Amir Hossein Shirani Rad / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 2, Issue 1,Jan-Feb 2012, pp.1168-1173

Study on Drought Stress Tolerance in Rapeseed Varieties Based on Drought Stress Tolerance Indices

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Abstract- a two year experiment was carried out in a split plot design based on RCBD with four replications at the research field of Seed and Plant Improvement Institute, Karaj, Iran during 2002-2004 crop years with the objective to determine the drought stress tolerance of spring rapeseed (*Brassica napus* L.) varieties using drought stress tolerance indices (STI, MP and GMP) and identifying the most appropriate index for drought stress tolerance evaluation. Treatments were included Irrigation in two levels (I: I_1: irrigation after 80 mm evaporation from the class A pan (normal irrigation,) and I_2: no irrigation from stem elongation stage up to the end of growth (water stress) as main plots and varieties in 20 levels (V_1: Sarigol, V_2: Goliath, V_3: Heros, V_4: Comet, V_5: Amica, V_6: SW 5001, V_7: Cracker Jack, V_8: Eagle, V_9: Wild cat, V_{10}: SW Hot shot, V_{11}: Ogla, V_{12}: 19-H, V_{13}: Hyola 401 (Canada), V_{14}: Hyola 401 (Safi abad), V_{15}: Hyola 401 (Borazjan), V_{16}: Hyola 420, V_{17}: Syn 3, V_{18}: Option 500, V_{19}: Hyola 308, V_{20}: Quantum) as sub plots. The results of combined analysis indicated that no irrigation from stem elongation stage up to the end of growth decreased seed yield. Syn 3 variety produced the highest seed yield and STI under water stress condition among varieties, while under normal irrigation condition the highest seed yield obtained by Hyola 401 (Canada) variety. Quantum variety with the lowest seed yield under normal irrigation, low seed yield in water stress condition and the lowest STI was known as the most susceptible variety to drought stress. STI known as the most appropriate index for drought stress tolerance evaluation due to highest correlation with seed yield in both water and non water stress conditions.

Keywords: *Rapeseed; variety; Water stress; Drought stress tolerance indices; seed yield.*

I. Introduction

Drought is one of the most limiting environmental stresses for plant production [1]. Plants respond to drought by closing their stomata, which reduces leaf transpiration and prevents the development of excessive water deficits in their tissues. The drawback of the stomatal closure for plants is that their carbon gain is lowered and their growth is impaired. The effect of drought stress is a function of genotype, intensity and duration of stress, weather conditions, growth and developmental stages [2] which the occurrence time is more important than the water stress intensity [3]. Severe stress decreases the duration of reproductive growth [4] and stress during flowering or ripening stages results in large yield losses [5].

The rapeseed cultivated area has been increased during recent years in Iran. This points out the necessity of more research about this crop concerning dry climate of this region and its irregular rainfall patterns. However, low heritability for drought tolerance and lack of effective selection approaches limit development of resistant crop cultivars to environmental stress [6]. To evaluate response of plant genotypes to drought stress, some selection indices based on a mathematical relation between stress- and optimum conditions has been proposed [7-8- 9- 10]. Fernandez (1992) classified plants according to their performance in stressful and stress free environments to four groups: genotypes with similar good performance in both environments (Group A); genotypes with good performance only in non-stress environments (Group B) or stressful environments (Group C); and genotypes with weak performance in both environments (Group D). To improve rapeseed yield and stability in stressful environments, there is a necessity to identify selection indices able to distinguish high yielding rapeseed varieties in these situations. Thus, our purpose was evaluation of the drought stress tolerance of spring rapeseed varieties using drought stress tolerance indices and identifying the most appropriate index for drought stress tolerance evaluation to achieve varieties that can tolerate long irrigation intervals or likely no irrigation at sensitive growth stages.

II. Materials and Methods

The experiments were carried out at the research field of Seed and Plant Improvement Institute, Karaj, Iran (50°75′E, 35°59′N) during the 2002-2003 and 2003-2004 crop years. Average monthly precipitation in this region, during the two years of experiment is presented in Table 1.

