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EVALUATION OF RAPESEED (*BRASSICA NAPUS* L.) CULTIVARS FOR RESISTANCE AGAINST WATER DEFICIT STRESS

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Abstract

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Among abiotic stresses, drought stress is one of the most serious detrimental factors affecting the growth and production of the oil seed canola plant (*Brassica napus* L.) in arid and semi arid regions worldwide particularly Iran. Identification of crop cultivars tolerant to drought stress will allow more extensive use of lands characterized as marginal because of water shortage in arid and semi-arid areas. To evaluate the effects of water deficit stress on some qualitative and quantitative characteristics of canola cultivars, this experiment in a field trial carried out as a split-plot design based on randomized complete block design (RCBD) with four replications at the experimental farm of Seed and Plant Improvement Institute, Karaj, Iran. Tow irrigation levels were applied in main plots and subplots, which consisted of split application of cultivars at 23 levels. Cultivars differed significantly with respect to seed yield. Zarfam and Elvice cultivars under stress condition had the lowest seed yields. The percent reductions at recommended cultivars were 5.51% for Elvice and 11.04 % for Zarfam, in plants grown in stress as compared to control. Overall, the results of this study suggested that, Zarfam and Elvice cultivars would be important for breeding programs designed for water-stress environments and in identifying drought-tolerant lines under arid and semi-arid conditions.

Key words: drought stress; drought tolerance; cluster analysis; seed yield; oil yield

Introduction

Water deficit is one of the most significant stresses of agriculturally important crops, affecting growth, development and yield (Micheletto et al., 2007). Significant yield losses in crop species due to drought are expected to increase with global climate change as temperatures rise and rainfall distribution changes in key traditional production areas. In Iran, water is a scarce resource, due to the high variability of rainfall. The effect of drought stress is a function of genotype, intensity and duration of stress, weather conditions, growth, and developmental stages of rapeseed (Robertson and Holland, 2004). Water deficit in plants may lead to physiological disorders, such as a reduction in photosynthesis and transpiration (Sarker et al., 2005; Petropoulos et al., 2008). For example, water deficit decreased the oil yield of rosemary (*Rosmarinus officinalis* L.) and anise (*Pimpinella anisum* L.) (Singh and Ramesh, 2000; Zehtab-Salmasi et al., 2001). By contrast, water stress had a positive effect on pepper (*Capsicum annuum* L. var. *annuum*) by increasing the phenolic capsaicinoids (capsaicin and dihydrocapsaicin) and thereby increasing pungency (Estrada et al., 1999). Therefore, the reaction of plants to water stress differs significantly, at various organizational levels, depending upon intensity and duration of stress, as well as plant species and its stage of development (Munns, 2002).

In the water deficit condition, tolerance genotypes having more ability for adapting that this is excellent factor for them. In contrast to the cultivated *Brassica napus*, the genetic diversity of its relatives may provide useful genes for improving this tolerance (Shaheed Siddiqui et al., 2008; Hosseini and Hassibi, 2011).

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Although water stress caused a significant reduction in the growth and oil yield of citronella grass (*Cymbopogon winterianus Jowitt.*) per acre, oil yield expressed on the basis of plant fresh weight increased, with the severity of the water stress response varying with cultivar and plant density (Fatima et al., 2000). Seed yield can be primarily limited even by the relatively short period of soil moisture shortage during the reproductive development (Ahmadi and Bahrani, 2009; Shirani Rad and Aabbasian, 2011). Water stress and high temperature can reduce crop yield by affecting both source and sink for assimilates (Mendham and Salsbury, 1995). Content of oil yield has the highest importance in production profitability (Robertson, Holland, 2004; Shirani Rad and Aabbasian, 2011).

A long-term drought stress effects on plant metabolic reactions associate with plant growth stage, water storage capacity of soil and physiological aspects of plant. Achieving a genetic increase in yield under these environments has been recognized to be a difficult challenge for plant breeders while progress in yield grain has been much higher in favorable environments (Richards et al., 2002). These differences in drought tolerance may be used as criteria for genotype selection in different climate regions. Moreover, interspecific differences are observed at the geographical distribution level. Improvement of productivity of rapeseed genotypes under drought stress has rarely been included in breeding programs (Cheema and Sadaqat, 2004). In addition, research on drought tolerance in rapeseed is limited and mostly based on a few genotypes (Tahir et al., 2006). Many researchers have reported a marked reduction in the yield of rapeseed because of drought (Cheema and Sadaqat 2004). There are quantitative differences in drought tolerance in collections of inbred rapeseed lines, so it is possible to improve genetically drought tolerance.

