Journal of Crop Nutrition Science
ISSN: 2423-7353 (Print) 2538-2470 (Online)
Vol. 7, No. 1, 2021
http://JCNS.iauahvaz.ac.ir
OPEN ACCESS

Effect of Terminal Drought Stress on Seed Yield and Its Components of Rapeseed Cultivars

Peyman Davami[1,2], Mojtaba Alavi Fazel[2]*, Davood Habibi[3], Afshin Mozaffari[4]

1-*Ph.D. Student, Department of Agronomy, Khuzestan Science and Research Branch, Islamic Azad University, Ahvaz, Iran.*
2- *Department of Agronomy, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran.*
3- *Department of Agronomy, Karaj Branch, Islamic Azad University, Karaj, Iran.*
4- *Department of Agronomy, Ilam Branch, Islamic Azad University, Ilam, Iran.*

RESEARCH ARTICLE

ARTICLE INFO.
Received Date: *31 Dec. 2020*
Received in revised form: *3 Feb. 2021*
Accepted Date: *7 Mar. 2021*
Available online: *31 Mar. 2021*

To Cite This Article:
Peyman Davami, Mojtaba Alavi Fazel, Davood Habibi, Afshin Mozaffari. Effect of Terminal Drought Stress on Seed Yield and Its Components of Rapeseed Cultivars. ***J. Crop. Nutr. Sci.***, 7(1): 42-56, 2021.

ABSTRACT

BACKGROUND: Drought stress is known as the most important factor limiting the growth and crop production. Therefore, the selection of genotypes that has higher yield stability in good crops can play a significant role and impact in the development of rapeseed cultivation with acceptable economic performance in the country.

OBJECTIVES: Current study was carried out to assess effect of terminal drought stress on seed yield and its components of Rapeseed cultivars.

METHODS: An experiment was performed as a factorial split plot and in the form of a randomized complete block design with three replications. Irrigation treatment included normal irrigation (irrigation after 80 mm of evaporation from Class A pan) and irrigation cut-off from the pod formation stage onwards in the main plots, planting dates including September 26 and October 26 and four rapeseed cultivars including Tassilo, Elvise, Neptune, and Okapi were evaluated in a factorial form in sub-plots.

RESULT: The results revealed that irrigation cut-off and delay in planting date had a significant effect on reducing plant height, number of sub-branches per plant, number of pods per plant, number of grains per pod, and 1000-grain weight. Cultivars were significantly different in terms of all evaluated traits. Elvise and Neptune cultivars had the highest grain yield with (3346) and (3220 $kg.ha^{-1}$), respectively, under normal irrigation conditions and with a mean of (3211) and (3081 $kg.ha^{-1}$), respectively, under irrigation cut-off conditions. This advantage was mainly due to an increase in the tank capacity of the yield components. Therefore, Elvise and Neptune cultivars can be introduced with acceptable production stability under normal irrigation conditions and water stress conditions after silique formation.

CONCLUSION: Among the studied cultivars of rapeseed, under normal irrigation and cut-off of irrigation conditions on both planting dates of Sep. 26 and Oct.26, Elvise cultivar showed the highest grain yield per unit area of production and good compatibility. The mentioned cultivar can be recommended in the areas similar to the studied area (Karaj), where there is a possibility of water stress in the late stages of growth.

