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# Evaluation of Crop Production of Canola (*Brassica napus* L.) Cultivars Due to Irrigation Cut-off and Different Planting Dates in Karaj Climatic Conditions

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**RESEARCH ARTICLE**


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## ABSTRACT

**BACKGROUND:** The response of different canola varieties to irrigation cut-off and changes in planting dates depends on various factors such as climatic conditions, soil type, and specific characteristics of the varieties and growth stages of the plants. Each canola variety may react differently to variations in water and shifts in planting dates.

**OBJECTIVES:** To investigate the effects of irrigation cut-off and planting date on the seed yield and its components of rapeseed cultivars current research was done.

**METHODS:** This study was conducted as factorial split plot experiment based on randomized complete block design (RCBD) with three replications. The main plots were assigned to irrigation treatments [including regular irrigation (where irrigation was applied after 80 mm of evaporation from Class A pan) and irrigation cut-off from silique formation stage onwards]. The sub-plots were assigned to different planting dates, including September 27 and October 27 and four winter rapeseed cultivars (Tassilo, Elvise, Neptune and Okapi) were evaluated in a factorial arrangement in sub-plots.

**RESULT:** Both irrigation cut-off and delayed planting date had a significant impact on various growth and yield-related traits in rapeseed cultivars. Reduced plant height, fewer sub-branches per plant, fewer siliques per plant, fewer seeds per pod and lower 1000-seed weight. Also, different rapeseed cultivars that were studied exhibited significant variations in all evaluated traits. Among the cultivars, Elvise and Neptune stood out as they achieved the highest seed yields. Under normal irrigation conditions, Elvise yielded 3346 $kg.ha^{-1}$, while Neptune produced 3220 $kg.ha^{-1}$. Even under irrigation cut-off conditions, these cultivars still demonstrated promising performance, with Elvise yielding an average of 3211 $kg.ha^{-1}$ and Neptune yielding 3081 $kg.ha^{-1}$.

**CONCLUSION:** This advantage in seed yield was primarily attributed to an increase in the sink capacity of the yield components. As a result, Elvise and Neptune cultivars can be recommended as suitable choices for rapeseed production, as they have shown not only high seed yields under normal irrigation conditions but also stable production capabilities even under water stress conditions after pod formation.

**KEYWORDS:** *Drought stress, Genotypes, Rapeseed, Seed yield, Sowing date.*

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## 1. BACKGROUND

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 pod, pod length, number and weight of seeds 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 pod. Irrigation in these stages increases the number of pod 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 pod per plant (Tohidi Moghadam *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 seed filling significantly affects seed 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 seed 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 (LAI) in the vegetative stage to a reduction in total dry matter. They also stated that severe drought stress in the reproductive stage affects seed 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 pod and seed 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 seeds and ultimately seed 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 seed yield and quality of rapeseed oil (Asgari and Moradie dalini, 2008). Yield components in crops are influenced by planting date and cultivar. Choosing the right variety is of particular importance for the success of the production and in this selection, attention should be paid to the type and compatibility of the variety, seed quality, weather conditions, seed yield, resistance to diseases and other product characteristics. Selecting suitable cultivar improves germination power and increases the production capacity of each yield component such as number of flowers and number of seed and proper distribution of photosynthetic materials is effective in them.

## 2. OBJECTIVES

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.

## 3. MATERIALS AND METHODS

### *3.1. Field and Treatments Information*

This experiment was conducted as factorial split plot design in the form of randomized complete block design (RCBD) with three replications during the 2015-2016 and 2016-2017 cropping seasons at the Pars water and soil field in Karaj, Iran (with a longitude of 50° 57′ E and a latitude of 35° 46′ N and an altitude of 1321 meters above sea level). The main plots were assigned to two irrigation treatments (including regular irrigation (where irrigation was applied after 80 mm of evaporation from Class A pan) ($I_1$) and irrigation cut-off from the silique formation stage onwards) ($I_2$). The sub-plots were assigned to different planting dates, including September 27 ($D_1$) and October 27 ($D_2$) and four winter rapeseed cultivars [Tassilo ($V_1$), Elvise ($V_2$), Neptune ($V_3$) and Okapi ($V_4$)] were evaluated in a factorial arrangement in the sub-plots.

