Investigation the Response of Rapeseed Cultivars to Moisture Regimes in Different Growth Stages

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Abstract

In order to evaluate the response of rapeseed cultivars to moisture regimes and correlation analysis in different growth stages, a field experiment was conducted in 2006-7 in seed and plant improvement institute of Karaj, Iran. Results showed that number of pods per plant, pod length, stem diameter, 1000-seed weight, oil seed content and branch numbers per plant were reduced significantly under water deficit stress. Also, grain yield was decreased more than biological yield and this resulted in decreased harvest index. Correlation coefficient analysis revealed that number of pods per plant, number of seeds per main and secondary pod, 1000-seed weight, pod length, biological yield and oil seed content had positive and significant correlation with seed yield. Stopping the irrigation from flowering stage also had undesirable effect on seed yield and its components. Among cultivars, Opera cultivar produced more seed yield (4053 kg ha^{-1}) than the others under normal irrigation and under water deficit stress conditions, Zarfam cultivar had the maximum seed yield during stem elongation (3569 kg ha^{-1}), flowering (2135 kg ha^{-1}) and podding stages (2476 kg ha^{-1}). Okapi had the least changes of oil content than other cultivars. Based on the result of this study can be concluded that Zarfam cultivar had better capability to tolerate drought stress and could produce greater seed yield under stress conditions

Keywords: Rapeseed, Water deficit stress, Seed yield, Yield components

INTRODUCTION

Brassica nupus L., an ancient crop plant, belongs to the *Cruciferae* (*Brassicaceae*) family [23]. Oilseed rape is now one of the most important oil crops in the world. Most oilseed rape crops grown in Iran are established in autumn and usually drought is an important limiting factor.

Drought is a major stress factor which limits crop production in most areas in the world. Even temporary drought can cause substantial losses in crop yield [22]. The greatest challenge for the coming decades will be the task of increasing food production with less water, particularly in countries with limited water and land resources. Water productivity in terms of out put per unit of food per m3 of water used needs to be increased in both irrigated and rain fed agriculture substantially: in short: more crop per drop [9].

The effect of drought stress is a function of genotype, intensity and duration of stress, weather, conditions, growth and developmental stages of rape seed [29]. Reproductive organs and seeds of crops are constructed from resources either recently acquired or previously stored in the vegetative parts [6]. The occurrence time is more important than the water stress intensity [13]. Mingeau [19] demonstrated a critical period from anthesis to anthesis +2 weeks when water supply was reduced by 50% in this period. Seed yield was reduced by 20%, the greatest effects being upon number of pods and seeds per plant. Nevertheless, some compensation occurred when the water stress was relieved before ripening time. According to investigation of Mir Mousavi *et al*. [20], seed yield in plant has most positive direct effect on oil yield and next oil content. Harvest index had great positive correlation with oil yield. Great positive correlation was due to its indirect effect via seed yield in each plant. Pazouki [26] showed that shortening interval irrigation increases 1000-seed weight, also It is observed that with increasing water to 80 % evaporation from class “A” pan, 1000-seed weight achieves to uttermost and with increasing period of irrigation, 1000-seed weight decreases significantly. In experiment with nine summer rapeseed, Chango and McVetty [5] observed that total dry matter and harvest index had a significant correlation with seed yield. Under field conditions, Krogman and Hobbs [14], Henry and MacDonald [11] and Wright *et al*. [35] found that early drought (occurring at green bud stage) could lead to seeds containing less oil compared with the control, implying that allocation of assimilates to the ovule at the early stage of the megaspore could be related to the final oil concentration.

The most pronounced effects are observed when water shortage occurs during the flowering or pod filling stages [7, 28]. Ali *et al*. [2] also showed that harvest index had a significant correlation with seed yield. In the yield components, number of pods per plant was correlated significantly with seed yield [25]. Also a significant correlation was observed between pod numbers per plant and seed yield in species of *B. napus* and *B. compestris* [33]. This showed that among yield component number of pods had the greatest and seeds per pod and seed weight had weak influence on seed yield.