Year	2002-03	2003-04
Month		
Sept	0.0	0.0
Oct	3.3	20.0
Nov	27.9	18.0
Dec	84.6	37.2
Jan	11.9	44.0
Feb	34.4	8.0
March	48.2	36.7
April	80.0	58.2
May	18.3	18.9
Total	308.6	241.0

Table1. Amount of precipitation (mm) in 2002-2003 and 2003-2004 crop years at Karaj research station

The soil type where the experiment took place was a clay loam soil with 175 ppm available K, 3.3 ppm available P, 44% Organic carbon, 7.8 (1:1 H_2O) pH, and 1.70 μ moh cm^{-1} EC. The experimental design was a randomized complete block design arranged in split plot form with four replications. Treatments were included two agents: Irrigation in two levels including I_1: irrigation after 80 mm evaporation from the class A pan (normal irrigation) and I_2: no irrigation from stem elongation stage up to the end of growth (water stress) as the main plots and variety including 20 spring varieties as the subplots which are presented in Table 2.

Name	Origin	Growth type	Variety	Hybrid
Sarigol	Germany	Spring	*	
Goliath	Denmark	Spring	*	
Heros	Germany	Spring	*	
Comet	Italy	Spring	*	
Amica	Germany	Spring	*	
SW5001	Swede	Spring	*	
Cracker Jack	Swede	Spring	*	
Eagle	Swede	Spring	*	
Wild cat	Swede	Spring	*	
SW Hot shot	Swede	Spring	*	
Ogla	Germany	Spring	*	
19-H	Pakistan	Spring	*	
Hyola 401 (Canada)	Canada	Spring		*
Hyola 401 (Safi abad)	Iran	Spring		*
Hyola 401 (Borazjan)	iran	Spring		*
Hyola 420	Canada	Spring		*
Syn 3	iran	Spring	*	
Option 500	Canada	Spring	*	
Hyola 308	Canada	Spring		*
Quantum	Germany	Spring	*	

Table2. Growth type and origin of studied rapeseed cultivars

Each experimental plot consisted of 6 rows, 5 m long with 30 cm spaced between rows and 4 cm distance between plants on the rows. Among blocks 6 m distance was kept to prevent treatments mingling. Seeds were planted at 5 Oct. in each year. According to soil analysis, N, P and K fertilizer rates recommended. P and K fertilizers applied pre-plant and N fertilizer applied in three stages: one-third pre plant, one-third in stemming stage and one-third in flowering stage. The crop was kept free from weeds by applying 2.5 L ha^{-1} Terfelan pre-plant.

Seed yield was measured by 12% moisture. The degree of drought stress tolerance of varieties calculated using three following indices:

1) Stress Tolerance Index:

STI= $(Y_s \times Y_p)/(\bar{Y}_p)^2$ (Fernandez, 1992)

2) Mean Productivity:

MP= $(Y_s + Y_p)/2$ (Rosielle, and Hamblin, 1981)

3) Geometric Mean Productivity:

GMP = $\sqrt{Y_s Y_p}$ (Fernandez, 1992)

Where Y_s is seed yield of each variety in water stress condition, Y_p is seed yield of each variety in normal irrigation and $\bar{Y}_p$ is average seed yield of varieties in normal irrigation.

Then to determine the most appropriate index for identifying drought stress tolerant variety, simple correlation among indices and seed yield in both water and non water stress condition calculated using SAS software. The index with the highest correlation with seed yield in both water and non water stress condition considered as the best index [9].

Combined analysis of variance was performed for seed yield after 2 years of experiment using SAS software. Also Duncan's Multiple Range Test (DMRT) ($P = 0.05$) was used to conduct means comparison using MSTAT-C software.