### *3.2. Farm Management*

The experimental site chosen for the study had been cultivated with wheat in the previous year. Prior to preparing the land for the current experiment, soil samples were collected from the field at two depths: 0-30 cm and 30-60 cm. These soil samples were analyzed to determine the physical and chemical properties of the soil. The results of the soil analysis and weather information are presented in table 1 and 2. The irrigation cycle was based on 80 mm of evaporation from a Class A evaporation pan, where each irrigation event aimed to replace 80% of the evaporated water, equivalent to 64 mm or 640 $m^3.ha^{-1}$. For the normal irrigation treatment, a total of eight irrigation stages were scheduled, while for the stress treatment, six stages were considered, which is two times less frequent than the normal irrigation conditions. So, the total amount of water used for control treatment was 5120 $m^3.ha^{-1}$ and for stress treatment, it was approximately 3840 $m^3.ha^{-1}$.

**Table 1.** Physical and chemical properties of field soil

| Sampling depth (cm) | 0-30 | 30-60 |
|---|---|---|
| **Electrical conductivity (ds.m$^{-1}$)** | 2.2 | 1.7 |
| **Soil acidity** | 7.7 | 7.8 |
| **Saturation (%)** | 36 | 39.5 |
| **Organic carbon (%)** | 0.53 | 0.42 |
| **Absorbable phosphorus (ppm)** | 9.7 | 4.52 |
| **Absorbable potassium (ppm)** | 168 | 175 |
| **Total nitrogen (%)** | 0.09 | 0.07 |
| **Clay (%)** | 29 | 27 |
| **Silt (%)** | 45 | 46 |
| **Sand (%)** | 26 | 27 |
| **Soil texture** | Clay loam | Clay loam |

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

| Month/year | 2015-2016 | | 2016-2017 | |
|---|---|---|---|---|
| **Month** | **Mean temperature (°C)** | **Mean Rainfall (mm)** | **Mean temperature (°C)** | **Mean Rainfall (mm)** |
| **April** | 75.15 | 9.32 | 95.14 | 5.49 |
| **May** | 65.21 | 95.10 | 6.21 | 3.17 |
| **September** | 2.17 | 3.12 | 8.16 | 6.3 |
| **November** | 35.8 | 95.28 | 8.9 | 75.0 |
| **December** | 5.7 | 5.34 | 7.5 | 9.22 |
| **January** | 35.5 | 8.8 | 6.4 | 85.14 |
| **February** | 95.6 | 95.17 | 45.5 | 1.19 |
| **March** | 3.10 | 35.27 | 3.10 | 5.31 |

The experimental setup had a spacing of 2 meters between blocks and main plots. Each experimental plot had dimensions of 1.8 × 5 meters, covering an area of 9 m$^2$. The plot was divided into six five-meter cultivation lines, with two side lines designated as margins. Before sowing, the seeds were screened and sorted based on the two designated planting dates to ensure uniformity in seed size. After planting and before emergence, the herbicide Butisan Star (41.6% suspension) was applied at a rate of 2.5 lit.ha$^{-1}$ to control a wide range of thin-leaved and broad-leaved weeds, especially those belonging to the rapeseed family. To promote initial vegetative growth and maintain uniformity in the development of rapeseed leaves, any additional plants were removed. This was done to overcome weed shading and achieve the desired plant density of 45 plants per square meter at the 4-6 leaf stage.