Rahnema and Bakhshande [27] reported that the highest rate of yield reduction was occurred by spring irrigation cut off and one spring irrigation treatments in PF which was the late maturity variety. Also the lowest rate of yield reduction was obtained in spring irrigation cut off and one spring irrigation treatments in H308 hybrid, respectively. Nielsen [24] reported that water stress during the seed-filling stage resulted to decrease yield through fewer branches per plant, pods per branch and smaller seed. Mailer and Cornish [15] 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*. [12] 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. Thus, it is very important to determine critical stages of oilseed rape crops against drought stress.

In the present study, four rapeseed genotypes were subjected under water stress by withholding irrigation during three different stages. At harvest, various parameters related to seed biochemical and nutritional composition were determined with the aim of, firstly, defining windows of sensitivity to stress during development and, secondly, evaluating the degree of coupling between seed quality and vegetative

MATERIALS AND METHODS

Experimental Treatments and Field Design: This study was carried out at the experimental farm of Seed and Plant Improvement Institute, Karaj, Iran (latitude 35°55′ N, longitude 50°54′ E, elevation 1313m above mean sea level) in 2006-2007. The climate data of region are representing in (Table1). The soil has loam texture with low organic matter and some physical and chemical proprties are shown in the Table 2.

Table 1: Climatic data of experimental farm of Seed and Plant Improvement Institute in 2006-7 (in growth period) *,**

Year and Months 2006-7	Total Rainfall (mm)	Min Temp. (°c)	Average Temp. (°c)	Max Temp. (°c)	Relative Humidity (%)
October	72	12.82	18.5	24.21	55.06
November	16	3.46	8.16	12.8	58.21
December	35.9	-2.33	1.17	4.80	70.41
January	11.6	-2.93	6.72	1.89	60.35
February	40.8	1.28	9.77	5.53	62.89
March	34.9	3.87	13.08	8.47	58.7
April	29.9	8	15.3	21.7	47
May	20.8	13.5	21.2	29.2	36

* Taken from the recording of irrigation department in agricultural & natural resource faculty of Seed and Plant Improvement Institute., ** (Data recording): meteorological data were collected 300m from the experiment site. Maximum and minimum temperature, rainfall and class A pan evaporation data for the experimental period

Table 2: Result of some chemical and physical analysis of experimental soil

Depth (cm)	Potassium (mg kg^{-1})	Phosphorus (mg kg^{-1})	N (%)	Saturation (%)	EC (mmos cm^{-1})	pH
0-30	285	9.7	0.53	36	7.0	7.7
30-60	307	6.52	0.32	39.5	6.0	7.8

*Soil analysis was done at the laboratories of soil science department in Seed and Plant Improvement Institute.

The experimental design was split plot on basis of randomized complete block design (RCBD) with three replications. Four irrigation levels consist of irrigation after 80 mm evaporation from class “A” pan as control, stopping the irrigation from stem elongation stage, flowering stage, podding stage were applied in main plots and subplots which consisted of split plots were devoted of four cultivars (Opera, Modena, Zarfam and Okapi).

Growth experiment: Individual plot consist of 6 rows, 6 m long and spaced 30 cm apart using a seeding rate of 7 kg ha^{-1}. The experimental fields were mould-board ploughed and seedbed preparation consisted of two passes with a tandem disk. Seeds were planted 1 to 1.5 cm deep at a rate of 100 seeds m-2 on 4th October 2006. For all treatments, N:P:K fertilizers applied at a rates of 150:60:50 kg, respectively. P, K and one-third of N were applied per plant and incorporated. Other two-third of N was split equally at the beginning of stem elongation and flowering. Weeds were controlled by application of gallantsuper (Haloxyfop R-methyl ester) at 0.6 L ha^{-1}. Broadleaf weeds were also hand weeded during the season. Final harvests were carried out at the 10th June 2007.

