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NITROGEN DEFICIENCY STRESS INDICES OF SEED YIELD IN RAPESEED (*BRASSICA NAPUS* L.) GENOTYPES

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ABSTRACT. 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 nitrogen deficiency stress effects. Some of important seed yield stress indices based on application and non application of nitrogen (N+ and N0) was studied using six spring rapeseed varieties and their 15 F2 progenies. Significant mean squares of genotypes effects 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 significant genetic differences of the genotypes for the stress indices. The genotypes including PF7045/91 and RGS003 had the high mean values of MP and GMP and STI, therefore considered as high potential parents in both nitrogen application conditions. On the basis of low mean value of TOL and SSI indices, PF7045/91 and 19H were considered as tolerant to nitrogen deficiency stress. Most of the crosses with high mean values of MP, GMP and STI had at least one parent with high mean values of these stress indices. Significant positive correlation of Yp and Ys with MP, GMP and STI, indicating selection based on these stress indices will increase the Yp and Ys of the genotypes. Heterozygosity had important role for stability of traits in different conditions, therefore in compare to parents their F_2 progenies had low mean values of SSI and TOL indices.

Key words: Diallel; Genetic parameters; Heterosis; Narrow-sense heritability; 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 management of soil fertility. In addition, the nutritional level of the plant will affect the crop response to stress factors such as disease and

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adverse weather condition (Rathke *et al.*, 2005). A number of investigations showed that nitrogen fertilizers gave substantial rapeseed yield increases even in diverse and contradicting conditions (Maroni *et al.,* 1994; 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.

Several yield-based stress indices have been developed that may be more applicable to work on environmental stress tolerance such as drought tolerance (Cheema and Sadaqat, 2004; Clark *et al.* 1992), salinity tolerance (Rameeh *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, 1992), mean productivity (MP) and tolerance index (TOL), (Rosielle and Hamblin, 1981) were defined. The ranges 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 have 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.

The objectives of this study were therefore (i) to evaluate whether spring rapeseed varieties and their F_2 rapeseed hybrids utilize nitrogen more efficiently than pure lines at low and high N levels, (ii) to identify relationship among nitrogen stress tolerance indices and seed yield mean of rapeseed genotypes 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 and their fifteen F_2 progenies were evaluated at Baykola Agriculture Research Station, located in Neka, Iran (13°, 53′ E longitude and 43° 36′ N latitude, 15 m above sea level). These genotypes were grown in a randomized complete block design (RCBD) with four replicates 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^{-1}) was recorded based on three middle rows of each plot.

The stress tolerance indices were determined using the equations including stress intensity, SI = 1-(μs/μp), 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, $GMP=(Ys.Yp)^{0.5}$, respectively. 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 parents and their crosses was done based RCBD, using SAS software.

RESULTS AND DISCUSSION

Significant mean square of genotypes were determined 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 significant genetic variation for this trait and related stress indices (*Table 1*). A great variation in nitrogen uptake in rapeseed has been reported (Holmes, 1980).

Yp was varied from 2218.58 to 3131.92 kg ha^{-1} in Option500 and PF7045/91, respectively (*Table 2*). The parents including PF7045/91 and RGS003 with 3131.92 and 2971.83 kg ha^{-1} had high seed yield in normal condition and these parents had also high seed yield in stress condition.

Table 1 - Analysis of variance for Yp, Ys , MP, GMP, TOL, STI and SSI in six parents of rapeseed and their 15 crosses

SOV	Df	Mean square (MS)						
		Yp	Ys	MP	GMP	TOL	STI	SSI
Replicates	3	276606.58	67901.97**	68169.60	69438.31**	266950.29	0.02	0.41
Genotypes	20	456133.05**	197402.5**	672141.912**	755319.94**	288389.80*	0.25**	0.68**
Error	60	146217.31	14946.74	60063.69	60438.21	154289.33	0.02	0.15

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

Table 2 - The means of Yp and Ys , MP, GMP, TOL, STI and SSI for the six parents of rapeseed and their 15 crosses

