept for sowing in the next crop season for evaluation.

Sixty crosses, their parents, and two check varieties were planted in 234 pots for each treatment in a completely randomized design with two factors, in a factorial arrangement. Three levels of salinity i.e., T0: 0mM, T1: 120mM, and T2: 150mM were maintained by adding salt solution in pots filled with 12kg of soil using the following protocol.

Salts per kg of soil= TSS × Eq. Wt. of NaCl×SP/1000×100

Total Soluble Salts (TSS) = Required EC×10

Saturation percentage of soil (SP) = Loss in wt. oven drying /Wt. of saturated soil paste without china dish

Required EC= Desired EC – Original EC

Calculated amounts of salt i.e., 14.6 g to develop the required salinity level of 120mM and 18.96 g for developing the required salinity level of 150mM were used to prepare one liter salt solution for each pot separately. Amount of soluble salts was measured using saturated paste method (Dellavalle, 1992). Soil samples were taken from all the treatments using tube sampler. Soil samples were saturated by adding double distilled water to the beaker containing sieved soil,and spatula was used to keep stirring. Mixture was allowed to stand overnight; prepared paste was shifted to Buchner funnel with filter paper lined in place and saturated paste extract was obtained in flask by applying vacuum. Portable EC meter (HI 99300) was used for EC measurement in order to ensure the required EC in each treatment.

Two plants per treatment and per replication were tagged and data were documented on various pre- and post-harvest characters including Na^+/K^+ ratio, proline contents, osmotic potential,days to 50% flowering (DTF 50%), plant height, primary branches, days to maturity (DTM 50%), silique per plant, seeds per silique, thousand seed weight, seed and oil yield per plant.Na^+ and K^+ ions were measured using the method as described by Wolf 1982. Oven dried crushed leaves (0.1 g) were taken in a digestion flask and 2.5 ml of $H_2SO_4$was added to the flask and incubated over night at room temperature. Then 1 ml of H_2O_2 (35%) was poured down the sides of digestion flask and heated at 350 ˚C on hot plate until fumes were produced. The digestion flasks were cooled and placed back on the hot plate after adding 1 ml of H_2O_2. The procedure was repeated until the cooled material became colorless. The volume of extract was maintained to 50 ml in the volumetric flasks by adding distilled water. The extract was filtered and used for the determination of Na^+ and K^+ ions from single channel flame photometer (Spectroniccamspec Ltd, Model Jenway, PFP-7 UK).Leaf osmotic potential were determined from the leaf sap extracted from the frozen leaf samples by vapor pressure osmometer (Vapro-5520).Leaf free proline contents were determined by taking the leaf sample (500mg) and titrated it against 10 ml of 3% (w/v) sulfosalicyclic acid (MP, Biomedicals, Inc) solution. The crushed sample was filtered and 2.0 ml of filtrate was taken in a test tube, mixed with 2.0 ml acid ninhydrin solution and 2.0 ml glacial acetic acid. Acid ninhydrin was prepared by mixing 1.25g ninhydrin with 30 ml glacial acetic acid and 20 ml phosphoric acid. The reaction was performed at 100 ˚C and it was terminated in a container filled with ice. After cooling sample mixture, toluene was added to it. The aliquots containing toluene were vortexed. The optical density of filtrate was measured using spectrophotometer (JENWAY 6315) at 520 nm. Toluene was added as blank and prolinewas calculated by the following formula: µmol proline g^{-1} fresh weight = (µg proline mL^{-1} x mL of toluene/115.5)/sample wt (g)

Biometrical Analysis: Two way analysis of variance was performed on recorded data following (Steel *et al.*, 1997). Correlation analysis was executed following statistical approach defined by Kwon and Torrie 1964).Path coefficient analysis was carried out ensuing approach defined by Dewey and Lu (1959), keeping per plant seed yield as resultant variable (effect) and seedling and yield attributes as causal variables (causes). Statistical software pakcakge "R-studio" is used to carried out these analysis.

RESULTS AND DISCUSSION

Soil salinization is becoming a major issue that is badly effecting crop yield and quality. It becomes prerequisite for the plant breeders to develop and introduce high yielding cultivars that perform well in normal as well as saline environmental conditions. Therefore, it is direly needed to have a genetic variability in crop plants for targeted development and improvement. So, it is important to introduce new desirable traits or improve the genetic ability of crop varieties to withstand the changes in environmental conditions. This study is designed to evaluate and select lines having high salinity tolerance which is indirectly related to other plant traits. In the present studies, the parental genotypes and crosses were developed and evaluated for various morphological and physiological traits under different levels of salinity.