Estimation of traits: Data collected included achene yield determined after drying at 70°C for at least 48 h (obtained by combining the six center rows at each experimental unit), dry matter was in an air oven. The following measurements were carried out: biological (aboveground) and seed yields, harvest index (seed yield divided by biological yield), number of pods per plant (with at least on seed), pod length, stem diameter, branch numbers per plant, number of seed per main and secondary pod and 1000-seed weight. Seed oil was determined by the Nuclear Magnetic Resonance (NMR). Numbers of pods per plant and seeds per pod were counted from 40 randomly selected pods after hand threshing. Main stem length was measured as the plant height.

Statistical analysis: The experimental data were statistically analyzed for variance using the SAS system and SPSS program for correlation parameter [30]. When analysis of variance showed significant treatments effects, Duncan Multiple Range Test was applied to compare the means at $P<0.05$.

RESULT

Effect of irrigation treatments and cultivars were significant on all of traits except number of grain per main and secondary pod. Number of pods in plant, branch number per plant, seed yield and harvest index was significantly different among cultivars. Sinaki *et al*, [32] reported the existence of variation for drought response among the cultivars under irrigation regimes. The irrigation × cultivars interaction for pod length, seed weight, biological and seed yield and oil content was significant (Table 3).

Mean values and variation of traits: Stopping the irrigation from stem elongation, flowering and podding stage decreased biological yield by 18.98, 33.93 and 27.41 %

and seed yield by 1.44, 8.67 and 14.1 % compared to the moderate irrigation, respectively (Table 4). Modena was the most sensitive cultivar to water stress in terms of biological and seed yield. Opera produced the most seed yield; however stopping irrigation from stem elongation, flowering and podding stage decreased its seed yield by 12.25, 40.54 and 32.78 % compared to the control, respectively. Silim *et al.* [31] and Grazesiak *et al*. [10] reported that yield was reduced under drought stress. In Table 3, seed yield was most sensitive traits to water stress,while oil content was more tolerant ones according to the coefficient variance. Under moderate irrigation, Okapi produced more number of pods per plant than other cultivars, while fewer under water stress treatments. Ozer *et al*. [25] suggested that pod numbers could be a good selection criterion for increasing seed yield in rapeseed. Numbers of seeds per pods and 1000-seed weight in Ebonit were significantly higher than other cultivars. In Opera, biological yield was significantly higher than other cultivars as well as seed yield. Also, oil content in Modena was significantly higher than other cultivars (Fig.1, Table 4). The effect of water stress intensity was significant ($p = 0.05$) on the seed oil content (Table 4). Oil content was decreased by 2.83, 10.67 and 17.21 % under stopping the irrigation from stem elongation, flowering and podding stage compared to the control, respectively. There were statistically significant decreases in oil seed concentration during stem elongation and flowering water-stressed cv. Opera and podding water stressed cv. Modena (Fig. 1).

Correlation between traits: The correlation coefficient between traits in different growth stages are showed in Table 5. Seed yield was significantly correlated with biological yield ($r=0.919$ $p< 0.01$). This is expected to occur where more assimilates available to seed development ate associated with more vegetative growth. These results were consistent with findings of Migdadi and Duwayri [18]. Seed yield significantly correlated with number of pods per plant, number of seeds per main and secondary pod, 1000-seed weight, pod length, biological yield and oil content. These results revealed the importance of these traits as a criterion for winter oilseed rape yield improvement. Therefore, selection for increasing seed yield through these traits might be more successful. It can be suggest that these traits are important characters under water deficit stress conditions. Regarding oil content, correlation study revealed that in general, the association between seed oil content and the other characters showed consistent trend. It was positively correlated with number of grain per main and secondary pod, number of pods in plant, stem diameter, seed weight, biological and seed yield and harvest index. Obviously, Oil content was negatively correlated with only Branch number per plant.

