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Valiollah Rameeh

Agriculture and Natural Resources Research Center of Mazandran, Sari, Iran;
e-mail: vrameeh@yahoo.com

COMBINING ABILITY ANALYSIS OF SOME OF GRAIN YIELD STRESS INDICES IN RAPESEED (*BRASSICA NAPUS* L.) VARIETIES

ABSTRACT:

Although most of investigations showed that nitrogen fertilizers gave substantial rapeseed yield increases even in diverse and contradicting conditions but in a few studies were focused on genetic parameters of nitrogen stress effects. Combining ability of some of important grain yield stress indices based on application and non application of nitrogen (N+ and N0) was studied using half diallel of six spring rapeseed varieties and their 15 F2 progenies. Significant mean squares of general and specific combining abilities (GCA and SCA) were observed for potential yield(Yp), Stress yield(Ys), mean productivity (MP), geometric mean productivity (GMP), tolerance index (TOL), stress tolerance index (STI) and stress susceptibility index (SSI), indicating importance of additive and non-additive genetic effects for them. Non significant ratio of GCA to SCA mean square and low narrow-sense heritability estimates were detected for all the indices, indicating the prime importance of non-additive genetic effects. Significant positive GCA effect of Yp, Ys, MP, GMP and STI for PF7045/91 and significant negative GCA effects of them for Option500, indicated the same direction of GCA effects of these indices and GCA effects of Yp and Ys. On compare to SCA effects, most of crosses had significant high parent heterosis for Yp, Ys and and all the stress indices, therefore selection the better combinations based on heterosis will be more effective than SCA effect.

Key words: Diallel, genetic parameters, heterosis, narrow-sense heritability and rapeseed.

INTRODUCTION

Brassica species especially *Brassica napus* have important role in oil seed production because of their wide adaptation to different climatic conditions (Downey and Rimer 1993). Profitable canola production relies heavily on adequate plant nutrition, which in turn is affected by manage-

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ment of soil fertility. In addition, the nutritional level of the plant will affect the crop response to stress factors such as disease and adverse weather condition (Rathke and Diepenbrock 2005). A number of investigations showed that nitrogen fertilizers gave substantial rapeseed yield increases even in diverse and contradicting conditions (Maroni *et al.* 1994 and Sieling and Christen 1997). However, fertilizer nitrogen requirements can differ significantly according to soil type, climate, management practice, timing of nitrogen application and cultivars used (Fageria and Baligar 2005;Holmes and Ainsley 1977; Kalkafi *et al.* 1998; Rathke *et al.*, 2005). A great variation in nitrogen uptake in rapeseed has been reported (Holmes 1980). Colnenne *et al.* (1998) proposed that rapeseed has a higher critical N demand for biomass formation than wheat. Although most of investigations showed that nitrogen fertilizers gave substantial rapeseed yield increases even in diverse and contradicting conditions but in a few studies were focused on genetic parameters of nitrogen deficiency effects.

Most of the studies based on diallel and other genetic designs showed significant GCA and SCA effects for yield and its component characters indicating that both additive and non-additive gene action were important in the inheritance of these traits(Amiri-Oghana and *et al.*,.2009; Brandle and McVetty 1989;Cheema and Sadaqat 2004; Cho and Scott, 2000). For those traits that are controlled by additive gene action, simple selection in early segregating generation is suggested, whereas for those traits controlled by non-additive gene action selection in later segregating generation would be more effective (Kearsey and Pooni1996; Mhater and Jinks 1982; Singh and Chaudhary 1985). Although F1 data of diallel crosses is mostly used to estimate the genetic parameters in Griffing's method (1956), but it is usually difficult to obtain sufficient F1 seeds especially for multi location testing in *B. napus* L. Due to production of large quantity of F2 seeds, many researchers use F2 generation for diallel analysis to estimate of combining abilities (Amiri-Oghana and *et al.*,.2009; Cho and Scott, 2000). These researchers all reported that F2 diallel analysis provide reliable and better information than F1 generation. Multi locations or conditions testing of GCA and SCA effects and other genetic parameters will reveal the stability of theses parameters for selection criteria (Kearsey and Pooni1996; Mhater and Jinks 1982). Earlier breeders concluded in their research that with the changes in environment gene effects for different traits contributing to yield or yield itself changes in rapeseed (*B. napus* L.),therefore for different environment one has to suggest different selection criteria for the improvement in the yield(Cheema and Sadaqat, 2004; Thakur and Sagwal, 1997).