KEYWORDS: *Canola, Grain yield, Irrigation, Planting dates, Seed Oil content.*

***Corresponding Author:** Mojtaba Alavi Fazel ✉ mojtaba_alavifazel@yahoo.com

1. BACKGROND

Rapeseed with the scientific name of *Brassica napus* L. is one of the most important oil crops in the world and is second in terms of area under cultivation after soybeans and third in terms of oil supply after soybeans and oil palms (FAO. 2005). Drought is one of the non-living environmental stresses known as the most important factor limiting the growth and production of crops in most parts of the world and Iran (Mariani and Ferrante. 2017). Iran with an average rainfall of about (240 mm) per year is considered as one of the areas under drought stress (Salehi Shanjani *et al.,* 2015). Several studies have reported that the negative impact of dehydration stress on many morphological characteristics of rapeseed such as plant height, plant dry weight, leaf area and yield components including number of pods, pod length, number and weight of grains leads to a decrease in final yield (Eziz *et al.,* 2017). Rapeseed is sensitive to drought in the stages of germination, flowering and growth of siliques. Irrigation in these stages increases the number of pods per square meter (Sinaki *et al.,* 2007). The most sensitive stage to drought stress in most crops is the interval between spike formation to flowering and cultivars that can produce more biomass and store more assimilates in the stem before flowering are considered drought tolerant cultivars (Blum., 2012). Drought stress in the stem elongation and flowering stages causes the most damage to rapeseed by reducing the number of pods per plant (Tohidi *et al.,* 2009). According to the results of a study conducted by Zhang *et al.* (2012), water shortage from the flowering stage to the end of grain filling significantly affects grain yield. Majidi (2012) reported that there is difference between rapeseed cultivars and hybrids in terms of yield-dependent traits under drought stress, which can be used to improve and increase production in rapeseed breeding. The physiological efficiency of crops in converting total biomass to grain yield is called the harvest index, which is significantly influenced by water stress (Saikumar *et al.,* 2016). Moradi *et al.,* (2008) attributed the positive and high correlation between dry matter and photosynthesis and leaf area index in the vegetative stage to a reduction in total dry matter. They also stated that severe drought stress in the reproductive stage affects grain yield more than dry matter. Thus, it reduces the harvest index. The effect of water stress on rapeseed showed that water shortage during the vegetative growth and flowering stages of the plant reduced the accumulation of total dry matter. Plants under water stress produced fewer siliques and grains compared to plants grown under normal conditions (Zhang *et al.,* 2012). The most important component compatible with climatic diversity is the issue of suitable planting date so that the vegetative and reproductive stages of the plant are adapted to favorable environmental conditions and photosynthetic efficiency, transfer and storage of photosynthetic materials in grains and ultimately grain yield increase (Safari *et al.,* 2010). Delay in the usual planting date in rapeseed reduces the number of pods, plant height, number of stems per plant, finally grain yield, and quality of rapeseed oil (Asgari and Moradie-dalini., 2008). Yield components in crops are influenced by planting date and cultivar. Selection of suitable cultivar for production success has a special importance and in this selection, the species, type and adaptation of cultivar, grain quality, climatic conditions, grain yield, resistance to fall, diseases and other crop properties should be considered. Several studies have shown that grain and oil yield of a genotype are equally influenced by planting date. Selecting suitable cultivar improves germination power and increases the production capacity of each yield component such as number of flowers and number of grain and proper distribution of photosynthetic materials is effective in them. The present study was conducted to evaluate rapeseed cultivars under the conditions of irrigation cut-off and planting date in the late stages of reproductive growth and to evaluate the strengths and weaknesses of crop and morphological reactions to select superior cultivars to recommend them for autumn cultivation in field experiments during 2- years.

2. OBJECTIVES

Current study was carried out to assess effect of terminal drought stress on, crop production and yield components of four rapeseed cultivars.

3. MATERIALS AND METHODS

3.1. Experimental setup

This experiment was conducted at Pars Water and Soil Field, of Karaj, Iran, and 1320 above sea level. Based on weather statistics, the area falls into hot and dry with the semi-arid Mediterranean climate, having 150-180 days and occasionally up to (200) dry days. A factorial split-plot experiment in the form of a randomized complete block design with three replications for two years (2015-2016 and 2016-2017) was an ducted. Irrigation treatments were assigned the main plots and planting date and cultivars were placed in subplots. Two planting dates were conventional and late planting. Irrigation was also carried out at two levels of normal irrigation and irrigation cut-off from the pod formation stage onwards. Four winter cultivars of rapeseed were tested, including three rapeseed hybrids of Tassilo (originated from Germany), Elvise, Neptune, and Okapi (open pollinated cultivar) (originated in France). The reason for selecting these cultivars was to study and compare them for cultivation in cold temperate and semi-arid areas under late cultivation and terminal drought. Soil samples, at a depth of 0–30 cm, were collected from studied field with rotary core drill and were poured into bag and then mixed. Then, a sample was prepared from it and transferred to the soil laboratory. The results of field soil analysis are listed in Table 1. Based on soil parameters, sufficient nitrogen (urea 100 kg ha^{-1}; one-third at sowing time, one-third at stem elongation stage and one-third at the beginning of flowering stage), phosphorus (75 kg ha^{-1} triple superphosphate at sowing time), and potassium (100 kg ha^{-1} potassium sulphate at sowing time) fertilizers were applied in two both years.

Table 1. Chemical and physical characteristics of the experimental soil

Characteristic	Soil texture	OC (%)	pH	EC (dS m^{-1})	N (%)	P (ppm)	K (mg.kg^{-1})
2015-16	Clay loam	0.53	7.7	2.2	0.09	9.7	168
2016-17	Clay loam	0.42	7.8	1.7	0.07	4.52	175

OC, organic carbon; EC, electrical conductivity; N, nitrogen; P, phosphorus; K, potassium.

Further, 2.5 liters per hectare of Butisan Star herbicide (41.6% suspension) was used after planting and before emergence to control a wide range of narrow- and broad-leaf weeds. Moreover the weeds were controlled by manual weeding following the emergence and establishment of rapseed seedlings. Experimental plots were 2 ×6 m, with rows 30 cm apart and plant spacing of 4 cm on the rows. Two lateral rows per plot were left aside as marginal rows and, thus, four middle rows were used for measuring grain yield attributes and biochemical traits. Furrow irrigation using siphon pipes was implemented on the basis of 80 mm evaporation from the surface of Class A Evaporation pan. Metasystox (EC 25%, 1.5 L ha^{-1}) insecticide was applied at two stages, namely stemming and budding for the pest control, particularly aphid.

