The Effect of Sowing Date, Cultivar and Seed Rate on Yield and Quality Characteristics in Rapeseed (*Brassica napus* L.)

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Abstract: This study was carried out to determine the effect of different sowing dates and seeding rate on seed yield, oil and protein contents of seed in two rapeseed cultivars in the field of experiment and application of Aydin Adnan Menderes University Faculty of Agriculture during 2014/2015 and 2015/2016. The experiment was the split-split-plot design with 4 replications. The sowing dates, cultivars and seeding rates were arranged to main, sub and sub-sub plots, respectively. This experiment was conducted applying two sowing dates (early and late), two winter type cultivars (NK Petrol and NK Caravel) and five seeding rates (3, 5, 7, 9 and 11 kg ha^{-1}). The early sowing date and 7.0 kg ha^{-1} seeding rate given the highest seed yield for both cultivars based on two-year results. The interaction between sowing dates and cultivars for crude oil rate was significant, and the highest crude oil rate was recorded in NK Petrol cultivar (43.34 - 43.54%) at the first sowing date in both years. Non-significant protein content for all factors and interactions varied from 19.10% to 23.72%. Finally, it was recommended the earliest possible sowing with 7.0 kg ha^{-1} seeding rate for seed yield and quality in winter rapeseed growing. Moreover, it was recommended that NK Petrol for early sowing dates and NK Caravel for late sowing dates should be used as a cultivar.

Keywords: early sowing, late sowing, oil, plant density, protein

Kanolada (*Brassica napus* L.) Farklı Ekim Zamanı, Çeşit ve Tohumluk Miktarının Verim ve Kalite Özelliklerine Etkisi

Öz: *Bu çalışma farklı ekim zamanı ve tohumluk miktarının iki farklı kanola çeşidinin verim, yağ ve protein oranı üzerine etkisini belirlemek amacıyla 2014/2015 ve 2015/2016 yetiştirme periyodunda Aydın Adnan Menderes Üniversitesi Ziraat Fakültesi Araştırma ve Uygulama alanlarında yürütülmüştür. Deneme deseni olarak 4 yinelemeli Bölünen Bölünmüş Parseller kullanılmıştır. Ekim zamanları (erken ve geç) ana parsellerde, çeşitler (NK Petrol ve NK Caravel) alt parsellerde ve tohumluk miktarları (300 g, 500 g, 700 g, 900 g ve 1100 g da^{-1}) alt-alt parsellerde yer almıştır. Denemenin yürütüldüğü her iki yılda da erken ekim zamanında uygulanan 700 g da^{-1} tohumluk miktarı her iki çeşitte de en yüksek verimi vermiştir. Ham yağ oranı yönünden ekim zamanı x çeşit interaksiyonu önemli bulunmuş ve en yüksek ham yağ oranları her iki yılda olmak üzere erken ekim zamanında NK Petrol kanola çeşidinden (%43.34 - %43.54) elde edilmiştir. Protein içeriği yönünden çalışmada incelenen faktörlerin ve interaksiyonlarının önemli olmadığı ve protein oranlarının %19.10 ile %23.72 arasında değiştiği saptanmıştır. Sonuç olarak, kışlık kanola yetiştiriciliğinde verim ve kalite özellikleri yönünden ekimin mümkün olduğu kadar erken yapılması ve 700 g da^{-1} tohumluk miktarının uygulanması kanısına varılmıştır. Ayrıca, erken ekimlerde NK Petrol buna karşın geç ekimlerde NK Caravel çeşidinin kullanılması önerilmiştir.*

Anahtar kelimeler: *erken ekim, geç ekim, yağ, bitki sıklığı, protein*

INTRODUCTION

In the world, rapeseed (*Brassica napus* L.) considered as the third most important oilseed crop followed by soybean and oil palm and used as edible oil and biodiesel production (Velasco and Fernandez-Martinez, 2002; Langhof and Rühl, 2017). Especially, it is a rotation crop in regions dominated by wheat (Miralles et al., 2001). Its vegetable oil with the lowest content of saturated fatty acids and moderate content of polyunsaturated fatty acids is very important for human oil requirements (Molazem et al., 2013).

The sowing area, production and yield of rapeseed in the world are 35.0 million ha, 68.2 million tons and 1.94 tons ha^{-1}, respectively (FAOSTAT, 2019). In Turkey, rapeseed reached a sowing area of 52.5 thousand ha and, its production and yield are 180 thousand tons and 3.43 tons ha^{-1}, respectively (Anonymous, 2019). The winter types of rapeseed are grown in Trakya, Marmara, Central Anatolia and their transitional regions while spring types can be grown in the Mediterranean, Aegean and Southeast Anatolian regions of Turkey.