DISCUSSION

The results of this experiment showed that marked changes in traits were because of agents of climate particular water stress and population of plant didn’t have effect in measured traits. First, flowering was the critical stage of rapeseed to water stress. At this stage, the maintenance of a positive turgor potential through a low leaf water potential (-1 Mpa) was decisive in the control of water deficit. Variation between species was evident. On the basis of results presented here for the drought tolerance of the four rapeseed cultivars, it can be concluded that Zarfam was the most tolerant and Okapi the most sensitive to high drought stress. By contrasting the four cultivars, defined that the Zarfam had a higher tolerance to water deficit condition, that the reason of these were higher physiological performances such as relative water content, stomatal conductance, leaf relative water content, chlorophyll and proline under water deficit conditions. On the other hand, Zarfam created higher osmotic potential and could absorbed more water from lower depths in soil. Also, this variety had a high potential of production in normal irrigation and high nitrogen consumption. Improvement in adaptation of rapeseed to water stress environments requires improved tolerance to water deficient during flowering and podding stage.

Seed yield and quality are the product of many growth processes occurring throughout the development of the plant [21]. Seed yield reduction due to water stress during flowering (I_3) was associated with the reduction of the biological yield and harvest Index. Seed yield reduction at I_2 and I_4 treatments were also associated mostly with the reduction of number of pods per plant. Since, water stress during seed development did not affect on the sink size (seeds per plant), decreased source capacity led to reduction of seed weight. Champolivier and Merrien [3] reported that the most sensitive period of *B.napus* to water stress was between flowering and pod development. Water stress during vegetative or early reproductive stages of soybean usually reduces yield by reducing seed numbers per unit area [13], while stress during seed filling reduced seed size [3, 8, 16]. In rapeseed, Mendham *et al*. [17] have argued that canola breeders should be aiming to produce plants with fewer pods but with a higher potential number of seeds per pod as this maximize seed survival and hence increased seed numbers per unit area. Between water stress treatments, harvest index was higher at I_1 treatment because water stress during stem elongation was more affected straw dry matter production than seed yield. The reduction of vegetative dry matter is due to reduction of leaf area and photosynthesis rate [34]. Ali *et al*. [1] observed an increase in harvest index following drought stress, but Wright *et al*. [35] obtained reduction of harvest index. The degree of branching depends on variety and environmental conditions; branches originate in the axils of the highest leaves on the stem, and each terminates in an inflorescence [23].

