EFFECT OF IRRIGATION CUT-OFF AND PLANTING DATE ON YIELD AND YIELD COMPONENTS OF RAPESEED CULTIVARS

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Abstract

An experiment was performed as a factorial split plot and in the form of a randomized complete block design with three replications for two cropping years (2015-2016 and 2016-2017) in Pars water and soil field located in Karaj(Iran) to investigate the effect of irrigation cut-off and planting date on yield and yield components of rapeseed cultivars. Irrigation treatment included regular irrigation (irrigation after 80 mm of evaporation from Class A pan) and irrigation cut-off from the silique formation stage onwards in the main plots, planting date including September 27 and October 27 and winter rapeseed cultivars including Tassilo, Elvise, Neptune, and Okapi were evaluated in a factorial form in sub-plots. 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 siliques per plant, number of grains per pod, and 1000-grain weight. The studied 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, respectively, under normal irrigation conditions and with a mean of 3211 and 3081 kg / ha, 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.

Keywords; Drought stress, Planting date, Grain yield, Rapeseed cultivars.

Introduction

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 & 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 siliques, silique 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 siliques 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 siliques 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 siliques, plant height, number of stems per plant, finally grain yield, and quality of rapeseed oil (Asgari & 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 two crop years.

Materials and Methods

This research was conducted during the two crop years of 2015-2016 and 2016-2017 in Pars Water and Soil Field, located in Karaj with a longitude of 50˚57’ 50.2’’ E , a latitude of 30◦46’ 53.3’’ N and an altitude of 1321 meters above sea level as a factorial split plot in a randomized complete block design with three replications. The selected experimental land was under wheat cultivation in the previous year. Before preparing the land, the soil of the field was sampled at two depths of 0.30 and 30-60 cm to determine the physical and chemical properties of the soil. The results of field soil decomposition are presented in Table 1.

Table 1- Physical and chemical properties of field soil

Sampling depth (cm)	0-30	30-60
Electrical conductivity (ds / m)	2.2	1.7
Soil acidity	7.7	7.8
Saturation percentage	36	39.5
Percentage of organic carbon	0.53	0.42
Absorbable phosphorus (ppm)	9.7	4.52
Absorbable potassium (ppm)	168	175
Percentage of total nitrogen	0.09	0.07
Percentage of clay	29	27
Percentage of silt	45	46
Percentage of sand	26	27
Soil texture	Clay loam	Clay loam

Treatments, including irrigation in two levels of normal irrigation and irrigation cut-off from the stage of silique formation onwards in the main plots and planting date in two levels including September 27 and October 27 and four rapeseed cultivars with winter growth type including Tassilo with origin of Germany Elvise, Neptune and Okapi with origin of France and average oil percentage of 44%, were placed in sub-plots as factorial. Irrigation cycle was based on 80 mm of evaporation from Class A evaporation pan so that in each irrigation, 80% of evaporated water was equal to 64 mm or 640 m3/ha. For normal irrigation treatment, eight stages, and for stress treatment, six stages (two times less than normal irrigation conditions) were considered. In total, the amount of water used for control treatment was 5120 m3/ha and for stress treatment, it was about 3840 m3/ha. The distance between the blocks was 2 m and the distance between the main plots was 2 m. The dimensions of each experimental plot were 1.8× 5 m and with an area of 9 square meters, including 6 five-meter cultivation lines that 2 side lines were considered as margins. The seeds were screened before sowing based on two designated planting dates to be uniform in size. Butisan Star herbicide (41.6% suspension) was used after planting and before emergence at the rate of 2.5 l/ha to control a wide range of thin-leaved and broad-leaved weeds, especially weeds of the rapeseed family. The additional plants were removed to increase the initial vegetative growth power and maintain uniformity in the development of rapeseed leaves and overcome weed shading, and achieve the desired plant density (45 plants per square meter) in the 4-6 leaf stage.