In rapeseed growing, it was emphasized that early-seeded rapeseed produced higher yield and quality (Oz, 2002; Celik, 2006; Epirturk, 2009) and better yields are achieved by sowing the crop late enough to prevent early freezing damage. Wang et al. (2012) revealed that decreased rapeseed yield in late sowing date mainly depends on shortened vegetative growth stages.

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In the coastal zone of the Aegean Region such as Aydin, excessive precipitation in early autumn in some years limited the early sowing date and sowing shift to December. In studies carried out on whether the delayed sowing date affects the use of variety and seeding rate, non-significant seeding rate x cultivar interactions for seed yield and oil content were found (Shahin and Valiollah, 2009; Sargin, 2012). The significant interaction effects of sowing date, rate and cultivar on seed yield were determined by Hasm and Mahmood (2016). In general, plant densities for rapeseed hybrids in Europe and China changed from 30 plants m^{-2} to 60-70 plants m^{-2} whereas the results of some researchers showed that optimum plant density was 100-200 plants m^{-2} (McGregor, 1987; O'Donovan, 1994). For conventional (non-hybrid) *B. napus* varieties, it was recommended that plant density should be 150 plants m^{-2}, generally requiring seeding rates of 7-8 kg ha^{-1} (Gunstone, 2004).

Numerous studies focused on research about effects of sowing date x cultivar, sowing date x plant density and plant density x cultivar on the yield of rapeseed (Hanson et al. 2008; Molazem et al., 2013; Harker et al., 2015; Hasm and Mahmood, 2016). However, the number of studies investigating the sowing date x cultivar x seeding rate in many years is still limited. Consequently, this study was aimed to determine the seed yield and quality relationships of two winter type cultivars of rapeseed grown at five different seeding rates and two sowing dates in the Aegean Region, Turkey.

MATERIAL AND METHODS

Experimental site

The present research was conducted at the experimental area of the Field Crops Department of the Agricultural Faculty of Aydın Adnan Menderes University (37^0 45' north, 27^0 45' east) during the winter season of 2015 and 2016. The area is characterized by the Mediterranean type of climate with warm and rainy winter and spring.

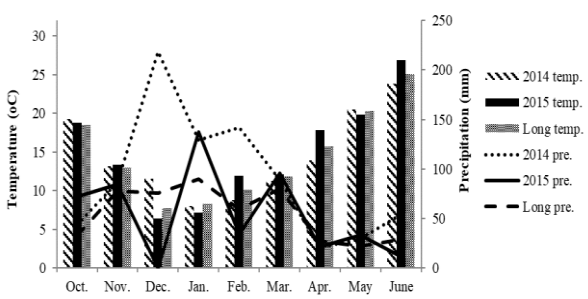


Figure 1. Precipitation and temperature during the cropping season in 2014, 2015 and long period

The mean temperatures from October to June show that May and June exceed the long term mean temperatures (Figure 1). The experiment area was established on loamy soil having pH 8.26 (alkali), organic matter 1.37% (insufficient), lime 2.65% (high) and total salt 0.0093% (low).

Experimental design

The experiment was an arrangement to split-split plot design with four replications. The sowing dates served as main plots (6 November and 9 December in 2014; 5 October and 7 November in 2015). The subplots were NK Petrol and NK Caravel (from Syngenta) rapeseed cultivars. Five different seeding rate (3, 5, 7, 9 and 11 kg ha^{-1}) were used as a sub-sub plot. Soil moisture and rainfall during the October-December period affected the sowing date (Figure 1). All the cultural managements such as fertilization and irrigation were applied as recommended for rapeseed growing of the Aegean Region.

Crop management

Rapeseed was planted at 13 cm row space according to different seeding rate viz., 3, 5, 7, 9 and 11 kg ha^{-1} with a grain sowing machine. The plant densities were 39, 65, 91, 117 and 143 plants m^{-2} for each seeding rate, respectively. Each sub-sub plot has 7 m length, 21 rows and 19.11 m^2. For all parcels, the recommended fertilizer rate of 160:80:80 of NPK was applied using a compound fertilizer (NPK 15:15:15) to supply 80 kg each of NPK ha^{-1} before sowing as basal application and ammonium nitrate (33% N) to supply the remaining dose (80 kg ha^{-1}) of nitrogen before the early spring season. The herbicide (Metazachlor, 333 g/l + Quinmerac 83 g/l effectively) were applied for the weed challenge after sowing.

Measurements

Seed yield (t ha^{-1}), crude oil content (%) and crude protein content (%) were recorded. Seed yield was determined based on 5% moisture level with all plants in each plot which harvested by hand after the completion of pod filling. The oil content of seeds was obtained following the Soxhlet method (AOAC, 1990) while crude protein was determined following the Dumas method (Dumas, 1831).

Data analysis

The data of seed yield, crude oil rate and crude protein rate were statistically analyzed according to the method proposed by Yurtsever (1984) in TOTEM STAT Statistical Package Program (Acikgoz et al., 2004). The differences between the means were compared by the least significant difference (LSD) at the 5% level (Steel et al., 1997).