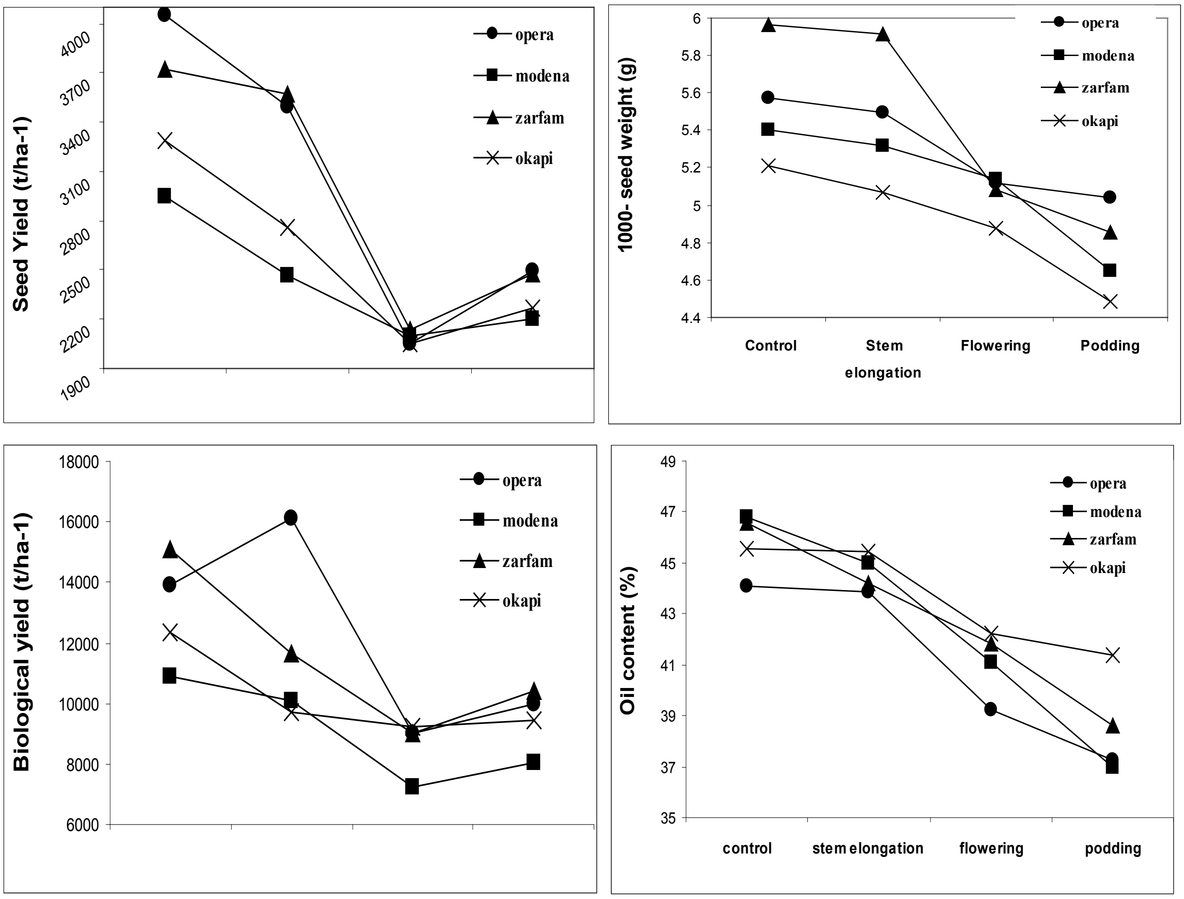

Figure. 1. Changes in seed and biological yield, 1000- seed weight and oil content at different growth stages in four rapeseed cultivar.

Fatty acid composition of storage triglycerides is subject to both environmental and endogenous controls. According to Mingeau [19], water shortage during the late flowering period could induce a delay in lipid biosynthesis in rape seeds involving oleic acid accumulation at the expense of the linolenic and erucic acid contents. In the present study, seeds produced by droughted plants showed significant change in stored oil content concentrations. In our study, the observed variations in oil contents of seeds were apparently more dependent on environmental factors such as water availability than on genotypic traits and reduction of oil content was at podding stage. From the present results, it also appears that water availability during a restricted period of the early stages of rape vegetative growth is of major importance in final yield and accumulation of seed storage components.

It seems that in this study, occurrence of water deficit stress during flowering stage with shorting flowering period and development stage, infertile in some of flowers and their downfall causes reduction of number of bud in plant. In this study, the reason of reduction in seed weight under water deficit conditions could be by reason of stress in development stage caused reduction in absorption of water and nutrient and therefore it reduces photosynthesis and production of elaborate sap. The results of this study showed that performance of supplementary irrigation in rapeseed, length of flowering period increases number of pod and seed in plant. This status presumably is because of more leaf area in length of flowering period and thereupon produces more photosynthesis materials. When this difference studied between mustard species, it was cleared that in water stress conditions, Indian mustard has higher number of seed in each pod as its reason was osmotic adjustment in period of filling seed.

In conclusion, the observed modifications of seed composition in response to water deficits show that there are immediate or long-term, delayed effects on seed composition, depending on the application stage of the constraint. The immediate effects of drought stress during flowering and seed maturation could arise from disturbance in pod and seed metabolic processes, disorders in production and transfer of assimilates in grain filling and/or increased production of undesirable secondary compounds. Delayed effects of water deficits occurring during the vegetative life of the plant are also carried through to final grain yield and quality.

Further experiments need to be performed to identify the attributes that confer yield and seed quality under water-limited conditions, and to define the respective stages of the plant development that are sensitive and resistant to water stress.