Table 2- Mean temperature and rainfall of the experiment site during two cropping years

Month/year	First year of 2015-2016		Second year of 2016-2017	
month	Mean temperature (Co)	Mean rainfall (mm)	Mean temperature (Co)	Mean rainfall (mm)
April	15.75	32.9	14.95	49.5
May	21.65	10.95	21.6	17.3
September	17.2	12.3	16.8	3.6
November	8.35	28.95	9.8	0.75
December	7.5	34.5	5.7	22.9
January	5.35	8.8	6.4	14.85
February	6.95	17.95	5.15	19.1
March	10.3	27.35	10.3	31.5

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 siliques per plant and number of grains in their siliques were measured. To determine the total number of siliques 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 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 siliques, the grain weight was calculated with accurate weighing scales and grain yield was calculated as kg/ha. To determine the 1000-grain yield, some grain of each experimental plot were randomly selected and 1000 grain were counted by grain counting device, and their total weight was calculated by accurate laboratory weighting scale. To measure biological yield, after separating each experimental plot and before separating the grain from the siliques, the total weight of the plants was determined and the biological yield was determined in kg/ha and by dividing the grain yield by the biological yield (biomass), the harvest index was obtained according to the Equation (1).

Equation 1

$$\text{Harvest index (percentage)} = \frac{\text{Economic yield (grain yield)}}{\text{Biological yield (total plant weight plus grain weight)}} \times 100$$

Statistical analysis

After collecting data, Bartlett test was used to test the homogeneity of variances and composite analysis of variance was performed in SAS software. Mean comparisons were also calculated using the LSD test at 5% probability level.

Results and Discussion

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 date interaction, irrigation × cultivar interaction, planting date × cultivar interaction, cultivar × irrigation interaction, and planting date × cultivar interaction at the probability level of 5% (Table 3). 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 September 27 in normal irrigation conditions compared to the same date of planting in the irrigation cut-off conditions (Table 4). 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 and 131.93 cm, respectively, and the lowest mean height plant in normal irrigation and irrigation cut-off conditions belonged

to Tassilo cultivar with 115.90 and 119.28 cm, respectively (Table 5).
The results of comparing the means regarding 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 (September 27) 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, 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 siliques per plant and number of grains per silique 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).

Number of sub-branches per plant

The number of sub-branches in rapeseed plant was significantly affected by irrigation, planting date, cultivar and interaction of irrigation × planting date, irrigation × cultivar, planting date × cultivar and irrigation × planting date × cultivar at the probability level of 1% (Table 3). Although no significant difference was observed between the two planting dates in terms of sub-branches of plants under irrigation cut-off conditions, on earlier planting date (September 27), rapeseed cultivars grown under normal irrigation conditions had the highest number of sub-branches compared to later planting date and under irrigation cut-off conditions (Table 4). The desired number of sub-branches per unit area is closely associated with soil moisture regime during plant growth period (Ardell et al., 2001). Comparison of the means of interaction of irrigation × cultivar showed that the highest number of sub-branches per plant in both normal irrigation and irrigation cut-off conditions was related to Elvise cultivar with a mean of 5.59 and 5.55, respectively, and the lowest was related to Tassilo cultivar with a mean of 3.99 sub-branches under normal irrigation conditions. Interestingly, Tassilo cultivar produced more sub-branches under irrigation cut-off conditions than under normal irrigation conditions, which followed a different trend compared to other cultivars (Table 5).
The study conducted by Gunasekera et al. (2006) referred to the effect of drought stress on reducing the number of sub-branches, which was consistent with the results of this study. The interaction effect of planting date × cultivar indicated that the highest number of sub-branches per plant with 5.95 plants was obtained in with Elvise cultivar on the September 27 planting date, while the lowest number of sub-branches per plant was obtained in the Tassilo cultivar with 4.12 plants on October 27. The number of sub-branches of each cultivar in the two planting dates of September 27 and October 27 did not show a significant difference (Table 6). There was a difference between rapeseed cultivars in terms of the number of siliques per plant and also the 1000-grain weight so that the number of siliques in the main branch was less and because the grains formed on the sub-branches have less weight, this non-uniformity can be attributed to the number of sub-branches formed in the plant (Sharghi et al., 2011). Comparison of interaction of irrigation × planting date × cultivar also showed that the highest number of sub-branches per plant belonged to Elvise cultivar with 5.5 sub-branches under normal irrigation conditions and earlier planting date (September 27) and the lowest number of sub-branches per plant with 3.92 plants belonged to Tassilo cultivar under normal irrigation conditions (Table 7). Ahmadi & Bahrani., (2009) reported that complete irrigation increases the number of sub-branches, the number of siliques per plant and the number of grains per pod, which is consistent with the results of the present study.