Several yield-based stress indices have been developed that may be more applicable to work on environmental stress tolerance such as drought tolerance (Cheema *et al.* 2004; Clark *et al.* 1992), salinity tolerance(Rameeh and *et al.* 2004) and temperature tolerance(Porch and Jahn, 2001). In order to obtain selection criteria based on stress and non-stress environments, some selection criteria including geometric productivity (GMP), stress intensity (SI), (Fisher and Maurer 1978), stress tolerance index (STI), (Fernandez, 1993),mean productivity (MP) and tolerance index (TOL), (Rosielle and Hamblin 1981) were defined. The range of SI estimates are between zero and one and the larger value of SI, indicates the more severe of stress intensity. A larger value of TOL represents relatively more sensitivity to stress, thus a smaller value of TOL is favored. The higher value of MP, GMP and STI for a genotype indicates its stress tolerance and yield potential. The stress susceptibility index (SSI) (Fisher and Maurer 1978) is a ratio of genotypic performance under stress and non-stress conditions, adjusted for the intensity of each trial, and has been found to be correlated with yield and canopy temperature in wheat (Rashid *et al.* 1999). In addition, deviations from the regression of stressed on non-stressed yield have been used to identify lines with stress tolerance in bean (Beebe *et al.* 1997, Smith 2004). Saba *et al.*, ((2001) reported that the stress indices including GMP, MP and STI were highly correlated with each other as well as with Ys and Yp, therefore through these indices it is possible to distinguish high yielding genotypes in either condition. Rezai and Saeidi(2005) reported significant GCA , SCA and high parent heterosis effects for STI and TOL related to Shoot dry weight of rapeseed in early stage of growth.

Although diallel analyses are frequently used in rapeseed breeding to assess genetic parameters for yield associated traits and yield-based stress indices but in a few studies were focused on nitrogen deficiency stress effects and its stress indices. The objectives of this study were therefore (i) to evaluate whether F_2 rapeseed hybrids utilize nitrogen more efficiently than pure lines at low and high N levels, (ii) to identify general and specific combining abilities for nitrogen deficiency stress indices among a set of adapted cultivars and (iii) relation ship among nitrogen stress tolerance indices and grain yield mean of rapeseed cultivars and their F_2 progenies at nitrogen application (Yp) and non application of nitrogen(Ys) environments.

MATERIALS AND METHODS

Six spring rapeseed (*B. napus* L.) cultivars including RGS-003, Option500, RW008911, RAS-3/99, 19H and PF7045/91 were crossed in half diallel method during 2004-05. In order to produce F_2 progenies, fifteen F_1s were selfed at Biekol Agriculture Research Station, located in Neka, Iran (13°53′ E longitude and 43°36′ N latitude, 15 m above sea level) during winter 2005-06. F_2 progenies and 6 parents were grown in a randomized complete block design with four replications at two experiments including N_0: without nitrogen as stress condition and N_+ : 150 kg nitrogen per hectare as non stress condition during 2006-07. The plots related to each experiment were consisted of four rows 5 m long and 40 cm apart. The distance between plants on each row was 5 cm resulting in approximately 400 plants per plot, which were sufficient for F_2 genetic analysis in each experiment. The soil was classified as a deep loam soil (Typic Xerofluents, USDA classification) contained an average of 280 g clay × kg^{-1}, 560 g silt × kg^{-1}, 160 g sand × kg^{-1}, and 22.4 g organic matter × kg^{-1} with a pH of 7.3. Soil samples were found to have 45 kg × ha^{-1} (mineral N in the upper 30-cm profile. Fertilized experiment (N_+) received 150 kg × ha^{-1} N as Urea (50 kg N at planting time, beginning of stem elongation, and at initial of flowering stage) while unfertilized experiment (N_0) received no N. All the plant protection measures were adopted to make the crop free from insects. Seed yield (adjusted to kg/ha) was recorded based on three middle rows of each plot.

