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Effect of Late Sowing Date on Agronomic and Quality Traits of Four Winter Oilseed Rape (*Brassica napus*) Cultivars in Hamedan, Iran

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ABSTRACT

Appropriate planting date is directly related to the geographical situation and climatic conditions of the region. Due to the declining trend of rainfall and lack of soil moisture in most parts of Iran, applying the maximum possible delay in planting is essential due to less autumn irrigation and getting closer to autumn rainfall. Therefore, to investigate the effect of delay in planting on quality traits, yield, and yield components of rapeseed, an experiment was conducted in 2012 as split plots in a randomized complete block design with three replications in Hamedan province, Iran. The main factor was planting date in 4 levels, including 10 September, 20 September, 30 September, and 10 October. The second factor was four genotypes of Okapi cultivar and hybrids of Tassilo, Octans-NK, and Elite. The results showed that the number of pods per plant, biological yield, seed yield, harvest index, and oil yield at 1% probability level and the number of seeds per pod and Thousand seed Weight (TSW) at 5% probability level were affected by the interaction of planting date and genotype. Also, the simple effect of genotype on the percentage of seed oil was significant at the level of 1% probability. The highest seed yield in the first planting date with 5083.3 kg/ha belonged to the Octans-NK genotype and the lowest yield in the last planting date (1244.4 kg/ha) belonged to the Okapi genotype.

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1. Introduction

Oilseed rape is the most important oilseed crop in temperate and cold regions and the second most important oilseed crop in the world after soybeans (Talawat and Siadat, 2012). The unique characteristics of oilseed rape and its adaptation to the climatic conditions of most parts of the country have led to the cultivation of this plant as a point of hope to supply the crude oil needed by the government and get rid of dependence (Dehshiri, 1999). Canola (*Brassica napus*) is a particular type of oilseed rape with less than 2% erucic acid in oil and less than 30 micromoles of glucosinolates per gram in meal dry weight. These two characteristics make oilseed rape oil suitable for human consumption and meal as a high protein source for animal feed (Roodi *et al.*, 2003). Oilseed rape oil has been imported to Iran for the past years, and several types of research have been done on it. In recent years, due to more attention to the development and promotion of oilseed rape cultivation, its area under cultivation has increased significantly, so that in the 2012-2013 crop year, the area under oilseed rape cultivation in Iran was 126933 hectares, with a production of 263792 tons (Agriculture Statistics, 2012). Oilseed rape is one of the plants that are very sensitive to planting dates. Therefore, determining the most appropriate date for planting oilseed rape in each region is of great importance for developing this plant in the country (Roodi *et al.*, 2003). Different oilseed rape cultivars, such as other species, are adapted to specific

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climatic conditions (Mandal *et al*., 1995). Seed yield response of oilseed rape cultivars to planting date depends on climatic conditions of the region and genotype characteristics (Faraji, 2010). Since planting date has the most significant effect on the phenological and physiological aspects of the crop compared to other cropping treatments, choosing the appropriate planting date can make the most adjustment between the plant growth process and climatic conditions. This study aimed to evaluate oilseed rape genotypes to determine the superior genotype with desirable characteristics for late cultivation in terms of adaptation to growth and development with the climatic conditions of the Hamedan region and to obtain the most suitable yield.

The purpose of determining the most appropriate planting date is to find the proper climatic factors for all vegetative and reproductive growth stages of the plant and help the plant in each stage of development to be less exposed to adverse environmental conditions. Delay in planting reduces the length of maturation, the number of pods per plant, number and seed weight, and finally yields by reducing the size of vegetation period, unsuitable temperature conditions during flowering, inoculation, and pod formation (Kazerani and Ahmadi, 2004). On the other hand, due to the declining trend of rainfall and lack of soil moisture in most parts of the country, applying the maximum possible delay in planting, due to less need for autumn irrigation and getting closer to autumn rainfall, is important. Therefore, in this study, Oilseed rape genotypes were evaluated to determine the superior genotype with desirable characteristics for delayed cultivation in terms of adaptation of growth and development to the climatic conditions of the Hamedan region and obtaining the most suitable yield.