Number of siliques per plant

The results obtained from the analysis of variance of the number of siliques per plant showed that the number of siliques per rapeseed plant is influenced significantly by irrigation, planting date, cultivar and interactions of irrigation × planting date, irrigation × cultivar and planting date × cultivar significantly at the probability level of 1% (Table 3). The number of siliques 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 siliques by shortening the flowering period, infertility of some flowers, reducing photosynthetic material for transfer to newly formed and growing plants (Jabbari et al., 2015). The results of comparing the interaction of irrigation × planting date showed that planting date of September 27 in normal irrigation conditions led to the production of the highest number of siliques per plant in the rapeseed cultivars (262.96 siliques) and irrigation cut-off conditions on later planting date (October 27) led to the production of the lowest number of siliques in the rapeseed cultivars (220.54 siliques) (Table 4). 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 225.83 and 239.42, respectively (Table 5).

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 siliques per plant (Soleimani et al., 2011). Nazeri et al., (2018) also reported a significant decrease in the number of siliques 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 siliques per plant was obtained with 256.08 siliques with planting of Elvise cultivar on the planting date of September 27, while the lowest number of siliques per plant was obtained with 215.17 siliques in Tassilo cultivar on the October 27 (Table 6). Decreased grain yield due to drought stress at flowering and growth of siliques was due to a decrease in the number of siliques in rapeseed plant (Sinaki et al., 2007).

Number of grains per silique

The number of grains per silique 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 grains (Table 3). 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 grains per silique with 16.71 was obtained earlier planting date (September 27) under normal irrigation conditions, while the lowest number of grains in the silique was observed with 13.32 the cultivars planted on the planting date of October 27, especially under irrigation cut-off conditions (Table 4). A decrease in the number of grains per silique in the irrigation cut-off conditions can be attributed to lack of inoculation and the formation of flowers and grains. Faraji et al. (2009) reported that the effect of planting year on the number of grains per silique 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 grains per silique, 1000-grain weight, number and length of siliques in rapeseed decreased significantly, which ultimately reduced the final grain yield.

1000-grain weight

1000-grain 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 3), 1000-grain weight of rapeseed is significantly affected by irrigation, planting date, cultivar and interaction of irrigation × planting date and irrigation × cultivar and interaction of planting date × cultivar and irrigation × planting date × cultivar at the probability level of 5%. Comparison of the interaction effect of irrigation × planting date showed that the planting date of September 27 in normal irrigation conditions with a mean of 4.57 g and then the planting date of October 27 under normal irrigation conditions with a mean of 4.46 g had the highest 1000-grain weight (Table 4). Interaction of irrigation × cultivar showed that the highest 1000-grain weight belonged to Elvise cultivar with a mean of 4.25 g under normal irrigation conditions and the lowest belonged to Tassilo cultivar with a mean of 3.95 g under irrigation cut-off conditions (Table 5).

The interaction effect of planting date × cultivar indicated that the highest 1000-grain weight with a mean of 4.77 was obtained on the earlier planting date (September 27) and in the Elvise cultivar and the lowest 1000-grain weight with a mean 3.96 g was obtained on the late planting date (October 27) in the Tassilo cultivar (Table 6). 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-grain 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-grain 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 date and irrigation cut-off, the rate of reduction in weight of the studied cultivars was significantly different, so that the maximum 1000-grain weight with a mean of 4.98 was obtained in the Elvise cultivar under normal irrigation conditions and on the earlier planting date (September 27) and the lowest 1000-grain weight was obtained in the Tassilo cultivar under irrigation cut-off conditions and on the late planting date (October 27) (Table 7). The increase in 1000-grain weight can be attributed to the length of period or the rate of grain filling, in which tank strength plays a key role. Robertson & Holland (2004) stated that one of the reasons for a reduction in 1000-grain weight due to planting delay was an increase in temperature during the grain-filling period (2018). Elferjani & Soolanayakanahally reported that drought stress significantly reduces 1000-grain weight in rapeseed.