Analysis of variance is the basic tool to assess existence of genetic variability in the breeding material. Analysis of variance showed differences for studied traits within and among the treatments (Table 1). Genotypes differed significantly for all traits except silique per plant under all the treatments, plant height and DTM under treatment 1, and DTM, seeds per silique and thousand seed weight under treatment 3. Parental genotypes were found significantly different for Na^+/K^+ ratio, proline contents, osmotic potential, primary branches, and oil contents under all treatments. Significant differences among parents vs. crosses were observed for Na^+/K^+ ratio, proline contents, osmotic potential, plant height and DTM 50% under all treatments. Crosses were significantly different for plant height, seeds per silique and oil content. Among lines, significant differences were observed for all traits except DTF 50%, primary branches, and yield per plant under control conditions. However, under treatments 1 and 2 the lines were significantly differed for Na^+/K^+ ratio, proline contents, osmotic potential, thousand seed weight, and oil contents. Testers were found significantly different under all treatments for Na^+/K^+ ratio, proline contents, thousand seed weight, and oil content. Line by tester interactions were significantly differed for plant height, DTF 50%, seeds per silique, and thousand seed weight under all the treatments.

The results of presented research revealed that DTF 50% and DTM 50% increased by increasing salinity stress whereas, the plant height, primary branches, siliquae per plant, seeds per silique, thousand seed weight, and seed and oil production per plant were decreased. Entries and parents vs. crosses differed significantly for most of the traits indicating that breeding material possesses genetic variability which may be exploited in future breeding program for effective upgradation of yield and salinity tolerance. Genetic variability for salinity tolerance and yield attributes has also been reported in *Brassica napus* genotypes (Shahzad *et al.,* 2015). Significant differences in parents vs. crosses in *B. napus* have also been reported in the past studies (Ahsan *et al*., 2013; Kang *et al*., 2013; Kang *et al*., 2014).

Correlation analysis helps in driving attention to traits with more impact on seed yield for efficient improvement of crop (Tuncturk and Ciftci, 2007). Estimation of correlation is important for quantification of genetic and nongenetic association between plant traits (Hallauer and Miranda Filho 1988). Genotypic correlation coefficients are more important than phenotypic correlations. Estimation of positive and negative correlation helps the breeders to define the strategy to improve favorable characters simultaneously or by tandem selection (Bernardo 2010). Genotypic and phenotypic correlations among traits under control and salinity stress treatments were computed (Tables 2 and 3). Seed yield had important and positive genotypic association with DTF 50%, DTM 50%, primary branches, and oil content per plant under control and saline conditions also with silique per plant and number of seeds per silique only under salinity stress. Oil contents had significant and positive association with seed yield per plant, primary branches, thousand seed weight, silique per plant, DTM 50% and plant height. Seed yield per plant and oil content had significantly negative correlation with Na^+/K^+ ratio under salinity stress treatments. Thousand seed weight had significant and positive association with plant height, DTF 50%, DTM 50%, seeds per silique, primary branches, and oil content under all the treatments. However, 1000-seed weight had negative association with proline content and osmotic potential under control condition. Silique per plant had significant positive genotypic correlation with proline contents, DTF 50%, and oil content under all the salinity stress treatments. Phenotypic correlation coefficient showed positive association of seed yield with DTF 50%, DTM 50%, primary branches, and oil content per plant under all the treatments.

Results indicated the existence of association between studied traits. The trait like DTF 50% and DTM 50% increased by increasing salinity stress whereas, the plant height, primary branches, siliquae per plant, seeds per silique, thousand seed weight, yield per plant, and oil content decreased. Salinity restricts the uptake of nutrients and also influence the assimilation of CO_2 negatively which causes the reduction in rate of photosynthesis ultimately reducing the plant growth and yield attributes like silique per plant, seeds per silique, seed weight per plant, and oil content (Bybordi, 2010; Bahrani, 2013). Salinity upsets the mechanisms of osmotic adjustment, nutritional balance, and biochemical processes causing decrease in yield attributes (Francois, 1994; Akhtar *et al*., 2002; Villata*et al*., 2008, Wu *et al*., 2019). Accumulated proline may provide energy to increase salinity tolerance by preserving sinks of carbohydrates in chloroplasts (Nazarbeygi*et al*., 2011; Saadia *et al*., 2012). It improves the osmoregulatory function which helps in protection of proteins from denaturation. More tolerance of brassicas for salinity may be the result of higher accumulation of proline under salinity stress (Toorchi*et al*., 2011). High proportion of Na^+ ions under salinity had negative influence on seed yield per plant. The Na^+/K^+ ratio had negative whereas, proline content showed positive association with seed and oil yields. Higher accumulation of proline content at higher salinity levels helps the plant to cope with the salinity stress and produce the higher seed yield (Munns and James, 2003; Ashraf, 2004). Various scientist reported significant positive genotypic as well as phenotypic correlation of seed yield per plant with various morphological characters in *B. napus* L. under normal conditions (Khan *et al*., 2006; Zhang and Zhu 2006; Jeromela*et al*., 2007; Tuncturk and Cifit, 2007; Sabaghnia*et al*., 2010; Hoveize*et al*., 2016).

Effects (either direct or indirect) of various morphological traits on seed yield under T0, T1 and T2 are presented in Table 4. Maximum direct effects were observed through silique per plant, followed by oil content, seeds per silique, DTM 50%, and thousand seed weight under control treatment. Thousand seed weight followed by dry root weight, siliquae per plant, and oil content showed maximum indirect effects through various traits under T0. Maximum indirect effects of various traits under T0 were observed through DTM 50%. Maximum direct effects under T1 were observed for thousand seed weight, followed by silique per plant and seeds per silique. Thousand seed weight and primary branches followed by DTM 50% had the maximum indirect effects through various traits under T1. Various traits showed maximum indirect effects through silique per plant and thousand seed weight. Seed yield under T2, seeds per silique and silique per plant; were directly influenced by oil content. Primary branches, followed by DTF 50% and silique per plant had the maximum indirect effects through various traits. Maximum indirect effects of various traits were observed through oil content, followed by seeds per silique. silique per plant, and seeds per silique had maximum direct effects under all the treatments.