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Table 3: Analysis of variance for yield and yield components of rapeseed cultivars

		MS										
SOV	df	Number of seeds per main pod	Number of seeds per secondary pod	Number of pods in plant	Stem diameter (cm)	Pod length (cm)	Branch numbers per plant	Seed weight (g)	Biological yield (kg ha-1)	Seed yield (kg ha-1)	Harvest index	Oil content (%)
irrigation	3	ns	ns	**	**	**	**	**	**	**	**	*
variety	3	ns	ns	ns	*	**	ns	**	ns	**	ns	**
Variety × irrigation	9	ns	ns	ns	Ns	**	ns	**	ns	**	ns	**
CV %	-	12.9	11.9	23.33	11	6	22.5	7.1	24.32	15.4	23.6	3.09

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

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Table 4. Mean comparison for number of seeds per main pod (G/MP), number of seeds per secondary pod (G/SP), number of pods per plant(P/Pl), stem diameter (SD), pod length (PL), branch number per plant (BNP), seed weight (SW), biological(BY) and seed (SY) yields, harvest index(HI), oil content(OC), Control (I1), stopping the irrigation from stem elongation stage (I2), stopping the irrigation from flowering stage (I3) and stopping the irrigation from podding stage (I4)

Treatment	G/MP	G/SP	P/Pl	SD (cm)	PL (cm)	BNP	SW (g)	SY (t ha-1)	BY (t ha-1)	HI (%)	OC (%)
I1	28.16 a	26.63 a	104 a	0.95 a	6.68 a	4.21 a	5.53 a	3501.9 a	13060 a	40.1a	45.9 a
I2	25.8 a	25.61 a	80.68 ab	0.7 b	6.36 ab	2.6 c	5.45 a	3072.9 ab	10580 b	26.8 ab	44.6 a
I3	25.55 a	24.81 a	66.74 b	0.73 b	6.1 b	3.06 bc	5.05 b	2082.3 c	8628 b	24.5 b	41 b
I4	24.43 a	23.38 a	58.38 b	0.77 b	5.9 b	3.5 ab	4.75 b	2354.4 bc	9479 b	24.9 b	38 c
LSD 5%	2.77	2.48	27.69	0.077	0.55	0.80	0.30	862.2	199	12.77	0.57
Opera (V1)	26.08a	25.18 a	7.71 a	0.78 ab	6.83 a	3.76 a	5.3 a	3022.8 a	11500 a	30.3 a	41.3 b
Modena (V2)	25.73 a	24.91 a	84.5 a	0.78 ab	5.93 b	3.35 ab	5.12 ab	2428 a	9062 b	29.7 a	42.4 a
Zarfam (V3)	25.5a	24.76 a	68.62 a	0.75 b	6.09 b	3.06 b	5.45 a	2974.8a	10950 a	28.5 a	42.7 a
Okapi (V4)	26.63a	25.58 a	78.95 a	0.85 a	6.22 b	3.2 ab	4.91 b	2591 a	10190 ab	27.8 a	43.6 a
LSD 5%	2.82	2.52	15.20	0.075	0.31	0.63	0.31	796.5	162	7.31	1.11
Irrigation(I) × Variety (V)											
I1 * V1	26.13 a	27.80 a	87.13 bcd	0.8867bcd	7.36 a	4.20 ab	5.57 ab	4053 a	13890 ab	30.48 ab	44.08 abc
I1 * V2	28.67 a	26.60 a	104.6 ab	0.9067bc	6.32 cde	4.133 abc	5.4 ab	2944 ab	10900bcde	25.56 b	46.79 a
I1 * V3	28.53 a	25.87a	100.3 abc	0.9333ab	6.57 bc	3.867abcd	5.96 a	3719 ab	15070 a	24.28 b	46.58 ab
I1 * V4	26.13 a	26.27a	123.9 a	1.077 a	6.46 bcd	4.667 a	5.21 bc	3292 ab	12360 abc	27.08 ab	45.53 abc
I2 *V1	25.93 a	26.33 a	80.8bcde	0.7133de	7.12 ab	3.26abcde	5.49 ab	3497 ab	10870bcde	43.33 a	43.88 cd
I2 *V2	24.87 a	25.00 a	102.3 abc	0.7000 e	5.96 cde	2.667bcde	5.32 abc	2465 ab	10070 cde	38.86 ab	45.01 abc
I2 *V3	26.27 a	25.27a	64.40 de	0.6667 e	6.08 cde	2.40 de	5.91 a	3596 ab	11670abcd	42.82 a	44.19 bcd
I2 *V4	25.87 a	25.87a	75.2bcde	0.7400cde	6.29 cde	2.067 e	5.07 bcd	2760 ab	9722 cde	35.48 ab	45.42 abc
I3 * V1	25.73 a	24.20 a	67.83 cde	0.7533cde	6.63 bc	3.667abcd	5.14 bcd	2049 b	9028 cde	22.80 b	39.25 fg
I3 * V2	24.47 a	24.73 a	59.20 de	0.760cde	5.63 e	3.067bcde	5.11 bcd	2097 b	7222 e	27.28 ab	41.11 fg
I3 * V3	26.13 a	24.60 a	50.67e	0.6800e	5.97 cde	2.867bcde	5.08 bcd	2135 b	9028 cde	23.48 b	41.83 de
I3 * V4	23.00 a	25.73 a	55.80 de	0.760cde	6.16 cde	2.667bcde	4.88 bcd	2048 b	9236 cde	24.48 b	42.2 de
I4 * V1	25.13 a	22.40 a	75.0bcde	0.773bcde	6.25 cde	3.933abc	5.04 bcd	2493 ab	10000 cde	24.61 b	37.28 g
I4 * V2	24.00 a	23.33 a	71.9bcde	0.766bcde	5.78 de	3.53abcde	4.65 cd	2205 ab	8056 de	27.18 ab	37 g
I4 * V3	25.60 a	23.33 a	59.13 de	0.7067 e	5.75 de	3.13 bcde	4.85 bcd	2476 ab	10420bcde	23.76 b	38.59 g
I4 * V4	26.13 a	24.47 a	60.90 de	0.833bcde	5.97 cde	3.4 abcde	4.48 d	2264 ab	9444 cde	24.38 b	41.36 ef
LSD 5%	5.65	8.99	30.4	0.15	0.63	1.27	0.62	1593	325	14.63	2.22