Therefore, the objective of the present investigation was to survey the effect of water deficit stress on the agronomic characters and physiological exchanges and quantitative and qualitative Characteristics of Canola genotypes (*Brassica napus* L.) cultivars. These findings can provide a good foundation to guide rapeseed breeders researching the potential of heterosis expression for seed yield in cultivars relatively tolerant and sensitive to drought.

Materials and Methods

Experiments were laid out in a split-plot design based on randomized complete block design (RCBD) with four replications at the experimental farm of Seed and Plant Improvement Institute, Karaj, Iran (latitude 35°55′N, longitude 50°54′E, elevation 1313 m above mean sea level) during 2008-2010.

Factor A included Two irrigation levels (irrigation after 80 mm evaporation from class "A" pan as control (irrigation during full season) and no irrigation from stem elongation stage) and factor B consisting of winter rapeseed at 23 cultivars ('SW0756', 'Modena', 'Geronimo', 'Elite', 'Opera', 'ARC-4', 'ARG-91004', 'ARC-5', 'ARC-2', 'Digger', 'Adder', 'Milena', 'RG9908', 'Dexter', 'Alice', 'Olara', 'Ebonite', 'Syn-4', 'Zarfam', 'SLM046', 'Okapi', 'Orient' and 'Elvice'). These twenty-three rapeseed genotypes were chosen based on their considerable level of variability in yield and drought tolerance. Every plot consisted of six rows of 6 m length with a row distance of 0.3 m. Distances between plots were 1.5 m.

The water amount used was regularly calculated according to the collected evaporation of a Class A Basin using the equation:

$$IW/CPE = 0.8,$$

where IW=the amount of irrigation water (mm) and CPE=the collected evaporation calculated from evaporation pan (mm). Amount of precipitation was measured by an udometer and daily evaporation by a Class A evaporation pan.

Seeds were planted 1 to 1.5 cm deep at a rate of 100 seeds m^{-2} on 5 October 2008 and 2009. Nitrogen fertilizer was applied uniformly by hand across all treatments (50 kg N ha^{-1} at sowing in the form of urea (46 % N), 50 kg N ha^{-1} top-dressed at the start of stem elongation, and 50 kg N ha^{-1} top-dressed at the start of flowering stages). Other fertilizers were applied before plowing at recommended rates (60 kg ha^{1} P_2O_5 and 50 kg ha^{1} K_2O). Weeds were controlled by application of haloxyfop- R-methyl ester (Gallant Super, 10% EC) at 0.6 L ha^{-1}. Broadleaf weeds were also hand weeded during the season. Final harvests were carried out on 10 June 2009 and 25 June 2010.

During crop growth and at harvesting, many characteristics were measured, including number of pods per plant, number of seeds per pod and 1000-seed weight. Main stem length was measured as the plant height. The seed yield was measured by harvesting 4.8 m^2 of the central part of each plot at crop maturity. Oil content was determined by the nuclear magnetic resonance (NMR). Oil yield was obtained multiplying seed yield by oil content.

The data were analyzed using SAS software (SAS System, 1996) for analysis of variance and cluster analysis of genotypes based on Euclidean distance, and Duncan's multiple range test ($p \leq 0.05$) was employed for the mean comparisons.

Results and Discussion

Based on variance analysis, irrigation treatments were significant differences on all of traits except of oil contents; cultivar effects were significant in all evaluated attributes. The combined analysis of variance showed that except of number of seeds per pod, variety-by-irrigation interaction was significant under drought conditions and the differences among the 23 studied genotypes from the first year to the second year were not similar (Table 1). Thus, the results of these experiments indicated that the variety × irrigation interactions are unavoidable in agricultural investigations. The main effect of year was significant and showed that mean traits of genotypes across two years were different (Table 1). Yan (2002) indicated that, typically, environment (year) explains most (up to 80% or higher) of the total yield variation in multi-environment trials, and genotype and G × Y are usually relatively small. The humidity regime was different, but also other climatic conditions were variable for both of the experiments across years.