Table 3- Combined analysis of variance of studied traits of rapeseed cultivars at different levels of

irrigation and planting date during two cropping years

Source of variations	df	Squared mean							
		Plant height	Number of sub-branches	Number of siliques per plant	Number of grans per silique	1000-grain weight	Grain yield	Biological yield	Harvest index
year	1	2.54 **	0.01 ns	25.01 ns	0.88*	0.003 ns	446901.04 ns	252606*	49.59*
Replication (year)	4	0.06	0.06	24.54	0.01	0.005	729.17	191681.14	9.61
irrigation	1	107.78**	0.45**	23095.01**	114.19**	2.59**	3561251.04**	514208.06**	1528.01**
year × irrigation	2	0.01 ns	0.002 ns	5.51 ns	0.14 ns	0.0003	84.37 ns	2074.74 ns	0.01 ns
primary error	4	3.16	0.1	23.29	0.13	0.02	4315.23	71180.67	4.56
Planting date	1	3016.39**	9.08**	3116.76**	35.07**	1.25**	2978626.04**	40966.71 ns	765.01**
year ×planting date	1	0.082 ns	0.0002 ns	1.76 ns	0.02 ns	0.00003 ns	759.37 ns	35428.23 ns	1.26 ns
Irrigation × planting date	1	114.14**	0.48**	1127.51**	0.66*	0.03**	3384.37 ns	1158027.75**	119.26**
year × irrigation × planting date	1	1.40 ns	0.0001 ns	0.84 ns	0.01 ns	0.00007 ns	551.04 ns	64066.15 ns	4.59 ns
cultivar	3	947.12**	9.91**	3608.16 **	33.563 **	1.37 **	489789.93**	1114271.67**	215.31**
year × cultivar	3	0.04 ns	0.0001 ns	4.37 ns	0.01 ns	0.0001 ns	201.04 ns	5534.68 ns	0.45 ns
irrigation ×cultivar	3	21.31**	0.41**	109.48**	0.07 ns	0.08**	5645.49 ns	446903.85**	22.2**
Planting date × cultivar	3	139.13**	0.35**	131.29**	0.094 ns	0.019*	2453.82 ns	585878.94**	25.32**
year × irrigation × cultivar	3	0.071 ns	0.0009 ns	1.62 ns	0.027 ns	0.0013 ns	87.15 ns	1259761.67*	0.01 ns
year × planting date × cultivar	3	0.093 ns	0.0001 ns	0.76 ns	0.003 ns	0.0007 ns	89.93 ns	0.19 ns	0.43 ns
irrigation × planting date ×cultivar	3	28.91**	0.17**	17.04 ns	0.017 ns	0.014*	18039.93*	29351.58 ns	50.45**
year× irrigation × planting date × cultivar	3	0.09 ns	0.0006 ns	1.88 ns	0.027 ns	0.01 ns	14641.15 ns	3261.29 ns	0.23 ns
Secondary error	56	2.53	0.02	16.68	0.08	0.005	1716.66	58976.95	1.38
C. v (%)		1.46	3.11	1.73	2.48	1.62	2.28	4.28	4.18

** indicates significant difference at the probability level of 1% and * indicates significant difference at the level of 5% and ns indicates no significant difference

Table 4 - Comparison of the mean interactions of irrigation × planting date on studied traits of rapeseed cultivars

Irrigation regime	Planting date	Plant height (cm)	Number of sub-branches per plant	Number of siliques per plant	Number of grans per silique	1000-gran weight (g)	Biological yield	Harvest index (%)
Normal irrigation	September 27	131.92	5.4	262.96	16.71	4.57	5538.00	57.71
	October 27	118.6	5.12	244.71	14.36	4.46	5380.85	54.29
Irrigation cut	September 27	127.62	4.64	225.08	15.33	4.36	5427.27	51.96
	October 27	118.53	4.64	220.54	13.32	4.02	5252	44.08
	LSD5%	0.14	0.06	2.39	0.15	0.03	66.51	0.89

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

Table 5 - Comparison of mean interaction effects of irrigation × cultivar on studied traits of rapeseed cultivars

