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Effect of Row Spacing on Yield, Yield Components and Crude Oil of Autumn and Spring Sowed Mustard (*Sinapis arvensis* L.) in Eight Locations of Turkey

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ABSTRACT

This study was conducted to evaluate the effect of autumn and spring sowing and row spacings (20, 30, 40, 50 and 60 cm) on yield, yield components and crude oil percentage of mustard (*Sinapis arvensis* L.) at eight locations lying in different ecological zones (Ankara, Aydın, Erzurum, Eskişehir, Isparta, Şanlıurfa, Tekirdağ and Tokat) during 2013-14 and 2014-15 growing seasons. The experiment was designed according to the "Split Plots on Randomized Complete Block" with four replications. Autumn and spring sowing were main plots, row spacings were sub-plots in each location. The results showed that, autumn and spring sowing and row spacing significantly affected yield, yield components and crude oil yield across locations. In general, increasing row spacing reduced seed yield and crude oil percentage. The plants from autumn sowing increased crude oil yield compared to the plants from spring sowing. The maximum seed yield and crude oil yield (2525.5 and 695.3 kg ha^{-1}, respectively) was obtained from Tokat during autumn sowing at 50 cm row spacing. It was determined that autumn sowing was more suitable for Aydın, Tekirdağ, Tokat and Şanlıurfa locations. Autumn sowing could also be possible at Ankara, Eskişehir and Isparta locations if plants enter to winter at the right time (8-10 leaves rosette stage). Agronomic performances of mustard at Erzurum was not promising. For autumn and spring sowing, the most suitable row spacing must be 20-30 cm in Ankara, Aydın, Erzurum, Eskişehir, Isparta, Tekirdağ and Şanlıurfa; 50 cm in Tokat in autumn sowing.

Keywords: Autumn and spring sowing; *Sinapis arvensis* L.; Crude oil percentage; Mustard; Row spacing; Yield; Yield components

1. Introduction

Many *Brassica* species are used for oil or biodiesel production in the world. Two species of mustard *Sinapis alba* L. and *Sinapis arvensis* L. family Cruciferae, grow widely in Turkey under natural conditions as weed. Mustard is not cultivated for the production of vegetable oil or biodiesel production in our country.

Mustard oil is not suitable for consuming as edible oil due to high erucic acid but it is convenient for industrial use (İlisulu 1973; Jham et al 2009). Therefore, mustard has been preferred on account of its capacity of providing raw material for biodiesel energy industry (Khan et al 2011; Ahmad et al 2012; Kayaçetin et al 2016).

It has been known that mustard is grown in mild winter regions as late fall and in hard winter regions as late spring crop (İlisulu 1973; Thurling 1974). Limited water and high temperature are two significant factor restricting crop productivity (Angadi et al 2003). Mustard plant might be effected differently under autumn and spring sowing and environment conditions that are based on temperature and cold prevailing during the crop life cycle.

Different mustard varieties are grown in spring and autumn all over the world (Jankowski & Budzyn'ski 2003; Demirel & Cranshaw 2006; Wu et al 2011). The optimum sowing space favorably affects the absorption of nutrients and the exposure of the plant to light. While Christensen & Drabble (1984) in canola, Arif et al (2012) in mustard reported that more uniform distribution of seeds per unit area decreased competition among plant populations so the seed yield of plant was higher in closer row spacings. Kazemeini et al (2010) obtained higher seed yield wider row spacings in canola. Kaur & Sidhu (2006) and Keiwanrad & Zandi (2014) suggested that the crude oil yield of mustard was higher in closer row spacings.

Yield and its development process of mustard like other crops depend on genetic, environmental and agronomic factors (like row spacing, irrigation, seed rate, fertilizer) as well as the interaction between them (Zukalova et al 1988; Shekhawat et al 2012; Keiwanrad & Zandi 2014). Establishment of optimum population density per unit area is a prerequisite for an increased grain yield. Population density is known to influence yield and yield components of mustard in positive or negative way (Johnson et al 2003). Successful adaptation of a plant to the environment involves reducing unfavorable risk factors and increasing favorable factors like optimum radiation, temperature and moisture (Mendham & Salisbury 1995). The aim of the study is to evaluate the effect of row spacing on yield, yield components and crude oil percentage of autumn and spring sowed mustard in eight different locations of Turkey.

2. Material and Methods

2.1. Experimental conditions

The experiments were conducted during the growing seasons of 2013-14 and 2014-15 at eight locations (Ankara, Erzurum, Eskişehir, Isparta, Tekirdağ, Tokat and Şanlıurfa) of Turkey lying at altitudes from 29 to 1893 m above sea level (Table 2). The seeds of mustard were collected from the plants growing under wild conditions in Konya province. Thereafter, these were multiplied for use in the experiment in Central Research Institute for Field Crops in 2012-13.