2. Materials and methods

This experiment was carried out in 2012-2013 crop year in the research farm of the Agricultural and Natural Resources Research Center of Hamadan province (Ekbatan station), Iran with coordinates of latitude 34 degrees and 52 minutes north and longitude 48 degrees and 32 minutes east, with an altitude of 1757 meters above sea level. The experiment site was fallow in the previous year. The soil of the experiment site had a clay sand texture with 0.34% organic matter and a pH of 7.7. During the growing season, the mean maximum temperature was 19.73°C, and the mean minimum temperature was 5.7°C. The amount of rainfall during the growing season was equal to 185.2 mm, and the maximum rainfall of 58.3 mm was related to November. Raining in the year of the experiment was more than 38% lower than the average long-term rainfall in Hamedan (300 mm). In September 2012, to prepare the seedbed, two stages of vertical plowing were performed by a reversible plow, and then a rotary machine (rotary plow) was used for crushing the lumps. Based on the soil test results, 100 kg/ha of phosphorus fertilizer from a triple superphosphate source and 183 kg/ha of pure nitrogen from the urea source was used. One-third of urea fertilizer as base fertilizer and total phosphorus fertilizer was mixed with the soil by a rotator. Then, furrows were prepared for planting at a distance of 60 cm by the furrow machine. Oilseed rape seeds were sown on different dates by hand and wet planting method, according to thousand seed weight and their potency, with an initial density of 1,500,000 seed per hectare and at a depth of 2 to 3 cm. Each experimental plot consisted of 4 furrows with a distance of 60 cm, and each furrow also consisted of 2 planting rows with a length of 5 m and a distance of 30 cm. There was a distance of 60 cm between the experimental plots and 2 m between the blocks. The first irrigation was light and sprinkler. After germination, according to the plant's soil moisture and water requirement during the growing season, regular irrigation was done. The remaining two parts of urea fertilizer were applied as top-dressing at the beginning of rapid longitudinal stem growth and early flowering.

During the growing season, to control aphid pests, Metasystox (oxidimethomethyl) at a rate of one liter per hectare was used twice: in the early stages of growth in (October) and early pod formation, respectively. In addition, weeding was done inside the plots manually, and between replications by a rotator during the growing season. To measure yield components at the time of physiological maturity, 0.5 m long rows were harvested from rows 3 and 6 from each plot. The number of pods per plant, the number of seeds per pod, were measured and determined. At the end of the season, 2m2 was harvested to determine biological yield, economic yield, and thousand seed weight, and the plants were kept in each plot for one week to dry completely. Then, after weighing and determining the biological yield, the plants of each plot were threshed separately, the straw was separated from the seeds, and the final seed yield in each plot was obtained. Then, by counting and weighing one thousand seeds from each plot, the Thousand seed Weight was determined. Oil was also measured by the Soxhlet method. Oil yield per unit area was calculated by multiplying seed yield by the percentage of seed oil.

Normality tests and analysis of test data were performed using SAS statistical software. The means were compared using the least significant difference test at the level of 1% probability by MSTATC software. Excel software was also used to draw the graphs.

3. Results and discussion

3.1. Performance and performance components

3.1.1. Number of pods per plant

The simple and interaction effects of planting date and genotype on the number of pods per oilseed rape plant were significant at the level of 1% probability (Table 1). This trait can be considered as one of the essential components of yield, which includes the number of seeds and also produces some of the assimilates needed to increase the weight of seeds because the pods in the early stages of seed filling through photosynthesis participate in seed growth and development (Fig. 1). Okapi genotype at the first planting date and Octans-NK genotype at the fourth planting date had the highest and lowest number of pods per plant at 101.3 and 49.3, respectively. The highest decrease in the fourth planting date compared to the first date (51.3%) belonged to the Octans-NK genotype. In contrast, the Tassilo genotype showed a reduction of at least 2.2% on the fourth planting date compared to the first. Tassilo genotype had more pods per plant at the last planting date than other genotypes. It had a difference of 42 to 44% with different genotypes, which probably goes back to the rapid growth and less sensitivity to the planting date in this genotype (Fig. 1). The results obtained from slicing planting dates to study the interaction of planting date and genotype on the number of pods per plant showed that on the first and fourth planting date (at 1% level) and the second and third planting date (at 5% level) the effect of genotype on the number of pods per plant became significant (Table 2). In the first sowing date, Okapi, Octans-NK, and Tassilo genotypes averaged 96.6, 94.6, and 90.3, respectively. In the second sowing date, the response of the genotypes was almost similar to the first sowing date. So, Okapi, Tassilo, and Octans-NK genotypes were in one statistical group, and Elite genotype was in the next group. In the third and fourth dates, the response of genotypes was different from the first and second dates. In the last two planting dates of the Tassilo genotype with 67 and 83.3 pods per plant, the third and fourth dates had the highest number of pods per plant. However, the difference with Octans-NK and Elite genotypes at the third planting date was not significant (Fig. 1).