III. Results and discussion

III.I. Seed yield

The results of combined analysis of variance revealed that the simple effect of year on seed yield was significant at $P = 0.05$ and the simple effect of irrigation and variety on this trait were significant at $P = 0.01$. The interaction effects of treatments were not significant for this trait (Table 3). Normal irrigation by average of 4137.5 kg ha^{-1} showed a significant preference in comparison to no irrigation from stem elongation stage up to the end of growth by average of 3184.9 kg ha^{-1}. Also assessed varieties from the seed yield point of view placed in different statistical groups as Syn 3 by average of 4068 kg ha^{-1} and Quantum by average of 3220 kg ha^{-1} produced the highest and lowest seed yield, respectively (Table 4).

S. O .V	DF	Seed yield
Year (Y)	1	10315397.9 *
Replication × Year (Error a)	6	989814.4
Irrigation (I)	1	72588216.9 **
Year × Irrigation (Y×I)	1	101527.6 ^{ns}
(Error b)	6	1326731.8
Variety (V)	19	837496.8 **
Year × Variety (Y×V)	19	370783.1 ^{ns}
Irrigation × Variety (I×V)	19	275163.1 ^{ns}
Year × Irrigation × Variety (Y×I×V)	19	226570.3 ^{ns}
(Error c)	228	418280.1
Total	319	-
C. V.	-	17.66

ns: not significant, * and ** Significant at the 5% and 1% levels of probability, respectively

Table3. Combined Analysis of variance for seed yield (2002-2004)

Treatment	**mean**
	Seed yield (kg ha^{-1})
Irrigation	
Normal irrigation	4137.5 a
Water stress	3184.9 b
Variety	
Sarigol	3453 cd
Goliath	3730 a-d
Heros	3711 a-d
Comet	3608 a-d
Amica	3932 abc
SW5001	3702 a-d
Cracker Jack	3681 a-d
Eagle	3671 a-d
Wild cat	3488 bcd
SW Hot shot	3563 a-d
Ogla	3394 cd
19-H	4023 ab
Hyola 401 (Canada)	3858 abc
Hyola 401 (Safi abad)	3542 a-d
Hyola 401 (Borazjan)	3640 a-d
Hyola 420	3922 abc
Syn 3	4068 a
Option 500	3726 a-d
Hyola 308	3290 d
Quantum	3220 d

Means followed by similar letters are not significantly different at 5% probability level- using Duncan Multiple Range Test (DMRT).

Table4. Mean comparison of main effects for seed yield (2002-220)

variety	**Seed yield (kg ha^{-1})**	
	Normal irrigation	**Water stress**
Sarigol	3922 a-f	2984 hi
Goliath	4085 a-e	3375 e-i
Heros	4174 a-d	3248 f-i
Comet	4179 a-d	3037 hi
Amica	4520 a	3344 e-i
SW5001	3967 a-f	3436 d-i
Cracker Jack	4237 abc	3126 ghi
Eagle	4083 a-e	3260 f-i
Wild cat	3863 a-g	3114 ghi
SW Hot shot	4091 a-e	3035 hi
Ogla	3898 a-g	2891 hi
19-H	4543 a	3504 c-i
Hyola 401 (Canada)	4588 a	3127 ghi
Hyola 401 (Safi abad)	4117 a-e	2967 hi
Hyola 401 (Borazjan)	3828 a-g	3452 d-i
Hyola 420	4470 a	3375 e-i
Syn 3	4558 a	3577 b-h
Option 500	4315 ab	3137 ghi
Hyola 308	3820 a-g	2761 i
Quantum	3492 c-i	2948 hi

Means followed by similar letters are not significantly different at 5% probability level- using Duncan Multiple Range Test (DMRT).