3.2. Measurements

After the plant approached the physiological maturity stage, 10 plants were randomly selected from each experimental plot and the traits of plant height, number of sub-branches and number of pods per plant and number of grains in their pods were measured. To determine the total number of pods per plant in the main stem and sub-branch, 10 plants were selected separately and randomly, and the number of grains in them was calculated and by summing up the mean number of grains in the main stem and sub-branch, the number of grains per pod was determined. To determine the weight of 1000 seeds, some seeds of each experimental plot were randomly selected and the number of 1000 seeds was counted with a seed meter and calculated by accurate laboratory balance in terms of grams and weights. To determine the grain yield, nine square meters of each experimental plot were separated and for final drying and reaching 12% humidity, it was kept in the open air for one week and after separating the grains from the pods, the seed weight was calculated with accurate weighing scales and grain yield was calculated as kg ha^{-1}. To measure biological yield, after foaming the plants of each experimental plot and before separating the seeds from the pods, the total weight of the plants was determined and the biological yield was determined in kg ha^{-1}, The amount of Seed Oil content was measured using a Soxhlet extractor.

3.3. Statistical analysis

After performing Bartlett test for homogeneity of variances, all the data were subjected to Analysis of Variance (ANOVA) using Statistical Analysis System (SAS) 9.2. Comparison of means was also done using LSD test at 5% probability level.

4. RESULT AND DISCUSSION

4.1. Plant height

The results of analysis of variance showed that rapeseed plant height was significantly under the effect of year, irrigation, planting date, cultivar and irrigation × planting dates interaction, irrigation × cultivar interaction, planting date × cultivar interaction, cultivar × irrigation interaction, and planting date × cultivar interaction at the probability level of 5% (Table 2). In addition to genetic characteristics of the cultivar, stem height in rapeseed is also influenced by environmental factors (Danaie *et al*., 2014). The results of comparing the means of irrigation × planting date showed that the highest plant height with (131.92 cm) was obtained by planting rapeseed cultivars on Sep. 26 in normal irrigation conditions compared to the same date of planting in the irrigation cut-off conditions (Table 3). Comparison of the mean of irrigation × cultivar showed that the highest mean plant height in both normal irrigation and irrigation cut-off conditions belonged to Elvise cultivar with (132.09 cm) and (131.93 cm), respectively, and the lowest mean height plant in normal irrigation and irrigation cut-off conditions belonged to Tassilo cultivar with (115.90cm) and (119.28 cm), respectively (Table 4). The results of comparing the means regaring the interaction of irrigation × planting date × cultivar also showed that the highest plant height belonged to Elvise cultivar with (140.56 cm) under normal irrigation conditions and earlier planting date (Sep. 26) and the lowest plant height belonged to Tassilo cultivar under both normal irrigation and irrigation cut-off conditions (no significant difference) (Table 6). Irrigation cut-off, especially in the stages of stem formation and grain filling, causes the plant to have little vegetative and reproductive growth. As a result, the photosynthetic potential decreases, which leads to a decrease in plant height, number of sub-branches per plant, number of pods per plant and number of seed per pod compared to normal conditions (Soleymani *et al.,* 2011). Reduced plant height due to water stress can be attributed to impaired photosynthesis and reduced production of photosynthetic material and its transfer to the growing parts of the plant, which ultimately prevents the plant to achieve genetic potential in terms of plant height Shirani Rad *et al.,* 2010).

4.2. Pods per plant

The results obtained from the analysis of variance of the number of pods per plant showed that the number of pods per rapeseed plant is influenced significantly by irrigation, planting dates, cultivar and interactions of irrigation × planting date, irrigation × cultivar and planting date × cultivar significantly at the probability level of 1% (Table 2). The number of pods per plant is among the most sensitive components of rapeseed yield to water stress (Sinaki *et al.,* 2007). Water stress will reduce the number of pods by shortening the flowering period, infertility of some flowers, reducing photosynthetic material for transfer to newly formed and growing plants (Jabbari *et al.,* 2015).

Table 2. ANOVA for studied traits

S.O.V	df	Plant height	No. Pods per plant	No. Seed per pod	1000-seed weight
Year (y)	1	2.54 **	25.01 ns	0.88*	0.003 ns
Replication (r)	4	0.06	24.54	0.01	0.005
Irrigation (a)	1	107.78**	23095.01**	114.19**	2.59**
y×a	1	0.01 ns	5.51 ns	0.14 ns	0.0003
Error	4	3.16	23.29	0.13	0.02
planting date(b)	1	3016.39**	3116.76**	35.07**	1.25**
y × b	1	0.082 ns	1.76 ns	0.02 ns	0.00003 ns
a × b	1	114.14**	1127.51**	0.66*	0.03**
y × a × b	1	1.40 ns	0.84 ns	0.01 ns	0.00007 ns
Cultivar (c)	3	947.12**	3608.16 **	33.563 **	1.37 **
y× c	3	0.04 ns	4.37 ns	0.01 ns	0.0001 ns
a× c	3	21.31**	109.48**	0.07 ns	0.08**
b × c	3	139.13**	131.29**	0.094 ns	0.019*
y × a × c	3	0.071 ns	1.62 ns	0.027 ns	0.0013 ns
y × b × c	3	0.093 ns	0.76 ns	0.003 ns	0.0007 ns
a × b × c	3	28.91**	17.04 ns	0.017 ns	0.014*
y × a × b × c	3	0.09 ns	1.88 ns	0.027 ns	0.01 ns
Error	56	2.53	16.68	0.08	0.005
C.V (%)		1.46	1.73	2.48	1.62

S.O.V, sources of variations; df, degree of freedom; CV, Coefficient of variation, ns: Not significant; **P<0.01; *P≤0.05.