### 3.3. *Measured Traits*

At the physiological maturity stage, several measurements were taken. These included the plant height, number of sub-branches, number of pods per plant and the number of seeds per pod. To obtain data for analysis, ten plants were randomly selected from each experimental plot. The total number of pods and the number of seeds on both the main stem and branches of the ten selected plants were counted and recorded. To calculate the seed yield, a 9 m2 area was selected from each experimental plot. The harvested material from this area was left to dry in the air for a week until it reached a final humidity level of 12%. After separating the seeds from the pods, the seeds were weighed using a precise measuring scale and the seed yield was determined in $kg.ha^{-1}$. To determine the 1000-seed weight, the seeds are counted in two groups, each consisting of 500 seeds. These two groups are then individually weighed using a digital scale with a precision of 0.001g. If the weight difference between the two groups is less than 5%, their combined weight is considered as the 1000-seed weight for each treatment. In other words, if the weight difference is within the acceptable range of 5%, the average weight of the two groups is taken as the 1000-seed weight measurement for that specific treatment. To calculate the biological yield, fully ripened plants were carefully collected from the center of each plot, covering an area of $3m^2$. After removing any marginal lines, the collected plants were dried for 48 hours in an oven set at $70^oC$. Subsequently, the dried plants were weighed using a digital scale with an accuracy of 0.01gr and the yield was calculated in grams per square meter.

### 3.4. *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 (Ver.8). Mean comparisons were also calculated using the LSD test at 5% probability level.

## 4. RESULT AND DISCUSSION

### 4.1. *Plant height*

The results of analysis of variance showed that plant height was significantly affected 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 probability level of 5% (Table 3). Also genetic characteristics of 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 same date of planting 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 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). Comparing interaction effect 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 one belonged to Tassilo cultivar under both normal irrigation and irrigation cut-off conditions (no significant difference) (Table 6).

**Table 3.** Combined analysis of variance of studied traits of rapeseed cultivars at different levels of irrigation and planting date during two cropping years

| S.O.V | df | Plant height | No. sub-branches | No. pod per plant | No. seed per pod |
|---|---|---|---|---|---|
| **Year** | 1 | 2.54 ** | 0.01 ns | 25.01 ns | 0.88* |
| **Replication (year)** | 4 | 0.06 | 0.06 | 24.54 | 0.01 |
| **Irrigation (a)** | 1 | 107.78** | 0.45** | 23095.01** | 114.19** |
| **Year × a** | 2 | 0.01 ns | 0.002 ns | 5.51 ns | 0.14 ns |
| **Error I** | 4 | 3.16 | 0.1 | 23.29 | 0.13 |
| **Planting date (b)** | 1 | 3016.39** | 9.08** | 3116.76** | 35.07** |
| **Year× b** | 1 | 0.082 ns | 0.0002 ns | 1.76 ns | 0.02 ns |
| **a× b** | 1 | 114.14** | 0.48** | 1127.51** | 0.66* |
| **Year × a × b** | 1 | 1.40 ns | 0.0001 ns | 0.84 ns | 0.01 ns |
| **Cultivar (c)** | 3 | 947.12** | 9.91** | 3608.16 ** | 33.563 ** |
| **Year × c** | 3 | 0.04 ns | 0.0001 ns | 4.37 ns | 0.01 ns |
| **a× c** | 3 | 21.31** | 0.41** | 109.48** | 0.07 ns |
| **b × c** | 3 | 139.13** | 0.35** | 131.29** | 0.094 ns |
| **Year × a ×c** | 3 | 0.071 ns | 0.0009 ns | 1.62 ns | 0.027 ns |
| **Year × b ×c** | 3 | 0.093 ns | 0.0001 ns | 0.76 ns | 0.003 ns |
| **a × b ×c** | 3 | 28.91** | 0.17** | 17.04 ns | 0.017 ns |
| **Year × a × b × c** | 3 | 0.09 ns | 0.0006 ns | 1.88 ns | 0.027 ns |
| **Error II** | 56 | 2.53 | 0.02 | 16.68 | 0.08 |
| **C.V (%)** | | 1.46 | 3.11 | 1.73 | 2.48 |

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

Irrigation cut, especially in the stages of stem formation and seed 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 seeds 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 and Nasr Esfahani, 2010).

