Iran Agricultural Research (2020) 39(2) 69-78

Shiraz University

Research Article

Agro-physiological parameters for improving drought tolerance in rapeseed genotypes to cultivate in saline soils

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DOI: 10.22099/IAR.2021.38123.1403

ARTICLE INFO
***Article history*:**
Received **11 August 2020**
Accepted **8 January 2021**
Available online **13 February 2021**

***Keywords*:**
Cluster analysis
Pod length
Seed yield
Stomatal conductance

ABSTRACT- This study was conducted to introduce agro-physiological traits for improving drought tolerant rapeseed winter genotypes for cultivation in saline areas. Eighteen rapeseed genotypes were evaluated under non-stressed and drought-stressed conditions from flowering and seed filling stages to seed maturity for two years (2012-2014) at the saline soils (EC=6.7 dS m^{-1}) in Agricultural and Natural Resources Research and Education Center of East Azarbaijan, Iran. Drought stress significantly decreased pod length, plant height, seed yield, yield components and stomatal conductance and increased canopy temperature. Among the genotypes, significant differences were observed for pod length, the number of seeds in a pod, seed and oil yields, and stomatal conductance. The correlations among the traits were significantly positive. According to the results of genotypes grouping, HW101, L183, L73, and L72 having higher pod length, the number of seeds in a pod, stomatal conductance, seed and oil yields, which were recognized as the promising ones. The results of this study indicated that, the pod length, the number of seeds in a pod and stomatal conductance as simple and easy parameters can be used to select late season drought tolerant rapeseed winter genotypes for cultivation in saline areas. Also, the cluster analysis method was able to discriminate productive genotypes. Water deficit during flowering and seed filling stages, decreased the mean of seed yields by 800 and 584 Kg h^{-1} during the first year and 1764 and 1154 Kg h^{-1} during the second year of the experiment, of this study respectively. Thus, it was concluded that the evaluated rapeseed genotypes at the flowering stage were more sensitive to drought compared to the seed filling stage.

INTRODUCTION

The growth rate and seed yield of rapeseed are mainly restricted via water deficit especially in saline soils that can become acute in marginal lands (El Sabagh, 2019). In water deficit conditions, farmers increasingly utilize growth stage timed irrigation management through regulated deficit irrigation (Dejonge et al., 2015). Drought affected the carbon assimilation rate mainly via the limitation of CO_2 diffusion through the stomata by decreasing stomatal conductance in rapeseed (El ferjani and Soolanayakanahally, 2018). Grewal (2010) indicated that rapeseed might be a better option to grow for higher water use efficiency in sodic vertisols with higher subsoil NaCl salinity. Yanagawa and Fujimaki (2013) indicated that canola (*Brassica napus* L.) was more tolerant to salinity compared to drought. Canola plants indicated higher water use efficiency (WUE) under moderate levels of irrigation (Hamzei, 2011). Majidi Nasab et al. (2014) indicated that occurring drought stress from flowering in rapeseed, decreased stomatal conductance. Stomatal conductance under drought stress condition was 16 percent less than that in normal water conditions. Drought stress in wheat plants significantly decreased CO_2 assimilation and net photosynthetic rates via diminishing stomatal conductance (Gupta and Tind, 2015).

Infrared thermometry is a suitable method to determine drought stress because it is a non-destructive method and it is easier than many alternative methods (Dejonge et al., 2015). Takele (2001) indicated that canopy temperature is a suitable trait for the selection of the water deficit tolerant cultivars of teff. (*Eragrostis tef* [Zucc.] Trotter.).

Dejonge et al. (2015) reported a linear relationship between canopy temperature and crop water stress index (CWSI) with the soil water deficit at high temperature in maize. They concluded that canopy temperature and CWSI could be used to monitor drought stress in maize crops as a non-destructive, cheap and simple method.

Peltonen Sainio and Jauhiainen (2008) reported that environmental variations markedly affected seed yield and the number of seeds per square meter in rapeseed cultivation. It was also reported that when drought stress occurs since the flowering stage, seed yield is diminished due to a decrease in the number of pods per plant in oilseed rape (Pasban Eslam, 2009). Evaluation of rapeseed genotypes in a Mediterranean climate revealed that seed yield was strongly correlated with the number of pods per plant, 1000-seeds weight, plant height, and the number of primary branches in a plant (Gunasekera et al., 2006). Rapeseed genotypes with higher seed oil content produced higher dry matter at the end of the seed filling stage (Hua et al., 2012). Evaluation of simple correlation coefficients among seed yield and its components in rapeseed illustrated that plant height, total dry matter, 1000-seeds weight, the number of pods per plant, and seeds in a pod had positive and significant correlations with seed yield (Khayat and Karami, 2012). The objectives of this study were to introduce agro-physiological traits for selecting drought tolerant rapeseed genotypes to cultivate in saline areas and to evaluate the effects of occurring drought stress in flowering and seed filling stages on rapeseed seed and oil yields.