The stress tolerance indices were determined using the equations including stress intensity (respectively):

$$SI=1-(\mu s/\mu p),$$

tolerance index:

$$TOL=Yp-Ys,$$

stress susceptibility index:

$$SSI=[1-(Ys/Yp)]/SI,$$

stress tolerance index:

$$STI=(Yp.Ys)/(Yp)^2,$$

mean productivity:

$$MP=(Ys+Yp)/2$$

and geometric mean productivity:

$$GMP=(Ys.Yp)^{0.5},$$

Ys and Yp are the mean yield of all genotypes per trial under stress and non-stress conditions and also µs and µp are the mean yield of all genotypes per trial under stress and non-stress conditions.

Analysis of variance for the crosses and their parents was based on Griffing's method 2, model 1 for fixed genotypes (Griffings, 1956).The analysis was performed using the diallel-SAS program written by Zhang and Kang (1997). [A] *t*-test was used to test whether the GCA and SCA effects were different from 0. For each hybrid and each stress tolerance index, the difference between hybrid and the mean of high parents was computed. A least significant difference (LSD) was used to test whether these differences were different from 0 (Mather and Jinks 1982).

RESULTS

Half diallel analysis of Griffing's method revealed significant GCA and SCA mean squares for grain yield at N_+ (Yp) and N_0 (Ys) and also grain yield-based stress indices including MP, GMP, TOL, STI and SSI(Table 1), indicating importance of additive and non-additive genetic effects for them. Non- significant GCA to SCA mean square and low narrow-sense heritability estimates for these stress tolerance indices the prime importance of non-additive genetic effects for the stress indices.

Table 1

Analysis of variance for Yp and Ys , MP, GMP, TOL, STI and SSI based on Griffing's method two with mixed-B model

S.o.v.	df	M.S.						
		Yp	Ys	MP	GMP	TOL	STI	SSI
Replication	3	276606.58	67901.97**	68169.60	69438.31**	266950.29	0.02	0.41
Cross	20	456133.05**	197402.5**	672141.912**	755319.94**	288389.80*	0.25**	0.68**
GCA	5	493071.66**	204668.3**	699203.38	769577.17**	180230.86	0.23**	0.56**
SCA	15	443820.18**	194980.5**	663121.42**	750567.53**	324442.78*	0.25**	0.72**
Error	60	146217.31	14946.74	60063.69**	60438.21	154289.33	0.02	0.15
MS(GCA)/MS		1.13	1.05	1.05	1.03	0.56	0.91	0.78
Narrow sense		0.15	0.16	0.16	0.16	0.02	0.14	0.10

* and ** - significant at 0.05 and 0.01 probability levels, respectively. GCA - general combining ability. SCA - specific combining ability. Yp and Ys - grain yield at N+ and N0, respectively, MP - mean productiity. GMP - geometric mean productivity. TOL - tolerance index, STI - stress tolerance index and SSI - stress susceptibility index

Significant positive GCA effect of Yp, Ys, MP, GMP and STI were observed for PF7045/91(Table 2), so this parent has broad base genetic for increasing seed yield. Option500 had significant positive and negative GCA effect for SSI and STI, respectively but non of the parents had significant GCA effect of TOL, indicating among the yield-based stress indices TOL had less efficiency for differentiation of GCA effect. Significant positive correlation was observed between GCA effect of Yp and grain yield mean of parents at N+ (0.95**) and also for GCA effect of Ys and grain yield mean of parents at N_0 (0.94**). Due to low amount of TOL and SSI is tolerance to stress environment, significant positive correlation was exhibited between GCA effects of these two stress indices and there was not significant correlation between GCA effect of TOL and GCA effects of any other stress tolerance indices.

Table 2

Estimates of GCA effects for Yp and Ys , MP, GMP, TOL, STI and SSI in six parents of *B. napus* L.

Parents	Yp	Ys	MP	GMP	TOL	STI	SSI
RAS-3/99	43.22	10.48	56.80	63.27	-28.11	0.033	-0.06
RW008911	-31.50	-43.81	-54.37	-60.09	44.79	-0.030	0.08
19H	-80.48	-12.08	-63.88	-65.44	-34.10	-0.040	-0.04
RGS 003	55.50	-10.64	8.47	-6.70	93.17	-0.005	0.07
Option 500	-173.01**	-90.55**	-194.31**	-195.66**	41.66	-0.104**	0.16**
PF7045/91	186.26**	146.60**	247.30**	264.62**	-117.41	0.146**	-0.21**