Clark and Simpson (1978) and Ozer (2003) stated that the decrease in the number of plant pods at a later planting date, which is a significant factor in reducing seed yield, was the weakness of the plants at the time of flowering. Delay in planting causes the plant to flower in unfavorable environmental conditions, and due to heat, several flowers become sterile and fall off. The plant provides its heat needs in a shorter period due to high ambient temperature. In this case, the plant's flowering period is shortened, and the production potential of pods is reduced (Whitfield, 1992).

Table 1. Mean squares of yield and yield components.

S.O.V	df	Seed weight (g/1000)	Number of seeds per pod	Number of pods per plant	Seed Yield	Biological yeild	Harvest index
Replication	2	0.0018 $^{n.s}$	11.52*	43	56406.75 $^{n.s}$	194465.4 $^{n.s}$	5.75
Planting date	3	1.98**	8.72*	4086.96**	19091290.83**	159327651**	172.87**
Main plot Error	6	0.017	5.49	24.77	44739.93	592574.8	0.99
Genotype	3	0.14**	48.72**	732.46**	1557343.54**	15390195.7**	26.84**
P.Date × Genotype	9	0.068*	7.66*	323.07**	195166.2**	9240014.9**	4.79
Subplot Error	24	0.025	2.8	17.44	53450.76	478391.6	1.1**
C.V		4.73	6.74	5.58	7.41	4.25	5.64

*,** and $^{n.s}$ were significant at the probability level of 5%, 1% and not significant, respectively.

Table 2. Slicing effect of genotype on yield and yield components of oilseed rape cultivars in each planting date.

S.O.V	df	Seed weight (1000/g)	Number of seeds per pod	Number of pods per plant	Seed Yield	Harvest index	Biological yield
Planting date: 10 September 2012							
Replication	2	0.018 n.s	7 n.s	48.08 n.s	22592.51 n.s	1.15 n.s	573006.33 n.s
Genotype	3	0.07**	27.97*	260.97**	1119598.93**	22.84**	6286806.75**
Error	6	0.007	2.88	17.63	608517.7	1.93	33.265343
C.V		1.17	7	4.69	7.44	6.25	2.67
Planting date: 20 September 2012							
Replication	2	0.004 n.s	5.08 n.s	3.08 n.s	3773.14 n.s	0.48	777231 n.s
Genotype	3	0.142 n.s	8.44 n.s	235.63*	176113.73**	12.24**	8223872.08**
Error	6	0.041	3.86	28.63	7939.69	7.44	3253117
C.V		5.73	7.96	5.81	1.17	3.11	2.96
Planting date: 30 September 2012							
Replication	2	0.035 n.s	10.33	50.08 n.s	58427.54 n.s	1.85	16270794.8 n.s
Genotype	3	0.122 n.s	28.75**	126.55**	313701.66 n.s	1.72 n.s	37900356.7 n.s
Error	6	0.034	1	12.97	95832.62	1.57	19993623.4
C.V		5.86	3.83	6.22	13.23	7.83	3.43
Planting date: 10 October 2012							
Replication	2	0.002 n.s	5.58 n.s	16.08 n.s	10583.3	5.24	474545.25
Genotype	3	0.008 n.s	9.55 n.s	1078.52*	5334427.77**	4.05*	12173996.22**
Error	6	0.019	3.47	10.52	8611.09	0.44	415776.14
C.V		4.71	7.65	5.41	5.27	4.5	5.42

* ,** and n.s were significant at the probability level of 5%, 1% and not significant, respectively

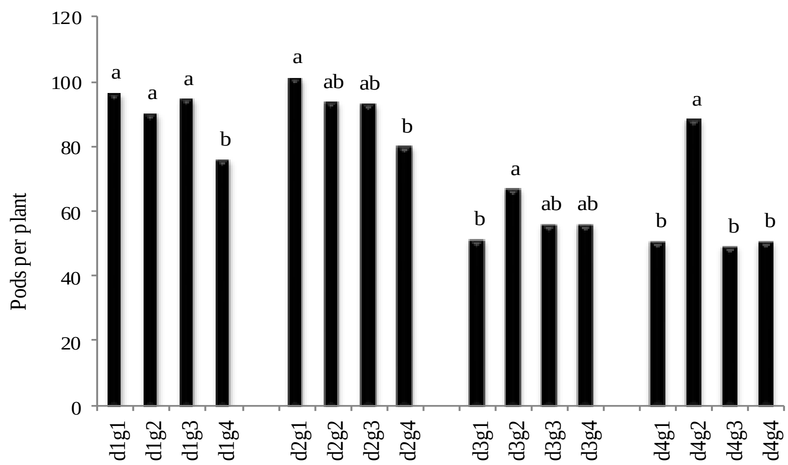

Figure 1. Slicing effect of interaction between planting date and genotype on the number of pods per plant in oilseed rape. (d1, Planting date: 10/09/2012; d2, Planting date: 20/09/2012; d3, Planting date: 30/09/2012; d4, Planting date: 10/10/2012)