The results of comparing the interaction of irrigation × planting date showed that planting date of Sep. 26 in normal irrigation conditions led to the production of the highest number of pods per plant in the rapeseed cultivars (262.96 pods) and irrigation cut-off conditions on later planting dates (Oct. 26) led to the production of the lowest number of pods in the rapeseed cultivars (220.54 pods) (Table 3). The results of irrigation× cultivar treatment showed that Elvise cultivar showed the highest production compared to other cultivars under both normal irrigation and irrigation cut-off conditions with a mean of (265.83) and (239.42), respectively (Table 4). The results showed that under irrigation cut-off conditions, a severe stress is created in the plant, which causes a severe decrease in the number of pods per plant (Soleimani *et al.,* 2011). Nazeri *et al.* (2018) also reported a significant decrease in the number of pods per plant with a delay in rapeseed planting date and irrigation cut-off. Investigation of the interaction effect of planting date × cultivar indicated that the highest number of pods per plant was obtained with (256.08 pods) planting of Elvise cultivar on the planting date of Sep. 26, while the lowest number of pods per plant was obtained with (215.17 pods) in Tassilo cultivar on the Oct. 26 (Table 5).

Continue Table 2. ANOVA for studied traits

S.O.V	df	Seed Oil content	Seed yield	Biological yield
Year(y)	1	31.51**	446901.04 ^{ns}	252606*
Replication (r)	4	0.02	729.17	191681.14
Irrigation(a)	1	0.07 ^{ns}	3561251.04 **	514208.06 **
y × a	1	0.07 ^{ns}	84.37 ^{ns}	2074.74 ^{ns}
Error	4	0.78	4315.23	71180.67
planting date(b)	1	37.5**	2978626.04 **	40966.71 ^{ns}
y × b	1	0.06 ^{ns}	759.37 ^{ns}	35428.23 ^{ns}
a × b	1	0.006 ^{ns}	3384.37 ^{ns}	1158027.75 **
y × a × b	1	0.007 ^{ns}	551.04 ^{ns}	64066.15 ^{ns}
Cultivar (c)	3	91.62**	489789.93 **	1114271.67 **
y× c	3	0.009 ^{ns}	201.04 ^{ns}	5534.68 ^{ns}
a× c	3	0.03 ^{ns}	5645.49 ^{ns}	446903.85 **
b × c	3	1.91**	2453.82 ^{ns}	585878.94 **
y × a × c	3	0.06 ^{ns}	87.15 ^{ns}	1259761.67 *
y × b × c	3	0.03 ^{ns}	89.93 ^{ns}	0.19 ^{ns}
a × b × c	3	0.01 ^{ns}	18039.93 *	29351.58 ^{ns}
y × a × b × c	3	0.03 ^{ns}	14641.15 ^{ns}	3261.29 ^{ns}
Error	56	0.03	1716.66	58976.95
CV (%)		1.86	2.28	4.28

S.O.V, sources of variations; df, degree of freedom; CV, Coefficient of variation, ns: Not significant; **P<0.01; *P≤0.05.

Decreased grain yield due to drought stress at flowering and growth of pods was due to a decrease in the number of pods in rapeseed plant (Sinaki *et al.,* 2007).

4.3. Seed per pod

The number of Seed per pod and the grain weight are yield components in rapeseed (Angadi *et al.,* 2003). The results of analysis of variance of the studied traits showed a significant difference in the effects of year, irrigation, planting date, cultivar at the probability level of 1% and on interaction of irrigation × planting date for the number of seeds (Table 2). The results of comparing the means in the interaction of irrigation × planting date (significant at the level of 5%) showed that the highest number of Seed per pod with (16.71) was obtained earlier planting date (Sep. 26) under normal irrigation conditions, while the lowest number of seeds in the pod was observed with (13.32) the cultivars planted on the planting date of Oct. 26, especially under irrigation cut-off conditions (Table 3). A decrease in the number of Seed per pod in the irrigation cut-off conditions can be attributed to lack of inoculation and the formation of flowers and seeds. Faraji *et al.* (2009) reported that the effect of planting year on the number of Seed per pod was significant at the level of 1%, which can be attributed to the sharp decrease in the number of sunny hours during March and April months in the first year of this researcher. Pasban Eslam (2014) reported that under water stress conditions, the number of Seed per pod, 1000-seed weight, number and length of pods in rapeseed decreased significantly, which ultimately reduced the final grain yield.

4.4.1000 seed weight

1000 seed weight indicates the importance of grain development and plays an important role among yield components to show the yield of a cultivar. According to the results of analysis of variance table (Table 2), 1000 seed weight of rapeseed is significantly affected by irrigation, planting date, cultivar and interaction of irrigation × planting dates and irrigation × cultivar and interaction of planting date × cultivar and irrigation × planting dates × cultivar at the probability level of 5%. Comparison of the interaction effect of irrigation × planting date showed that the planting dates of Sep. 26 in normal irrigation conditions with a mean of (4.57 gr) and then the planting date of Oct.26 under normal irrigation conditions with a mean of 4.46 g had the highest 1000-seed weight (Table 3). Interaction of irrigation × cultivar showed that the highest 1000-seed weight belonged to Elvise cultivar with a mean of (4.25 gr) under normal irrigation conditions and the lowest belonged to Tassilo cultivar with a mean of (3.95 gr) under irrigation cut-off conditions (Table 4). The interaction effect of planting date × cultivar indicated that the highest 1000-seed weight with a mean of (4.77) was obtained on the earlier planting date (Sep. 26) and in the Elvise cultivar and the lowest 1000-seed weight with a mean (3.96 gr) was obtained on the late planting date (Oct. 26) in the Tassilo cultivar (Table 5).

