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Late sowing stress tolerance indices for seed yield and contributing traits in rapeseed (*Brassica napus* L.) genotypes

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Abstract

To assess effects of sowing dates on pod number and seed yield in rapeseed (*Brassica napus* L.), 10 spring rapeseed genotypes were evaluated in form of randomize complete block design with four replications in normal and late sown conditions. Significant differences of genotypes were determined for number of pods in normal and late sown (P_N and P_S, respectively) and seed yield in normal and late sowing dates (Y_N and Y_S, respectively) and their stress tolerance indices except stress tolerance index and stress susceptibility index of seed yield (Y(STI) and Y(SSI), respectively). Two stress indices including Y(STI) and Y(SSI) could not separate the genotypes, and all of the genotypes were classified under the same statistical group but Y(TOL) separated the genotypes in different statistical groups. The genotypes including Safi7, Safi31 and S841 with low mean value of Y(TOL) were less affected by stress condition under late sown. High mean value of P_N and P_S were exhibited for Zabol0 but high mean value of Y_N (3300 kg ha^{-1}) and Y_S (1947 kg ha^{-1}) were detected in Zafar and Zabol0, respectively. The higher value of P(MP), P(GMP) and P(STI) indicate more stress tolerance for pod number, were shown in Zafar, Zabol0 and Zabol15. Due to high mean value estimate of P(TOL) for Safi47 and Safi31 and Zabol15, these genotypes were more affected under late sown conditions.

Keywords*: Coefficient of variation, rapeseed, sowing dates, yield components*

Introduction

Rapeseed (*Brassica napus*) is an important oilseed crop under rapeseed-mustard group of Brassica. It is highly useful crop can be grown under crop rotation to increase the rapeseed production in the region with cereal-fallow or continuous cereal based cropping systems (Mahasi and Kamundia, 2007; Abtali *et al.*, 2009). To increase the yield, study of direct and indirect affecting of yield components affords the basis for its successful breeding program (Marjanovic-Jeromela *et al.*, 2009; Rameeh, 2014). Specifying suitable sowing date has important role in conformation of plant growth stages with desirable environmental conditions which results in maximum yield. Sowing date has a considerable effect on seed yield by influencing the yield components so that late sowing decreases the most important traits i.e. pods per plant which cause a remarkable reduction in seed yield (Sharief and Keshta, 2002; Siadat and Hemayati, 2009). Seed yield is a complex character that can be determined by several components reflecting positive or negative effects upon this trait, whereas it is important to examine the contribution of each of the various components in order to give more attention to those having the greatest influence on seed yield (Thurling, 1991; Oghan *et al.*, 2016). The ideotype concept provides opportunity to define the desired high-yield phenotype in terms of several relatively simple plant characters (Marjanovic-Jeromela, *et al.*, 2007). Therefore, knowing the variations of the quantitative traits in different environmental conditions make more successful breeding programs (Sharief and Keshta, 2002; Marjanovic-Jeromela, *et al.*, 2009). 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), 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 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 (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 Y_N, therefore through these indices it is possible to distinguish high yielding genotypes in either condition.

The objectives of this study, therefore, were to evaluate rapeseed genotypes for number pod & seed yield, and to determine the variations on the basis of different stress tolerance indices and to identify the relationship among the stress tolerance indices for pod number and seed yield.

Materials and Methods

In order to determine the effects of sowing dates on yield associated traits and correlation of the traits in rapeseed varieties, ten spring rapeseed genotypes were studied in form of randomized complete block design with four replications in normal (18 October) and late (16 November) sowing dates at Baykola Agriculture Research Station, located in Neka, Iran (53Ú, 13^2 E longitude and $36^{Ú}$ 43^2 N latitude, 15 m above sea level) during 2012-13. The genotypes under study were RGS003, Zabol0, Zabol15, Safi7, Safi6, Safi5, Safi31, S841, L7 and Zafar. 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 7.3. Each sub plot was consisted of four rows 5 m long and 30 cm apart. The distance between plants on each row was 5 cm resulting in approximately 400 plants per plot, which were sufficient for statistical analysis. Crop management factors like land preparation, crop rotation, fertilizer, and weed control were followed as recommended for local area. All the plant protection measures were adopted to make the crop free from insects. The data were recorded on ten randomly selected plants of each entry of each replication for number of pods on main raceme, number of pods per plant. Seed yield (adjusted to kg/ha) was recorded based on two middle rows of each plot. Pearson correlation of coefficient was estimated for relationship of the traits in normal and late sown conditions. The stress tolerance indices were determined using the equations including stress intensity: $SI=1-(\mu s/ \mu_N)$, tolerance index: $TOL=X_N-Xs$, (X will be substituted by P and Y for pods number and seed yield, respectively): stress susceptibility index: $SSI=[1-(Xs/ X_N)]/SI$, stress tolerance index: $STI=(X_N.Xs)/(X_N)^2$, mean productivity: $MP=(Xs+X_N)/2$ and geometric mean productivity: $GMP=(X_N.Xs)^{0.5}$, respectively. Xs and X_N are the mean of see yield or pods number of all the genotypes per trial under stress (late sowing date) and non-stress (normal sowing date) conditions and also μs and μ_N are the mean yield of all genotypes per trial under stress and non-stress conditions. All the analyses were performed using MS-Excel and SAS softwares (SAS Institute Inc. 2004).