The experiment was set up in "Split Plots on Randomized Complete Block" design with four replication. Autumn and spring sowing were done in main plots using row spacing of 20, 30, 40, 50, and 60 cm in sub-plots at eight locations. Each plot was 5 m long and consisted of 15 rows (20 cm), 10 rows (30 cm), 7 rows (40 cm), 6 rows (50 cm), 5 rows (60 cm). Seeds were sown at 1-2 cm depth. Nitrogen, phosphorus and sulphur fertilizers were applied at the rate of 100, 50 and 35 kg ha^{-1} in the form of diammonium phosphate, ammonium nitrate and ammonium sulfate respectively (Pyare et al 2008). The total quantity of phosphorus and sulphur fertilizer was applied at the time of sowing. The total nitrogen fertilization was applied in two equal doses, at the time of sowing and rosette formation. No irrigation was done to the experimental plots during the study period of two years.

According to autumn and spring sowing, location and row spacing ratio of winter survival

(%), sowing, emergence, flowering and harvest date of mustard are shown in Table 1. Sowing and harvest date of mustard were made at optimum time under locations ecological conditions. The data could not be obtained due to cold damage at Ankara, Eskişehir and Isparta locations in the first year. Significant cold damage losses didn't observed in the second year as plants entered to winter at 8-10 leaves rosette stage. Ratio of winter survival were 79%, 66% and 83%, at Aydın, Tekirdağ, Tokat and Şanlıurfa locations respectively in the second year. Erzurum ecological conditions, emergence could not be achieved despite irrigation for both years due to high coldness (Table 1).

2.2. Meteorological data of the experimental area

Monthly meteorological data during mustard development in the experimental areas are shown in Table 2.

The total rainfall in 2013-2014 ranged 257.4 to 647.9 mm. The maximum rainfall was found at Tekirdağ location while the lowest rainfall was at Eskişehir location. The total rainfall during 2014-2015 ranged 406.7 to 791.0 mm. While the maximum rainfall were found at Aydın location, the lowest rainfall was at Tokat location. Şanlıurfa location had the maximum average temperature and Erzurum location had the lowest average temperature (Table 2).

Table 1- According to autumn and spring sowing, location and row spacing sowing, ratio of winter survival (%), emergence, flowering and harvest date of mustard

Year	*Autumn and spring sowing*	*Location*	*Ratio of winter survival (%)*	*Sowing date*	*Emergence date*	*Flowering date*	*Harvest date*
2013-14	Fall sowing	Ankara	-	02-Oct-2013	28-Oct-2013	Cold damage	Cold damage
		Aydın	100	25-Oct-2013	15-Nov-2013	06-Mar-2014	10-Jun-2014
		Erzurum	-	12-Oct-2013	-	-	-
		Eskişehir	-	01-Oct-2013	18-Oct-2013	Cold damage	Cold damage
		Isparta	-	10-Oct-2013	29-Oct-2013	Cold damage	Cold damage
		Şanlıurfa	100	31-Oct-2013	12-Nov-2013	25-Mar-2014	22-May-2014
		Tekirdağ	100	02-Oct-2013	24-Oct-2013	21-Mar-2014	17-Jun-2014
		Tokat	100	08-Oct-2013	25-Oct-2013	06-Apr-2014	09-Jun-2014
	Spring sowing	Ankara	-	16-Apr-2014	29-Apr-2014	14-Jun-2014	4-Aug-2014
		Aydın	-	20-Mar-2014	28-Mar-2014	20-Apr-2014	15-Jul-2014
		Erzurum	-	24-Apr-2014	18-May-2014	11-Jul-2014	18-Aug-2014
		Eskişehir	-	08-Apr-2014	24-Apr-2014	02-Jun-2014	22-Jul-2014
		Isparta	-	21-Mar-2014	10-Apr-2014	03-Jun-2014	19-Jul-2014
		Şanlıurfa	-	26-Feb-2014	07-Mar-2014	26-Apr-2014	16-Jun-2014
		Tekirdağ	-	04-Apr-2014	19-Apr-2014	22-May-2014	26-Jul-2014
		Tokat	-	05-Mar-2014	21-Mar-2014	07-May-2014	7-Jul-2014
2014-15	Fall sowing	Ankara	79	14-Oct-2014	02-Nov-2014	26-May-2015	15-Jul-2015
		Aydın	100	03-Nov-2014	22-Nov-2014	18-Feb-2015	26-Jun-2015
		Erzurum	-	16-Oct-2014	-	-	-
		Eskişehir	66	14-Oct-2014	27-Oct-2014	08-May-2015	30-Jun-2015
		Isparta	100	23-Oct-2014	05-Nov-2014	07-May-2015	13-Jul-2015
		Şanlıurfa	83	27-Oct-2014	11-Nov-2014	10-Apr-2015	1-Jun-2015
		Tekirdağ	100	16-Oct-2014	02-Nov-2014	20-Apr-2015	8-Jul-2015
		Tokat	100	14-Oct-2014	25-Oct-2014	04-May-2015	29-Jun-2015
	Spring sowing	Ankara	-	01-May-2015	12-May-2015	22-Jun-2015	10-Aug-2015
		Aydın	-	17-Apr-2015	24-Apr-2015	7-Jun-2015	09-Jul-2015
		Erzurum	-	15-May-2015	30-May-2015	30-Jun-2015	01-Sep-2015
		Eskişehir	-	04-Mar-2015	06-Apr-2015	11-Jun-2015	10-Jul-2015
		Isparta	-	17-Mar-2015	10-Apr-2015	1-Jun-2015	17-Jul-2015
		Şanlıurfa	-	27-Feb-2015	12-Mar-2015	3-May-2015	09-Jun-2015
		Tekirdağ	-	16-Apr-2015	30-Apr-2015	10-May-2015	15-Jul-2015
		Tokat	-	28-Feb-2015	17-Mar-2015	30-May-2015	06-Jul-2015