**Continue table 3.**

| S.O.V | df | 1000-seed weight | Seed yield | Biological yield |
|---|---|---|---|---|
| **Year** | 1 | 0.003 ns | 446901.04 ns | 252606* |
| **Replication (year)** | 4 | 0.005 | 729.17 | 191681.14 |
| **Irrigation (a)** | 1 | 2.59** | 3561251.04** | 514208.06** |
| **Year × a** | 2 | 0.0003 | 84.37 ns | 2074.74 ns |
| **Error I** | 4 | 0.02 | 4315.23 | 71180.67 |
| **Planting date (b)** | 1 | 1.25** | 2978626.04** | 40966.71 ns |
| **Year× b** | 1 | 0.00003 ns | 759.37 ns | 35428.23 ns |
| **a× b** | 1 | 0.03** | 3384.37 ns | 115827.75 * |
| **Year × a × b** | 1 | 0.00007 ns | 551.04 ns | 64066.15 ns |
| **Cultivar (c)** | 3 | 1.37 ** | 489789.93** | 1114271.67** |
| **Year × c** | 3 | 0.0001 ns | 201.04 ns | 5534.68 ns |
| **a× c** | 3 | 0.08** | 5645.49 ns | 446903.85** |
| **b × c** | 3 | 0.019* | 2453.82 ns | 585878.94** |
| **Year × a ×c** | 3 | 0.0013 ns | 87.15 ns | 1259761.67* |
| **Year × b ×c** | 3 | 0.0007 ns | 89.93 ns | 0.19 ns |
| **a × b ×c** | 3 | 0.014* | 18039.93* | 29351.58 ns |
| **Year × a × b × c** | 3 | 0.01 ns | 14641.15 ns | 3261.29 ns |
| **Error II** | 56 | 0.005 | 1716.66 | 58976.95 |
| **C.V (%)** | | 1.62 | 2.28 | 4.28 |

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

4.2. *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).

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

| Irrigation | Planting date | Plant height (cm) | No. sub-branches per plant | No. pod per plant | No. seeds per pod | 1000-seed weight (g) |
|---|---|---|---|---|---|---|
| $I_1$ | September27 | 92.131* | 4.5 | 96.262 | 71.16 | 57.4 |
| | October 27 | 6.118 | 12.5 | 71.244 | 36.14 | 46.4 |
| $I_2$ | September 27 | 62.127 | 64.4 | 80.225 | 33.15 | 36.4 |
| | October 27 | 53.118 | 64.4 | 54.220 | 32.13 | 20.4 |
| LSD (5%) | | 14.0 | 60.0 | 39.2 | 15.0 | 30.4 |

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

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 pods per plant and also the 1000-seed weight so that the number of pods in the main branch was less and because the seeds 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 and Bahrani (2009) reported that complete irrigation increases the number of sub-branches, the number of pods per plant and the number of seeds per pod, which is consistent with the results of the present study.

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

| Irrigation | Cultivar | Plant height (cm) | No. sub-branches per plant | No. pod per plant | 1000-seed weight (g) | Biological yield ($kg.ha^{-1}$) |
|---|---|---|---|---|---|---|
| $I_1$ | Tassilo | 115.9* | 3.99 | 242.33 | 4.25 | 5948.05 |
| | Elvis | 132.09 | 5.59 | 265.83 | 4.88 | 5927.37 |
| | Neptune | 124.11 | 5.22 | 258.17 | 4.62 | 5556.47 |
| | Okapi | 120.34 | 4.73 | 249 | 4.32 | 5413.64 |
| $I_2$ | Tassilo | 119.28 | 4.51 | 205.58 | 3.95 | 5911.37 |
| | Elvis | 131.93 | 5.55 | 239.42 | 4.41 | 5683.13 |
| | Neptune | 128.03 | 5.22 | 227.5 | 4.25 | 5637.66 |
| | Okapi | 121.67 | 4.79 | 218.85 | 4.13 | 5380.27 |
| LSD (5%) | | 0.14 | 0.06 | 2.39 | 0.04 | 66.51 |