3.1.2. Number of seeds per pod

Simple and interaction effects of culture date andgenotype on the number of seeds per pod were significant (Table 1). The results obtained from the interaction section of planting date and genotype at the level of planting date on the number of seeds per pod showed that in the first planting date (at 5% level) and in the third planting date (at 1% level) the effect of genotype became significant. There was no statistically significant difference in the second and fourth planting dates of the genotypes (Table 2). On the first sowing date, the Okapi genotype had the highest mean number of seeds per pod (28 seeds per pod), and Elite, Octans-NK, and Tassilo genotypes (24.3, 23.6, and 21 seeds per pod) were in a statistical group, respectively. On the third planting date, the Okapi genotype produced the highest average number of seeds per pod (30.33 seeds per pod), and Octans-NK, Elite, and Tassilo genotypes were included in a statistical group and produced 26, 25, and 23 seeds per pod, respectively (Fig. 2). The importance of this trait is because more seeds mean a more extensive reservoir for plant photosynthetic materials. Therefore, the yield increases as a result. The highest and lowest number of seeds per pod was assigned to the Okapi genotype on the third planting date (30.33 seeds per pod) and the Tassilo genotype on the first planting date (21 seeds per pod) (Fig. 2). The number of seeds per pod (mean of four genotypes) remained unchanged by changing the planting time. It indicates that the number of seeds per pod is probably a genetic trait and is less affected by the planting date. Mendham et al. (1984) explained the increase in the number of seeds per pod in timely oilseed rape cultivation that the number of seeds per pod increases with increasing plant dry weight at the flowering stage. The higher dry weight of the plant at the flowering stage (especially in autumn cultivars) depends on the temperature, the initial nutrition of the plant before the rosette stage, and sufficient nitrogen reserves to start regrowth in spring. Abdoli et al. (2004) showed that with a 45-day delay in canola planting, a 27.1% reduction in the number of seeds per pod occurs. Azizi et al. (1999) also stated a direct relationship between the amount of dry matter produced before the flowering stage and the final number of seeds. Taylor and Smith (1992) concluded that delay in canola planting shortens the vegetative stage of the plant so that the plant does not reach the desired leaf area index at the right time. For this reason, in addition to reducing the amount of dry matter produced in the vegetative stage, the plant is not able to have enough sap to fill the formed seeds, especially the seeds in the pods on the branches, and therefore, the final number of seeds has reduced and the percentage of seed porosity increases in late planting. According to Anvare (1996) the number of seeds per pod is more influenced by genetic factors and less by environmental factors.

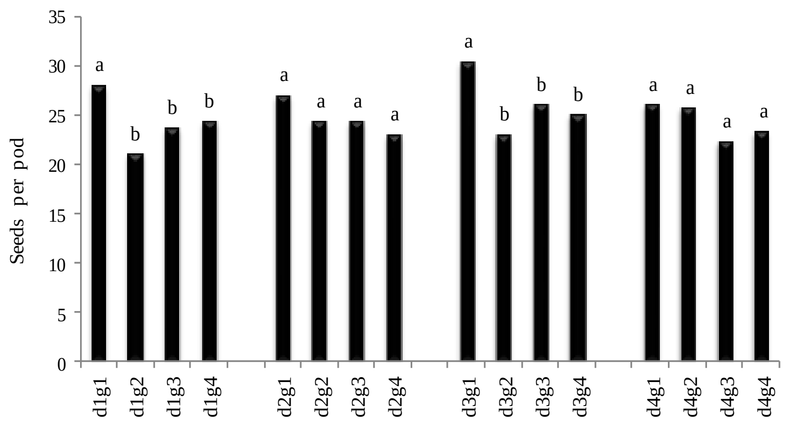

Figure 2. Slicing effect of interaction between planting date and genotype on seeds per pod of oilseed rape.
(d1, Planting date: 10/09/2012; d2, Planting date: 20/09/2012; d3, Planting date: 30/09/2012; d4, Planting date: 10/10/2012)