Table 2- Montly meteorological data of mustard during growing seasons in experimental areas

Location	*Altitude (m)*	*Climatic factors*	*Years*	*Months*												*Total or average*
				September	*October*	*November*	*December*	*January*	*February*	*March*	*April*	*May*	*June*	*July*	*August*	
Ankara	925	Precipitation (mm)	Long term	16.1	35.5	37.5	41.7	37.6	35.6	39.9	49.3	49.1	34.2	16.0	10.2	402.7
			2013-14	1.8	26.0	1.4	4.8	33.8	8.0	47.6	32.2	69.2	58.6	2.4	21.2	307.0
			2014-15	56.8	38.4	26.5	39.5	54.3	39.0	92.1	25.0	67.2	133.7	5.1	25.4	603.0
		Relative humidity (%)	Long years	49.2	61.1	70.8	76.1	71.4	70.3	63.4	59.7	56.6	52.1	46.3	45.4	60.2
			2013-14	44.4	51.1	64.7	74.2	90.4	59.9	60.6	53.1	59.0	56.5	38.7	48.7	55.5
			2014-15	55.1	68.4	69.3	84.0	77.8	70.4	66.3	53.1	63.4	65.8	39.1	43.9	63.1
		Average temperature (ºC)	Long years	18.8	12.8	6.6	2.3	0.6	2.0	5.8	11.3	15.9	20.1	23.5	23.5	11.9
			2013-14	16.9	10.2	6.9	-2.9	1.6	4.4	6.7	11.9	15.0	18.3	24.2	23.6	11.4
			2014-15	19.3	13.3	7.7	5.6	1.2	3.3	7.1	9.5	14.9	18.4	24.9	24.7	12.5
		Maximum temperature (ºC)	Long years	26.0	19.4	12.0	6.1	4.5	6.6	11.3	17.1	22.1	26.6	30.0	30.4	30.0
			2013-14	30.9	26.0	20.6	12.3	14.3	18.1	20.6	26.4	27.7	32.6	34.6	36.9	34.6
			2014-15	34.9	24.7	18.3	14.2	12.3	16.4	21.3	24.0	32.1	28.1	38.0	34.7	38.0
		Minimum temperature (ºC)	Long years	11.9	7.5	2.3	-0.5	-2.3	-1.8	0.9	5.7	9.7	13.1	16.3	16.4	-2.3
			2013-14	5.7	-1.6	-4.7	-13.4	-6.1	-8.7	-6.4	0.2	5.4	8.6	13.2	13.7	-13.4
			2014-15	5.6	-0.3	-2.4	-2.8	-16.0	-8.2	-5.1	-2.6	5.7	11.0	13.2	11.6	-16.0
Aydın	86	Precipitation (mm)	Long years	10.2	39.9	84.3	110.7	97.8	91.0	70.8	55.5	36.8	10.7	2.5	2.8	613.0
			2013-14	18.8	38.8	81.6	12.4	45.8	14.2	72.0	42.0	41.2	41.0	0.0	0.0	407.8
			2014-15	5.2	21.8	117.6	216.9	135.1	126.1	102.8	28.2	25.4	8.9	3.0	0.0	791.0
		Relative humidity (%)	Long years	55.2	61.5	68.2	72.5	68.7	67.8	64.4	62.1	55.8	48.1	48.3	52.5	60.4
			2013-14	45.1	55.7	65.0	63.2	78.5	71.8	64.8	63.9	57.1	52.5	44.9	47.5	59.2
			2014-15	57.9	61.8	72.4	81.9	73.9	68.0	70.9	53.4	57.1	52.5	46.6	51.9	62.4
		Average temperature (ºC)	Long years	23.3	18.3	12.9	9.1	8.0	8.9	11.6	15.8	20.9	26.0	28.5	27.6	17.6
			2013-14	23.6	16.1	12.8	6.2	9.5	9.9	12.6	16.9	21.6	25.8	29.6	30.2	17.9
			2014-15	23.8	19.6	13.6	11.7	8.1	9.2	12.1	14.6	22.1	24.2	29.4	29.1	17.4
		Maximum temperature (ºC)	Long years	32.1	26.4	19.3	14.2	13.2	14.4	17.8	22.5	28.4	33.5	36.4	35.8	36.4
			2013-14	37.5	31.2	28.5	17.4	19.1	22.1	27.3	38.1	35.3	40.6	40.4	43.3	43.3
			2014-15	35.8	32.8	25.6	20.6	20.3	23.1	25.1	31.6	35.3	37.4	41.2	39.8	41.2
		Minimum temperature (ºC)	Long years	17.0	11.0	10.0	3.0	7.0	6.0	8.0	11.0	15.0	18.1	20.6	20.5	3.0