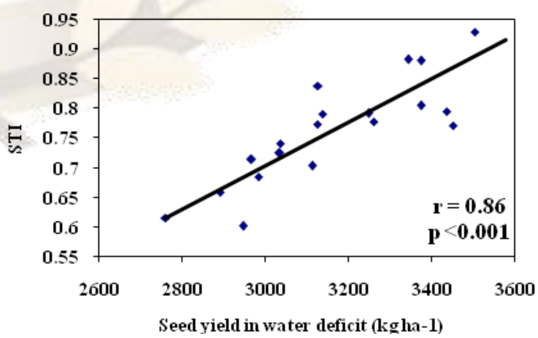
Table5. Mean comparison for seed yield of varieties under normal irrigation and water stress conditions

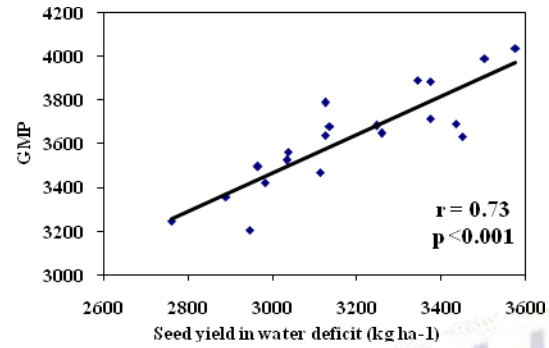
III.II. Drought stress tolerance indices

To identify the degree of susceptibility and tolerance to drought stress, the STI, MP and GMP indices were calculated for rapeseed varieties (Table 6) and the correlation among these indices and seed yield in both irrigation regimes determined. Although there is a significant and positive correlation among assessed indices and seed yield in both irrigation regimes, but STI had the most significant and positive correlation at P = 0.01 with seed yield in both irrigation regimes (Fig. 3-4). According to Fernandez (1992) the best drought stress tolerance index is the one that highly correlated with seed yield in both water and non water stress conditions [9], so STI index can evaluate the drought stress tolerance better than MP and GMP indices. Also Bahram *et al.* (2006) reported STI could be more efficient in evaluation of drought tolerance of spring rapeseed cultivars in comparison to SSI (Stress Susceptibility Index) and TOL (Tolerance Index) [11]. Naeemi *et al* (2008) reported due to significant and positive correlation among STI, GMP and MP indices and seed yield in water and non water stress conditions, these indices considered as appropriate criteria to identify drought stress tolerance cultivars [12]. Evaluation of assessed varieties from the drought stress tolerance point of view according to STI, MP and GMP indices which higher rates of them show the higher tolerance to drought stress presented the same results, as Syn 3 variety with the highest rates of MP (4068), GMP (4038) and STI (0.952) produced the highest rate of seed yield in water stress (3577 kg ha^{-1}) and high yield in normal irrigation (4558 kg ha^{-1}) and known as the most tolerant variety (Table 6). While Quantum variety which had the lowest rates of these indices (MP: 3220, GMP: 3208 and STI: 0.601) produced the lowest rate of seed yield in normal irrigation (3492 kg ha^{-1}) and low yield in water stress (2948 kg ha^{-1}) condition and known as the most susceptible variety (Table 6). Sio-Se mardeh *et al.* (2006) reported MP index is useful in genotypes selection under stress condition when the stress is not severe and the difference among seed yields in stress and non stress conditions was not so high. They reported MP as a good index in their experiment which could be due to low degrees of stress intensity in their experiment [10]. Fernandez (1992) reported using STI index cause to selection of cultivars which have a high tolerance to drought as well as production of desirable yields in complete irrigation condition [9]. So STI index is better than the other indices of evaluating genotypes under drought stress condition and the higher rates of STI show the higher tolerance of the genotype to drought and therefore higher yields.

Variety	MP	GMP	STI
Sarigol	3453	3421	0.684
Goliath	3730	3713	0.805
Heros	3711	3682	0.792
Comet	3608	3563	0.741
Amica	3932	3888	0.883
SW5001	3702	3692	0.796
Cracker Jack	3682	3639	0.774
Eagle	3672	3648	0.778
Wild cat	3489	3468	0.703
SW Hot shot	3563	3524	0.725
Ogla	3395	3357	0.658
19-H	4024	3990	0.930
Hyola 401 (Canada)	3858	3788	0.838
Hyola 401 (Safi abad)	3542	3495	0.714
Hyola 401 (Borazjan)	3640	3635	0.772
Hyola 420	3923	3884	0.881
Syn 3	4068	4038	0.952
Option 500	3726	3679	0.791
Hyola 308	3291	3248	0.616
Quantum	3220	3208	0.601