In all cultivars, stress at the beginning of stem elongation reduced plant height. Reduction of plant height could be due to the reduction in the area of photosynthesis, dropping in producing chlorophyll, rising of the energy consumed by the plant in order to take in water and to increase the density of the protoplasm and to change respiratory paths and the activation of the path of phosphate pentose, or the reduction of the root deploy, etc. (Moaveni et al., 2010). The lowest and highest amount of plant height was in 'Okapi' (90.2 cm) and 'Elvice' (120.5 cm) in water deficit, respectively (Table 2). It is a general observation that dwarf varieties over yield than tall ones, they resist lodging and more efficient in nutrient uptake (Inayt-ur-Rahman, 2009). The reduction in plant height causes an increase in grain yield, because of good response to higher doses of fertilizer and tolerance to lodging under unfavorable weather conditions (Olejniczak and Adamska, 1999). Shah et al. (1990) revealed that the dwarfness in plant height is associated with earliness in maturity.

Genotypes with having more pods per plant will give more seed and more oil. Most mean values for number of pods per plant for 23 genotypes in stress condition (Table 3), belonged to Elvice cultivar (154.5) and Modena, Digger, Milena, Dexter and SLM046 had least pods per plant with 55.6, 52.6, 49.5, 50.2 and 53.8, respectively. Islam et al. (2004) have reported similar results for number of pod per plants. Sieling et al. (1997) reported that oil-seed rape grown after wheat had more pods per plant, due to an increase in the number of pods on the higher category branches. Investigations showed that water movement into leaf depends on existence of water potential gradient between xylem and leaf, so that reduction in water potential of xylem decreases water potential gradient between xylem and leaf. Therefore, number of seed per pod de-

Table 1
Variance analysis of determined characteristics in winter rapeseed cultivars in combined analysis over two successive years (2008-2010)

SOV	df	Plant height, cm	Number of pods per plant	Number of seeds per pod	1000-seed weight, g	Seed yield, kg ha^{-1}	Oil content, %	Oil yield, kg ha^{-1}
Year	1	120799.5**	523238.3**	3424.42**	55.646**	74529000.3**	1074.7**	7709581.3**
Error	6	116.799	3123.23	8.932	0.255	957957.6	22.22	140654.8
Irrigation	1	19085.76**	333393.6**	669.17**	32.976**	84158609.4**	35.7ns	19905142.5**
Irrigation×Year	1	1.753ns	3856.84ns	14.339ns	1.693**	3962420.1**	173.1**	2334566.7**
Error	6	37.766	3150.94	3.263	0.046	248432.3	6.237	604/37820
Variety	22	32.944**	25358.61**	35.013**	1.158**	1300144.4**	4.84**	299527.9**
Variety×Year	22	210.363**	15086.6**	25.516**	0.624**	524509.4**	3.2ns	105786.9**
Variety×Irrigation	22	284.426**	3374.45**	2.803ns	0.213**	408024**	5.89**	89645.7*
Variety×Irrigation× Year	22	79.305*	2043.87**	3.494	0.126ns	203255.6ns	3.515ns	56310.6ns
Error	264	45.577	233.96	2.353	0.107	192750.2	2.224	47390.9
CV %		5.7	13.19	6.96	7.52	12.44	3.22	13.35

ns, * and **: nonsignificant, significant at the 5% and 1 % levels of probability, respectively.

creased under water deficit stress. Number of seed per pod revealed that genotype ARC-2 has highest number (25.56) of seeds per pod followed by SW0756 with 24.59 seeds per pod, while lowest mean value of seed per pod is 19.2 for Zarfam.

1000-seed weight differed among the test varieties and was highest in 'SLM046' (Table 3). The reduction in seed weight was due to reductions in number of seeds plant^{-1} as well as number of seeds pod^{-1}.Water stress was effective on sink size, reduced the sources capacity, and caused reduction of seed weight consequently. Ahmadi and Bahrani (2009) expressed that in the water stress during reproductive stage of rapeseed (particularly flowering and sacs formation) was a critical period for seed and oil yields and caused reduction of sacs per plant. Under stress condition, decrease in storage of assimilates in leaves had reduced the photosynthate supply to the grains of wheat due to decrease of sucrose and fructan contents of the internodes leading to weight reductions (Kuhbauch and Thome, 1989). McEwen et al. (1981) reported a decrease of about 34% in the mean seed weight of the stressed faba bean plants, compared to the fully irrigated treatment. Although seed weight is a known component of yield, which reflects relationship between source and sink of photosynthate during pod filling stage, and it is where compensation for earlier losses of pods may occur, thus enhancing the final yield (Dantuma and Thompson, 1983).