Results and Discussion

Analysis of variance

Significant mean squares for genotypes were exhibited for pod number in normal and late sown (P_N and P_S, respectively), mean productivity of pod number P(MP), geometric mean productivity of pod number P(GMP), stress tolerance index of pod number P(STI), stress susceptibility index of pod number P(SSI) and tolerance index of pod number P(TOL) (Table 1). The genotypes also had significant difference for seed yield in normal and late sowing dates (Y_N and Y_S, respectively), mean productivity of seed yield Y (MP), geometric mean productivity of seed yield Y(GMP), and tolerance index of seed yield Y(TOL) but they revealed non-significant differences for stress tolerance index of seed yield Y(STI), stress susceptibility index of seed yield Y(SSI). Sowing date has a considerable effect on seed yield by influencing the yield components so that late sowing decreases the most important traits (Sharief and Keshta, 2002; Siadat and Hemayati, 2009).

Means performance of the genotypes

The means of the genotypes for pods number in normal and late sowing dates (P_N and P_S, respectively) and its stress tolerance indices are presented in Table 2. In normal sowing date, pods number (P_N) was varied from 164.2 to 107.7 in Zafar and Safi 5, respectively. The genotypes including Zafar, Zabo l0 and Zabo l5 had high mean value of P_N. P_S ranged from 77.9 to 129.8 in Safi 7 and Zafar, respectively. Most of the genotypes with high mean value of P_N had high mean value of P_S, therefore selection of the genotypes with high mean value of P_N can be good indicator for improving P_S. P($MP_)$ as indicator of pods number performance in both normal and stress conditions, was varied from 98.7 to 147 in Safi 31 and Zafar, respectively. The high value of P(MP) was detected for Zafar, Zabo l0 and Zabo l15 (Table 2). All of the genotypes with high value of P(MP), had high mean value of P(GMP). P(STI) ranged from 0.69 in Safi7 to 0.87 in S841 and L7. Low mean value of P(SSI) and P(TOL) were determined in L7, S841, Zafar Safi5 indicating less effect of stress conditions on pod number in these genotypes. Significant

Table1: Analysis of variance of pods number in normal and late sowing dates (P_N and P_S, respectively) and seed yield in normal and late sowing dates (Y_N and Y_S, respectively) and their stress tolerance indices for 10 rapeseed genotypes

S.O.V	df	P_N	Ps	P(MP)	P(GMP)	P(STI)	P(SSI)	P(TOL)
Replication	3	2081**	311**	197*	84	0.13**	2.75**	3994**
Genotypes	9	1589**	1091**	1214**	1228**	0.02*	0.40*	502*
Error	27	151	45	46	38	0.01	0.17	209
S.O.V	df	Yp	Ys	Y(MP)	Y(GMP)	Y(STI)	Y(SSI)	Y(TOL)
Replication	3	2364388**	50703	477392**	242274**	0.189**	1.12**	2920722**
Genotypes	9	569329**	230320**	343088**	328362**	0.012	0.07	226907*
Error	27	82590	24461	29047	23592	0.007	0.04	97911

*, ** Significant at p<0.05 and 0.01, respectively.

P_N: Pods number in normal sowing date, P_S: Pods number in late sowing date (stress) condition, P(MP): mean productivity. P(GMP): geometric mean productivity. P(TOL): tolerance index, P(STI): stress tolerance index and P(SSI): stress susceptibility index.