MATERIALS AND METHODS

This study was carried out at the saline soils (EC=6.7 dS m^{-1}, pH=7.8) of Agricultural and Natural Resources Research and Education Center of East Azarbaijan (Khosrow Shah Station), Iran (46°2′E, 37°58′N) during the growing seasons of 2012-2014. It was conducted on loamy soil with 1.5 percent organic matter and CEC=17 $cmol_{(+)}\ kg^{-1}$ as factorial based on a randomized complete block design with three replications. Eighteen winter rapeseed open pollination genotypes (Table 1) were evaluated under non-stressed and water deficit conditions from flowering and seed filling stages to seed maturity. To avoid precipitation on stressed plots, polyethylene-covered the rain shelters were used during rain period that occurred one time for 2 hours in the second year.

Plants were irrigated at 30-35% and 70-75% soil water depletion in non-stressed and stressed plots, respectively Table 2).

The treatments under normal irrigation received 30 liters water per m^2 six times (at 30-35% AW depletion), and treatments under stress from flowering, and seed filling stages received 70 liters water per m^2 one and two times, respectively (at 70-75% AW depletion) during the stress period. Water stress was applied by MAD (mean allowable depletion) method (Stegman, 1983). The irrigation water EC was 2.7 dS m^{-1}. The weather characteristics during the growing seasons are summarized in Table 3. The plot size was 5×1.8 meters. The distance between the rows was 30 cm and plants were fixed at 7 cm spacing from each other in a row. Seeding time was September 14th for two years of experiment.

Stomatal conductance (K_l) was measured by an AP4 leaf Prometer (Delta-T Devices, UK). An infrared thermometer (Class 2, Testo, Germany) was used to measure canopy temperature. Its emission ability index was adjusted to 0.56 for green leaf surface. Measurements were made on five samples of each plot on youngest fully expanded leaves at on a third of the top of the plants at 1200 to 1400 h (Dejonge et al., 2015 and Takele, 2001).

Table 1. Pedigree of studied winter rapeseed genotypes

Genotype	Parents	Origin	Growth period (days)
HW113	Opera x Zarfam (1)(2)	Iran	281
KS12	Orient x Modena(2)(4)	Iran	282
Karaj1	Okapi x Opera (2)(2)	Iran	280
KR18	Okapi x Opera (3)(5)	Iran	280
L73	Orient x Modena (5)(3)	Iran	280
L72	Okapi x Opera (1)(4)	Iran	280
HW101	Opera x Zarfam (3)(5)	Iran	279
L146	Orient x Modena(1)(3)	Iran	281
L210	Opera x Modena (2)(4)	Iran	279
L183	Okapi x Zarfam (5)(2)	Iran	279
SW101	Okapi x Orient (1)(2)	Iran	280
L5	Okapi x Modena (2)(5)	Iran	280
L201	Okapi x Zarfam (1)(3)	Iran	281
HW118	Okapi x Orient (3)(5)	Iran	284
KR4	Zarfam x Modena(1)(3)	Iran	283
Karaj2	Okapi x Licord (1)(2)	Iran	280
Karaj3	Orient x Licord (3)(5)	Iran	283
KS7	Zarfam x Licord (2)(4)	Iran	283

Plants were harvested from 7.2 m^2 area of each plot on June 18th and 21st, of the first and second years of research, respectively. The humidity of seeds in harvest time was 16-18%. To control the border effects, plants were removed from the sides of each plot, before harvesting. Finally, pod length, plant height, seed yield, the number of pods per plant, the number of seeds in a pod, and 1000-seeds weight were measured. Ten plants from each plot were randomly selected and were used to determine plant height and components of seed yield.

The seed oil content was also determined by NMR (nuclear magnetic resonance, Siemens Co.) method. Statistical evaluations of the data were performed using the MSTATC for analysis of variance means comparisons and correlation analysis, and the SPSS service pack. 22 (software package) for grouping of genotypes.

Table 2. Characteristic of the soil water content in the experimental field of this study

	FC (%)		PWP (%)		AWC (%)	
Soil depth (cm)	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
0-30	26.7	25.2	12.6	12.8	14.1	12.4
30-60	20.8	20.4	10.0	11.4	10.8	9.0
60-90	13.7	13.1	7.5	8.0	6.2	5.1

FC= Field capacity, PWP= Permanent wilting point, AWC= Available water capacity.