Table 3. Comparison of the mean interactions of irrigation × planting date on studied traits of rapeseed cultivars

Irrigation	Planting date	Plant height (cm)	No. pods per plant	No. Seed per pod	1000-seed weight (gr)	Biological yield (kg.ha^{-1})
Normal irrigation	Sep. 26	131.92*	262.96	16.71	4.57	5538.00
	Oct. 26	118.6	244.71	14.36	4.46	5380.85
Irrigation cut- off	Sept. 26	127.62	225.08	15.33	4.36	5427.27
	Oct. 26	118.53	220.54	13.32	4.02	5252
LSD 5%		0.14	2.39	0.15	0.03	0.89

*The means that their differences are larger than LSD are significantly different at the 5% level.

Since Elvise cultivar has a high initial growth rate, it is not exposed to high temperature at the end of the season, and more suitable environmental factors during their grain-filling period increase the 1000-seed weight of this cultivar. One of the important factors in increasing yield is grain filling stages exposure to cooler climate, which increases yield by increasing the 1000-seed weight (Shabani *et al.,* 2010). The results of comparing the means of interaction of irrigation × planting date × cultivar also showed that with the delay of planting dates and irrigation cut-off, the rate of reduction in weight of the studied cultivars was significantly different, so that the maximum 1000-seed date (Oct. 26) (Table 6). The increase in 1000-seed weight can be attributed to the length of period or the rate of grain filling, in which tank strength plays a key role. Robertson and Holland (2004) stated that one of the reasons for a reduction in 1000-seed weight due to planting delay was an increase in temperature during the grain-filling period. Elferjani and Soolanayakanahally (2018) reported that drought stress significantly reduces 1000-seed weight in rapeseed.

Table 4. Comparison of mean interaction effects of irrigation × cultivar on studied traits of rapeseed cultivars

Irrigation	Cultivar	Plant height (cm)	No. pods per plant	1000-seed weight (gr)	Biological yield (kg.ha^{-1})
Normal irrigation	Talliso	115.9*	242.33	4.25	5277.42
	Elvis	132.09	265.83	4.88	5894
	Neptune	124.11	258.17	4.62	5582
	Okapi	120.34	249	4.32	5400
Irrigation cut-off	Talliso	119.28	205.58	3.95	4981.25
	Elvis	131.93	239.42	4.41	5594
	Neptune	128.03	227.5	4.25	5332
	Okapi	121.67	218.85	4.13	5102
LSD5%		0.14	2.39	0.04	66.51

*The means that their differences are larger than LSD are significantly different at the 5% level.

4.5. Seed Oil content

Examining the results of analysis of variance, the data showed that the effect of year, planting dates; cultivar and interactions of planting date × cultivar on seed oil content were significant (Table 2). Sharghi *et al.* (2011) also reported the effect of irrigation on the amount of seed oil, which contradicted the results of the present study that irrigation was not significant on this trait. The reason for this discrepancy can be attributed to the different responses of rapeseed cultivars to irrigation treatment. In the study of Zarei *et al.* (2010) it was concluded that drought stress did not significantly reduce the amount of seed oil and it can be used to further control the amount of seed oil by genetic factors and the high impact of oil yield on changes in grain yield relative to oil percentage. Seed knowledge (Jabbari *et al.,* 2015). Comparison of means showed that the amount of seed oil in the first year with (43.39%) was superior to the second year with (43.25%). Interactions of planting date × cultivar showed that the highest amount of seed oil related to Elvis cultivar was obtained earlier (Oct.26) with (45%) and the amount of oil in Tasillo cultivar was unchanged in both planting dates (40%), Neptune cultivars And Okapi were ranked second and third in terms of oil content (Table 5). The percentage of oil usually decreases at a later planting dates (Hackenin-Vostaper, 2001). The amount of seed oil is an inherited trait and is partially affected by environmental effects.

Table 5. Comparison of mean interaction effects of planting date × cultivar on studied traits of rapeseed cultivars

Planting date	Cultivar	Plant height (cm)	No. pods per plant	1000-seed weight (gr)	Seed Oil content (%)	Biological yield (kg ha^{-1})
Sep. 26	Talliso	120.48*	232.75	4.24	40	5120
	Elvis	140.4	256.08	4.77	45	5856.17
	Neptune	132.72	247.25	4.51	44	5462.42
	Okapi	125.51	240	4.33	42	5272.08
Oct. 26	Talliso	114.7	215.17	3.96	40	5138
	Elvis	123.63	249.17	4.51	40	5832.25
	Neptune	119.43	238.42	4.35	45	5453
	Okapi	116.51	227.75	4.12	44	5230.75
LSD5%		0.14	2.39	0.04	42	66.51

*The means that their differences are larger than LSD are significantly different at the 5% level.