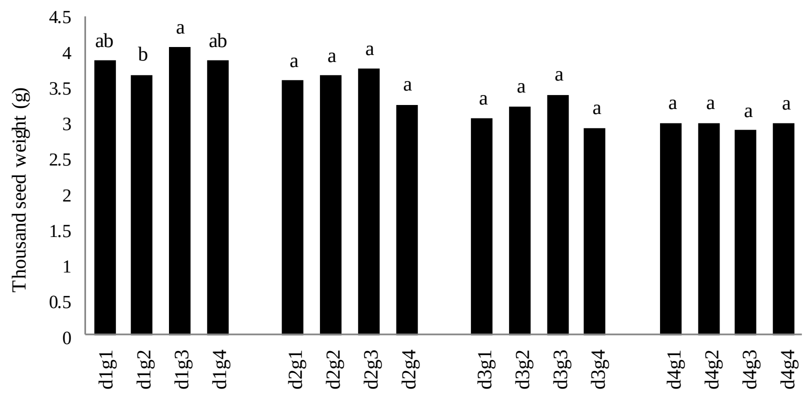

Figure 3. Slicing effect of the interaction of planting date and genotype on thousand seed weight of oilseed rape.
(d1, Planting date: 10/09/2012; d2, Planting date: 20/09/2012; d3, Planting date: 30/09/2012; d4, Planting date: 10/10/2012)

3.1.2. Number of seeds per pod

Simple and interaction effects of culture date andgenotype on the number of seeds per pod were significant (Table 1). The results obtained from the interaction section of planting date and genotype at the level of planting date on the number of seeds per pod showed that in the first planting date (at 5% level) and in the third planting date (at 1% level) the effect of genotype became significant. There was no statistically significant difference in the second and fourth planting dates of the genotypes (Table 2). On the first sowing date, the Okapi genotype had the highest mean number of seeds per pod (28 seeds per pod), and Elite, Octans-NK, and Tassilo genotypes (24.3, 23.6, and 21 seeds per pod) were in a statistical group, respectively. On the third planting date, the Okapi genotype produced the highest average number of seeds per pod (30.33 seeds per pod), and Octans-NK, Elite, and Tassilo genotypes were included in a statistical group and produced 26, 25, and 23 seeds per pod, respectively (Fig. 2). The importance of this trait is because more seeds mean a more extensive reservoir for plant photosynthetic materials. Therefore, the yield increases as a result. The highest and lowest number of seeds per pod was assigned to the Okapi genotype on the third planting date (30.33 seeds per pod) and the Tassilo genotype on the first planting date (21 seeds per pod) (Fig. 2). The number of seeds per pod (mean of four genotypes) remained unchanged by changing the planting time. It indicates that the number of seeds per pod is probably a genetic trait and is less affected by the planting date. Mendham et al. (1984) explained the increase in the number of seeds per pod in timely oilseed rape cultivation that the number of seeds per pod increases with increasing plant dry weight at the flowering stage. The higher dry weight of the plant at the flowering stage (especially in autumn cultivars) depends on the temperature, the initial nutrition of the plant before the rosette stage, and sufficient nitrogen reserves to start regrowth in spring. Abdoli et al. (2004) showed that with a 45-day delay in canola planting, a 27.1% reduction in the number of seeds per pod occurs. Azizi et al. (1999) also stated a direct relationship between the amount of dry matter produced before the flowering stage and the final number of seeds. Taylor and Smith (1992) concluded that delay in canola planting shortens the vegetative stage of the plant so that the plant does not reach the desired leaf area index at the right time. For this reason, in addition to reducing the amount of dry matter produced in the vegetative stage, the plant is not able to have enough sap to fill the formed seeds, especially the seeds in the pods on the branches, and therefore, the final number of seeds has reduced and the percentage of seed porosity increases in late planting. According to Anvare (1996) the number of seeds per pod is more influenced by genetic factors and less by environmental factors.