Table 3. Weather records for two growing seasons during experimental periods of this study

Year	Month	Mean minimum air temperature (°C)	Mean maximum air temperature (°C)	Mean of total air temperature (°C)	Rainfall (mm)
2012	September	16.3	31.1	23.7	0.0
	October	9.8	26.4	18.1	2.4
	November	3.5	17.7	10.6	7.5
	December	0.4	13.2	6.8	0.0
2013	January	-4.6	5.5	-0.6	9.4
	February	-5.1	5.5	0.18	17.4
	March	-1.1	10.2	4.6	39.3
	April	5.2	13.8	11.8	34.2
	May	16.1	21.2	18.7	129.4
	June	21.0	28.7	13.2	5.0
	September	16.1	30.4	23.2	3.4
	October	10.6	25.1	17.8	6.7
	November	5.6	16.6	11.1	35.9
	December	-0.1	8.6	3.8	42.9
2014	January	-4.9	3.8	-0.5	14.8
	February	-0.8	8.0	3.6	34.3
	March	1.2	11.7	6.4	21.5
	April	5.1	18.1	11.6	33.3
	May	8.4	19.9	14.1	34.7
	June	13.2	27.9	20.6	43.0

Data were collected from Khosrow Shah station of Agricultural and Natural Resources Research and Education Center of East Azarbaijan

RESULTS AND DISCUSSION

Seed Yield, Yield Components and Physiological Traits

Significant differences were observed in all of the traits except in pod length and seed oil for two years of experiment at 1% level, also the effects of drought stress on all of the traits under this study were significant. Among the rapeseed winter genotypes, significant differences were observed for pod length, the number of seeds in a pod, seed and oil yields, and stomatal conductance. Interaction effects between drought stress by genotype were also significant on pod length and stomatal conductance (Table 4).

Drought stress during the flowering stage significantly decreased pod length, plant height, the number of pods per plant, the number of seeds in a pod, seed and oil yields, stomatal conductance, and increased canopy temperature (Table 5).

Moreover, drought stress during the seed filling stage, significantly decreased above mentioned traits, except for the number of pods per plant and increased canopy temperature. Water deficit during flowering and seed filling stages, decreased mean seed yield by 1459 and 692 Kg ha^{-1}, respectively (Table 5). Among the rapeseed winter genotypes HW101, L183, L72, and L73 indicated higher pod length, the number of seeds in a pod, stomatal conductance, seed and oil yields in normal and water deficit conditions compared to other genotypes (Table 5).

Table 4. Analysis of variances of traits measured on rapeseed genotypes during 2012-2014

Source	df	Mean squares				
		Pod length	Plant height	Pods per plant	Seeds in a pod	1000-seeds weight
Year (Y)	1	0.19	40334.0**	29967.4**	937.0**	30.61**
Replication/Y	4	0.96	261.9	2296.7	19.1	00.68
Stress (S)	2	21.35**	3709.8**	20670.8**	12.1*	0.95**
S ×Y	2	0.26	096.5**	2184.8**	18.2**	1.09**
Genotype(G)	17	0.56**	116.4	316.2	6.2**	0.11
G × Y	17	0.05	131.7	350.3	2.0**	0.06
S × G	34	0.38*	129.2	244.6	3.8	0.14
S ×G × Y	34	0.03	112.4	254.4	3.4	0.09
Error	212	0.23	120.2	220.9	2.9	0.09
C.V (%)		9.38	9.87	16.99	6.33	8.52

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

Table 4. Continue

Source	df	Mean squares				
		Seed yield	Seed oil	Oil yield	Canopy temperature	Stomatal conductance
Year (Y)	1	188522053**	1.81	29094748**	693.4**	0.008**
Replication/Y	4	2162751	122.37	676034	36.3	0.001
Stress (S)	2	54937849**	35.85**	9396529**	784.4**	4.404**
S ×Y	2	6063339**	15.04**	1088666**	834.8**	0.003*
Genotype(G)	17	736338*	1.35	128941*	2.0	0.006**
G × Y	17	393124	1.50	70542	1.5	0.001
S × G	34	601083	1.68	99399	2.2	0.005**
S ×G × Y	34	633151	2.11	106171	2.9	0.001
Error	212	438069	3.13	73690	2.9	0.001
C.V (%)		22.61	4.46	23.21	7.29	6.22