			2013-14	11.1	5.6	1.2	-3.4	-0.7	-1.2	1.8	5.1	9.7	11.7	18.7	19.1	-3.4
			2014-15	13.5	10.3	3.0	2.0	-5.1	-1.5	1.9	3.9	12.7	13.6	19.5	19.7	-5.1
Erzurum	1893	Precipitation (mm)	Long years	19.7	48.2	30.5	22.0	17.7	22.1	32.8	56.7	68.9	40.5	24.4	16.6	400.1
			2013-14	13.6	16.8	19.6	8.3	11.3	8.0	35.7	31.6	88.6	21.6	27.8	42.8	325.7
			2014-15	42.8	45.8	13.4	19.0	13.2	33.6	25.8	61.6	69.8	73.3	13.6	56.0	467.9
		Relative humidity (%)	Long years	53.0	65.4	74.1	78.9	76.1	77.8	74.2	66.8	63.8	58.7	53.4	50.5	66.1
			2013-14	49.8	59.6	74.1	78.6	83.9	80.4	70.2	64.5	68.7	54.9	46.9	52.0	65.3
			2014-15	52.0	71.9	77.2	86.6	82.6	86.7	79.4	67.3	66.6	58.7	46.4	45.4	68.4
		Average temperature (ºC)	Long years	13.7	7.3	0.0	-6.9	-9.8	-8.6	-2.3	5.2	10.0	14.5	18.9	18.9	5.1
			2013-14	13.6	6.0	2.3	-13.4	-10.1	0.3	2.3	7.5	11.3	15.3	20.5	14.6	5.9
			2014-15	14.6	8.4	0.2	-0.8	-8.1	-7.4	-1.6	4.9	10.2	15.7	20.0	20.5	6.4
		Maximum temperature (ºC)	Long years	23.1	15.5	6.3	-1.4	-3.8	-2.4	3.0	11.4	16.8	22.1	26.9	27.6	27.6
			2013-14	28.8	23.7	16.6	1.2	4.0	13.8	14.4	20.8	23.9	28.8	33.4	30.9	33.4
			2014-15	30.9	20.0	13.2	7.8	5.8	6.3	11.1	19.5	23.4	29.8	33.1	34.8	34.8
		Minimum temperature (ºC)	Long years	4.2	0.3	-5.3	-12.1	-15.5	-14.4	-7.7	-0.5	2.9	5.7	9.7	9.5	-15.5
			2013-14	-3.4	-9.0	-11.9	-27.1	-28.5	-18	-16.9	-10.2	-3.2	0.8	6.0	-3.7	-28.5
			2014-15	-3.7	-3.6	-11.0	-14.1	-23.6	-24.6	-23.7	-7.2	-3.4	1.3	7.1	9.2	-24.6
Eskişehir	788	Precipitation (mm)	Long years	13.9	32.5	35.3	42.1	33.1	27.8	30.7	42.4	40.6	25.7	13.0	7.7	344.8
			2013-14	3.0	51.0	19.6	1.6	15.2	3.4	13.1	51.4	31.2	63.7	4.2	0.0	257.4
			2014-15	41.4	34.5	18.2	77.4	54.3	39.0	92.1	25.0	67.2	133.7	5.1	25.4	613.3
		Relative humidity (%)	Long years	57.8	65.4	71.6	77.0	75.1	72.2	66.3	63.1	60.7	56.9	53.5	54.4	64.5
			2013-14	49.5	59.0	66.9	72.6	79.7	60.6	63.2	57.4	61.5	62.7	55.6	57.5	62.2
			2014-15	69.7	77.9	81.2	89.8	89.9	76.7	72.3	59.7	54.6	72.8	55.0	60.3	71.7
		Average temperature (ºC)	Long years	16.8	11.3	5.4	1.3	0.0	1.1	4.5	9.8	14.7	18.7	21.6	21.4	10.6
			2013-14	17.6	10.9	8.5	-1.0	3.8	6.2	8.1	13.2	16.6	20.2	23.8	24.0	12.7
			2014-15	18.4	13.4	7.6	5.5	-0.1	3.4	6.5	9.2	17.5	17.9	23.4	23.4	12.2
		Maximum temperature (ºC)	Long years	25.3	18.9	11.7	5.3	3.9	6.3	11.1	16.4	21.7	25.7	28.9	29.2	29.2
			2013-14	33.2	25.5	21.6	10.6	18.0	22.3	23.4	27.2	28.5	35.4	37.2	36.4	37.2
			2014-15	33.3	25.5	17.5	14.4	12.9	18.1	21.0	27.7	31.8	29.1	36.9	33.4	36.9
		Minimum temperature (ºC)	Long years	8.6	4.5	0.2	-1.8	-3.3	-3.2	-0.8	3.3	7.2	10.7	13.5	13.3	-3.3
			2013-14	6.4	-2.0	-0.6	-8.9	-2.8	-6.4	-2.8	1.3	6.6	8.9	13.6	15.4	-8.9
			2014-15	6.4	0.3	-1.0	-2.8	-13.1	-6.7	-3.6	-2.4	6.6	9.6	12.6	13.6	-13.1