3.1.3. Thousand seed weight (TSW)

The results showed that Thousand Seed Weight (TSW) became significant (Table 1). The results obtained from slicing the interaction of planting date and genotype at the level of planting date on TSW showed that in all planting dates of genotypes, there was no statistically significant difference (except for the first planting date, which was significant at 1% probability level) (Table 2). At the first sowing date, the Octans-NK genotype had the highest mean of TSW (4.1 g), and Tassilo genotype had the lowest mean of TSW (3.7 g) (Fig. 3). Toliat Abulahsani (1995) and Khayyat et al. (2009) stated that the decrease in TSW for the delay in planting is due to the reduction of vegetative growth and the reduction of photosynthetic material that can be transferred during the developmental stages. According to Rahnama and Bakhshandeh (2009), Khayyat and Gohari (2006), and Robertson et al. (2004) delay in planting reduced TSW due to the period of seed filling with high ambient temperature, which prevents heat from optimal seed filling. Whitfield (1992) also concluded that as the temperature rises during the seed filling stages, the respiration rate of the pods increases rapidly, leading to excessive sap loss. Therefore, not enough nutrients reach the seeds, and the percentage of light and hollow seeds increases.

3.1.4. Seed yield and biological yield

Simple and interaction effects of planting date and genotype on seed yield and biological yield were significant at a 1% probability level (Table 1). Also, the results obtained from the interaction of planting date and genotype on economic yield and biological yield showed that the effect of genotype on the first, second and fourth planting date was significant ($P<0.001$). In the third planting date, seed yield and biological yield were not affected by genotype (Table 2). At the first sowing date, the Octans-NK genotype had the highest mean seed yield (5083.3 kg/ha), and the Elite genotype had the lowest mean seed yield (3611kg/ha). On the second planting date, Okapi, Tassilo, and Octans-NK genotypes were in a statistical group with mean seed yield (4066.6, 4233.3, and 4338.8 kg/ha, respectively), and the Elite genotype had the lowest mean seed yield (3783.3 kg/ha). At the third planting date, the genotypes did not differ statistically in terms of mean seed yield. At the last planting date, the Octans-NK genotype produced the highest mean seed yield (2424.4 kg/ha), and the Okapi genotype had the lowest mean seed yield (1244.4 kg/ha) (Fig. 4). The trend of changing the yield of genotypes with delay in planting shows that genotypes had different reactions compared to biological yield in terms of grain yield in the first and second planting dates. This issue can be the reason for the difference in their harvest index. The results of other research have shown that the delay in planting time greatly affects the allocation of plant dry matter to the economic reservoirs of the plant and causes inefficiency in the transfer of photosynthetic materials to the seeds. Therefore, seed yield is best obtained from plants with higher dry weight (Bilsborrow and Norton, 1993; Taylor and Smith, 1992). Khayyat and Gohari (2006) investigated the interactions of planting date and genotype on seed yield and reported that the superiority of some cultivars could be attributed to genetic characteristics such as higher yield potential, early maturity, and optimal use of environmental conditions along with excellence in all physiological and phenological indicators. Gunasekera et al. (2006) also concluded that seed yield as a quantitative trait is influenced by genotype, environment, and the interaction of genotype and environment. Cultivation date is the most critical factor determining seed yield and plant use of environmental conditions such as radiation, temperature, and carbon dioxide. In this experiment, genotypes produced the highest seed yield in the first and second planting dates due to more extended growing periods and receiving higher GDD (growing degree day). The last planting date (October 10) had lower yields due to less opportunity to have a suitable canopy and less absorption of food and radiation. Many researchers have stated that delay in oilseed rape planting reduces seed yield (Johnson *et al*., 1995; Mandal *et al*., 1994) and various reasons for this reduction in yield have been reported. Bilsborrow and Norton (1993) said that delay in oilseed rape planting reduced seed yield by reducing TSW and the number of pods. Delay in planting accelerates growth due to collision of stem time and reproductive development with high temperatures in early summer and reduces the seed filling. As a result, it leads to loss of yield components and reduced seed yield. Morrison and Stewart (2002) showed that high temperatures at the end of the growing season could reduce yields because flowering is limited to temperatures above 27°C. Dhawan (1985) also showed that cold and frost stress could reduce seed yield in canola by up to 70%. Lunn et al. (2001) in their study of planting date (September 1 and late) during four years of experimentation in London, England, reported that cold reduced grain yield by reducing the optimal canopy volume in late autumn dates.