RESULTS AND DISCUSSIONS

Seed Yield (t/ha)

The results of ANOVA indicated that the differences between the two years were significant for yield whereas the effects of years on crude oil and protein content were non-significant (non-tabulated data). Seed yield in the first year was significantly higher than that of the second year. The precipitation in December, January and February of the first year were very intensive, and also June rains were higher than that of the second year (Figure 1). The total precipitations for both years were 812.6 mm and 489.5 mm, respectively. There were non-significant differences in terms of monthly temperature values of both years.

It could be concluded that seed yield was mainly affected by precipitation amount and monthly distribution. Data presented in Table 1 indicated that interactive effects of sowing dates, cultivars and seeding rates for rapeseed yield were significant in both cropping seasons (Table 1). Therefore, adjustments in seeding rate were needed for each rapeseed cultivars and sowing dates. The highest rapeseed seed yields recorded in the first sowing date of the 2015 year with 7 kg ha^{-1} seeding rate in NK Petrol (3.99 t ha^{-1}) and seeding rate of 9 kg ha^{-1} in NK Caravel (3.93 t ha^{-1}). The lowest rapeseed seed yields recorded in the second sowing date of 2015 year. These yields of 2.56 t ha^{-1} and 2.92 t ha^{-1} obtained in NK Petrol cultivar with 9.0 and 11.0 kg ha^{-1} seed rates, respectively. Also, NK Caravel cultivar at second sowing date with 11.0 kg ha^{-1} seed rate gave the lowest values from yield (2.93 t ha^{-1}). In the 2016 year, the highest rapeseed seed yields recorded in the first sowing date with 7 kg ha^{-1} seeding rate both in NK Petrol (3.63 t ha^{-1}) and in NK Caravel cultivar (3.60 t ha^{-1}). Also, the second-highest yields obtained from the second date with 7 kg ha^{-1} in both NK Caravel and NK Petrol cultivars (3.46 and 3.40 t ha^{-1}, respectively). Likewise, to 2015, the lowest rapeseed seed yields recorded in the second sowing date of the 2016 year with 11 kg ha^{-1} seeding rate in NK Caravel (2.36 t ha^{-1}) and NK Petrol cultivar (2.20 t ha^{-1}). It was concluded that an early sowing date and 7.0 kg ha^{-1} seeding rate could be recommended for both cultivars based on two-year results. Similarly, many researchers found that higher seeding rates (5.6-8.4 kg ha^{-1}) increased rapeseed seed yield (Brandt et al., 2007; Hanson et al., 2008; Harker et al., 2012). Contrary to our results, Kutcher et al. (2013) and Harker et al. (2015), rapeseed yield was not affected by higher seeding rates. At the same time, delay in sowing date more negatively affected the yields of the highest seeding rate (11 kg ha^{-1}) that of 3-5 kg ha^{-1} seeding rate. In terms of climate parameters such as temperature, day length and rainfall, sowing date is one of the most important crop management for best yield. Many studies emphasized that sowing date significantly affected rapeseed yield (Johnson et al., 1995; Turhan et al., 2011; Balalic et al., 2017) and late sowing of rapeseed in winter type decreased seed yield (Pritchard et al., 2000; Ozer 2003; Uzun et al., 2009). It was concluded that rapeseed could be planted during the October-November period in the coastal zone of the Aegean region with a mild Mediterranean climate.

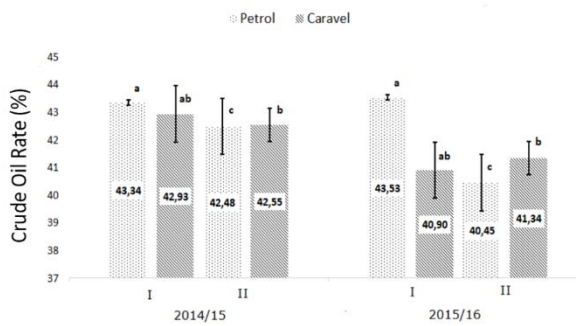
Table 1. Rapeseed yields by sowing dates, cultivars and seeding rates in 2014/15 and 2015/16 seasons