Path coefficient analysis coupled with correlation analysis has been used in various crops for determination of parameters having high and direct effects towards yield (Punia and Gill, 1994; Shalini *et al*., 2000; Tuncturk and Ciftci 2007; Basalma 2008; Ejaz-ul-Hassan *et al*., 2014). Results showed that the seed yield is directly influenced by the silique per plant and seeds per silique under all the treatments. Past studies showed that the days to 50% maturity, sailique per plant, seeds per silique and thousand seed weight have direct positive effects on seed yield (Shalini *et al*., 2000; Marijnovic-Jeromela *et al*., 2007; Khayat *et al*., 2012; Hoveize*et al*., 2016).

Under saline conditions, the Na^+ often competes with the K^+ uptake via Na^+/K^+ co-transporters and may also hinder root cell K^+ specific transporters. Large amount of exchangeable Na^+ ions in salt affected soils becomes available to plants and they uptake the Na^+ ions preferably thereby increasing the Na^+ content which generally disturbs the balance of nutrients causing toxicity of ions in cytoplasm (Islam *et al*., 2001; Villata*et al*., 2008). The Na^+ ion accumulation through changing membrane permeability under salinity stress also causes metabolic disruption in pathways where more K^+ is needed for optimal function (Marschner, 1995; Tester and Davenport, 2003). These factors ultimately restrict the plant growth resulting in reduced yield and quality (Cramer *et al*., 1987; Grieve and Fujiyama, 1987).

The present results further suggested that seed yield per plant and oil content under the higher levels of salinity may be improved by improving the siliquae per plant, seeds per silique, DTF 50%, DTM 50% and primary branches. Ion discrimination may be used as salinity stress tolerance indicators. These yield attributes may be used as selection criteria for improvement in the yield of brassica under the higher levels of salinity. The traits silique per plant, seeds per silique, DTF 50% and DTM 50%, and oil content may be used as selection criteria for development of salinity tolerant *B. napus* types with higher seed yield. Aimed at salinity tolerance, the accumulation of proline and Na^+/K^+ ratio may also be used as selection criteria in future breeding programs.

Table 1. Mean square values for various traits in brassica under control and salinity stress treatments.

SOV	DF	Na/K	PC	OP	PH	DTF	DTM	SP	SS	TSW	PB	OC	YP
							T0 (0mM)						
Replications	2	8.19**	9.20**	5.92*	254.92*	15.76	4.75	0.26**	66.93	14.97**	4.49**	19.43*	97.99
Entries	75	9.71**	8.02*	2.35**	132.35**	41.78*	34.11**	10.02	75.42**	21.63**	4.58**	3.44*	40.96*
Parents (P)	15	17.09**	6.01**	1.91**	103.96**	101.98**	39.81**	0.01	43.40	32.24	8.34**	3.42*	32.46*
Crosses (C)	59	4.8*	9.32*	3.96**	114.08**	21.95	28.90**	0.3	48.58*	64.93**	3.19**	3.40*	10.47
P vs C	1	9.00**	12.32**	4.08**	370.91**	23.38	153.52**	1.003	21.15**	24.31**	11.99**	5.10	21.64
Lines (L)	9	22.87*	22.88*	4.50**	764.50**	35.93	34.86**	2.05*	55.11**	16.18*	1.47	5.00*	62.82
Testers (T)	5	36.78**	2.66**	3.10	930.10	49.02	24.11**	4.03	64.48*	49.75*	4.71**	2.97*	61.33
L× T	30	1.91	0.90	0.08	240.80**	33.54*	28.67	1.02	37.89*	19.51**	3.23**	3.17	29.82
Error	75	8.19**	9.20**	5.92*	360.63	14.48	6.78	4.42	20.47	4.02	0.67	4.69	5.47
							T1 (120mM)						
Replications	2	26.13*	23.5*	4.97**	67.10	31.97*	90.03**	35.86	274.83*	80.72	97.99	5.281	50.72
Entries	75	44.74*	9.90*	2.63**	90.81	15.91*	111.86	68.12	268.90*	38.52*	140.96*	51.012**	38.52*
Parents (P)	15	31.5*	26.8*	6.31**	96.21	66.23	164.79	49.41	135.15	11.66	232.46*	63.27**	11.66
Crosses (C)	59	10.9*	13.6*	2.24	76.58*	19.88	95.69	70.30	231.69*	48.03	110.47	22.4**	18.03
P vs C	1	26.13*	30.5*	4.93**	129.34*	53.55	95.67*	197.64	42.80	1.10	201.64	31.32**	1.10
Lines (L)	9	44.74*	19.9*	6.18*	59.28	83.49	155.00	76.88	424.91	89.49*	62.82	5.51**	9.49
Testers (T)	5	13.9*	13.6*	0.75	75.56	49.60	78.82	43.52	170.23	38.00	61.33*	9.28	38.00
L× T	30	0.5	2.8	0.05	60.24*	21.21*	87.20	74.34	205.34*	41.74*	129.82	72.7**	41.74
Error	75	26.13*	23.5*	4.97**	111.82	6.29	8.36	8.31	15.17	0.48	2.47	0.98	1.48
							T2 (150mM)						
Replications	2	15.7*	9.76*	4.75	16.92*	98.95*	107.10	651.07*	1001.03**	23.06	51.80*	60.12	4.83*
Entries	75	8.06*	5.80*	4.11**	99.30*	52.12*	98.01	123.11*	99.06	48.02	32.10*	26.52*	8.90*
Parents (P)	15	12.61*	19.60*	13.52**	14.12	23.05	78.11	87.13	105.99	29.11	75.25*	9.66*	5.15
Crosses (C)	59	1.78*	8.60*	39.81**	95.09**	108.01**	96.08	99.08	45.79*	25.37	13.49	68.03*	21.69
P vs C	1	15.70*	9.70*	8.90**	20.09*	13.04	89.34*	29.45	39.07	119.24	66.09	0.90	8.80
Lines (L)	9	788.6*	4.80*	14.86**	99.88	145.88*	123.18	99.69	175.00	66.89*	39.01	79.39*	4.91
Testers (T)	5	99.78*	7.60*	4.11**	99.07*	100.09*	85.06	189.50*	88.22	47.32	19.03*	28.00	9.23
L× T	30	0.86	1.6	0.67	108.15**	109.06**	89.04	111.01	89.10*	78.04*	23.04	22.04	5.34
Error	75	15.7*	9.76*	4.75	45.03	14.09	10.32	15.14	21.26	1.01	1.07	12.78	0.70