The yield response to water deficit of different crops is of major importance in production planning. Water deficit in crops and resulting water stress on plants affect crop evapotranspiration (ET) and crop yield. When water supply does not meet crop water requirements, actual evapotranspiration (ETa) will fall below maximum evapotranspiration (ETm). Under such conditions, water stress will develop in plants, which adversely affects crop growth and ultimately crop yield. However, for a full evaluation

Table 2
Mean comparison of simple effects for yield and yield components of rapeseed cultivars over two successive years (2008-2010)

Treatment	Plant height, cm	Number of pods per plant	Number of seeds per pod	1000-seed weight, g	Seed yield, kg ha^{-1}	Oil content, %	Oil yield, kg ha^{-1}
SW0756	117.9 c-i	151.2 d	24.59 ab	4.19 h	3293 d-g	46.03 b-e	1517 e-h
Modena	122.9 a-d	78.16 jkl	22.88 cde	4.22 gh	3923 a	46.64 a-e	1833 ab
Geronimo	124.4 ab	145.7 de	23.94 bc	4.37 c-h	3817 ab	46.77 a-d	1773 ab
Elite	122 a-e	96.79 h	21.76 d-h	4.59 bc	3931 a	47.16 abc	1850 a
Opera	109.4 j	149.1 de	22.14 d-g	4.58 bcd	3251 e-h	45.94 cde	1488 fgh
ARC-4	116.4 f-i	91.16 hi	22.42 def	4.26 fgh	3462 b-f	45.49 e	1560 c-h
ARG-91004	115.4 ghi	132.8 f	24.18 b	4.47 b-g	3587 a-e	46.4 b-e	1656 b-f
ARC-5	113.6 ij	72.6 klm	21.64 e-h	4.68 b	3777 abc	46.14 b-e	1736 abc
ARC-2	125.4 a	163.1 c	25.56 a	4.24 gh	3430 c-g	45.92 cde	1561 c-h
Digger	113 ij	82.5 ijk	22.94 cd	4.38 c-h	3328 d-g	46.33 b-e	1534 d-h
Adder	117.1 d-i	139.2 def	21.34 f-i	4.31 e-h	3293 d-g	45.49 e	1495 e-h
Milena	121.5 a-f	62.56 m	20.64 hi	4.32 d-h	3593 a-e	46.68 a-e	1675 a-e
RG-9908	123.3 abc	138.5 ef	22.04 d-g	4.56 b-e	3727 abc	46.03 b-e	1711 a-d
Dexter	118.7 c-i	81.1 ijk	21.36 f-i	4.37 c-h	3733 abc	47.71 a	1766 ab
Alice	116.5 e-i	141.8 def	20.56 hi	4.22 gh	2933 h	47.23 ab	1384 h
Olara	120.9 a-g	88.67 hij	21.67 e-h	4.55 b-e	3614 a-e	45.78 de	1658 b-f
Ebonite	122.4 a-d	144 def	22.17 d-g	4.23 gh	3880 a	46.29 b-e	1796 ab
Syn-4	115.1 hi	71.56 klm	23/20 ij	4.32 c-h	3922 a	46 b-e	1805 ab
Zarfam	115.4 ghi	120.1 g	19.2 j	4.998 a	3310 d-g	46.59 a-e	1534 d-h
SLM046	119.3 b-h	66.76 lm	21.34 f-i	4.52 b-f	3634 a-d	46.25 b-e	1670 a-e
Okapi	113.5 ij	177.9 b	21.05 ghi	3.68 I	3450 c-f	45.94 cde	1574 c-g
Orient	116.3 f-i	75.28 kl	22.43 def	4.33 c-h	3222 fgh	46.22 b-e	1482 fgh
Elvice	125.1 a	196.6 a	21.05 ghi	3.83 i	3088 gh	46.81 a-d	1437 gh