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

Table 5. Means of traits measured on rapeseed genotypes at different stress levels during 2012-2014

Stress levels	Genotype	Pod length (cm)	Plant height (cm)	Pods per plant	Seeds in a pod	1000-seeds weight (g)	Seed yield (Kg h^{-1})	Seed oil (%)	Oil yield (Kg h^{-1})	Canopy temperature (°C)	Stomatal conductance (cm s^{-1})
Non-stressed	HW113	5.61	115.83	104.83	27.83	3.45	3482.0	41.56	1447.1	20.66	0.690
	RS12	5.55	112.50	91.50	27.13	3.43	3443.2	41.51	1429.3	20.83	0.675
	Karaj1	5.58	115.00	101.83	27.00	3.45	3554.8	39.60	1407.7	21.58	0.648
	KR18	5.60	113.33	102.17	27.00	3.60	3560.5	40.28	1434.2	22.08	0.700
	L73	5.61	118.66	108.50	28.56	3.65	3979.1	40.73	1620.7	20.33	0.700
	L72	5.63	118.33	107.00	28.53	3.35	3901.3	41.08	1603.4	20.33	0.688
	HW101	6.31	118.33	109.17	28.80	3.66	4304.2	40.91	1760.8	20.00	0.747
	L146	4.95	121.66	92.83	27.03	3.65	3405.2	40.00	1362.1	21.33	0.670
	L210	5.40	115.00	89.66	27.00	3.63	3551.5	40.30	1431.3	21.50	0.598
	L183	6.48	120.00	112.50	28.83	3.66	4443.8	40.45	1798.0	20.23	0.753
	SW101	5.50	119.16	102.17	27.16	3.50	3414.0	40.31	1376.2	20.66	0.676
	L5	5.58	119.16	102.83	27.83	3.58	3464.7	40.86	1415.6	21.08	0.660
	L201	5.48	115.00	103.83	27.00	3.48	3479.2	40.73	1417.1	21.33	0.665
	HW118	5.05	118.33	90.66	27.03	3.53	3604.3	40.53	1460.8	20.16	0.660
	KR4	5.33	120.83	96.66	27.43	3.46	3566.7	40.95	1460.5	20.75	0.695
	Karaj2	5.36	115.00	102.00	27.16	3.51	3526.4	40.33	1422.0	20.83	0.676
	Karaj3	5.45	113.33	100.17	27.16	3.71	3494.0	38.88	1358.5	21.33	0.668
	KS7	5.33	115.83	97.00	27.20	3.68	3421.0	40.93	1400.2	21.50	0.672
LSD 5%		0.4453	10.1815	13.8025	1.5814	0.2786	614.64	1.6429	252.09	0.7907	0.0293

Table 5. Continue

Stress levels	Genotype	Pod length (cm)	Plant height (cm)	Pods per plant	Seeds in a pod	1000-seeds weight (g)	Seed yield (Kg h^{-1})	Seed oil (%)	Oil yield (Kg h^{-1})	Canopy temperature (°C)	Stomatal conductance (cm s^{-1})
Stress from flowe ring	HW113	4.50	101.66	67.50	26.00	3.56	2296.7	39.73	912.47	25.66	0.293
	RS12	4.45	103.33	79.50	25.16	3.58	2194.5	39.41	865.40	24.00	0.285
	Karaj1	4.55	100.00	64.16	26.16	3.46	2129.3	39.20	859.00	24.16	0.283
	KR18	4.33	98.33	73.33	26.00	3.43	2079.7	39.78	827.32	24.50	0.263
	L73	5.06	110.00	81.00	27.23	3.48	2433.5	40.70	990.4	24.00	0.298
	L72	5.00	108.33	80.66	27.21	3.50	2437.5	40.68	991.57	23.83	0.332
	HW101	5.45	112.50	82.50	27.76	3.68	2902.7	40.34	1171.30	24.83	0.373
	L146	4.53	106.66	67.00	26.33	3.66	1754.3	40.08	703.12	24.00	0.256
	L210	4.34	102.50	82.16	26.83	3.65	2265.2	40.13	909.82	24.50	0.310
	L183	5.55	106.66	81.00	27.84	3.58	2630.7	40.10	1055.30	23.66	0.398
	SW101	4.40	114.16	74.83	26.11	3.48	1953.7	39.61	767.00	24.66	0.272
	L5	4.61	102.50	67.00	26.33	3.50	2060.8	39.28	809.28	24.16	0.276
	L201	4.66	104.16	61.16	26.16	3.58	2121.5	39.10	830.48	25.50	0.272
	HW118	4.36	103.33	67.00	25.16	3.51	1945.0	39.10	760.50	24.00	0.265
	KR4	4.51	98.33	72.00	26.13	3.53	2063.2	39.83	822.98	25.00	0.262
	Karaj2	4.58	110.83	71.33	26.00	3.58	1863.5	39.63	739.12	25.50	0.270
	Karaj3	4.38	105.00	77.33	26.00	3.46	2125.7	40.36	857.9	24.16	0.280
	KS7	4.55	104.16	69.16	26.33	3.51	2070.2	39.76	823.05	24.50	0.276
LSD 5%		0.4453	10.1815	13.8025	1.5814	0.2786	614.64	1.6429	252.09	0.7907	0.0293