*: Significant at 0.05 probability level, **: Significant at 0.01 probability level, SOV: Source of variation, DF: Degrees of freedom, Na^+/K^+: Na^+/K^+ ion ratio, PC: Proline content, OP: Osmotic potential PH: Plant height, DTF: Days to 50% flowering, DTM: Days to 50% maturity, SP: Silique per plant, SS: Seeds per silique, TSW: Thousand seed weight, PB: Primary branches, OC: Oil content, YP: seed yield per plant

Table 2. Genotypic correlation coefficient among morphological traits of *Brassica napus* under various salt stresses

Variables	Treatments	PC	OP	PH	DTF	DTM	SP	SS	TSW	PB	OC	YP
	T0	-0.14*	0.09	-0.10	0.04	0.08	0.04	-0.4**	-0.09	-0.11	-0.12	-0.07
Na^+/K^+	T1	-0.2**	0.07	-0.14*	0.16**	0.19**	-0.13*	-0.34**	-0.03	-0.04	-0.17**	-0.06*
	T2	-0.18**	-0.50**	-0.04	-0.3**	-0.12*	-0.05	-0.2**	-0.9**	-0.02	-0.06*	-0.2**
	T0		-0.02	-0.15*	0.04	-0.05	0.95**	0.05	-0.3**	-0.3**	-0.2**	-0.2**
PC	T1		-0.08	0.01	0.19**	0.24**	0.14*	0.05	0.01	-0.03	0.03	0.01
	T2		0.19**	-0.10	0.20**	0.17**	0.13*	0.26**	0.19**	0.19**	-0.02	0.06
	T0			-0.14*	0.15*	0.07	-0.2**	-0.1**	-0.13*	-0.3**	-0.01	-0.12
OP	T1			-0.10	-0.03	0.04	-0.10	-0.09	0.04	0.22**	0.001	-0.04
	T2			0.15*	0.08	-0.01	0.04	0.14*	0.51**	0.09	-0.04	0.07
	T0				0.13	0.21**	-0.4**	0.29**	0.29**	0.21**	0.25**	0.11
PH	T1				0.26**	0.10	0.53**	0.12	0.62**	0.64**	0.36**	0.49**
	T2				0.30**	0.21**	0.31**	0.12	0.42**	0.27**	0.17**	0.25
	T0					0.61**	0.34**	0.21**	0.52**	0.12	0.04	0.38**
DTF	T1					0.86**	0.31**	-0.09	0.78**	0.44**	0.34**	0.75**
	T2					0.99**	0.88**	0.06	0.47**	0.78	0.88**	0.72**
	T0						-0.04	0.10	0.89**	0.27**	0.37**	0.82**
DTM	T1						0.28**	-0.04	0.76**	0.45**	0.25**	0.72**
	T2						0.99**	0.67	0.33**	0.05	0.79**	0.71**
	T0							-0.6**	-0.10	0.08**	0.9**	0.12
SP	T1							0.39**	0.74**	0.54**	0.34**	0.72**
	T2							1.09	0.23**	0.74	0.85**	0.74**
	T0								0.19**	0.30**	0.10	-0.03
SS	T1								0.28**	0.01	0.12*	0.16*
	T2								0.58**	0.06	0.74**	0.83**
	T0									0.60**	0.80**	1.03
TSW	T1									0.71**	0.76**	0.06
	T2									0.44*	0.24**	0.02
	T0										0.19**	0.52**
PB	T1										0.50**	0.77**
	T2										0.76**	0.74**
	T0											0.68**
OC	T1											0.74**
	T2											0.44**

Na^+/K^+: Na^+/K^+ ion ratio, PC: Proline content, OP: Osmotic potential PH: Plant height, DTF: Days to 50% flowering, DTM: Days to 50% maturity, SP: Silique per plant, SS: Seeds per silique, TSW: Thousand seed weight, PB: Primary branches, OC: Oil content

Table 3. Phenotypic correlation coefficient among morphological traits of *Brassica napus* under various salt stresses.