		Seed Yield (t ha^{-1})				
		2014/2015				
		Seeding Rate (kg ha^{-1}) (SR)				
Sowing Date (SD)	**Cultivars (C)**	**3**	**5**	**7**	**9**	**11**
I	Petrol	3.55	3.73	3.99	3.50	3.40
	Caravel	3.72	3.77	3.82	3.93	3.11
II	Petrol	3.25	3.34	3.60	2.92	2.56
	Caravel	3.33	3.51	3.81	3.67	2.93
LSD $_{0.05}$ (AxBxC): 0.0186; Years (df=1): 753.68**, SD x C x SR (df=4): 10.55**, Replication (df=3): 1.32; Error (df=48)2.49, C.V. (%): 4.49						
		2015/2016				
		Seeding Rate (kg ha^{-1}) (SR)				
Sowing Date (SD)	**Cultivars (C)**	**3**	**5**	**7**	**9**	**11**
I	Petrol	2.95	3.32	3.63	2.81	2.48
	Caravel	2.86	2.89	3.60	2.86	2.73
II	Petrol	2.69	2.96	3.40	2.85	2.20
	Caravel	2.89	3.41	3.46	3.12	2.36
LSD $_{0.05}$ (AxBxC): 0.0168, SD x C x SR (df=4): 6.42**, Replication (df=3): 3.60, Error (df=48): 2.02, C.V. (%): 4.86						

Oil Rate

The interactive effects of sowing dates and cultivars for crude oil rate were significant in both cropping seasons. In our study, the crude oil rate varied from 39.75% to 45.13% depending on cultivars, sowing dates and years (Figure 2). The cultivar, crop management and the environment affected the oil rate of rapeseed in which it is grown and, the oil content of rapeseed changed was between 40.0% and 44.0% (Anonymous, 2014; Balalic et al., 2017).

The highest crude oil rate was recorded in NK Petrol cultivar (43.34-43.54%) at the first sowing date in both years. These values followed by NK Caravel cultivar with 42.93-42.21% at first sowing date whereas crude oil rate of Caravel cultivar in second sowing date was higher than that of Petrol cultivar in both years (Figure 2). It was clear that late sowing caused delayed flowering time, shortened flowering duration. Therefore, it can be said that NK Caravel responds more positively to the shorter vegetation period than the NK petrol in terms of crude oil. These results are in agreement with the comments made by Ginwal et al. (2005) and Turhan et al. (2011).



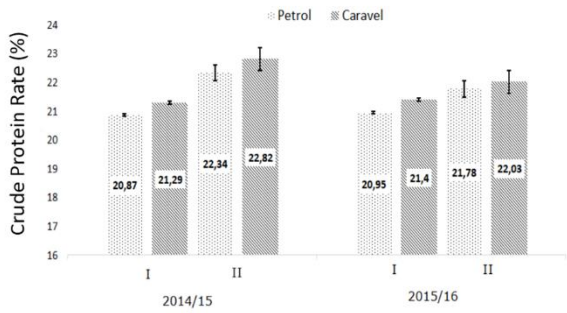
SDxC (df=1)	7.70**	56.67**
Rep. (df=3)	1.32	2.42
Error (df=6)	0.58	4.75
C.V. (%)	3.23	5.61

**: p<0.01, SD: Sowing date, Rep.: Replications

Figure 2. Crude oil rate (%) of rapeseed by sowing dates (I; first sowing date and II; second sowing date) and cultivars in 014/15 and 2015/16. Vertical bars represent standard errors of means. Different letters at the top of the histogram indicate significant differences at the LSD test (0.05 probability level)

Protein Rate

The results of variance analysis (non-tabulated data) from the present study showed that interactive effects of sowing dates, seeding rate and cultivars for crude protein rate were non-significant in both cropping seasons. Protein content varied from 19.10% to 23.72% (Figure 3). By contrast, many researchers reported that the protein content of rapeseed is affected by environmental conditions and agriculture management such as temperature, location, year, seeding rate and sowing date (Piljuk, 2006; Marinkovic et al., 2010; Laaniste et al., 2016; Ratajczak et al., 2019). However, our results in terms of protein content were similar to Turhan et al. (2011) and Balalic et al. (2017). It can be said that cultivar, sowing date and seeding rate are not able to change the protein content of rapeseed in Aydin ecological condition. Despite all this, NK Caravel cultivar produced the highest crude protein rate (23.23% - 23.72%) at the second sowing date in both years (Figure 3).



Rep. (df=3)	1.86	1.14
Error (df=6)	5.76	3.60
C.V. (%)	10.99	8.81

**: p<0.01, SD: Sowing date, Rep.: Replications

Figure 3. Crude protein rate (%) of rapeseed by sowing dates (I; first sowing date and II; second sowing date) and cultivars in 2014/15 and 2015/16. Vertical bars represent standard errors of means

CONCLUSIONS

Non-significant differences indicated that oil and protein content were not seriously affected by the agro-ecological condition and cultural managements in Aydin. Whereas seed yield with low heritable was affected by optimal sowing date and seeding rate and performance of cultivar. The higher yields recorded from the early sowing date and 7 kg ha^{-1} of seeding rate in both cultivars and years. The early planting of rapeseed depends on the harvest of the previous product such as cotton and maize and then the autumn precipitation. It may be concluded that increasing the seeding rate should be avoided especially in late planting.

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