Y_N: seed yield in normal sowing date, Y_S: seed yield in late sowing date (stress) condition, Y(MP): mean productivity. Y(GMP): geometric mean productivity. Y(TOL): tolerance index, Y(STI): stress tolerance index and Y(SSI): stress susceptibility index.

Table 2: Means comparison of pods number in normal and late sowing dates (P_N and P_S, respectively) and its stress tolerance indices including P(MP), P(GMP), P(TOL), P(STI) and P(SSI) for 10 rapeseed genotypes

Genotypes	P_N	Ps	P(MP)	P(GMP)	P(STI)	P(SSI)	P(TOL)
1-RGS003	141.9bc	105.8bc	123.9b	122.5c	0.75ab	1.13ab	36.1abc
2-Zabol0	163.6a	126.5a	145.1a	143.7a	0.78ab	1.01ab	37.0abc
3-Zabol15	154.0ab	114.0b	134.0b	131.9b	0.76ab	1.11ab	40.0ab
4-Safi7	130.1cde	85.4ef	107.7cde	104.5def	0.69b	1.43a	44.7a
5-Safi6	138.9bcd	109.7bc	124.3b	123.0c	0.80ab	0.93ab	29.2abc
6-Safi5	107.7f	93.1de	100.4de	100.0ef	0.87a	0.61b	14.6c
7-Safi31	119.5ef	77.9f	98.7e	95.6f	0.69b	1.43a	41.6ab
8-S841	117.2ef	101.6cd	109.4cd	109.0de	0.87a	0.60b	15.6c
9-L7	122.2def	104.1bc	113.2c	112.4d	0.87a	0.59b	18.1bc
10-Zafar	164.2a	129.8a	147.0a	145.5a	0.81ab	0.87ab	34.4abc

Means, in each column, followed by at least one letter in common are not significantly different at the 1% level of probability- using Duncan sõ Multiple Range Test

P_N: Pods number in normal sowing date, P_S: Pods number in late sowing date (stress) condition, P(MP): mean productivity. P(GMP): geometric mean productivity. P(TOL): tolerance index, P(STI): stress tolerance index and P(SSI): stress susceptibility index.

Table 3: Pearson correlation for pods per plant and its related stress tolerance indices

Traits/indices	PN	PS	P(MP)	P(GMP)	P(STI)	P(SSI)	P(TOL)
Yp	1						
Ys	0.83**	1					
P(MP)	0.96**	0.94**	1				
P(GMP)	0.94**	0.96**	0.99**	1			
P(STI)	-0.25	0.33	0.01	0.06	1		
P(SSI)	0.24	-0.34	-0.02	-0.07	-0.99**	1	
P(TOL)	0.55	-0.01	0.32	0.26	-0.93**	0.93**	1

*, ** Significant at p<0.05 and 0.01, respectively.

P_N: Pods number in normal sowing date, P_S: Pods number in late sowing date (stress) condition, P(MP): mean productivity. P(GMP): geometric mean productivity. P(TOL): tolerance index, P(STI): stress tolerance index and P(SSI): stress susceptibility index.

positive correlation of PN with P(MP) and P(GMP) indicating the genotypes with high mean value of PN will have high mean value of these two stress tolerance indices (Table 3). Significant negative correlation between P(TOL) and P(STI) indicated high mean value of P(STI) along with low mean value of P(TOL) can be used for selection of the genotypes with high mean value of pod number in rapeseed. 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 (Smith, 2004).

Seed yield of the genotypes was varied from 2173.3 to 3300 kg ha^{-1} in normal sowing and it ranged from 1193.1 to 1841.1 kg ha^{-1} in late condition (Table 4). The genotypes including Zafar, Zabol0, Zabol15, RGS003 and Safi6 had high mean value of Yp and all of these genotypes had high mean value of Ys. Y(MP) was varied from 1743.1 to 25706 kg ha^{-1} in Safi7 and Zafar, respectively. The genotypes including Zafar, Zabol0, RGS003 and Safi6 had high mean value of Y(MP). Most of the genotypes with high mean value of Y(MP) had high mean value of Y(GMP). Y(GMP) ranged from 1653.4 to 2450.9 kg ha^{-1} in Safi5 and Zafar, respectively. Two stress indices including Y(STI) and Y(SSI) could not separate the genotypes, and all of the genotypes were classified under same statistical group but Y(TOL) separated the genotypes in different statistical groups. The genotypes including Safi7, Safi31 and S841 with low mean value of Y(TOL) were less affected by late sowing stress condition.