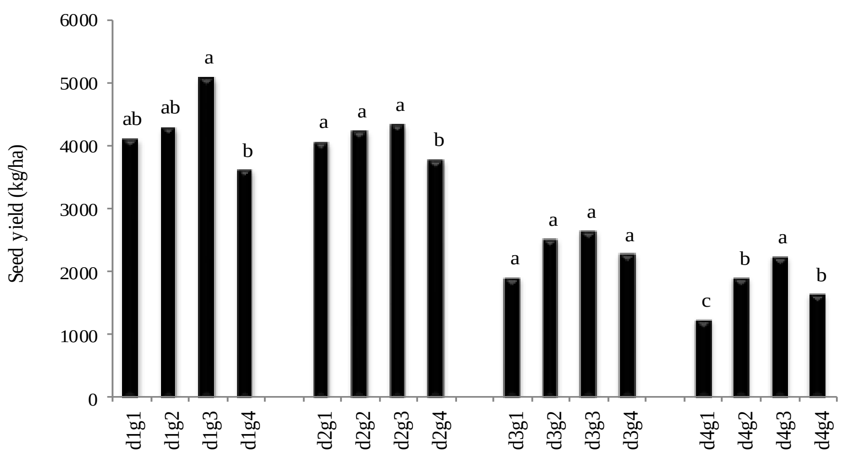

Figure 4. Slicing effect of interaction between planting date and genotype on seed yield of oilseed rape.
(d1, Planting date: 10/09/2012; d2, Planting date: 20/09/2012; d3, Planting date: 30/09/2012; d4, Planting date: 10/10/2012)

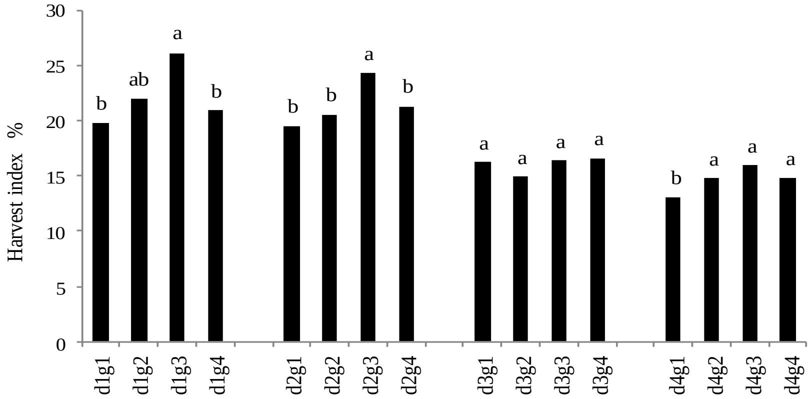

Figure 5. Slicing effect of the interaction of planting date and genotype on oilseed rape harvest index.
(d1, Planting date: 10/09/2012; d2, Planting date: 20/09/2012; d3, Planting date: 30/09/2012; d4, Planting date: 10/10/2012)

Table 3. Aalysis of variance for delay in planting and genotype on qualitative traits.

S.O.V		Oil content (%)	Oil yield (Kg/ha)
Replication	2	0.4008	9397.1
Planting Date	3	0.0378	3386256.97
Ea	6	0.2955	9929.03
Genotype	3	9.8045	280466.05
P.Date × Genotype	9	0.0430	41418.91
Eb	24	0.2603	8645.43
C.V		1.22	7.11

* ,** and $^{n.s}$ were significant at the probability level of 5%, 1% and not significant, respectively.

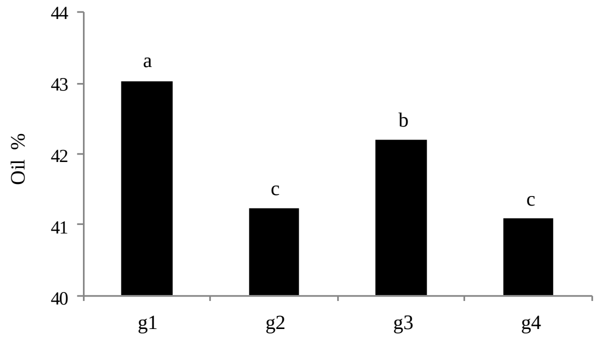

Figure 6. Effect of genotypes on seed oil percentage of oilseed rape.
(g1: Okapi g2: Elite g3: Tasilo g4: Octans NK)

3.1.5. Harvest index

The simple and interaction effects of cultivation date and genotype on harvest index were significant at the level of 1% probability (Table 1). Also, the results obtained from slicing the interaction of planting date and genotype at the level of planting date on harvest index showed that in the first and second planting dates, the effect of genotype was significant at the level of 1% and in the fourth planting date at the level of 5%. At the third planting date, the genotypes did not differ statistically significantly (Table 2). In the first sowing date, the Octans-NK genotype had the highest mean harvest index (26.1%), and Okapi and Elite genotypes had the lowest mean harvest index (19.8 and 20.9%). The Octans-NK genotype had the highest mean harvest index (24.3%). Okapi, Tassilo, and Elite genotypes were in the same statistical group with mean harvest index 19.5, 20.6, and 21.3%, respectively. At the third planting date, the genotypes did not differ statistically in terms of mean harvest index. At the last planting date, Octans-NK, Tassilo, and Elite genotypes in a statistical group had the highest mean harvest index (15.9, 14.8 and 14.83%), and Okapi genotype had the lowest mean harvest index (13.1%), respectively (Fig. 5).