** - significant at 0.01 probability levels. Yp and Ys - grain yield at N+ and N0, respectively. MP - mean productivity. GMP - geometric mean productivity. TOL - tolerance index, STI - stress tolerance index and SSI: stress susceptibility index

Significant SCA effect of Ys and Yp were found for Option500 × PF7045/91 and RAS3/99 × RW008911 (493.47** and 411.34* respectively). Significant positive SCA effect of Yp was detected for the crosses including RAS-3/99 × RW008911 and Option 500 × PF7045/91 but for Ys fifty percentage of crosses had significant positive SCA effect (Table 3). Most of crosses had significant SCA effect for MP and GMP but for TOL only 19H × RGS 003 had significant SCA effect and also this cross had significant negative SCA effect for Ys, MP, GMP, and SSI. Due to low amount of TOL indicating high stress tolerance, So RGS003 × PF7045/91 with significant negative SCA effect is the best combination based on tolerance index and this cross had the least mean of TOL (Table 5).

Table 3

Estimates of SCA effects for Yp and Ys , MP, GMP, TOL, STI and SSI in the half diallel crosses of six parents of *B. napus* L

Crosses	Yp	Ys	MP	GMP	TOL	STI	SSI
RAS-3/99 × RW008911	411.34*	173.01**	501.71**	529.44**	-179.93	0.313**	-0.33
RAS-3/99 × 19H	95.33	53.35	58.72	59.15	73.96	0.018	0.04
RAS-3/99 × RGS 003	351.84	244.45**	500.75**	534.99**	-297.06	0.333**	-0.44*
RAS-3/99 × Option 500	-178.90	-63.20	-129.18	-117.26	-98.47	-0.088	-0.10
RAS-3/99 × PF7045/91	71.08	69.45	48.91	38.93	39.52	0.028	0.04
RW008911 × 19H	75.04	170.77**	184.89	198.12	-218.94	0.108	-0.26
RW008911 × RGS 003	249.47	131.68*	312.75*	339.45**	-125.80	0.208**	-0.36
RW008911 × Option 500	-44.93	-150.36*	-157.18	-178.64	225.30	-0.120	0.28
RW008911 × PF7045/91	20.30	163.14**	103.46	112.83	-171.13	0.057	-0.25

Table 3

Continued

Crosses	Yp	Ys	MP	GMP	TOL	STI	SSI
19H × RGS 003	-115.55	-266.34**	-383.37**	-451.26**	536.84**	-0.245**	0.80**
19H × Option 500	285.71	167.79**	385.66**	417.58**	-199.15	0.212**	-0.36
19H × PF7045/91	290.61	190.09**	384.88**	408.23**	-193.41	0.262**	-0.23
RGS 003 × Option 500	164.32	246.00**	264.86*	298.39*	-200.34	0.140	-0.33
RGS 003 × PF7045/91	-522.87**	-70.05	-313.72*	-279.24*	-423.10*	-0.178	-0.38*
Option 500 × PF7045/91	493.47**	216.91**	507.98**	517.10**	-33.84	0.312**	-0.23

* and ** - significant at 0.05 and 0.01 probability levels, respectively. Yp and Ys - grain yield at N+ and N_0, respectively. MP - mean productivity.GMP - geometric mean productivity. TOL - tolerance index, STI - stress tolerance index and SSI - stress susceptibility index

Significant positive of high parent heterosis of Yp and Ys were observed for the crosses including 19H × Option 500 and RAS-3/99 × RW008911 and also these crosses had significant positive of high parent heterosis for the MP, GMP and STI (Table 4). Although most of the crosses had significant positive of high parent heterosis for Ys but only two crosses had had significant positive of high parent heterosis for Yp. Most of the crosses with significant positive SCA effect for MP, GMP and STI had significant positive of high parent heterosis for these stress tolerance indices. Most of crosses had significant negative heterosis for SSI and these crosses can be considered as stress tolerant genotypes.