Traits	Treatments	PC	OP	PH	DTF	DTM	SP	SS	TSW	PB	OC	YP
	T0	-0.14*	0.04	-0.09	0.04	0.07	0.01**	-0.2**	-0.04	-0.04	-0.12	-0.04
Na^+/K^+	T1	-0.2**	0.06	-0.10	0.16*	0.18**	-0.10	-0.21**	-0.03	-0.02	-0.16**	-0.04*
	T2	-0.17**	-0.47**	-0.03	-0.12	-0.07	-0.03	-0.11	-0.05	-0.03	0.02*	-0.2*
	T0		-0.02	-0.13*	0.03	-0.03	0.11	0.02	-0.4*	-0.11	-0.2**	-0.10
PC	T1		-0.08	-0.02	0.16**	0.21**	0.14*	0.08	0.03	0.01	0.03	0.02
	T2		0.17**	-0.06	0.11	0.10	0.10	0.13*	0.07	0.12	0.02	0.06
	T0			-0.13*	0.14*	0.06	0.01	-0.05	-0.03	-0.11	0.01	-0.07
OP	T1			-0.08	0.01	0.04	-0.06	-0.02	0.05	0.17**	0.01	-0.01
	T2			0.09	0.05	0.01	0.02	0.05	0.22**	0.06	-0.01	0.07
	T0				0.14	0.17**	-0.11	0.11	0.12	0.09	0.22**	0.07
PH	T1				0.20**	0.10	0.36**	0.01	0.26**	0.26**	0.30**	0.26**
	T2				0.02	0.00	0.06	0.06	0.15**	0.06	-0.03	0.16**
	T0					0.51**	0.20	0.07	0.21**	0.04	0.04	0.17**
DTF	T1					0.82**	0.25**	-0.09	0.47**	0.30**	0.31**	0.51**
	T2					0.91**	0.84**	0.82**	0.08	0.81**	0.51**	0.37**
	T0						-0.02	0.09	0.50**	0.18**	0.35**	0.58**
DTM	T1						0.24**	-0.05	0.45**	0.33**	0.23**	0.48**
	T2						0.87**	0.84**	0.05	0.83**	0.52**	0.35**
	T0							-0.14*	-0.02	0.01	-0.13*	0.06
SP	T1							0.23**	0.35**	0.25**	0.26**	0.36**
	T2							0.82**	0.10	0.86**	0.56**	0.41**
	T0								0.07	0.08	-0.04	0.04
SS	T1								0.13**	0.05	0.08*	0.09**
	T2								0.01	0.78**	0.52**	0.36**
	T0									0.36**	0.38**	0.86**
TSW	T1									0.53**	0.37**	0.89**
	T2									-0.01	0.04	-0.01
	T0										0.08	0.38**
PB	T1										0.30**	0.55**
	T2										0.56**	0.37**
	T0											0.40**
OC	T1											0.41**
	T2											0.24**

: Na^+/K^+ ion ratio, PC: Proline content, OP: Osmotic potential PH: Plant height, DTF: Days to 50% flowering, DTM: Days to 50% maturity, SP: Silique per plant, SS: Seeds per silique, TSW: Thousand seed weight, PB: Primary branches, OC: Oil content

Table 4. Direct and indirect effects of various traits on seed yield per plant under various salt stresses.