Significant positive correlation was detected between Yp and Y(TOL), indicating that performance of the genotypes for seed yield in normal sowing had important role on Y(TOL). Significant negative correlation between Y(TOL) and Y(STI), indicated two different dimensional of these

Table 4: Means comparison of seed yield in normal and late sowing dates (Y_N and Y_S, respectively) and its stress tolerance indices including Y(MP), Y(GMP), Y(TOL), Y(STI) and Y(SSI) for 10 rapeseed genotypes

Genotypes	Yp	Ys	Y(MP)	Y(GMP)	Y(STI)	Y(SSI)	Y(TOL)
1-RGS003	2962.5abc	1665.0bc	2313.8ab	2202.4bc	0.60ab	0.99a	1297.5ab
2-Zabol0	3115.0ab	1947.4a	2531.2a	2449.5a	0.64a	0.88a	1167.6ab
3-Zabol15	2997.5abc	1464.8cd	2231.2b	2093.8bc	0.49b	1.24a	1532.7a
4-Safi7	2173.3e	1312.9de	1743.1d	1679.2e	0.62ab	0.94a	860.3b
5-Safi6	2911.3abc	1768.0ab	2339.7ab	2255.7ab	0.62ab	0.93a	1143.2ab
6-Safi5	2361.3de	1193.1e	1777.2d	1653.4e	0.56ab	1.07a	1168.2ab
7-Safi31	2304.3de	1446.8cd	1875.6cd	1811.1de	0.67a	0.82a	857.4b
8-S841	2575.0cde	1684.8dc	2129.9bc	2077.4bc	0.67a	0.80a	890.2b
9-L7	2737.5bcd	1482.8cd	2110.2bc	2009.0cd	0.56ab	1.07a	1254.7ab
10-Zafar	3300.0a	1841.1ab	2570.6a	2450.9a	0.58ab	1.03a	1458.9a

Means, in each column, followed by at least one letter in common are not significantly different at the 1% level of probability- using Duncan sõ Multiple Range Test

Y_N: seed yield in normal sowing date, Y_S: seed yield in late sowing date (stress) condition, Y(MP): mean productivity. Y(GMP): geometric mean productivity. Y(TOL): tolerance index, Y(STI): stress tolerance index and Y(SSI): stress susceptibility index.

Table 5: Pearson correlation for seed yield and its related stress tolerance indices.

Traits/indiced	Yp	Ys	Y(MP)	Y(GMP)	Y(STI)	Y(SSI)	Y(TOL)
Yp	1						
Ys	0.79**	1					
Y(MP)	0.96**	0.91**	1				
Y(GMP)	0.93**	0.95**	0.99**	1			
Y(STI)	-0.31	0.31	-0.07	0.02	1		
Y(SSI)	0.30	-0.32	0.06	-0.02	-0.99**	1	
Y(TOL)	0.78**	0.24	0.61	0.52	-0.81**	0.81	1

*, ** Significant at $p<0.05$ and 0.01, respectively.

Y_N: seed yield in normal sowing date, Y_S: seed yield in late sowing date (stress) condition, Y(MP): mean productivity. Y(GMP): geometric mean productivity. Y(TOL): tolerance index, Y(STI): stress tolerance index and Y(SSI): stress susceptibility index.

two stress indices. 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 Y_N, therefore through these indices it is possible to distinguish high yielding genotypes in either condition.

Conclusions

Significant differences of genotypes determined for P_N and P_S, Y_N and Y_S, and their stress tolerance indices for the studied rapeseed genotypes except Y(STI) and Y(SSI). Significant positive correlation of PN with P(MP) and P(GMP) indicating the genotypes with high mean value of PN will have high mean value of these two stress tolerance indices. Significant negative correlation between P(TOL) and P(STI) indicating high mean value of P(STI) along with low mean value of P(TOL) can be used for selection of the genotypes with high mean value of pods number in rapeseed. Two stress indices including Y(STI) and Y(SSI) could not separate the genotypes, and all of the genotypes were classified in the same statistical group but Y(TOL) separated the genotypes in different statistical groups. The genotypes including Safi7, Safi31 and S841 with low mean value of Y(TOL) were less affected by late sowing stress conditions.

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