Table 5. Continue

Stress levels	Genotype	Pod length (cm)	Plant height (cm)	Pods per plant	Seeds in a pod	1000-seeds weight (g)	Seed yield (Kg h^{-1})	Seed oil (%)	Oil yield (Kg h^{-1})	Canopy temperature (°C)	Stomatal conductance (cm s^{-1})
Stress from seed filling	HW113	5.00	107.50	89.50	28.00	3.30	2729.0	39.13	1067.8	26.16	0.540
	RS12	5.18	115.00	87.50	26.13	3.46	3069.3	39.61	1215.7	25.66	0.530
	Karaj1	5.03	109.16	85.16	26.80	3.46	2766.0	39.13	1082.3	26.00	0.540
	KR18	5.08	114.16	86.00	26.20	3.60	2635.5	39.85	1050.2	26.00	0.545
	L73	5.30	111.66	86.33	28.00	3.46	3136.7	39.30	1232.7	26.43	0.566
	L72	5.30	97.50	85.83	28.23	3.45	3115.3	39.50	1230.5	26.33	0.563
	HW101	5.71	112.50	85.50	28.36	3.55	3179.8	39.93	1269.7	26.50	0.592
	L146	5.23	117.50	84.16	25.68	3.63	3138.8	38.41	1205.6	26.16	0.506
	L210	5.10	104.16	93.00	26.40	3.51	2782.0	39.33	1094.2	26.66	0.518
	L183	5.81	113.33	89.16	28.30	3.51	3257.0	39.35	1281.6	26.33	0.583
	SW101	5.06	102.50	82.00	26.33	3.41	3100.0	39.06	1210.8	27.00	0.535
	L5	5.01	115.83	87.83	26.66	3.58	3023.7	39.91	1206.7	26.00	0.553
	L201	5.05	109.16	83.00	26.43	3.30	3075.7	39.58	1217.4	26.33	0.512
	HW118	5.13	120.00	85.66	26.16	3.43	2973.8	39.11	1163.1	25.66	0.533
	KR4	5.01	108.33	85.83	26.61	3.48	2611.2	39.35	1027.5	25.66	0.548
	Karaj2	5.25	115.83	91.83	26.33	3.51	2958.7	38.98	1153.3	26.66	0.560
	Karaj3	5.14	117.50	90.33	26.16	3.38	2493.0	39.96	996.2	26.33	0.502
	KS7	5.00	113.33	85.66	26.63	3.43	3095.7	39.43	1220.6	25.16	0.500
LSD 5%		0.4453	10.1815	13.8025	1.5814	0.2786	614.64	1.6429	252.09	0.7907	0.0293

Correlation and Grouping of Genotypes

Positive and significant correlations were observed among seed, and oil yields with each other and with pod length, the number of pods per plant, and the number of seeds in a pod, 1000-seeds weight and stomatal conductance. The correlation among seed yield components with each other was significantly positive.

The pod length, stomatal conductance, seed and oil yields, and its components indicated significant and negative correlations with canopy temperature (Table 6).

The genotypes were grouped based on the traits evaluater in this study using the cluster analysis method. The genotypes were formed in three groups of 5 units, in three groups of 4.5 units, and in four groups of 2 units by cutting clusters in non-stressed, stress from flowering and seed filling stages, respectively (Fig. 1). According to the results of genotypes grouping, HW101, L183, L73, and L72 were located in the same groups during all water conditions. They indicated higher values of pod length, the number of seeds in a pod, stomatal conductance, seed, and oil yields than others (Table 5).