Table6. Evaluation of rapeseed varieties with drought tolerance indices





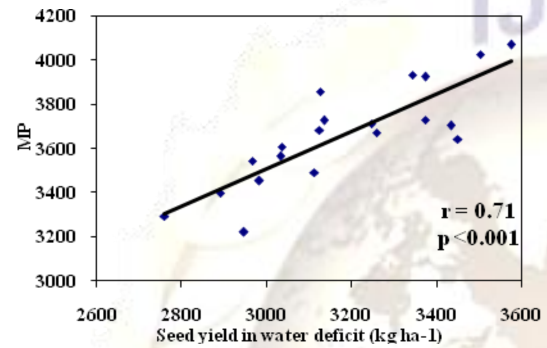
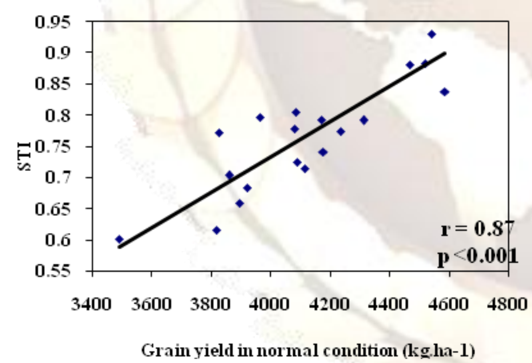
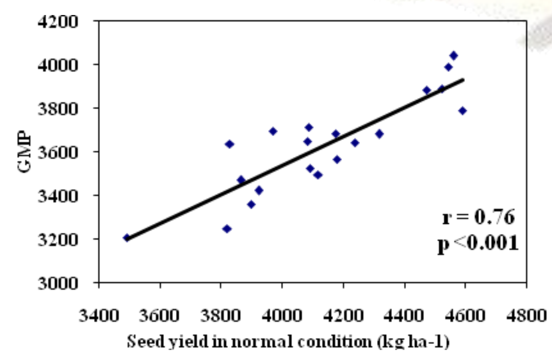


Fig. 4- Correlation between stress tolerance indices and seed yield under normal irrigation condition (n=20).





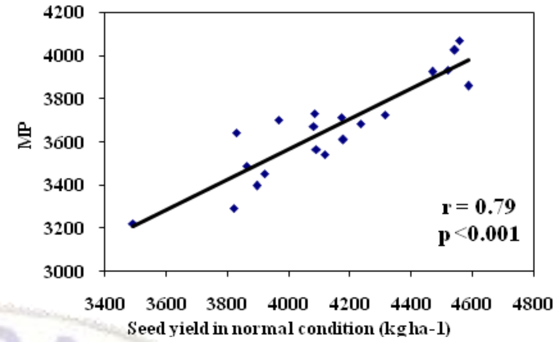


Fig. 3- Correlation between stress tolerance indices and seed yield under water stress condition (n=20).

IV. Conclusions

This study provides new information about the effect of water stress from the stem elongation stage on seed yield of spring rapeseed varieties and usage of drought stress tolerance indices (STI, MP and GMP) which help us to choose the most appropriate and tolerant variety for cultivation. Our results of evaluating spring rapeseed varieties based on the highly used indices of drought tolerance in two years of experiment revealed that Syn 3 variety produced the highest seed yield and STI under water stress condition among varieties, while under normal irrigation condition the highest seed yield obtained by Hyola 401 (Canada) variety. It show Syn 3 genetically have a high potential in seed yield production under normal irrigation in addition to tolerance to drought stress. Quantum variety with the lowest seed yield under normal irrigation, low seed yield in water stress condition and the lowest STI was known as the most susceptible variety to drought stress. Also STI known as the most appropriate index for drought stress tolerance evaluation due to highest correlation with seed yield in both water and non water stress conditions.

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