Irrigation regime	cultivar	Plant height (cm)	Number of sub-branches per plant	umber of siliques per plant	1000-grain weight (g)	Biological yield (kg / ha)	Harvest index (%)
Normal irrigation	Talliso	115.9	3.99	242.33	4.25	5277.42	50.67
	Elvise	132.09	5.59	265.83	4.88	5894.00	59.33
	Neptune	124.11	5.22	258.17	4.62	5582.00	57.75
	Okapi (control)	120.34	4.73	249.00	4.32	5400.00	56.25
Irrigation cut	Talliso	119.28	4.51	205.58	3.95	4981.25	44.5
	Elvise	131.93	5.55	239.42	4.41	5594	48.92
	Neptune	128.03	5.22	227.5	4.25	5332	49.17
	Okapi (control)	121.67	4.79	218.85	4.13	5102	49.5
	LSD5%	0.14	0.06	2.39	0.04	66.51	0.34

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

Table 6 - Comparison of mean interaction effects of planting date × cultivar on studied traits of rapeseed cultivars

Planting date	cultivar	Plant height (cm)	Number of sub-branches per plant	umber of siliques per plant	1000-grain weight (g)	Biological yield (kg / ha)	Harvest index (%)
September 27	Talliso	120.48	4.37	232.75	4.24	5120	49.17
	Elvise	140.4	5.95	256.08	4.77	5856.17	57.75
	Neptune	132.72	5.95	247.25	4.51	5462.42	57.17
	Okapi (control)	125.51	5.11	240.00	4.33	5272.08	55.25
October 27	Talliso	114.7	4.12	215.17	3.96	5138.00	46.00
	Elvise	123.63	5.19	249.17	4.51	5832.25	50.05
	Neptune	119.43	4.86	238.42	4.35	5453.00	49.75
	Okapi (control)	116.51	4.4	227.75	4.12	5230.75	50.05
	LSD5%	0.14	0.06	2.39	0.04	66.51	0.34

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

Table 7. Comparison of mean interaction effects of irrigation × planting date × cultivar on study traits of rapeseed cultivars

Irrigation regime	Planting date	cultivar	Plant height (cm)	umber of siliques per plant	1000-grain weight (g)	Grain yield (kg/ha)	Harvest index (%)
Normal irrigation	September 27	Talliso	117.33	254.66	4.31	3036.66	52.83
		Elvise	140.56	271.50	4.98	3346.67	60.33
		Neptune	128.32	266.67	4.63	3220.00	59.50

		Okapi (control)	124.29	259.00	4.37	3103.00	58.16
	October 27	Talliso	114.47	230.00	4.18	2686.33	48.50
		Elvise	123.62	260.17	4.77	3030.00	58.33
		Neptune	119.90	249.67	4.60	2870.00	56.00
		Okapi (control)	116.40	239.00	4.27	2736.67	54.33
Irrigation cut	September 27	Talliso	123.64	210.83	4.18	2913.33	45.50
		Elvise	140.23	240.67	4.56	3211.67	55.17
		Neptune	137.11	227.83	4.39	3081.61	54.83
		Okapi (control)	126.73	221.00	4.29	2976.67	52.33
	October 27	Talliso	114.92	200.33	3.73	2540.00	43.50
		Elvise	123.63	237.16	4.26	2880.00	42.67
		Neptune	118.95	227.17	4.11	2827.00	43.50
		Okapi (control)	116.62	216.50	3.97	2603.33	46.67
LSD5%		0.14	2.39	0.04	38.65	1.26	1.26	

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

Grain yield

The results of data analysis showed that the effect of irrigation, planting date and cultivar on grain yield was significant at the probability level of 1% and the interaction effect of irrigation × planting date × cultivar on rapeseed grain yield was significant at the probability level of 5% (Table 3), so that Elvise cultivar had the highest grain yield on planting date of September 27 and under normal irrigation conditions with a mean of 3346.67 kg / ha. 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 (September 27) with 2540 kg. In general, Elvise cultivar had higher grain yield in both planting dates. Under irrigation cut-off on the planting date of September 27, the grain yield in Elvise and Neptune cultivars was obtained in 3211.67 and 3081.61 kg/ha, respectively (Table 7). Irrigation cut-off in flowering and growth stage of siliques and exposure of rapeseed to water stress due to negative impact on silique formation and grain size, nutrient transfer to grains decreased, so grain yield decreased (Ghasemian-Ardestani., 2019).