Genotypes	Yp	Ys	MP	GMP	TOL	STI	SSI
1-RAS-3/99	2635.52	1650.00	2142.76	2074.04	985.52	0.50	1.26
2-RW008911	2505.83	1370.25	1938.04	1849.34	1135.58	0.40	1.60
3-19H	2447.92	1705.00	2076.46	2023.34	742.92	0.48	0.90
4-RGS 003	2971.83	1720.00	2345.92	2235.57	1251.83	0.60	1.48
5-Option 500	2218.58	1171.25	1694.92	1610.23	1047.33	0.30	1.68
6-PF7045/91	3131.92	2165.00	2648.46	2600.45	966.92	0.79	1.09
7- RAS-3/99 x RW008911	3347.50	2700.00	3023.75	3002.75	647.50	1.06	0.68
8- RAS-3/99 x 19H	2982.50	2160.00	2571.25	2527.10	822.50	0.75	0.92
9- RAS-3/99 x RGS 003	3375.00	2796.25	3085.63	3061.69	578.75	1.10	0.55
10- RAS-3/99 x Option 500	2615.83	1890.00	2252.92	2220.47	725.83	0.58	0.99
11- RAS-3/99 x PF7045/91	3225.00	2520.25	2872.63	2836.95	704.75	0.94	0.75
12-RW008911 x 19H	2887.50	2285.00	2586.25	2542.71	602.50	0.78	0.76
13-RW008911 x RGS 003	3197.92	2375.00	2786.46	2742.80	822.92	0.91	0.78
14- RW008911 x Option 500	2675.00	1552.50	2113.75	2035.74	1122.50	0.49	1.50
15- RW008911 x PF7045/91	3099.50	2532.50	2816.00	2787.48	567.00	0.91	0.60
16-19H x RGS 003	2784.17	1377.50	2080.83	1946.73	1406.67	0.45	1.81
17- 19H x Option 500	2956.67	2337.50	2647.08	2626.61	619.17	0.81	0.74
18- 19H x PF7045/91	3320.83	2855.00	3087.92	3077.54	465.83	1.11	0.49
19- RGS 003 x Option 500	2971.25	2226.00	2598.63	2566.17	745.25	0.77	0.88
20- RGS 003 x PF7045/91	2643.33	2280.00	2461.67	2448.81	363.42	0.70	0.46
21- Option 500 xPF7045/91	3431.17	2730.00	3080.58	3056.20	701.17	1.10	0.70
$LSD_{(\alpha=0.05)}$	624.4	199.6	400.2	401.5	641.4	0.2	0.6
$LSD_{(\alpha=0.01)}$	830.5	265.5	532.3	533.9	853.1	0.3	0.8

Yp and Ys - seed yield at N+ and N_0, respectively; MP - mean productivity; GMP - geometric mean productivity; TOL - tolerance index; STI - stress tolerance index; SSI - stress susceptibility index

The crosses including RAS-3/99 x RW008911, RAS-3/99 x RGS003, RAS-3/99 x PF7045/91, RW008911 x RGS003, RW008911 x PF7045/91, 19H x PF7045/91 and Option500 x PF7045/91 with seed yield of 3347.50, 3375, 3225, 3197.92, 3099.50, 3320.83 and 3431.17 kg ha^{-1} had high seed yield in normal condition and most of these crosses had high mean values of seed yield in stress condition. Most of the crosses with high mean values of Yp and Ys had at least one parent with high mean values of this trait in both environmental conditions. MP ranged from 1694.92 to 2648.46 kg ha^{-1} in Option500 and PF7045/91, respectively. It was varied from 2080.83 to 3087.92 kg ha^{-1} in 19H x RGS003 and 19H x PF7045/91, respectively. Although PF7045/91 and RGS003 had high mean values of seed yield, but their combinations with 19H had two dimensions effects on this stress index. GMP had the same trend of MP for parents and their cross combinations, therefore these two stress indices had high significant positive correlation (*Table 3*). 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. 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.

Table 3 - Correlation among Yp, Ys, MP, GMP, TOL, STI and SSI of seed yield for the six parents of rapeseed and their 15 crosses

Traits	Yp	Ys	MP	GMP	TOL	STI	SSI
Yp	1						
Ys	0.87**	1					
MP	0.95**	0.97**	1				
GMP	0.93**	0.98**	0.99**	1			
TOL	0.39	-0.79**	-0.65**	-0.68**	1		
STI	0.94**	0.98**	0.99**	0.99**	-0.67**	1	
SSI	-0.61**	-0.91**	-0.81**	-0.84**	0.95**	-0.82**	1

Yp and Ys - seed yield at N+ and N_0, respectively; MP - mean productivity; GMP - geometric mean productivity; TOL - tolerance index; STI - stress tolerance index; SSI - stress susceptibility index

Low mean value of TOL, indicating high tolerance to stress condition, therefore the parents including 19H and PF7045/91 were more tolerant to stress condition, in compare to other cultivars. The crosses, including RAS-3/99 x RGS003, RW008911 x PF7045/91, 19H x PF7045/91 and RGS003 x PF7045/91, with low mean values of TOL (578.75, 567, 465.83 and 363.42, respectively), were more tolerant to stress condition. All of these crosses had one parent with low mean value of TOL. PF7045/91 and RGS003 with high mean values of STI and low mean values of SSI were tolerant to stress condition. The combinations, including RAS-3/99 x RW008911, RAS-3/99 x RGS003 and 19H x PF7045/91, with high mean values of STI and low mean values of SSI, were considered as suitable genotypes. Significant positive correlation of Yp and Ys with MP, GMP and STI, indicating selection based on these stress indices, will increase the Yp and Ys of the genotypes.

CONCLUSIONS

Significant genetic differences was detected for Yp, Ys, MP, GMP, TOL, STI and SSI in parents and their F2 progeny crosses, indicating that seed yield of the parents can be improved using cross combination method. Heterozygosity had also important role for stability of traits in different conditions, therefore in compare to parents their F_2 progenies had low mean values of SSI and TOL indices. Significant positive correlation of Yp and Ys with MP, GMP and STI, indicating selection based on these stress indices, will increase the Yp and Ys of the genotypes.

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