Traits	Treatmentss	Na^+/K^+	PC	OP	PH	DTF	DTM	SP	SS	TSW	PB	OC
	T0	-0.091	0.002	0.0002	0.012	-0.004	0.045	0.003	0.082	-0.018	-0.027	-0.042
Na^+/K^+	T1	-0.180	0.030	-0.007	0.051	0.044	-0.014	-0.46	0.091	-0.18	-0.03	-0.41
	T2	-0.28	0.034	0.074	-0.008	-0.069	0.147	-0.02	0.062	-0.04	-0.05	-0.09
	T0	0.013	-0.017	0.001	0.018	-0.004	-0.029	0.065	-0.01	-0.068	-0.076	-0.073
PC	T1	0.038	-0.14	0.008	-0.003	0.050	-0.017	0.049	-0.03	0.003	-0.03	0.007
	T2	0.050	-0.19	-0.028	-0.020	0.060	0.236	0.128	-0.03	0.047	0.013	0.226
	T0	0.0003	0.0001	-0.075	0.017	-0.013	0.043	-0.01	0.031	-0.026	-0.077	-0.003
OP	T1	-0.012	0.012	-0.101	0.037	-0.07	-0.003	-0.35	0.023	0.020	0.020	-0.01
	T2	0.138	-0.06	-0.149	0.032	0.024	0.008	0.067	-0.69	0.023	0.031	0.064
	T0	0.010	0.003	0.011	-0.119	-0.001	0.121	-0.03	-0.05	0.058	0.049	0.085
PH	T1	0.025	-0.01	0.010	-0.369	0.070	-0.007	0.180	-0.02	0.333	0.059	0.087
	T2	0.011	0.018	-0.023	0.208	0.092	-0.25	0.061	-0.14	0.068	-0.14	0.527
	T0	-0.004	-0.001	-0.011	-0.001	-0.088	0.354	0.023	-0.04	0.105	0.030	0.015
DTF	T1	-0.030	-0.27	0.003	-0.096	0.268	-0.062	0.107	0.023	0.423	0.040	0.083
	T2	0.064	-0.38	-0.012	0.063	0.302	-0.16	0.545	-0.17	0.250	-0.73	0.785
	T0	-0.007	0.001	-0.005	-0.025	-0.053	0.385	-0.03	-0.02	0.180	0.064	0.125
DTM	T1	-0.035	-0.34	-0.004	-0.037	0.232	-0.072	0.094	0.011	0.411	0.041	0.061
	T2	0.035	-0.03	0.001	0.044	0.298	-0.18	0.502	-0.11	0.251	-0.65	0.703
	T0	-0.004	-0.016	0.015	0.052	-0.030	-0.024	0.669	0.127	-0.020	0.258	-0.302
SP	T1	0.024	-0.21	0.010	-0.194	0.084	-0.020	0.342	-0.05	0.398	0.049	0.083
	T2	0.057	-0.49	-0.020	0.026	0.330	-0.18	0.499	-0.19	0.264	-0.61	0.842
	T0	0.038	-0.001	0.012	-0.034	-0.018	0.061	-0.05	0.396	0.038	0.073	-0.033
SS	T1	0.061	-0.07	0.009	-0.044	-0.23	0.003	0.134	0.345	0.153	0.001	0.029
	T2	0.053	-0.06	-0.076	0.088	0.143	-0.39	0.289	0.405	0.107	-0.15	0.391
	T0	0.008	0.006	0.010	-0.034	-0.046	0.519	-0.07	-0.03	0.202	0.143	0.270
TSW	T1	0.006	-0.01	-0.004	-0.228	0.210	-0.055	0.252	-0.06	0.539	0.065	0.183
	T2	0.005	-0.37	-0.014	0.057	0.307	-1.25	0.535	-0.45	0.246	-0.62	0.787
	T0	0.010	0.005	0.024	-0.024	-0.011	0.156	0.074	-0.05	0.121	0.239	0.066
PB	T1	0.007	0.005	-0.022	-0.237	0.118	-0.032	0.184	-0.03	0.384	0.091	0.121
	T2	-0.18	0.003	0.006	0.035	0.267	0.930	0.368	-0.08	0.187	-0.83	0.439
	T0	0.011	0.004	0.001	-0.030	-0.004	0.216	-0.06	0.019	0.162	0.047	0.397
OC	T1	0.030	-0.04	0.0003	-0.133	0.092	-0.018	0.117	-0.32	0.408	0.046	0.243
	T2	0.015	-0.26	-0.006	0.065	0.318	-0.15	0.542	-0.07	0.259	-0.74	0.696

Na^+/K^+: Na^+/K^+ ion ratio, PC: Proline content, OP: Osmotic potential PH: Plant height, DTF: Days to 50% flowering, DTM: Days to 50% maturity, SP: Silique per plant, SS: Seeds per silique, TSW: Thousand seed weight, PB: Primary branches, OC: Oil content

REFERENCES

Ahsan, M.Z., F.A. Khan, S.A. Kang and K. Rasheed (2013). Combining ability and heterosis analysis for seed yield and yield components in *Brassica napus* L. J. Biol. Agri. Healthcare 3(9): 31-37.http://www.iiste.org/.../6854

Akhtar, J., M. Haq and Saqib, K. Mahmood (2002). Effect of salinity on yield, growth and oil contents of four Brassica species. Pakistan J. Agric. Sci. 39(2): 76 - 79. ISSN: 0552-9034 https://agris.fao.org/agris-search/search.do?recordID=PK2002000574

Ashraf, M. (2004). Some important physiological selection criteria for salt tolerance in plants. Flora 199:361-376.https://doi.org/10.1078/0367-2530-00165

Bernardo R., (2010). Breeding for Quantitative Traits in Plants, Stemma Press, Woodbury, Minnesota.

Bahrani, A (2013). Effect of Salinity on growth, ions distribution, accumulation and chlorophyll concentrations in two Canola (*Brassica napus* L.) Cultivars. Am-Euras. J. Agric. Environ. Sci. 13(5): 683-689. ISSN : 1818-4952 URL : http://www.idosi.org/.../14.pdf

Basalma, D (2008). The correlation and path analysis of yield and yield components of different winter rapeseed (*Brassica napus* ssp.*Oleifera* L.) cultivars. Res. J. Agric. Biol. Sci. 4(2): 120-125.