Among the environmental factors affecting the amount of oil, temperature is the most important factor that increases with it, a sharp drop in oil percentage is revealed. This reducing effect of temperature on the percentage of oil is more evident in late planting date (Fanaei *et al.,* 2005). The results of a study of rapeseed cultivars in low rainfall areas of South Australia on changes in oil content with planting date showed that for every two weeks of planting delay, about (1.1%) oil and (309) kg.ha^{-1} reduced grain yield, thus reducing the percentage. Oil was much higher than in rainy areas as a result of planting delays (Si and Walton, 2004). The results of this study were consistent with the report of Fallah Haki *et al.* (2010) regarding the reduction of oil content in delayed planting date due to exposure of rapeseed to high temperatures during ripening and grain filling. Therefore, early planting is essential to achieve higher oil content.

4.6. Seed yield

The results of data analysis showed that the effect of irrigation, planting date and cultivar on seed yield was significant at the probability level of 1% and the interaction effect of irrigation × planting date × cultivar on rapeseed seed yield was significant at the probability level of 5% (Table 3), So that Elvise cultivar had the highest seed yield on planting date of Sep. 26 and under normal irrigation conditions with a mean of (3346.67 kgha^{-1}). The amount of (2540 kg) was obtained. The lowest grain yield was obtained in Tassilo cultivar in the irrigation cut-off conditions and on the later planting date (Sep. 26) with (2540) kgha^{-1}. In general, Elvise cultivar had higher grain yield in both planting dates. Under irrigation cut-off on the planting date of Sep. 26, the seed yield in Elvise and Neptune cultivars was obtained in (3211.67) and (3081.61) kgha^{-1}, respectively (Table 6).

Irrigation cut-off in flowering and growth stage of pods and exposure of rapeseed to water stress due to negative impact on silique formation and seed size, nutrient transfer to seeds decreased, so seed yield decreased (Ghasemian-Ardestani., 2019). In a study in line with the present study, one-month delay in planting time, seed yield may decrease by 10 to 50% depending on the cultivar, and differences in rapeseed cultivars in terms of seed yield may be due to differences in these cultivars in growth traits such as number of branches, which is a reflection of the number of pods per plant and 1000-seed weight (Sharghi *et al.,* 2011). Based on the observations of Mostafavirad *et al.,* (2012), delay in planting in addition to shortening the seed-filling period reduces flowering and pollination due to exposure to hot weather, which will ultimately reduce seed yield. Although the effect of planting delay on yield reduction cannot be ignored, the effect of cultivar on yield is also very significant (Moradi Aghdam *et al.,* 2018).

4.7. Biological yield

Biological yield was significantly affected by irrigation and cultivar and interaction of irrigation × cultivar, planting dates × cultivar at the probability level of 1%. The effect of year, interaction of irrigation × planting dates and year × irrigation × cultivar was significant only on the biological yield at the probability level of 5% (Table 2). Comparison of the mean interactions of irrigation × planting date showed that the highest biological yield was in Tassilo cultivar under normal irrigation conditions and on the planting dates of Sep. 26 with a mean of (5538 $kg.ha^{-1}$) and the lowest biological yield was found under irrigation cut-off conditions and on later planting date (Octo.26) with a mean of (5252 $kg.ha^{-1}$) (Table 4). Investigating the results of comparing the mean interaction of irrigation × cultivar showed that the highest biological yield with (5894 $kg.ha^{-1}$) was related to normal irrigation treatment and Elvise cultivar, while under irrigation cut-off conditions, Tassilo cultivar compared to other cultivars showed a significant decrease in biological yield (Table 4). Comparison of the mean interactions of planting date × cultivar showed that the highest biological yield was observed in Tassilo cultivar on the planting date of Sep. 26 with a mean of (5856.17 $kg\ ha^{-1}$). The same cultivar on a later planting date (Oct. 26) showed a significant difference with other cultivars planted at different planting dates (Table 5). The results reported by Versace *et al*. (2011) indicate a significant effect of irrigation and cultivar and the interaction of cultivar and planting date on biological yield. By the comparing the mean interaction of year irrigation × planting date, it was found that the highest biological yield was obtained in the first year of the experiment under normal irrigation conditions and the planting date of Sep.26 with (5746.31 kg.ha^{-1}). Decreased biological yield is related to decreased grain and straw yield, and drought stress leads to reduced rapeseed straw yield, reduced photosynthetic storage in stem and leaves by reducing plant size and leaf area and accelerating leaf aging and decreasing the level of photosynthetic storage materials in stems and leaves will reduce the two components of tank size and grain yield and it will lead to a decrease in biological yield of rapeseed.

Table 6. Comparison of mean interaction effects of irrigation × planting date × cultivar on study traits of rapeseed cultivars

Irrigation	Planting date	Cultivar	Plant height (cm)	1000-grain weight (gr)	Grain yield (kg.ha^{-1})
Normal irrigation	Sep. 26	Talliso	117.33*	4.31	3036.66
		Elvis	140.56	4.98	3346.67
		Neptune	128.32	4.63	3220.00
		Okapi	124.29	4.37	3103.00
	Oct. 26	Talliso	114.47	4.18	2686.33
		Elvis	123.62	4.77	3030.00
		Neptune	119.90	4.60	2870.00
		Okapi	116.40	4.27	2736.67
Irrigation cut	Sep. 26	Talliso	123.64	4.18	2913.33
		Elvis	140.23	4.56	3211.67
		Neptune	137.11	4.39	3081.61
		Okapi	126.73	4.29	2976.67
	Oct. 26	Talliso	114.92	3.73	2540.00
		Elvis	123.63	4.26	2880.00
		Neptune	118.95	4.11	2827.00
		Okapi	116.62	3.97	2603.33
LSD5%			2.39	0.04	38.65

*The means that their differences are larger than LSD are significantly different at the 5% level.