Table 4

High parent heterosis estimates for Yp and Ys , MP, GMP, TOL, STI and SSI

Crosses	Yp	Ys	MP	GMP	TOL	STI	SSI
RAS-3/99 × RW008911	711.98*	357.24*	880.99**	928.71**	-488.08	0.55**	-0.93**
RAS-3/99 × 19H	346.99	233.75*	428.49*	453.06*	-163.02	0.25*	-0.34
RAS-3/99 × RGS 003	403.17	408.44**	739.71**	826.12**	-673.09*	0.50**	-0.93**
RAS-3/99 × Option 500	-19.77	74.29	110.16	146.44	-321.50	0.08	-0.69*
RAS-3/99 × PF7045/91	104.33	218.10*	224.17	236.50	-280.77	0.16	-0.51
RW008911 × 19H	381.67	296.88*	509.79**	519.38**	-533.08	0.30**	-0.85**
RW008911 × RGS 003	226.08	241.38*	440.54*	507.23**	-428.92	0.31**	-0.83**
RW008911 × Option 500	169.17	47.03	175.71	186.40	-13.08	0.09	-0.17
RW008911 × PF7045/91	-21.17	257.50*	167.54	187.04	-568.58*	0.12	-1.01**
19H × RGS 003	-187.92	-124.91	-265.08	-288.84	154.83	-0.15	0.33

Table 4

Continued

Crosses	Yp	Ys	MP	GMP	TOL	STI	SSI
19H × Option 500	508.75*	247.15*	570.62**	603.27**	-428.17	0.33**	-0.94
19H × PF7045/91	200.17	316.18*	439.46*	477.09**	-501.09	0.32**	-0.59*
RGS 003 × Option 500	-0.59	308.95*	252.71	330.60	-506.59	0.17	-0.79**
RGS 003 × PF7045/91	-477.33	57.48	-186.79	-151.63	-888.42**	-0.09	-1.02**
Option 500 × PF7045/91	310.50	264.53*	432.12*	455.75*	-346.17	0.30**	-0.98**

* and ** - significant at 0.05 and 0.01 probability levels, respectively. Yp and Ys - grain yield at N+ and N0, respectively. MP - mean productivity.GMP - geometric mean productivity. TOL - tolerance index, STI - stress tolerance index and SSI - stress susceptibility index

Table 5

The means of Yp and Ys , MP, GMP, TOL, STI and SSI for the six parents of rapeseed and their half diallel crosses

Genotypes	Yp	Ys	MP	GMP	TOL	STI	SSI
RAS-3/99	2635.52	1650.00	2142.76	2074.04	985.52	0.50	1.26
RW008911	2505.83	1370.25	1938.04	1849.34	1135.58	0.40	1.60
19H	2447.92	1705.00	2076.46	2023.34	742.92	0.48	0.90
RGS 003	2971.83	1720.00	2345.92	2235.57	1251.83	0.60	1.48
Option 500	2218.58	1171.25	1694.92	1610.23	1047.33	0.30	1.68
PF7045/91	3131.92	2165.00	2648.46	2600.45	966.92	0.79	1.09
RAS-3/99 × RW008911	3347.50	2700.00	3023.75	3002.75	647.50	1.06	0.68
RAS-3/99 × 19H	2982.50	2160.00	2571.25	2527.10	822.50	0.75	0.92
RAS-3/99 × RGS 003	3375.00	2796.25	3085.63	3061.69	578.75	1.10	0.55
1RAS-3/99 × Option 500	2615.83	1890.00	2252.92	2220.47	725.83	0.58	0.99
RAS-3/99 × PF7045/91	3225.00	2520.25	2872.63	2836.95	704.75	0.94	0.75
RW008911 × 19H	2887.50	2285.00	2586.25	2542.71	602.50	0.78	0.76
RW008911 × RGS 003	3197.92	2375.00	2786.46	2742.80	822.92	0.91	0.78
RW008911 × Option 500	2675.00	1552.50	2113.75	2035.74	1122.50	0.49	1.50
RW008911 × PF7045/91	3099.50	2532.50	2816.00	2787.48	567.00	0.91	0.60
19H × RGS 003	2784.17	1377.50	2080.83	1946.73	1406.67	0.45	1.81
19H × Option 500	2956.67	2337.50	2647.08	2626.61	619.17	0.81	0.74
19H × PF7045/91	3320.83	2855.00	3087.92	3077.54	465.83	1.11	0.49
RGS 003 × Option 500	2971.25	2226.00	2598.63	2566.17	745.25	0.77	0.88
RGS 003 × PF7045/91	2643.33	2280.00	2461.67	2448.81	363.42	0.70	0.46
Option 500 xPF7045/91	3431.17	2730.00	3080.58	3056.20	701.17	1.10	0.70