In a study in line with the present study, one-month delay in planting time, grain yield may decrease by 10 to 50% depending on the cultivar, and differences in rapeseed cultivars in terms of grain 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 siliques per plant and 1000-grain weight (Sharghi et al., 2011). Based on the observations of Mostafavirad et al., (2012), delay in planting in addition to shortening the grain-filling period reduces flowering and pollination due to exposure to hot weather, which will ultimately reduce grain 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).

Biological yield

Biological yield was significantly affected by irrigation and cultivar and interaction of irrigation × cultivar, planting date × cultivar at the probability level of 1%. The effect of year, interaction of irrigation × planting date and year × irrigation × cultivar was significant only on the biological yield at the probability level of 5% (Table 3). 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 date of September 27 with a mean of 5538 kg / ha and the lowest biological yield was found under irrigation cut-off conditions and on later planting date (October 27) with a mean of 5252 kg / ha (Table 4). Investigating the results of comparing the mean interaction of irrigation × cultivar showed that the highest biological yield with 5894 kg / ha 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 5). 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 September 27 with a mean of 5956.17 kg / ha. The same cultivar on a later planting date (October 27) showed a significant difference with other cultivars planted at different planting dates (Table 6).

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 September 27 with 5746.31 kg / ha. 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

Harvest index

Harvest index is a criterion of the efficiency of transferring photosynthetic material produced by plants to grains. The results of analysis showed that the effect of irrigation, planting date, cultivar and interactions of irrigation × planting date, irrigation × cultivar, planting date × cultivar and irrigation × planting date × cultivar were significant on this trait at a probability level of 1%, while the effect of year on this trait was significant only at the probability level of 5% (Table 3). Comparison of the mean interaction effects of irrigation × planting date showed that the planting date of September 27 in normal irrigation conditions led to the highest harvest index with 3.1%, followed by the irrigation cut-off conditions on the same planting date without a significant difference with normal irrigation conditions on October 27. The lowest harvest index was related to the irrigation cut-off conditions on the later planting date (October 27) with 44.08% (Table 4). Decreased rapeseed harvest index due to water stress has been reported in several studies (Faraji et al., 2009). Comparing the mean interaction effects of irrigation × cultivar in terms of the studied trait showed that Elvise cultivar had the highest harvest index under the normal irrigation conditions with a mean of 59.33%. The same figure showed the lowest harvest index in the irrigation cut-off treatment with a mean of 48.92, so that it was not significantly different from other cultivars, especially in the irrigation cut-off treatment (Table 5).

The interaction effect of planting date × cultivar was significant for harvest index trait, so that only Elvise cultivar had the highest harvest index with a mean of 57.75% on the earlier planting date (September 27), but the rank of other cultivars in terms of value of this trait was not affected by the mentioned interactions (Table 6). Hokmalipour et al., (2011) reported that the effect of planting date on harvest index was significant, although their results regarding the non-significance of planting date × cultivar were inconsistent from the results of this study. Its reason can be due to different environmental conditions in different regions. Fathi et al., (2003) reported a decrease in harvest index due to delay in planting date, which is consistent with the results of the present study. Harvest index was also affected by interaction of irrigation × planting date × cultivars, so that Elvise cultivar with a mean of 60.33% and Neptune cultivar with a mean of 59.50% had the highest harvest index on an earlier date (September 27) and under normal irrigation. However, on the later planting date (November 27), Akapi (control) cultivar under the irrigation cut-off conditions with a mean of 46.67% showed the highest harvest index compared to other cultivars (Table 7). In the study conducted by Naderi et al. (2005), drought stress at the most severe level increased the harvest index. He stated attributed one of the reasons for the higher harvest index to a decrease in the number of days reach physiological maturity along with an increase in drought stress severity.

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 September 27. Among the studied cultivars of rapeseed, under normal irrigation and cut-off of irrigation conditions on both planting dates of September 27 and October 27, 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.

Conflict of interest

The authors declared no conflict of interest.

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