5.CONCLUSION

Based on the results of this study, it was found that planting date, especially in interaction with irrigation treatments had a great impact on morphological traits of rapeseed cultivars, so that the most suitable planting date for studied cultivars in Karaj was found on planting date of Sep. 26. Among the studied cultivars of rapeseed, under normal irrigation and cut-off of irrigation conditions on both planting dates of Sept. 26 and Oct. 26, Elvise cultivar showed the highest grain yield per unit area of production and good compatibility. The mentioned cultivar can be recommended in the areas similar to the studied area (Karaj), where there is a possibility of water stress in the late stages of growth.

REFERENCES

Angadi, S. V., Cutforth, H. W., McConkey, B. G. and Gan, Y. 2003. Yield adjustment by canola grown at different plant population under semiarid conditions. Crop Sci. 43: 1358-1366.

Asgari, A. and Moradie-dalini, A. 2008. Evaluation, yield components and vegetative characters of rapeseed cultivars in different planting date. Seed and Plant J. 23: 419-430.

Blum, A. Drought resistance, *In*: Blum, A. (Eds.), 2012. Plant Breeding for water-limited environments. Springer, New York, Dordrecht Heidelberg London.

Danaie, A., Rashidi, A. M. and Darabi. and A. 2014. The effects of different sowing dates on some morphological and phenological characteristics, grain and oil yields of canola cultivars and new line in Khuzestan climatic conditions. Journal of Agriculture and Ecology Research International. 11(4): 1-8.

Elferjani, R. and Soolanayakanahally, R. 2018. Canola responsesto drought,heat,and combined stress:shared and specific effects on carbon assimilation, seedyield, andoilcomposition. PlantSci. 9: 1224.

Eziz, A., Z. Yan, D. Tian, W. Han, Z. Tang. and J. Fang. 2017. Drought effect on plant biomass allocation: A meta-analysis. Ecology and Evolution. 7(24): 11002–11010.

Fallah Heki, M. H., Yadavi, A. R., Movahhedi Dehnavi, M. and Balouchi, H. R. 2010. Evaluation of oil, protein and grain yield of canola cultivars in different planting date in Yasouj region. Electronic Journal of Crop Production. 4(2): 207-222. (Abstract in English)

Fanaei, H. R., Keykha, G. H., AkbariMoghaddam, H., Modarress Najafabadi, S. and Naruoie Rad, M. R. Effects of planting method and seed rate on yield and yield components of rapeseed Hyola 401 Hybrid in Sistan condition. Seed and Plant. Journal of Agricultural Research. 21(3): 399-409.

FAO. Food outlook. Globalomarket analysis. 2005. http://www. fao food outlook. com.

Faraji, A., Latifi, N., Soltani, A. Rad. and Shirani Rad, A. H. 2009. Seed yield and water use efficiency of canola (*Brassica napu*s L.) as affected by high temperature stress andsupplemental irrigation. Agricultural Water Management. 96(1): 132-140.

Ghasemian-Ardestani, H. 2019. Evaluation of agro -ophysiological response of selected rapeseed cultivars to different temperature and humidity regimes for adaptation to climate change. Ph.D. Thesis in Agroecology, Ferdowsi University of Mashhad. (Abstract in English)

Gunasekera, C. P. Martin, L. D., Siddique, K. H. M., Walton. and G. H. July. 2006. Genotype by environment interactions of Indian mustard (*Brassica juncea* L.) and canola (*Brassica napus* L.) in Mediterranean-type environments: II. Oil and protein concentrations in seed. European Journal of Agronomy 25(1): 13-21.

Hocking, P.J. and Stapper, M., 2001. Effect of sowing time and nitrogen fertilizer on Indian mustard. I. dry matter production, grain yield and yield component. Australian Journal of Agricultural Research. 52(6): 623-634.

Jabbari, H., Akbari, G. A. and Khoshkhalq Sima, N. A. 2015. Study of agronomic, physiological and qualitative characteristics of rapeseed under water stress. Journal of Environmental Stresses in Crop Science. 8(1): 35-49.

Majidi, M. 2012. Identification of canola cultivars for drought tolerance in germination and seedling growth stages using principal component analysis. Journal Crop Production and Processing. 4: 41-52. (Abstract in English)

Mariani, L. and Ferrante, A. 2017. Agronomic management for enhancing plant tolerance to abiotic stresses-drought,salinity, hypoxia, and lodging Horticulture. 3(4): 52.

Moradi aghdam A, Seyfzadeh. S, Sehrani rad A. H, Valadabadi S. A. and Zakerin H, 2018. The effect of irrigation cut on physiological characteristics and grain yield of rapeseed cultivars under different planting dates. Journal of Crop Physiology. 10(38): 59-76.