DISCUSSION

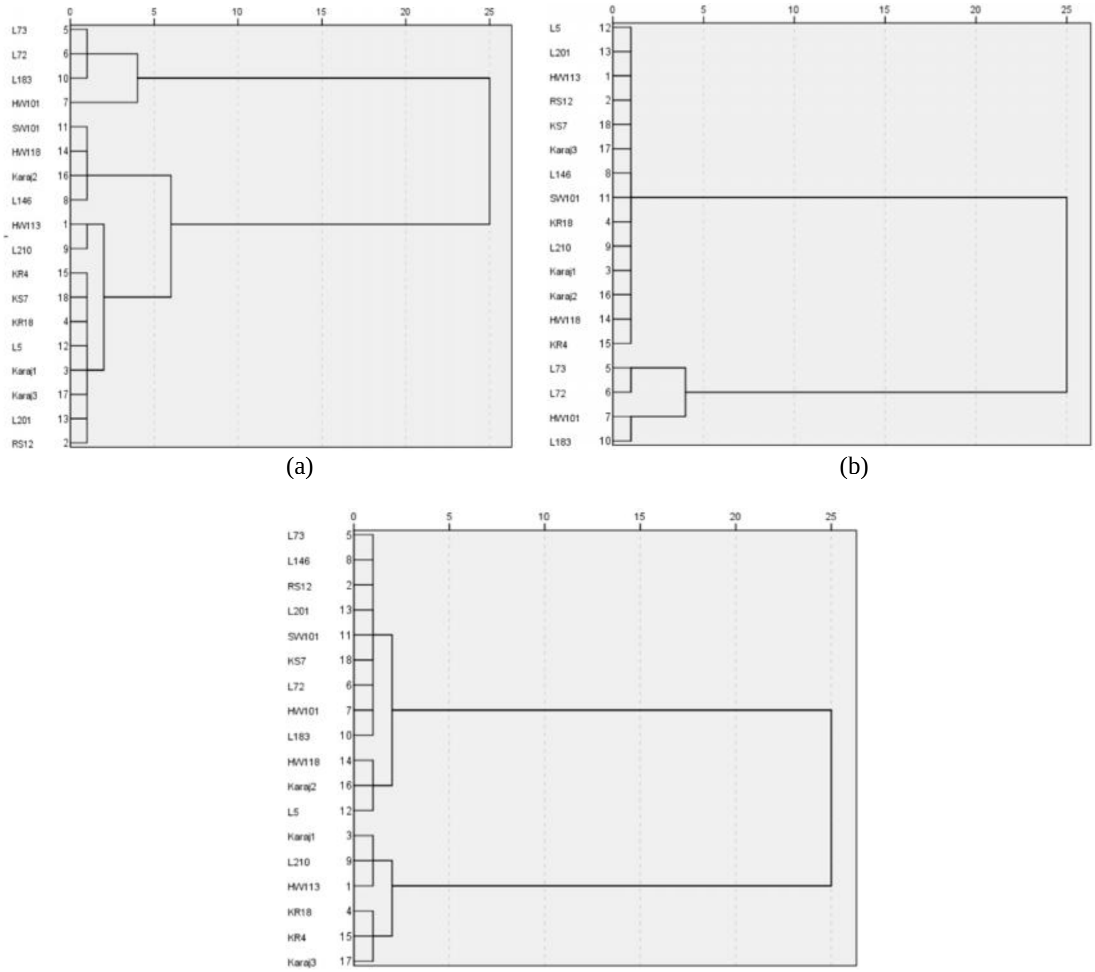
The results of this study indicated that drought stress significantly decreased pod length, plant height, yield components, seed and oil yields, stomatal conductance, and increased canopy temperature in rapeseed. It was shown that the abscisic acid content in leaves increases under drought stress and it leads to stomatal closure and temperature increasing in plants (Pantin et al., 2013). The stomatal conductance decreased under drought and heat stresses during flowering and seed filling stages. It led to decreasing of mesophyll conductance in rapeseed (El ferjani and Soolanayakanahally, 2018). It was reported that photosynthetic activity is sensitive to drought and heat, especially in C_3 metabolic pathway plants (Feller and Vaseva, 2014). As a result, lower carbon assimilation led to lower seed yield in rapeseed genotypes. Darjani et al. (2013) reported that interruption of irrigation from the pod development stage to seed maturity in rapeseed, significantly decreased the number of pods per plant, the number of seeds in a pod, 1000-seeds weight, and seed yield in canola winter varieties. The results of current study indicated that water deficit during flowering and seed filling stages, decreased the mean of seed yields by 800 and 584 Kg h^{-1} during the first year and 1764 and 1154 Kg h^{-1} during the second year of the experiment, respectively. Occurring drought during the flowering stage led to abortion of flowers and new pods and subsequently resulted in diminishing the numbers of pods per plant. Duration of drought at pod filling stage brought seed abortion and smaller seeds which led to decreasing the number of seeds in a pod and 1000-seeds weight, respectively. It is related to the limitation of the availability of pods to assimilate. The results of the experiment of this study indicated that rapeseed winter genotypes are significantly more sensitive to water deficit during the flowering stage than to the seed filling stage. Thus, it seems that irrigation at the time of flowering, would be more effective for seed and oil yields stability under water limiting conditions.