Bybordi A (2010). Effects of salinity on yield and component characters in canola (*Brassica napus* L.) cultivars. Not. Sci. Biol. 2(1): 81- 83. https://doi.org/10.15835/nsb213560

Cramer G.R., J. Lynch, A. Lauchli and E. Epstein (1987). Influx of Na+, K+, and Ca2+ into roots of salt-stressed cotton seedlings: effects of supplemental Ca2+. Plant Physiol. 83:510–516. https://doi.org/10.1104/pp.83.3.510

Dellavalle, N.B. (Ed.) (1992). Determination of soil-paste pH and conductivity of saturation extract. In: Handbook on reference methods for soil analysis. Soil and Plant Analysis Council.Inc. Athens GA. 40-43. http://s3.amazonaws.com/udextension/lawngarden/files/2012/10/CHAP10.pdf

Dewey, D.R. and K.H. Lu (1959). A correlation and path-coefficient analysis of components of crested wheatgrass seed production. Agron. J. 51: 515-518.https://doi.org/10.2134/agronj1959.00021962005100090002x

Ejaz-ul-Hassan, H.S.B. Mustafa, T. Bibi and T. Mahmeed (2014). Genetic variability, correlation and path analysis in advanced lines of rapeseed (B. napus) for yield components. Cerletari Agromice in Moldova1(157): 71-79. DOI:10.2478/cerce-2014-0008

Francois L.E (1994). Growth, seed yield, and oil content canola grown under salinity conditions. Agron. J. 86:233-237.https://doi.org/10.2134/agronj1994.00021962008600020004x

Grieve C.M. and H. Fujiyama (1987). The response of two rice cultivars to external Na/Ca ratio. Plant Soil.103:245-250.https://doi.org/10.1007/BF02370396

Hallauer, A. R., J.B.M. Filho. 1988. Quantitative genetics in maize breeding. 2nd ed. Ames, Iowa: Iowa State University Press. 468. DOI: 10.3923/ijpbg.2015.86.94

Hoveize, M.S., M. Moradi, T.S. Nejad, S.Z. Najed and A. Etaa (2016). Correlation, stepwise regression and path analysis of traits affecting grain yield of canola (*B. napus* L.). Int. J. Adv. Biotech. Res. 7: 200-204. doi:10.7537/marslsj170320.07

Ejaz-ul-Hassan, H.S.B. Mustafa, T. Bibi and T. Mahmeed (2014). Genetic variability, correlation and path analysis in advanced lines of rapeseed (B. napus) for yield components. Cercetări Agronomice în Moldova 1 (157): 71-79. DOI:10.2478/cerce-2014-0008

Kang, S.A., F. Saeed and M. Riaz (2013). Breeding for improving the seed yield and yield contributing traits in *Brassica napus* L. J. Plant Breed. Genet. 01(03): 111-116. ISSN: 2305-297X (Online), 2308-121X (Print)

Kang, S.A., F.A. Khan and M.A. Javed (2014). Heterosis and combining ability studies for exploitation of hybrid genotypes in *B. napus*. J. Agric. Res. 52(3): 303-316. http://www.jar.com.pk/upload/1414246614_114_2._132_composed.pdf

Khan, F.A., S. Ali, A. Shakeel, A. Saeed and G. Abbas (2006). Genetic variability and genetic advance analysis for some morphological traits in (*Brassica napus* L.). J. Agric. Res. 44(2): 83-88.
DOI: 10.5829/idosi.aejaes.2013.13.05.1952

Khan, F.A., S. Ali, A. Shakeel, A. Saeed and G. Abbas (2006). Genetic variability and genetic advance analysis for some morphological traits in (*Brassica napus* L.). J. Agric. Res. 44(2): 83-88. http://archive.saulibrary.edu.bd:8080/xmlui/handle/123456789/697

Khayat M., S.H. Lack, H. Karami (2012). Correlation and path analysis of traits affecting grain yield of canola (*Brassica napus* L.) varieties. J. Basic. Appl. Sci. Res. 2(6): 5555-5562. ISSN 2090-4304

Kwon, S.H. and J.H. Torrie (1964). Heritability and interrelationship among traits of two soybean populations. Crop Sci. 4(1): 196-198.https://sg.docworkspace.com/l/sICikltRh4s7HowY?sa=e1&st=0t

Marjanovic-Jeromela A., R. Marinkovic, A. Mijic, M. Jankulovska, Z. Zdunic (2007). Interrelationship between oil yield and other quantitative traits in rapeseed (*Brassica napus* L.). J. Central Eur. Agric.8:165-170.https://doi.org/10.5513/jcea.v8i2.448

Marschner, H (1995). Mineral nutrition of higher plants. 2nd (Ed), Academic Press London. 889.