Table 2 (Continue)- Montly meteorological data of mustard during growing seasons in experimental areas

Location	*Altitude (m)*	*Climatic factors*	*Years*	*Months*												*Total or average*
				September	*October*	*November*	*December*	*January*	*February*	*March*	*April*	*May*	*June*	*July*	*August*	
Isparta	1050	Precipitation (mm)	Long years	15.5	35.5	47.7	69.3	59.4	55.8	54.3	56.9	48.9	26.6	17.5	14.7	502.1
			2013-14	3.0	104.0	67.6	29.4	61.3	23.4	78.6	44.8	107.0	42.8	0.8	3.2	565.9
			2014-15	100.0	57.2	37.4	104.2	82.5	100.8	79.0	24.3	10.3	0.7	0.2	0.0	596.6
		Relative humidity (%)	Long years	16.5	19.5	20.1	21.3	19.0	22.8	21.0	20.5	20.4	17.3	15.8	15.0	19.1
			2013-14	43.3	54.0	65.5	64.2	76.7	60.8	63.3	59.5	60.3	49.8	43.5	44.2	57.1
			2014-15	60.2	64.9	69.3	76.6	73.8	68.5	65.2	60.0	60.1	63.5	43.9	51.0	63.1
		Average temperature (ºC)	Long years	18.4	12.5	6.8	3.0	1.7	2.7	5.8	10.4	15.3	20.3	23.5	23.1	12.0
			2013-14	18.9	10.7	8.7	1.0	3.7	5.2	7.3	11.7	15.1	20.0	24.5	24.9	12.6
			2014-15	18.1	13.1	7.0	5.9	1.9	3.3	6.7	9.0	14.8	18.3	24.2	23.8	12.2
		Maximum temperature (ºC)	Long years	26.5	20.3	13.5	7.8	6.3	7.6	11.5	16.4	21.8	26.7	30.4	30.5	30.5
			2013-14	33.1	25.3	22.4	17.1	13.8	18.7	18.9	25.6	27.3	35.4	34.9	36.9	36.9
			2014-15	31.2	25.2	19.7	15.7	12.9	14.2	17.6	22.7	29.2	28.7	36.1	34.9	36.1
		Minimum temperature (ºC)	Long years	10.2	6.0	1.8	-0.8	-2.0	-1.2	0.7	4.4	8.2	12.1	15.2	14.9	-2.0
			2013-14	4.8	-2.2	-3.3	-9.5	-5.3	-7.4	-3.0	-0.6	4.2	8.3	12.4	11.5	-9.5
			2014-15	6.8	0.1	-2.7	-4.7	-13.8	-7.0	-2.5	-3.2	4.8	8.4	11.7	12.8	-13.8
Tekirdağ	29	Precipitation (mm)	Long years	39.7	69.9	68.3	81.0	58.3	56.6	55.3	41.2	35.9	36.9	24.3	12.4	579.8
			2013-14	10.9	95.8	41.3	3.9	44.4	6.0	73.6	46.8	72.1	69.6	107.7	75.8	647.9
			2014-15	0.8	106.3	3.1	69.8	56.5	90.6	28.9	59.2	0.4	52.6	0.5	0	468.7
		Relative humidity (%)	Long years	74.2	79.3	82.4	82.7	80.1	80.8	80.0	78.3	76.8	73.5	69.7	71.4	77.4
			2013-14	60.3	76.2	78.8	73.7	89.8	84.7	81.3	82.2	78.1	75.0	72.2	73.2	77.1
			2014-15	77.8	79.6	84.9	89.2	82.2	78.8	81.8	74.8	74.9	73.3	67.8	67.1	77.7
		Average temperature (ºC)	Long years	19.9	15.3	10.4	6.5	4.8	4.9	7.3	11.7	16.7	21.2	24.0	23.8	13.9
			2013-14	21.8	14.2	12.9	6.1	8.0	8.5	9.8	13.6	17.8	22.0	24.9	25.3	15.4
			2014-15	20.7	15.9	11.0	9.4	5.6	6.5	8.5	11.3	18.5	21.3	25.6	26.4	15.1
		Maximum temperature (ºC)	Long years	24.3	19.5	14.1	9.7	8.4	8.7	11.0	15.7	20.4	25.1	28.1	28.3	28.3
			2013-14	33.1	22.4	22.4	15.3	20.4	20.6	24.0	22.8	27.0	36.9	34.6	33.4	36.9
			2014-15	30.0	27.7	19.6	17.5	16.7	21.1	18.3	24.6	27.9	33.3	33.9	32.1	33.9
		Minimum temperature (ºC)	Long years	15.8	11.8	7.3	3.7	2.2	2.1	4.0	8.0	12.3	16.5	19.1	19.4	2.1
