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EFFECTS OF PLANTING DATE ON SPRING RAPESEED (*Brassica napus* L.) CULTIVARS UNDER DIFFERENT IRRIGATION REGIMES

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ABSTRACT

Two field studies were conducted during 2011-2013 years using factorial split plot experiment laid out in RCBD with three replications, to assess the effects of planting date on some qualitative and quantitative traits of three spring rapeseed (*Brassica napus* L.) cultivars under different irrigation regimes. Planting date in three levels as February 24, March 6, and March 16 and Irrigation in two levels as normal irrigation and interruption of irrigation from the pod formation stage (water stress) were randomized in the main plots and spring cultivars including V_1: RGS003, V_2: Sarigol, and V_3: Zarfam were randomized in subplots. The results of experiments showed that water stress and delayed planting date negatively affected yield components of seed and oil yield of rapeseed cultivars as the highest means of all assessed traits (plant height, stem diameter, number of branches per plant, pod length, number of pods per plant, number of seeds per pod, 1000 seeds weight, seed yield, seed oil content, seed oil yield, total chlorophyll content and oleic acid content) obtained in first planting date and under normal irrigation by RGS003. RGS003 showed superiority in comparison to other cultivars in all planting dates and irrigation regimes.

Key words: Rapeseed; Cultivar; Planting date; Yield and Water stress.

INTRODUCTION

Rapeseed has been grown as an oilseed crop for both edible and industrial uses. Rapeseed yield is often restricted by water deficit and high temperatures during the reproductive growth. The limitation of plant growth imposed by low water availability under water stress condition is mainly due to reductions in plant carbon balance, which is dependent on the balance between photosynthesis and respiration. The effects of water stress depend on timing, duration, and magnitude of water deficiency (Pandey *et al.*, 2001) which the occurrence time is more important than the stress intensity (Masoud Sinaki *et al.*, 2007). Reproductive stage is the most susceptible stage to water deficit. Severe stress decreases the duration of reproductive growth and results in large yield losses (Hall, 1992). Since there is no logical way to increase precipitation in drought periods so using the most appropriate agricultural practices and also cultivars which are more tolerant than the others to dryness are the best solutions to modify the undesirable water stress effects. An important management factor in the production of all crops is planting date. Sowing at proper time allows sufficient growth and development of a crop to obtain a satisfactory yield and modify the undesirable effect of drought stress. Sowing either too early or too late has been reported to be unfavorable (Hocking and Stapper, 2001; Robertson *et al.*, 2004; Uzun *et al.*, 2009). Delay on sowing date causes flowering period falls in June when evapo-transpiration reaches high values and the crop experiences water stress (Yau, 2007). For producing high yield, it is important that the plant flowers as early as possible. By bringing forward the date of flowering, yield can ultimately increase (Koutroubas *et al*., 2004; Yau, 2007; Dordas *et al*., 2008).

The production of the rapeseed in Iran is also mainly limited by drought. Therefore evolution and selection of genotypes with increased drought tolerance is important for successful agriculture in water limited areas. This study aimed to evaluate the effects of irrigation regimes and planting date on spring rapeseed (*Brassica napus* L.) cultivars in order to find the most appropriate cultivar in each condition.

MATERIALS AND METHODS

Experimental site and design

Two field experiments were carried out at the research station of Takestan Branch of Islamic Azad University

Takestan, Iran (36°04′11″N 49°41′45″E) using factorial split plot experiment laid out in RCBD with three replications during the 2011-2012 and 2012-2013 sowing periods. Treatments were included three agents: Planting date in three levels (D_1: February 24, D_2: March 6, and D_3: March 16) and Irrigation in two levels (I_1: normal irrigation (non-water stress) and I_2: interruption of irrigation from the pod formation stage (water stress)) which were randomized on the main plots and spring cultivars including V_1: RGS003 (Originated from Germany), V_2: Sarigol (Originated from Germany), V_3: Zarfam (Originated from Iran) which were randomized in the subplots. Each experimental plot consisted of 6 rows, 6 m long with 30 cm spaced between rows and 5 cm distance between plants on the rows. According to soil analysis, N, P, and K fertilizer rates recommended. P and K were applied pre-plant and N fertilizer applied in three stages: one-third pre-plant (before sowing), one-third in stem elongation stage and one-third in flowering stage. Seeds were planted according to planting date treatments. The plants were thinned after complete emergence as keeping distances on row about 5 cm. The experiments were kept free from weeds by applying 2.5 L ha^{-1} Terfelan pre-plant. Cabbage aphid controlled during spring season using Ekatin at a rate of 1 L ha^{-1}. The final harvest was performed at physiological maturity. At harvest stage, four middle rows were used for sampling and measuring parameters of plant height, stem diameter, number of branches per plant, number of pods per plant, pod length, number of seeds per pod, 1000-seeds weight, seed yield, seed oil content, seed oil yield, total chlorophyll content and oleic acid content.