Munns R. and R.A. James (2003). Screening methods for salt tolerance: A case study with tetraploid wheat. PlantSoil253:201–218. DOI:10.1023/A:1024553303144

Munns, R. (2005) Genes and salt tolerance; bringing them together. New Phytologist, 167, 645-663. http://dx.doi.org/10.1111/j.1469-8137.2005.01487.xhttps://doi.org/10.1046/j.0016-8025.2001.00808.x

Nazarbeyygi, E., H.L. Yazdi, R. Naseri and R. Soleimani (2011). The effects of different levels of salinity on proline and A and B chlorophylls in canola. Am-Euras. J. Agric. and Environ. Sci. 10(1): 70-74. http://www.idosi.org/.../12.pdf

Punia, M.S. and H.S. Gill (1994). Correlation and path coefficient analysis for seed yield traits in sunflower. Helia 17(20): 7-12.

Rameeh, V (2011). Line × tester analysis for seed yield and yield components in spring and winter type varieties of oil seed rape. J. Cereals Oilseeds 2(5):66-70.http://www.academicjournals.org/JCO/P…

Saadia, M., M. Jamil, N.A. Akram and M. Ashraf (2012). A study of proline metabolism in canola (*Brassica napus* L.) seedlings under salt stress. Molecules17:5803-5815. https://doi.org/10.3390/molecules17055803

Sabaghnia, N., H. Dehghani, B. Alizadeh and M. Mohghaddan (2010). Heterosis and combining ability analysis for oil yield and its components in rapeseed. Aust. J. Crop Sci. 4: 390-397. https://search.informit.org/doi/epdf/10.3316/informit.414845453706585

Shahzad, A., H. A. Sadaqat, M. Ali and M.F. Ashraf (2015). Combining ability analysis and genetic effect studies for some important quality characters in *B. napus*. Turkish J. Agric-Food Sci. Technol.3(10):790-795. https://doi.org/10.24925/turjaf.v3i10.790-795.463

Shalini S., R.A. Sheriff, R.S. Kulkarni, P. Venkantarmana (2000). Correlation and path analysis of Indian mustard germplasm. Res. Crops India 1: 226-229.https://www.cabdirect.org/cabdirect/mobile/search/?q=sn%3a%220972-3226%22

Steel, R. G. D., J. H. Torrie and D. A. Dickey (1997). Principles and Procedures of Statistics; A biometrical approach. (2nd Ed). McGraw Hill BookCo.Inc.Singapore.https://doi.org/10.2131/jts.28.439

Tariq, H., S.K. Tanveer, M. Qamar, R.A. Javaid, S.G. Vaseer, H.M. Jahanzab, M.J. Hassan, H. Iqbal (2020). Correlation and path analysis of *Brassica napus* genotypes for yield related traits. Life Science J. 17(8):22-34. doi:10.7537/marslsj170820.05.

Tester, M. and R. Davenport (2003). Na+ tolerance and Na+ transport in higher plants. Ann. Bot. 91: 503-527. https://doi.org/10.1093/aob/mcg058

Toorchi, M., R. Naderi, A. Kanbar, M.R. Shakiba (2011). Response of spring canola cultivars to sodium chloride stress. Ann. Biol. Res. 2: 312–322.http://scholarsresearchlibrary.com/ABR-vol2-iss5/ABR-2011-2-5-312-322.pdf

Tuncturk M., V. Ciftci (2007). Relationships between yield and some yield components in rapeseed (*Brassica napus* ssp. *oleifera* L.) cultivars by using correlation and path analysis. Pakistan J. Bot. 39(1):81-84. https://sg.docworkspace.com/l/sILCkltRh7sPHowY?sa=e1&st=0t

Villata, I., A. Reina-Sanchez, M.C. Bolarin, J. Cuartero, A. Belver, K. Venema, E.A. Carbonell and M.J. Asins (2008). Genetic analysis of Na+ and K+ concentrations in leaf and stem as physiological components of salt tolerance in tomato. Theoret. and App. Gene. 116 (6): 869-880. https://doi.org/10.1007/s00122-008-0720-8

Wolf, B. 1982. A comprehensive system of leaf analysis and its use for diagnosing crop nutrient status. Comm. Soil. Sci. Plant. Anal. 13:1035-1059.https://doi.org/10.1080/00103628209367332

Wright, S (1921). Correlation and causation. J. Agric. Res.20(3):557-585.https://handle.nal.usda.gov/10113/IND43966364

Wu, H., J. Guo, C. Wang, K. Li, X. Zhang, Z. Yang, M. Li and B. Wang (2019). An Effective Screening Method and a Reliable Screening Trait for Salt Tolerance of *Brassica napus* at the Germination Stage. PlantSci.10(230):1-12.https://doi.org/10.3389/fpls.2019.00530

Zare, M. (2011). Interrelationship between grain yield and related traits in rapeseed (*Brassica napus* L.). Afr. J. Agric. Res. 6(32): 6684-6689. DOI: 10.5897/AJAR11.1471

Zhang, G. and W. Zhu (2006). Genetic analyses of agronomic and seed quality traits of synthetic oilseed *Brassica napus* produced from interspecific hybridization of *B. B. oleracesea*. J. Genet.85:45-51.https://www.ias.ac.in/article/fulltext/jgen/085/01/0045-0051

Zhang, H. and J. Hodson (2001). Engineering salt tolerant Brassica plants: Characterization of yield and seed oil quality in transgenic plants with increased vacuolar sodium accumulation. Proc. Nat.Acad.Sci.48:12832-12836.https://doi.org/10.1073/pnas.231476498.