			2013-14	13.6	4.2	1.0	-2.3	-2.5	1.4	1.8	4.9	8.9	12.7	17.1	16.1	-2.5
			2014-15	10.5	5.3	1.3	-1.2	-8.8	-5.2	0.0	1.7	8.9	13.4	16.7	18.2	-8.8
Tokat	571	Precipitation (mm)	Long years	16.8	49.2	52.7	44.4	37.6	36.2	40.8	57.2	62.9	37.9	12.8	7.4	455.9
			2013-14	12.3	45.0	13.8	40.3	14.5	12.6	55.1	12.7	29.2	61.5	7.3	1.1	305.4
			2014-15	39.0	51.6	63.1	39.4	38.4	25.8	57.0	34.5	34.8	35.6	0.2	7.6	425.0
		Relative humidity (%)	Long years	58.3	64.9	69.8	70.5	66.2	63.3	58.7	58.0	60.4	58.3	56.4	56.5	61.8
			2013-14	54.1	58.3	64.5	74.1	67.3	49.6	50.7	43.0	55.0	54.5	46.8	46.2	55.3
			2014-15	54.5	68.5	73.0	75.6	68.0	62.1	65.9	57.6	56.3	62.1	52.7	52.4	62.4
		Average temperature (ºC)	Long years	18.7	13.5	7.3	3.2	2.0	3.0	7.0	12.5	16.2	19.6	22.1	22.5	12.3
			2013-14	18.0	11.7	8.7	-1.0	4.4	8.0	11.1	16.2	17.7	20.5	24.6	25.4	13.8
			2014-15	19.9	14.1	7.1	7.0	2.4	5.2	8.1	10.0	17.2	20.1	22.5	25.4	13.3
		Maximum temperature (ºC)	Long years	26.6	20.4	12.8	7.3	6.0	8.0	12.7	19.1	23.1	26.6	28.9	29.9	29.9
			2013-14	35.3	30.7	21.6	14.7	17.1	21.4	24.9	29.2	34.2	34.4	40.6	40.5	40.6
			2014-15	37.3	24.5	22.1	18.2	15.0	18.8	22.6	26.9	36.4	30.9	37.4	36.4	37.4
		Minimum temperature (ºC)	Long years	12.0	8.1	2.9	0.0	-1.4	-1.0	2.0	6.5	9.5	12.8	15.4	15.6	-1.4
			2013-14	6.7	0.5	-0.8	-10.7	-5.5	-6.0	-4.4	-0.3	8.2	10.6	13.3	15.7	-10.7
			2014-15	5.8	0.8	-2.0	-2.1	-15.3	-7.2	-1.1	-1.0	4.4	9.6	10.7	10.9	-15.3
Şanlıurfa	410	Precipitation (mm)	Long years	4.2	27.5	50.5	68.9	79.7	69.5	61.1	42.1	25.4	4.7	0.9	1.2	435.7
			2013-14	0.0	0.0	19.5	76.7	44.3	20.8	91.6	33.3	6.0	20.6	0.0	1.0	313.8
			2014-15	28.8	25.8	79.4	55.2	82.5	100.8	79.0	24.3	10.3	0.7	0.2	0.0	487.0
		Relative humidity (%)	Long years	39.2	49.4	62.3	69.4	67.4	65.7	59.8	56.2	45.8	34.8	32.4	36.7	51.6
			2013-14	29.3	26.7	57.8	53.4	66.0	45.1	51.7	44.6	29.8	24.4	25.8	27.3	40.2
			2014-15	40.5	49.1	54.1	79.5	68.4	74.4	58.8	50.1	35.6	33.6	26.2	37.0	50.6
		Average temperature (ºC)	Long years	26.6	20.1	12.4	7.3	5.6	6.9	10.9	16.3	22.5	28.3	31.9	31.1	18.3
			2013-14	26.2	19.0	14.6	6.2	8.6	9.9	13.7	18.4	24.3	28.7	32.6	32.3	19.5
			2014-15	26.3	20.1	12.2	9.5	6.2	7.7	11.9	15.7	23.7	28.2	33.5	31.9	18.9
		Maximum temperature (ºC)	Long years	33.8	26.7	18.0	11.7	10.1	11.8	16.5	22.6	28.8	34.8	38.8	38.3	38.8
			2013-14	38.2	32.0	27.0	16.9	18.0	22.1	24.7	30.8	38.7	40.1	43.4	43.5	43.4
			2014-15	40.6	31.9	22.8	17.0	17.2	17.4	24.8	29.9	36.9	38.4	42.8	43.1	36.1
		Minimum temperature (ºC)	Long years	20.2	14.8	8.3	3.9	2.5	3.0	6.2	10.9	15.9	21.0	24.8	24.2	2.5
			2013-14	17.0	10.8	5.9	-2.5	2.4	-1.1	2.2	3.6	12.4	15.3	20.3	20.2	-2.5
			2014-15	14.5	9.5	4.8	2.5	-3.1	-0.6	2.5	4.7	11.8	16.7	21.4	22.1	-3.1