The results of a studying on physiological and agronomic response of rapeseed genotypes to drought stress indicated that the chlorophyll *a* and *b* contents of all genotypes declined due to drought stress at flowering and seed filling stages, but a greater reduction in seed yield was observed when stress was imposed at the flowering stage (Din et al., 2011). Nowosad et al. (2016) studied genotype by environment interaction for seed yield in rapeseed. They reported that 96.82 percent of the total seed yield variation was explained by the environment and 8.15 percent by genotype with the environment interaction. They concluded that the seed yield is highly influenced by environmental factors.

Table 6. Simple correlation coefficients among traits measured on rapeseed genotypes during 2012-2014

Trait		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1)	Pod length	0.19	0.30**	0.04	-0.22**	0.28**	-0.04	0.27**	-0.24**	
(2)	Plant height		-0.17	-0.41**	-0.43**	-0.25**	0.08	-0.23**	0.19	
(3)	pods per plant			0.32**	0.24**	0.63**	0.18	0.64**	-0.35**	
(4)	Seeds in a pod				0.39**	0.48**	-0.02	0.47**	-0.37**	
(5)	1000-seeds weight					0.32**	0.12	0.32**	-0.36**	
(6)	Seed yield						0.13	0.99**	-0.48**	
(7)	Seed oil							0.25**	-0.24**	
(8)	Oil yield								-0.51**	
(9)	Canopy temperature									
(10)	Stomatal conductance									

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



(a) (b) (c)

Fig. 1. Grouping of rapeseed genotypes evaluated in this study based on traits including pod length, plant height, the number of pods per plant, the number of seeds in a pod, 1000-seeds weight, seed oil, seed and oil yields, canopy temperature and stomatal conductance using cluster analysis method (ward linkage) in non-stressed (a), stress from flowering (b) and seed filling (c) stages

Positive and significant correlations were found among seed, and oil yields with each other and with pod length, the number of pods per plant, the number of seeds in a pod, 1000-seeds weight, and stomatal conductance in this study. A significant and positive correlation between seed yield and relative growth rate in spring genotypes of *B. napus* L. has also been previously reported (Arvin et al., 2010). Simply, selecting genotypes that indicate higher 1000-seeds weight, may allow for the election of saline-tolerant rapeseed genotypes (Rameeh et al., 2012). The correlations among seed and oil yields with canopy temperature and stomatal conductance were negative and positive, respectively. It is supposed that diminishing water availability in drought conditions by decreasing stomatal conductance and increasing temperature in rapeseed plants led to a disorder in oil production related to the enzymatic activities which decreased the seed oil.

The incidence of water deficit stress from the pod formation stage in rapeseed genotypes, negatively affected pod length, the number of pods per plant, the number of seeds in a pod, 1000-seeds weight, seed oil content, and seed yield (Darjani et al., 2013). Positive and significant correlations were reported among seed yield with the number of pods per plant and the number of seeds in a pod in canola winter genotypes, under normal and drought stress conditions (Darjani et al., 2013). The strong negative relationship between seed yield and canopy temperature during the reproductive stage of rapeseed genotypes has also been reported (Faraji et al., 2009). It seems that pod length, the number of pods per plant, the number of seeds in a pod, and 1000-seeds weight, have a main role to support seed yield at normal and late-season drought conditions in saline areas. Also among the rapeseed winter genotypes in this study, significant differences were observed only for pod length, the number of seeds in a pod, stomatal conductance, seed and oil yields.

The correlations among these traits with each other were significantly positive. Also according to the results of genotypes grouping based on the cluster analysis, the genotypes HW101, L183, L73, and L72 with having higher pod length, the number of seeds in a pod, stomatal conductance, seed and oil yields in all water conditions, were recognized as the promising ones to cultivate in saline soils (EC=6.7 dS m^{-1}) under late-season drought stress conditions. It was reported that sensitivity to salt in *Brassica* spp. is strongly dependent on the genotype used (Su et al., 2013). It appears that above mentioned genotypes had higher water uptake ability from soil under water deficit conditions and therefore could relatively maintain stomatal conductance, carbon assimilation, and finally seed and oil production. Moreover, the cluster analysis method was able to screen productive genotypes in the above-mentioned water conditions. In a study, Stepwise regression and path analysis indicated that the number of pods per plant and the number of seeds in a pod had the highest direct effect on seed yield. Thus, direct selection for these traits was suggested (Khayat and Karami, 2012).