Yp and Ys: grain yield at N+ and N0, respectively, MP: mean productivity.GMP: geometric mean productivity. TOL: tolerance index, STI: stress tolerance index and SSI: stress susceptibility index

DISCUSSION

Non- significant ratio of GCA to SCA mean square and low narrow-sense heritability estimates for Yp and Ys and all the related stress indices indicating the prime importance of non-additive genetic effects for Yp and Ys and all the stress indices, therefore Yp and Ys and all the stress indices must be improved based on hybridization method mainly using cytoplasmic male sterility (CMS). Most of the studies based on diallel and other genetic designs showed significant GCA and SCA effects for yield and its component characters indicating that both additive and non-additive gene action were important in the inheritance of these traits (Amiri-Oghana and *et al.*,.2009; Cheema and Sadaqat 2004; Cho and Scott, 2000). Also when SCA effects are predominant in self-pollinated crops, the major portion of the variability then, is due to additive × additive genetic effects or divergence among progenies in the same parental array, therefore, selection should be delayed to later generations (Kearsey and Pooni1996; Mhater and Jinks 1982).

Significant GCA effect of Yp, Ys, MP, GMP and STI were observed for two parents (Option500 and PF7045/91 with significant negative and positive GCA effects, respectively), so the efficiency of all these stress indices of GCA effect for grain yield are the same. Based on all the stress indices GCA effect, the parent PF7045/91 was considered more nitrogen deficiency stress tolerant than the other parents. Significant positive correlation was observed between GCA effect of each stress index and its respective mean except for TOL, indicating selection based on GCA effect of these stress indices make improve of their respective means. Saba *et al.*, ((2001) reported that the stress indices including GMP, MP and STI were highly correlated with each other as well as with Ys and Yp, therefore through these indices it is possible to distinguish high yielding genotypes in either condition.

Most of crosses had significant SCA effect for Ys, therefore selection of crosses based on SCA effects will be more efficient for grain yield at N0 than N+. SCA effects of MP, GMP and STI were more affected form the SCA effect of Ys than Yp and most of the crosses had significant SCA effect for these stress indices. The crosses including RAS-3/99 × RW008911, RAS-3/99 × RGS 003, 19H × PF7045/91 and Option 500 × PF7045/91 with high amount of Yp and Ys had significant SCA effect for MP, GMP and STI. Although significant positive correlation was found between Yp and Ys for the crosses but there was not significant positive correlation between SCA effect of Yp and Ys. MP and GMP had similar trend of significant SCA effect and also TOL and SSI had similar sign (positive or negative) for all the crosses. Significant positive correlation was found between Yp and Ys for parents (0.91**) but it was not significant(0.31) for the crosses. Significant positive correlation was observed between SCA effect of each stress index and its respective mean except for TOL, indicating selection based on SCA effect of these stress indices make improve of their respective means. Rezai and Saeidi(2005) reported significant SCA effects for STI and TOL related to Shoot dry weight of rapeseed in early stage of growth.

Significant positive of high parent heterosis was observed for most of the crosses at N0 ant it was not significant at N+, so detecting of high parent heterosis for grain yield at N0 is more efficient than N+. On compare to SCA effects, most of crosses had significant high parent heterosis for Yp, Ys and and all the stress indices, therefore selection the better combinations based on heterosis will be more effective than SCA effect. Most of the crosses with significant positive of high parent heterosis for Ys had significant positive heterosis for MP, GMP and STI. On the contrary of SCA effect most of the crosses had significant high parent heterosis for SSI. In general most of genetic parameters related to grain yield and its stress indices were more efficient at N_0. Rezai and Saeidi(2005) reported significant high parent heterosis effects for STI and TOL related to Shoot dry weight of rapeseed in early stage of growth.

CONCLUSION

Most of crosses had significant SCA and high parent heterosis effect for Ys, therefore selection of crosses based on SCA effects will be more efficient for grain yield at N0 than N+. Significant positive correlation was found between Yp and Ys for parents but it was not significant for the crosses, indicating different amount of heterosis in N+ and N0. Significant positive correlation was observed between SCA effect of each stress index and its respective mean except for TOL, indicating the less efficiency of TOL than the other stress indices.

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