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

4.3. *Number of pod 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 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 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). 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 pod per plant in the rapeseed cultivars (262.96 pod) and irrigation cut-off conditions on later planting date (October 27) led to the production of the lowest one in cultivars (220.54 pod) (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 plant, which causes a severe decrease in number of pod per plant (Soleimani *et al*., 2011). Nazeri *et al*. (2018) also reported a significant decrease in number of pods per plant with a delay in rapeseed planting date and irrigation cut-off. Assess interaction effect of planting date × cultivar indicated that the highest number of pod per plant was obtained with 256.08 pods with planting of Elvise cultivar on the planting date of September 27, while the lowest one was for 215.17 pod in Tassilo cultivar on October 27 (Table 6).

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

| Planting date | Cultivar | Plant height (cm) | No. sub-branches per plant | No. pod per plant | 1000-seed weight (g) | Biological yield (kg.ha$^{-1}$) |
|---|---|---|---|---|---|---|
| September 27 | Tassilo | 120.48* | 4.37 | 232.75 | 4.24 | 5984.72 |
| | Elvis | 140.4 | 5.95 | 256.8 | 4.77 | 5795.44 |
| | Neptune | 132.72 | 5.59 | 247.25 | 4.51 | 5552.29 |
| | Okapi (control) | 125.51 | 5.11 | 240 | 4.33 | 5449.33 |
| October 27 | Tassilo | 114.7 | 4.12 | 215.17 | 3.96 | 5874.69 |
| | Elvis | 123.63 | 5.19 | 249.17 | 4.51 | 5815.07 |
| | Neptune | 119.43 | 4.86 | 238.42 | 4.35 | 5641.85 |
| | Okapi (control) | 116.51 | 4.4 | 227.75 | 4.12 | 5344.56 |
| LSD (5%) | | 0.41 | 0.06 | 32.39 | 0.04 | 66.51 |

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

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

4.4. *Number of seeds per pod*

The number of seeds per pod and the seed 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 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 seeds per pod with 16.71 was obtained earlier planting date (September 27) 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 October 27, especially under irrigation cut-off conditions (Table 4). A decrease in the number of seeds 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 seeds 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 under water stress conditions, number of seeds per pod, 1000-seed weight and length of pod decreased significantly, which ultimately reduced the final seed yield.

4.5. *1000-seed weight*

1000-seed weight indicates the importance of seed 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-seed 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-seed weight (Table 4). Interaction of irrigation × cultivar showed that the highest 1000-seed 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-seed 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-seed 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 seed-filling period increase the 1000-seed weight of this cultivar. One of the important factors in increasing yield is seed 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 date and irrigation cut-off, the rate of reduction in weight of the studied cultivars was significantly different, so that the maximum 1000-seed 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-seed 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-seed weight can be attributed to the length of period or rate of seed filling, in which tank strength plays a key role. Robertson and Holland (2004) stated maybe reduction in 1000-seed weight due to planting delay was an increase in temperature during seed-filling period. Elferjani and Solanayakanahally (2018) reported that drought stress significantly reduces 1000-seed weight in rapeseed.

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 1% probability level and the interaction effect of irrigation × planting date × cultivar on seed yield was significant at 5% probability level (Table 3), so that Elvise cultivar had the highest seed yield on planting date of September 27 and under normal irrigation conditions with a mean of 3346.67 $kg.ha^{-1}$.