Mean followed by the same letter(s) in each column (between to horizontal lines) are not significantly different (Duncan 5%)

Table 3
Mean comparison of interaction effects for yield and yield components of rapeseed cultivars over two successive years (2008-2010)

Treatment	Plant height, cm		Number of pods per plant		1000-seed weight, g		Seed yield, kg ha^{-1}		Oil content, %		Oil yield, kg ha^{-1}	
	Common irrigation	Drought stress	Common irrigation	Drought stress	Common irrigation	Drought stress	Common irrigation	Drought stress	Common irrigation	Drought stress	Common irrigation	Drought stress
SW0756	121.8 d-k	114.1 k-p	181.9 de	120.5 i	4.32 e-l	4.06 k-o	3774 d-i	2813 mno	46.95 a-h	45.12 h-m	1766 e-i	1268 opq
Modena	132.3 ab	112.5 l-p	100.7 j-m	55.6 s	4.51 c-i	3.92 m-q	4504 ab	2342 h-m	47.95 ab	45.33 g-m	2154 a	1513 i-o
Geronimo	129.4 a-d	119.3 f-m	169.5 efg	121.9 i	4.69 b-e	4.05 k-o	4320 abc	3314 h-m	47.26 a-e	46.28 b-m	2038 a-d	1508 i-o
Elite	126.7 b-g	117.3 i-o	113.2 ijk	80.4 nop	5.02 b	4.16 h-o	4379 abc	3482 f-k	47.6 abc	46.72 a-k	2076 abc	1625 g-m
Opera	114.5 j-p	104.2 r	207.4 b	90.8 m-p	4.82 bcd	4.35 e-k	3967 c-g	2535 no	46.2 b-m	45.58 d-m	1823 c-h	1153 pq
ARC-4	121.1 e-k	111.7 m-r	108.8 i-l	73.6 pqr	4.45 d-j	4.07 j-o	3990 b-f	2934 lmn	45.37 f-m	45.6 d-m	1795 d-h	1325 n-q
ARG-91004	121.1 e-k	109.7 o-r	164.6 fgh	101.1 j-m	4.67 b-e	4.26 f-m	4119 a-e	3056 klm	46.49 a-l	46.32 b-m	1906 a-f	1406 m-p
ARC-5	118.3 h-n	108.9 pqr	87.7 m-p	57.7 rs	5.05 b	4.3 e-m	4365 abc	3189 j-m	46.1 b-m	46.19 b-m	2004 a-e	1468 k-o
ARC-2	132.6 ab	118.3 h-n	200.8 bc	125.5 i	4.54 c-h	3.95 k-q	4040 a-e	2819 mno	44.83 l-m	47 a-g	1802 d-h	1320 n-q
Digger	119.6 f-m	106.5 pqr	112.4 ijk	52.6 s	4.58 c-g	4.18 h-n	3751 d-i	2904 l-o	46.51 a-l	46.15 b-m	1741 f-j	1328 n-q
Adder	121.8 d-k	112.3 m-q	164.9 fgh	113.5 ijk	4.64 c-f	3.98 k-p	3769 d-i	2818 mno	45.38 f-m	45.59 d-m	1712 f-k	1279 opq
Milena	130.2 abc	112.7 l-q	75.6 opq	49.5 s	4.67 b-e	3.96 k-q	4140 a-d	3047 k-n	47.08 a-g	46.28 b-m	1942 a-f	1409 m-p
RG-9908	127.3 b-f	119.4 f-m	175.8 def	101.2 j-m	4.79 bcd	4.34 e-l	4555 a	2899 l-o	46.65 a-l	45.42 e-m	2111 a	1312 opq
Dexter	127.7 b-e	109.6 o-r	112.1 ijk	50.2 s	4.61 c-g	4.13 i-o	4072 a-e	3394 h-l	48.17 a	47.24 a-f	1951 a-f	1581 h-n
Alice	120.5 e-l	112.6 l-q	190.4 cd	93.2 l-o	4.5 c-i	3.94 l-q	3464 g-k	2402 o	46.94 a-h	47.52 abc	1629 g-m	1139 q
Olara	130.3 abc	111.5 m-r	116.9 ij	60.4 qrs	4.88 bc	4.23 g-m	3942 c-g	3286 h-m	47.03 a-g	44.52 m	1851 b-g	1464 k-o
Ebonite	125.9 b-h	118.9 g-m	190.3 cd	97.8 k-n	4.49 c-i	3.96 k-q	4504 ab	3256 i-m	46.53 a-l	46.04 c-m	2091 ab	1500 j-o
Syn-4	122.6 c-j	107.5 pqr	85.1 m-p	58 rs	4.82 bcd	3.83 n-q	4336 abc	3509 f-k	47.06 a-g	44.94 klm	2033 a-d	1577 h-n
Zarfam	125.2 b-i	105.6 qr	149.9 h	90.2 m-p	/5.5 a	4.17 h-n	3504 f-k	3117 j-m	46.81 a-j	46.36 a-m	1631 g-m	1436mno
SLM046	127.9 b-e	110.8 n-r	79.7 op	53.8 s	4.87 bc	4.49 c-i	4115 a-e	3154 j-m	46.56 a-l	45.94 c-m	1902 a-f	1439mno
Okapi	136.9 a	90.2 s	242.8 a	113.1 ijk	3.77 opq	3.58 q	3800 d-h	3100 j-m	45.07 i-m	46.82 a-j	1705 f-k	1443 l-o
Orient	127.3 b-f	105.2 qr	90.5 m-p	60.1 qrs	4.87 bc	3.79 n-q	3614 e-j	2829 mno	47.42 a-d	45.02 j-m	1702 f-l	1262 opq
Elvice	129.7 a-d	120.5 e-l	238.8 a	154.5 gh	4.04 k-o	3.62 pq	3175 j-m	3000 k-n	46.93 a-i	46.68 a-l	1481 k-o	1392 m-q