Measurements of traits

After eliminating the margin effect 10 plants were randomly harvested from middle of each plot and plant height, stem diameter, number of branches per plant and number of pods per plant determined. Pods of these plants were separated, 30 pods were randomly selected and pod length, number of seeds in each pod and 1000-seeds weight were determined. 1000-seeds weight was determined by measuring the weight of 8 random samples which each of them consisted of 100-seeds, from each plot and multiplying it by 10 in order to express it to 1000-seeds. Seed yield in each plot measured with 12-14% moisture. Seed oil and fatty acid content determined using the Soxhlet apparatus and HPLC method, respectively. Oil yield were determined by multiplying the oil content by the seed yield. Chlorophyll content measured using Arnon (1949) method.

Statistics

Analyses were performed with a computer using the SAS software. Combined analysis of variance (ANOVA) was performed for assessed traits after two years of experiment. Also Duncan's Multiple Range Test (DMRT) was used to conduct means comparison.

RESULTS AND DISCUSSION

Seed yield and yield components

The study of triple effects of treatments on these traits revealed that the highest number of pods per plant on average 74.6, the highest number of seeds per pod on average 18.75, the highest 1000-seeds weight on average 3.9 g, and the highest seed yield on average 3329 kg ha^{-1} obtained by RGS003 in the first planting date under normal irrigation. The lowest number of pods per plant on average 18.97, the lowest number of seeds per pod on average 3.28, the lowest 1000-seeds weight on average 0.7 g, and the lowest seed yield on average 258 kg ha^{-1} all obtained by Zarfam in the last planting date under water stress condition. RGS003 produced the highest number of pods per plant, number of seeds per pod, 1000-seeds weight, and seed yield in all planting dates and irrigation regimes (Table 1). Yield per area is the product of population density, the number of pods per plant, the number of seeds per plant and the individual seed weight. Long growing season, due to earlier planting, increases incoming radiation. At the same time, photosynthesis of crop increases, i.e. the duration of growth is correlated with a high yield potential. During the growth cycle, establishment of the stand, flower initiation, use of radiation and availability of assimilate for pod set and seed filling are decisive factor influencing yield. Delayed sowing and water stress generally reduces pod number. The physiological restrictions to pod formation are related to poor crop growth and leaf expansion, both of which limit the most sensitive stage of initiation of inflorescences. Seed weight depends to a lesser extent on environmental conditions than the other components of yield. Depending on patterns of flowering, the onset of seed growth of pods on different branches varies considerably, i.e., on the entire plant seed growth depends on the insertion of the pods (Diepenbrock, 2000). Wright *et al*. (1996) and Maliwal *et al*. (1998) reported the reduction of *Brassica* species yield in response to water stress. It appears that water stress hampered flowering and reduced the probability of developing flower to pod and its occurrence during flowering and pod formation resulted in pod abortion (Kimber and McGregor, 1995). Gammelvind *et al*. (1996) reported that water deficiency in late vegetative and early reproductive growth stages reduces photosynthetic rate in leaves and yield. Faraji *et al.* also (2009) reported 18% reduction of seed yield of rapeseed cultivars under water stress condition. Also delay on sowing date causes flowering period falls in June when evapo-transpiration reaches high values caused the crop experiences water stress too (Yau, 2007). In general during the flowering period, the crop is especially susceptible to drought stress, but cultivars were found to possess varying sensitivity. Morrison and Stewart (2002) reported the genetic difference among rapeseed cultivars from the seed yield point of view. Nasri *et al.* (2008) and Bitarafan and Shirani Rad (2012) reported water stress decreased number of pods per plant, number of seeds per pod, 1000-seeds weight and seed yield of rapeseed cultivars.