2.3. Soil properties

Soil samples features belonging to experimental areas are shown in Table 3. Soil of experimental areas were low in organic matter except for Eskişehir, clay loamy or loamy and in alkali (Table 3).

2.4. Yield and its components and crude oil percentage

In this study, plant height, number of lateral branches, number of pods per plant, pod length, number of seeds per pod, thousand-seed weight, seed yield, crude oil percentage and crude oil yield was determined as described by Öğütçü (1979).

The oil percentage was determined by grinding 10 g of powdered mustard seed samples and extracting by hexane were use with Gerhardt 2000 soxhlet apparatus.

2.5. Statistical analysis

All data were subjected to analysis of variance (ANOVA) using the MSTAT-C computer Statistical software. The significant differences between the group means were separated using Duncan's test.

3. Result and Discussion

Plant height, number of lateral branches, number of pods per plant, pod length, number of seeds per pod are presented in Table 4; thousand-seed weight, seed yield, crude oil percentage and crude oil yield are presented in Table 5.

In autumn sowing, statistically significant differences were found between the two consecutive years in terms of plant height, number of lateral branches, number of pods per plant, thousand-seed weight, seed yield, crude oil percentage, crude oil yield of mustard. However, no such differences were found in the pod length and number of seeds per pod during both years. The seed yield (1751.5 kg ha^{-1}) of the second year was higher compared to the yield of the first year (1205.4 kg ha^{-1}) (Table 4). This difference was due to higher rainfall during the growing period of plants in the second year.

The effect of location on the seed yield and yield components, including plant height, number of lateral branches, number of pods per plant, pod length, number of seeds per pod, thousand-seed weight and crude oil percentage and crude oil yield were found statistically significant for both years. The maximum plant height (218.97 and 235.96 cm) and the maximum number of lateral branches per plant (10.63 and 14.78) were determined at Şanlıurfa and at Aydın in both years respectively. The highest number of pods per plant (394.58 and 380.78, respectively) was obtained at Aydın during 2013-14 and at Tekirdağ during 2014-15. The maximum pod length (3.50 and 3.87 cm, respectively) were determined at Aydın during 2013-14 and at Eskişehir during 2014-15. The maximum number of seeds per pod (15.50 and 13.48, respectively) was obtained at Aydın during 2013-14 and at Isparta during 2014-15 (Table 4). The maximum thousand-seed weight (3.48 and 4.34 g, respectively) was obtained at Tekirdağ during 2013-14 and at Isparta during 2014-15. The maximum seed yield (1895.4 and 3674.2 kg ha^{-1}, respectively) was obtained at Aydın during 2013-14 and at Tokat during 2014-15. Although Aydın location had higher rainfall during the growing period of plants in the second year (791.0 mm) compared to the first year (407.8 mm), seed yield might be low due to diseases (white rust and mildew), causing significant losses in mustard (Sangeetha & Siddaramaiah 2007). Rainfall during the growing period of plants in the second year (406.7 mm) was higher compared to the first year (224.8 mm) at Tokat location. At flowering and ripening during 2014-2015, relatively low temperatures led to prolonged vegetation period as confirmed in previous studies (Schuster & Taghizadeh 1981; Kondra et al 1983). High seed yields resulted from higher rainfall due to regular and sufficient rainfall during second year (406.7 mm) compared to the first year (305.2 mm) at Tokat locations. Long drought period before flowering causes decreases in seed yield which is similar to previous study results (İptaş & Kolsarıcı 1988). Walton et al (1999) indicated that a longer ripening period affected seed yield positively. Results of the previous studies support that differences in yield