Mean followed by the same letter(s) in each column (between to horizontal lines) are not significantly different (Duncan 5%)

of the effect of limited water supply on yield and production, consideration must be given to the effect of the limited water supply during individual growth stages of the crops. The response of yield to water supply is quantified through the yield response factor, which relates relative yield decrease to relative ET deficit (Doorenbos and Kassam, 1979; Pejić et al., 2009). Lawler and Comic (2002) expressed that in the water deficit stress conditions, reducing of dry matter can be due to reduction of cell turgor pressure and chlorophylls. Sangtarash et al. (2009) reported that the water deficit stress condition decreased dry matter of individual plant and photosynthetic rate because biochemical restrictions in of water deficit condition, and reduced photosynthetic pigments, especially chlorophylls. Lowest rate of seed yield in stress conditions in 'Modena' (2342 kg ha^{-1}) and the highest in the normal condition of irrigation at 'RG-9908' (4555 kg ha^{-1}) were obtained (Table 3). Wright et al. (1995) compared compatibility of *Brassica napus* and *Brassica juncea* in water stress conditions. Results showed that both species decreased yield.

Significant difference in oil content was observed between treatments at water stress. With the comparison of interaction of cultivar and irrigation, control irrigation was found that Modena had the highest percentage of oil content with average 47.95 %, and the highest oil content under drought stress conditions belonged to Alice (47.52 %) (Table 3). Mailer and Cornish (1987) determined that oil content fell from 36.9 to 31.4% when high temperature occurred during the post anthesis seed development in canola. Jensen et al. (1996) found that under low evaporative demands (2-4 mm day^{-1}) oil and seed yields were not influenced by soil drying. Under high evaporative demands, (4-5 mm day^{-1}) oil and seed yields were significantly decreased.

Since oil yield was obtained through multiplying oil content by seed yield and magnitude of changing oil content in modified rapeseed cultivars is low, therefore seed yield has the greatest effect on oil yield. Through breeding and selecting of cultivars for achieving high seed yield, high oil yield can also be achieved. In all tested cultivars, water stress reduced oil yields (Table 3). Highest oil yields rate in 'Modena' (2154 kg ha^{-1}) of control condition and lowest rate of oil yields (1139 kg ha^{-1}) in 'Alice' variety in stress conditions was seen. Among the tested cultivars in this experiment, 'Elite' showed minimum reduction in the oil yields that can be cause of more tolerance of this cultivar to water stress. Sinaki et al. (2007) for determination of the effect of water deficit stress at different growth