Table 1. Interaction effect of irrigation, planting date and cultivar on assessed traits (2011-2013)

Planting date	Irrigation	Cultivar	*NP/P*	*NS/P*	*TSW* (g)	*SY* (kg ha^{-1})	*SOC* (%)	*SOY* (kg ha^{-1})
February 24	Normal	RGS003	74.60a	18.75a	3.90a	3329a	41.89a	1361a
		Sarigol	73.08ab	18.35a	3.80ab	3231ab	41.84a	1319ab
		Zarfam	70.32abc	17.93a	3.70abc	2830c	41.12b	1137c
	Stress	RGS003	65.02d	15.27bc	3.17cd	2630cd	40.91b	1051d
		Sarigol	60.38e	13.95cd	2.55e	1922f	40.13c	753f
		Zarfam	57.70ef	12.52de	2.35ef	1279h	39.83c	498h
March 6	Normal	RGS003	69.58bcd	17.32ab	3.60abc	3073b	41.54ab	1245b
		Sarigol	67.97cd	16.92ab	3.28bcd	2510d	40.97b	1003d
		Zarfam	66.22cd	15.6bc	3.18cd	2212e	40.23c	867e
	Stress	RGS003	45.63gh	9.97fg	2.25efg	1584g	39.94c	617g
		Sarigol	42.73hi	8.40gh	1.73ghi	1290h	39.11d	492h
		Zarfam	38.23ij	6.77hi	1.23i	367jk	38.88de	140jk
March 16	Normal	RGS003	55.45f	12.80de	2.77de	1973f	40.23c	775f
		Sarigol	49.72g	10.87ef	2.25efg	1422gh	39.89c	554gh
		Zarfam	46.23gh	9.42fg	1.63hi	560j	39.13d	213j
	Stress	RGS003	37.12j	6.67hi	1.85fgh	1054i	39.22d	403i
		Sarigol	26.95k	5.65i	1.33hi	970i	38.86de	368i
		Zarfam	18.97l	3.28j	0.70j	258k	38.42e	97k

Any two means sharing a common letter not differ significantly from each other at 5% probability

Planting date	Irrigation	Cultivar	*PH* (cm)	*SD* (mm)	*NB/P*	*PL* (cm)	*TCC* (mg/g$_{f\,w}$)	*OAC* (%)
February 24	Normal	RGS003	141.0a	10.97a	5.95a	5.85a	1.939a	66.10a
		Sarigol	140.6ab	10.65b	5.85ab	5.75a	1.841abc	65.59b
		Zarfam	140.2ab	10.47ab	5.75ab	5.62a	1.819abc	65.42bc
	Stress	RGS003	125.2cd	9.83abc	4.92abcd	4.92abc	1.694bcd	65.57b
		Sarigol	120.6de	9.42abc	4.62bcde	4.62bcd	1.524de	64.87de
		Zarfam	114.4ef	9.32abc	4.30cdef	4.20cde	1.450e	64.52f
March 6	Normal	RGS003	132.1bc	10.45ab	5.42abc	5.43ab	1.872ab	65.76b
		Sarigol	125.4cd	10.37ab	5.23abc	5.23ab	1.792abc	65.42bc
		Zarfam	117.6de	10.35ab	5.03abcd	5.02abc	1.755abc	65.07d
	Stress	RGS003	99.9ghi	7.49de	3.57efg	3.48efg	1.153f	64.70ef
		Sarigol	97.2hi	7.27def	3.20fgh	2.87ghi	1.112f	64.39fg
		Zarfam	93.9i	7.07ef	2.87ghi	2.47hij	1.024fg	64.04h
March 16	Normal	RGS003	107.8fg	8.92bcd	4.20cdef	4.02def	1.627cde	65.18cd
		Sarigol	106.4fg	8.62cde	3.80defg	3.80def	1.513de	64.52f
		Zarfam	104.1gh	8.32cde	3.42efg	3.28fgh	1.433e	64.16gh
	Stress	RGS003	80.9j	8.85fg	3.28fgh	2.67ghi	1.022fg	64.56ef
		Sarigol	73.4j	5.32g	2.15hi	2.17ij	0.944fg	63.84h
		Zarfam	63.9k	4.42g	1.83i	1.72j	0.869g	63.42i

Any two means sharing a common letter not differ significantly from each other at 5% probability
Traits in *italic*, *NP/P*, *NS/P*, *TSW*, *SY*, *SOC*, *SOY*, *PH*, *SD*, *NB/P*, *PL*, *TCC* and *OAC* are assigned for number of pods per plant, number of seeds per pod, 1000-seeds weight, seed yield, seed oil content, seed oil yield, plant height, stem diameter, number of branches per plant, pod length, total chlorophyll content and oleic acid content, respectively.