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

Table 5. Correlation coefficients between characters calculated from four cultivars of winter oilseed rape to moisture regimes during different Growth stages in 2007-8.

Characters	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) Number of seeds per main pod	1	0.821**	0.631**	0.707**	0.65**	0.422 ns	0.461 ns	0.557*	0.578*	0.256 ns	0.535*
(2) Number of seeds per secondary pod		1	0.553*	0.443 ns	0.686**	0.154 ns	0.555*	0.595*	0.647**	0.348 ns	0.78**
(3) Number of pods in plant			1	0.734**	0.419 ns	0.589*	0.463 ns	0.538*	0.63**	0.172 ns	0.526*
(4) Stem diameter				1	0.368 ns	0.805**	0.088 ns	0.351 ns	0.442 ns	0.022 ns	0.192 ns
(5) Pod length					1	0.431 ns	0.53*	0.471**	0.626**	-0.013 ns	0.346 ns
(6) Branch numbers per plant						1	0.088 ns	0.388 ns	0.295 ns	-0.278 ns	-0.185 ns
(7) Seed weight							1	0.696**	0.784**	0.275 ns	0.646**
(8) Biological yield								1	0.919**	-0.08 ns	0.502*
(9) Seed yield									1	0.21 ns	0.636**
(10) Harvest index										1	0.478 ns
(11) Oil content											1

NS, * and **: non significant, significant at the 5% and 1% levels of probability, respectively.

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