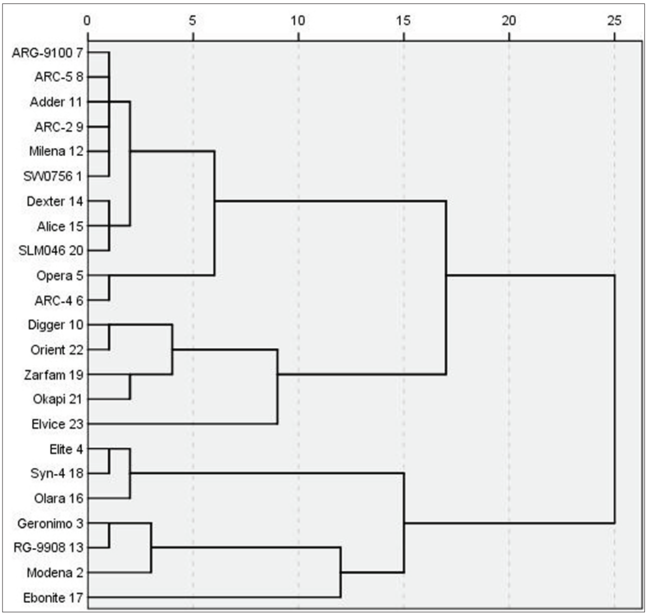

Fig. 1. Dendrogram resulting from cluster analysis of genotypes based on stress tolerance and susceptibility indices for grain yield in normal and stress condition

Table 4
Correlation coefficients between characters calculated from twenty three rapeseed cultivars over two successive years (2008-2010)

Characters	Plant height, cm	Number of pods per plant	Number of seeds per pod	1000-seed weight, g	Seed yield, kg ha^{-1}	Oil content, %
Number of pods per plant	0.54**	1				
Number of seeds per pod	0.6**	0.52**	1			
1000-seed weight	0.49**	0.16ns	0.41**	1		
Seed yield	0.67**	0.33*	0.59**	0.66**	1	
Oil content	0.31**	0.08ns	0.12ns	0.35*	0.32*	1
Oil yield	0.67**	0.32*	0.57**	0.67**	0.99*	0.42**

ns, * and **: nonsignificant, significant at the 5% and 1 % levels of probability, respectively.

stages of canola reported that at the time of occurrence of stress, oil concentration and the oil yields decreased.

A significant positive correlation between the oil yields and other traits observed (Table 4). Chaudhary et al. (1990) reported that grain yield has related to harvest index and caused increasing of dry matter and oil yields. Seed yield in plant has most positive direct effect on oil yield. Hosseini and Hassibi (2011) reported same results.

Cluster analysis has been widely used for description of genetic diversity and grouping based on similar characteristics (Golestani et al., 2007; Golabadi et al., 2006; Malek Shahi et al., 2009; Souri et al., 2005). As it appears in Figure 1, the genotypes were classified in three groups with low intra- and high extra-group similarities.

Conclusions

It should be possible to improve seed yield and drought tolerance in the rapeseed breeding programs by selecting within segregating populations. Successful breeding programs focus initially on yield enhancement under non-stress conditions, but should also incorporate genes that improve seed yield under drought (stress) conditions. As it was shown in the results of this study, water deficit stress had a negative effect on most of the morphological features under study. The selection of cultivars can increase quantity and quality yields of rapeseed under drought stress, which perform well over a wide range of environments. Consequently, our findings may give applicable advice to farmers and agricultural researchers for management and proper use of irrigation in farming of rapeseed under drought regions.

The overall performance of the genotypes for yield indicates that under Stress, Zarfam and Elvice cultivars are superior to all other cultivars. Hence, they can withstand low levels of water regimes. The higher tolerance of Zarfam and Elvice cultivars to water shortage may be related to their lowest intrinsic growth rate and stomatal control of gas exchange.

Majid and Simpson (1997) reported that low water condition might be attributed to increased senescence of leaves, which reduced photosynthetic rate thus causing low yield. Further investigation should address photosynthesis, water use efficiency, stomata1 conductance and growth under water deficit conditions. Additional research should be done to elucidate possible adaptive mechanisms such as osmotic adjustment, leaf ABA levels and morphological characteristics, which may enable field capacity (FC) to survive under water deficit conditions.

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