Moradi, Ahmadi. and Hosseinzadeh. 2008. Agronomic-physiological response of mung bean (Parto cultivar) to severe and mild drought stress in vegetative and reproductive growth stages. Journal of Agricultural Science and Technology and Natural Resources. 45: 671-659.

Mostafavirad, M., Shariati, F. and Mostafavi Rad, S. 2012. Evaluation of sowing date influence on quantitative and qualitative yield in four rapeseed cultivars adapted to cold regions in Arak, Iran. Electron. J. Crop Prod. 5(2): 159-167. (Abstract in English)

Nazeri, P., Shirani Rad, A. H., ValadAbadi, S. A., Mirakhori, M., Hadidi Masoule. and E. 2018. Effect of sowing dates and late season water deficit stress on quantitative and qualitative traits of canola cultivars. Outlook on Agriculture. 1- 7.

Pasban Eslam, B. 2014. Study of some physiological indices, grain yield and yield components of rapeseed Varieties under drought stress. Journal of Plant Production Research. 20(4): 149- 162.

Robertson, M. J. and Holland, J. F. 2004. Production risk of canola in the semi-arid subtropics of Australia. Australian Journal of Agricultural Research. 55: 525-538.

Safari, M., M. Agha Alikhany. and A. S. M. Modarres Sanavy. 2010. Effect of sowing date on phenology and morphological traits of three grain sorghum (*Sorghum bicolor* L.) cultivars. Iranian Journal of Agricultural Sciences. 12(4): 452-466.

Saikumar, S., Varma, C. M. K., Saiharini, A., Kalmeshwer, G. P., Nagendra, K., Lavanya. and K., Ayyappa, D. 2016. Grain yield responses to varied level of moisture stress at reproductive stage in an interspecific population derived from Swarna/O. glaberrima introgression line. NJAS-Wageningen Journal of Life Sciences. 78: 111-1222.

Salehi Shanjani, Izadpanah, Ramezani Yeganeh, Rasoulzadeh, Kavandi, Sardabi, Pahlavani, Amirkhani. and Seyedian, 2015. Comparison of the effect of drought stress on osmotic regulation, peroxidase, polyphenol peroxidazopigments in different seed samples of false chamomile and yellow chamomile *Anthemis tinctoria Tripleurospermum* servanes. Journal of Plant Research (Iranian Journal of Biology). 28 (1). 126-139.

Shabani, A., Kamgar Haghighi, A. A., Sepaskhah, A. R, Imam, Y. and Honar, T. 2010. The effect of water stress on grain yield, yield components and quality of autumn rapeseed (*Brasica napus.* L.) cv. Licord. Iranian Journal of Crop Sciences. 12 (4): 409- 421.

Sharghi, Y., Shirani Rad, A. H., Ayeneh Band, A., Noormohammadi, G., Zahedi. and H. 2011. Yield and yield components of six canola (*Brassica napus* L.) cultivars affected by planting date and water deficit stress. African Journal of Biotechnology. 10(46): 9309-9313.

Shirani Rad, A. H. and Nasr Esfahani, Sh. 2010. Evaluation of terminal drought tolerance in spring and autumn rapeseed cultivars. Iranian Journal of Crop Sciences. 12(2): 112-126.

Si, P. and Walton, G. H. 2004. Determinants of oil concentration and seed yield in canola and Indian mustard in the lower rainfall areas of Western Australia. Aus. J. Agric. Res. 55: 367-377.

Sinaki, M. J., Majidi Heravan, E., Shirani Rad, A. H., Noormohammadi, G., Zarei. and G. H. 2007. The effects of water deficit during growth stages of canola (*Brassica napus* L.). Am-Euras. J. Agric. Environ. Sci. 2: 417- 422.

Soleymani A, Moradi M. and Naranjani L. 2011. Effects of The Irrigation Cut-off Time in Different Growth Stages on Grain and Oil Yield Components of Autumn’s Canola Cultivars in Isfahan Region. Journal ofWater and Soil. 25(3): 426-435. (Abstract in English)

Tohidi-M, H. R., Shirani-Rad, A. H., Nour-Mohammadi, G., Habibi, D., Modarres-anavy, S. A. M., MashhadiAkbar-Boojar, M. and Dolatabadian, A. 2009. Response of six oil seed rape genotype to water stress and hydrogical application. L Pesq. Agropec. Trop., Goiânia. 3: 243-250.

Varseh, H., Shiranirad, A. H., Noormohammadi, G., Delkhosh B. and Varseh, B. 2011. Effect of planting season and drought stress on quantitative and qualitative characteristics of advanced rapeseed cultivars. Journal of Crop Plants Ecophysiology. 3(1): 56-66.

Zarei, G., Shamsi, H. and Dehghani, S. M. 2010. The effect of drought stress on yield, yield components and seed oil content of three autumnal rapeseed cultivars (*Brassica napus* L.). Journal of Research in Agricultural Science. 6: 29-37. 2010.

Zhang, K. M., Yu, H. J., Shi, K., Zhou, Y. H. ,Yu, J. Q. and Xia, X. J. 2012. Photo protective roles of anthocyanin in Begonia semperflorens. International Journal of Plant Science. 179: 202-208.