**Table 7.** Mean comparison of interaction effects of irrigation × planting date × cultivar on study traits of rapeseed cultivars

| Irrigation | Planting date | Cultivar | Plant height (cm) | No. pod per plant | 1000-seed weight (g) | Seed yield (kg.ha$^{-1}$) |
|---|---|---|---|---|---|---|
| $I_1$ | September 27 | **Tassilo** | 117.33 | 254.66 | 4.31 | 3036.66 |
| | | **Elvis** | 140.56 | 271.50 | 4.98 | 3346.67 |
| | | **Neptune** | 128.32 | 266.67 | 4.63 | 3220.00 |
| | | **Okapi(control)** | 124.29 | 259 | 4.37 | 3103.00 |
| | October 27 | **Tassilo** | 114.47 | 230 | 4.18 | 2686.33 |
| | | **Elvis** | 123.62 | 260.17 | 4.77 | 3030.00 |
| | | **Neptune** | 119.90 | 249.67 | 4.60 | 2870.00 |
| | | **Okapi (control)** | 116.40 | 239.00 | 4.27 | 2736.67 |
| $I_2$ | September 27 | **Tassilo** | 123.64 | 210.83 | 4.18 | 2913.33 |
| | | **Elvis** | 140.23 | 240.67 | 4.56 | 3211.67 |
| | | **Neptune** | 137.11 | 227.83 | 4.39 | 3081.61 |
| | | **Okapi (control)** | 126.73 | 221 | 4.29 | 2976.67 |
| | October 27 | **Tassilo** | 114.92 | 200.33 | 3.73 | 2540.00 |
| | | **Elvis** | 123.63 | 238.16 | 4.26 | 2880.00 |
| | | **Neptune** | 118.95 | 227.17 | 4.11 | 2827.00 |
| | | **Okapi (control)** | 116.62 | 50216.50 | 3.97 | 2603.33 |
| **LSD5%** | | | 0.14 | 2.39 | 0.04 | 38.65 |

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

The lowest seed yield was obtained in Tassilo cultivar in irrigation cut-off conditions and on planting date of September 27 (with an average of 2540 kg.ha$^{-1}$). Elvise cultivar had higher yield in both planting dates. Under irrigation cut-off on planting date of September 27, the seed yield in Elvise and Neptune cultivars was obtained in 3211.67 and 3081.61kg.ha$^{-1}$, respectively (Table 7). Irrigation cut-off in flowering and growth stage of pod and exposure of rapeseed to water stress due to negative impact on pod formation and seed size, nutrient transfer to seeds decreased, so seed yield decreased (Ghasemian-Ardestani, 2019). In present study, one-month delay in planting time, seed yield may decrease by 10 to 50% depending on 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 number of pod per plant and 1000-seed weight (Sharghi *et al*., 2011). Mostafavi Rad *et al*. (2012) reported delay in planting in addition to shortening seed-filling period reduces flowering and pollination due to exposure to hot weather, which will ultimately reduce seed yield. So effect of planting delay on yield reduction cannot be ignored, effect of cultivar on yield is too 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 date × cultivar at 1% probability level. The effect of year and year × irrigation × cultivar was significant only on the biological yield at the probability level of 5% (Table 3). Comparing interaction effect of irrigation × cultivar showed that the highest biological yield with 5948.05 $kg.ha^{-1}$ was for normal irrigation treatment and Elvise cultivar, while under irrigation cut-off conditions, Okapi cultivar compared to other cultivars showed a significant decrease in biological yield (Table 5). Compare interactions effect of planting date × cultivar showed that the highest biological yield was for Tassilo cultivar on the planting date of September 27 with a mean of $5948.72 kg.ha^{-1}$. The same cultivar on a later planting date (October 27) showed a significant difference with other cultivars planted at different planting dates (Table 6). Verseh *et al*. (2011) reported significant effect of irrigation and cultivar and interaction effect of cultivar and planting date on biological yield. Decreased biological yield is related to decreased seed, 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, accelerating leaf aging and decreasing level of photosynthetic storage materials in stems and leaves will reduce two components of sink size and seed yield and it will lead to a decrease in biological yield.

## 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 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 seed 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.

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**FOOTNOTES**

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