3.2. Quality trait

3.2.1. Oil content (%)

The simple effect of planting date and the interaction effect of planting date and genotype on oil percentage was insignificant. But the simple result of genotype was significant at a 1% probability level (Table 3). The mean oil content of Okapi, Tassilo, Octans-NK, and Elite genotypes were 43.0, 41.2, 42.2, and 41.09%, respectively, which did not differ significantly between Tassilo and Elite genotypes (Fig. 6). The amount of seed oil is an inherited trait with high heritability, which is also affected by environmental conditions. The results of the experiments of Azizi et al. (2006) reported that the amount of oil is an inherited trait with high heritability that is partially affected by environmental conditions. The temperature is the most important factor directly related to the percentage of fat in the seed among the environmental factors. Robertson et al. (2004) showed that for every 1°C increase in temperature during flowering and seed filling, the amount of seed oil decreases by 1.7%. Adamson and Coffelt (2005) also showed that delay in planting reduces oil content by reducing plant growth, exposure to heat during the seed filling the stage at the end of the season, increasing respiration, and reducing photosynthetic production.

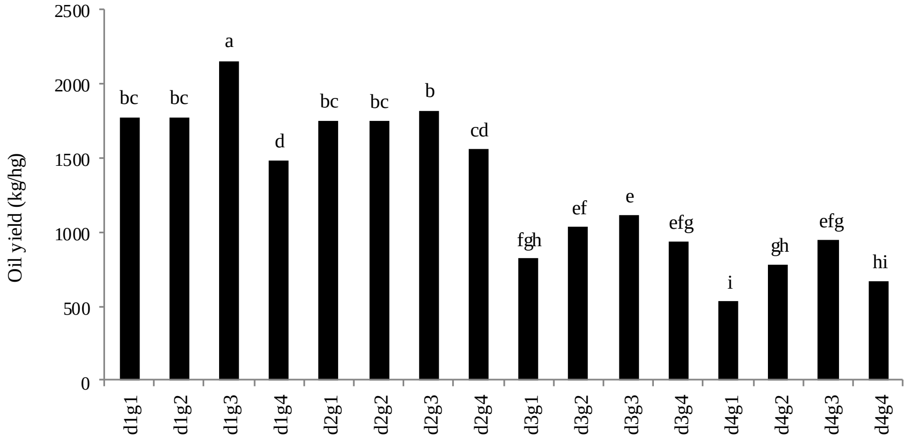

Figure 7. Interaction of planting date and genotype on oil yield in oilseed rape.
(d1, Planting date: 10/09/2012; d2, Planting date: 20/09/2012; d3, Planting date: 30/09/2012; d4, Planting date: 10/10/2012)

3.2.2. Seed oil yield

The simple and interaction effects of planting date and genotype on oil yield at the level of 1% probability were significant (Table 3). With the delay in planting, oil yield in all genotypes showed a decreasing trend, with the difference that the intensity of this trend increased from the second planting date onwards (Fig. 7). The highest oil yield was assigned to Octans-NK genotype on the first date (2155.5 kg/ha), and the lowest yield with a 75% decrease was assigned to the Elite genotype on the fourth planting date (536.5 kg/ha). The results of this experiment were consistent with the results of the investigations of Mandal et al. (1994), Johnson et al. (1995), and Adamson and Coffelt (2005). They stated that the delay in planting was due to reduced plant growth, exposure to heat during the seed filling phase at the end of the season, increased respiration, decreased photosynthetic production, and consequently lowered oil percentage, reduced oil yield compared to planting dates.

Conflict of Interests

All authors declare no conflict of interest.

Ethics approval and consent to participate

No human or animals were used in the present research.

Consent for publications

All authors read and approved the final manuscript for publication.

Availability of data and material

All the data are embedded in the manuscript.

Authors' contributions

All authors had an equal role in study design, work, statistical analysis and manuscript writing.

Informed Consent

The authors declare not to use any patients in this research.

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