CONCLUSIONS

The results of this study indicated that late-season drought stress significantly decreased yield components and stomatal conductance and increased canopy temperature in rapeseed winter genotypes. Among the genotypes, significant differences were observed for pod length, the number of seeds in a pod, seed and oil yields, and stomatal conductance. The correlations among these traits with each other were significantly positive. According to the results of genotypes grouping based on cluster analysis, HW101, L183, L73, and L72 with having higher pod length, the number of seeds in a pod, stomatal conductance, seed and oil yields, were recognized as the promising ones in saline condition, Therefore, pod length as a morphological parameter, the number of seeds in a pod as an agronomical trait, stomatal conductance as a physiological index can be used to select late-season drought tolerant rapeseed winter genotypes for cultivation in saline soils. Moreover, the cluster analysis method was able to discriminate productive genotypes in the mentioned water conditions. It is demonstrated that rapeseed genotypes were more sensitive to drought stress occurring in flowering stage than in seed filling stage and under water limiting conditions. So, irrigation at flowering stage of rapeseed could be quite effective to support seed and oil yields.

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تحقیقات کشاورزی ایران (۱۳۹۹) ۳۹(۲)۶۹-۷۸

مقاله علمی- پژوهشی

پارامترهای آگروفیزیولوژیکی برای بهبود تحمل به خشکی در ژنوتیپ‌های کلزا برای کشت در خاک‌های شور

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اطلاعات مقاله

تاریخچه مقاله:

تاریخ دریافت: ۱۳۹۹/۵/۲۱

تاریخ پذیرش: ۱۳۹۹/۱۰/۱۹

تاریخ دسترسی:۱۱/۲۵/ ۱۳۹۹

واژه‌های کلیدی:

تجزیه کلاستر

طول خورجین

عملکرد دانه

هدایت روزنه

چکیده- این مطالعه با هدف معرفی خصوصیات آگروفیزیولوژیکی برای بهبود ژنوتیپ‌های متحمل به-خشکی کلزای زمستانه برای کشت در اراضی شور اجرا گردید. هجده زنوتیپ کلزا در شرایط بدون تنش و خشکی در مراحل گل‌دهی و پرشدن دانه تا رسیدگی طی دوسال زراعی (۹۴-۱۳۹۲) در خاک‌های شور با $EC= ۶/۷\ dS\ m^{-1}$ مرکز تحقیقات و آموزش کشاورزی و منابع طبیعی آذربایجان شرقی، ایران ارزیابی شدند. تنش خشکی طول خورجین، ارتفاع بوته، عملکرد دانه، اجزای آن و هدایت روزنه را به-طور معنی‌داری کاهش و دمای تاج پوشش برگی را افزایش داد. بین ژنوتیپ‌ها اختلاف معنی‌داری در طول خورجین، تعداد دانه در خورجین، عملکرد دانه و روغن و هدایت روزنه دیده شد. همبستگی بین این خصوصیات باهمدیگر مثبت و معنی‌دار بودند. طبق نتایج گروه‌بندی ژنوتیپ‌های HW101، L183، L73 و L72 با داشتن مقادیر بالاتر طول خورجین، تعداد دانه در خورجین، هدایت روزنه، عملکرد دانه و روغن به‌عنوان ژنوتیپ‌های امید بخش شناسایی شدند. بنابراین طول خورجین، تعداد دانه در خورجین و هدایت روزنه به‌عنوان شاخص‌های ساده و آسان برای گزینش ژنوتیپ‌های زمستانه متحمل به تنش خشکی آخر فصل کلزا جهت کشت در اراضی شور قابل استفاده می‌باشند. همچنین روش تجزیه کلاستر توانست ژنوتیپ‌های با عملکرد بالا را تفکیک کند. به‌طور کلی بروز تنش خشکی در مراحل گل‌دهی و پرشدن دانه میانگین عملکرد دانه را به‌ترتیب ۸۰۰ و ۵۸۴ گیلوگرم در هکتار طی سال اول و ۱۷۶۴ و ۱۱۵۴ کیلوگرم در هکتار طی سال دوم آزمایش کاهش داد. بنابراین نتیجه‌گیری شد که ژنوتیپ‌های ارزیابی شده کلزا در مقایسه با مرحله پرشدن دانه به خشکی حساس‌ترند.

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