Plant height, Stem diameter, Number of branches per plant and Pod length

The study of triple effects of treatments on plant height, stem diameter, number of branches per plant, and pod length showed that the highest plant height on average 141 cm, the highest stem diameter on average 10.97 mm, the highest number of branches per plant on average 5.95, and the highest pod length on average 5.85 cm all obtained by RGS003 in the first planting date under normal irrigation. The lowest plant height on average 63.9 cm, the lowest stem diameter on average 4.42 mm, the lowest number of branches per plant on average 1.83, and the lowest pod length on average 1.72 cm all obtained by Zarfam in the last planting date under water stress condition. RGS003 produced the highest plant height, stem diameter, number of branches per plant and pod length in all planting dates and irrigation regimes (Table 1). The seed yield of individual plants is closely related to the number of pods per plant. During the course of development, this trait is ultimately determined by reduction in number of branches, buds, flowers, and young pods, by source capacity, the supply of nutrient and water rather than by the potential numbers of flowers and pods. Therefore the reduction of plant growth (plant height, stem diameter and number of branches per plant) due to water stress and delayed planting date directly affects pod numbers which is one of the most important yield components. Also seed number per pod is correlated with pod length as pods with good seed set are longer, thus the reduction of pod length shows the reduction of number of seeds per pod which is another important yield component (Diepenbrock, 2000).

Seed oil content and Seed oil yield

The study of triple effects of treatments on seed oil content and yield revealed that the highest seed oil content on average 41.89% and the highest seed oil yield on average 1361 kg ha^{-1} both obtained by RGS003 in the first planting date under normal irrigation. Also the lowest seed oil content on average 38.42% and the lowest seed oil yield on average 97 kg ha^{-1} both obtained by Zarfam in the last planting date under water stress condition. RGS003 produced the highest seed oil content and yield in all planting dates and irrigation regimes (Table 1). Nasri *et al.* (2008) also reported water stress decreased seed oil content and yield of five rapeseed cultivars.

Total chlorophyll content

The study of triple effects of treatments on total chlorophyll content revealed that the highest total chlorophyll content on average 1.939 mg/g fresh weight obtained by RGS003 in the first planting date under normal irrigation and the lowest total chlorophyll content on average 0.869 mg/g fresh weight obtained by Zarfam in the last planting date under water stress condition. RGS003 also produced the highest total chlorophyll content in all planting dates and irrigation regimes (Table 1). Certainly this reduction of chlorophyll content in water stress condition is due to destruction of chloroplasts and reduction of producing pigments. Chlorophyll is the centre of energy producing system in plants and any significant changes in chlorophyll concentration could seriously affect plant life cycle (Shweta and Agrawal, 2006). According to Schutz and Fangmeier (2001) water stress could speed up chlorophyll shattering. Studies showed severe drought stress significantly decrease chlorophyll content in rapeseed (Deepak and Wattal, 1995).

Oleic acid content

The study of triple effects of treatments on oleic acid content revealed that the highest oleic acid content on average 66.1% obtained by RGS003 in the first planting date under normal irrigation and the lowest oleic acid content on average 63.42% obtained by Zarfam in the last planting date under water stress condition. RGS003 also produced the highest oleic acid content in all planting dates and irrigation regimes (Table 1).

CONCLUSIONS

Irrigation and planting date are two key points for optimizing rapeseed productivity in a given location. This study provides new findings about the effect winter planting dates along with normal irrigation and water stress on three spring rapeseed cultivars. Our results indicated that water stress and delayed planting date negatively affect rapeseed cultivars productivity. The highest grain and oil yield obtained by RGS003 in first planting date under normal irrigation condition and also RGS003 showed superiority in comparison to other cultivars in all planting dates and irrigation regimes.

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