Table 3- Soil samples features belonging to experimental areas

Location	*Year*	*Depth (cm)*	*Texture*	*The ratio of saturation (%)*	*Total salt (%)*	*pH*	*Lime (%)*	*Phosphorus (P)*	*Potassium (K)*	*Organic substance (%)*
Ankara	2013-14	0-20	Clay loamy	64.00	0.041	7.79	28.12	6.63	162.04	1.31
		20-40	Clay loamy	63.00	0.035	7.85	27.40	4.87	149.86	1.31
		Average		63.50	0.038	7.82	27.76	5.75	155.95	1.31
	2014-15	0-20	Clay loamy	63.00	0.028	7.75	31.45	7.35	234.55	0.90
		20-40	Clay loamy	63.00	0.037	7.76	24.82	7.81	219.99	1.49
		Average		63.00	0.033	7.76	28.14	7.58	227.27	1.20
Aydın	2013-14	0-20	Loam	49.00	0.017	8.00	14.23	22.29	52.61	0.53
		20-40	Loam	49.00	0.017	8.06	13.98	17.17	50.13	1.16
		Average		49.00	0.017	8.03	14.11	19.73	51.37	0.85
	2014-15	0-20	Clay loamy	51.00	0.028	7.90	13.29	19.17	77.10	1.30
		20-40	Clay loamy	51.00	0.029	7.96	16.41	15.86	63.00	1.45
		Average		51.00	0.029	7.93	14.85	17.52	70.05	1.38
Erzurum	2013-14	0-20	Loam	50.00	0.018	7.93	5.94	11.23	105.60	0.64
		20-40	Clay loamy	51.00	0.018	7.98	6.20	12.77	92.44	0.53
		Average		50.50	0.018	7.96	6.07	12.00	99.02	0.59
	2014-15	0-20	Clay loamy	54.00	0.450	7.80	5.99	9.61	109.02	0.97
		20-40	Clay loamy	52.00	0.254	7.84	5.17	9.68	86.15	1.20
		Average		53.00	0.352	7.82	5.58	9.65	97.59	1.09
Eskişehir	2013-14	0-20	Clay loamy	61.00	1.000	8.08	10.99	8.59	132.00	3.45
		20-40	Clay loamy	60.00	0.836	7.99	8.06	8.51	136.00	3.87
		Average		60.50	0.918	8.04	9.525	8.55	134.00	3.66
	2014-15	0-20	Clay loamy	58.00	0.043	7.57	22.55	7.96	105.60	1.53
		20-40	Clay loamy	58.00	0.039	7.71	20.17	8.25	102.24	1.71
		Average		58.00	0.041	7.64	21.36	8.11	103.92	1.62
Isparta	2013-14	0-20	Loam	45.00	0.011	7.88	31.19	7.08	40.74	0.26
		20-40	Clay loamy	53.00	0.014	7.83	30.44	5.04	89.27	0.14
		Average		49.00	0.013	7.86	30.82	6.06	65.005	0.20
	2014-15	0-20	Loamy	43.00	0.011	7.88	30.55	3.69	145.90	0.67
		20-40	Loamy	42.00	0.008	7.93	32.93	4.68	149.86	0.99
		Average		42.50	0.005	7.91	31.74	4.19	147.88	0.83
Tekirdağ	2013-14	0-20	Clay loamy	53.00	0.022	7.88	8.10	5.18	92.44	0.13
		20-40	Clay loamy	52.00	0.022	7.83	8.21	4.05	40.74	0.25
		Average		52.50	0.022	7.86	8.16	4.62	66.59	0.19
	2014-15	0-20	Clay loamy	57.00	0.032	7.30	0.74	7.32	57.70	1.61
		20-40	Clay loamy	56.00	0.016	7.62	0.74	6.57	52.61	1.37
		Average		56.50	0.024	7.46	0.74	6.95	55.16	1.49
Tokat	2013-14	0-20	Loamy	46.00	0.015	7.74	11.85	7.44	43.01	0.40
		20-40	Loamy	46.00	0.018	7.79	11.28	5.16	34.21	0.55
		Average		46.00	0.020	7.77	11.57	6.30	38.61	0.48
	2014-15	0-20	Clay loamy	51.00	0.022	7.64	11.65	8.05	65.72	1.27
		20-40	Loamy	49.00	0.023	7.57	15.41	5.39	32.14	1.18
		Average		50.00	0.023	7.61	13.53	6.72	48.93	1.23
Şanlıurfa	2013-14	0-20	Clay loamy	69.00	0.045	7.68	30.0	6.01	160.8	1.74
		20-40	Clay loamy	68.00	0.053	7.73	30.0	2.63	72.0	1.49
		Average		68.50	0.049	7.71	30.0	4.32	116.4	1.62
	2014-15	0-20	Clay loamy	54.00	0.023	7.98	32.93	4.05	102.24	0.75
		20-40	Clay loamy	55.00	0.026	8.02	32.78	1.85	71.31	0.25
		Average		54.50	0.025	8.00	32.56	2.95	86.78	0.50

Table 4- Effects of autumn and spring sowing, location and row spacing on morphologic characteristics of mustard

Fall sowing

Location	*Row spacing (cm)*	*Plant height (cm)*		*Number of lateral branches (branch plant^{-1})*		*Number of pods per plant (pod plant^{-1})*		*Pod length (cm)*		*Number of seeds per pod (seed pod^{-1})*	
		2013-14	*2014-15*	*2013-14*	*2014-15*	*2013-14*	*2014-15*	*2013-14*	*2014-15*	*2013-14*	*2014-15*
Ankara	20	-	147.95	-	5.45	-	120.23	-	2.91	-	10.60
	30	-	156.33	-	6.05	-	143.93	-	2.86	-	10.40
	40	-	156.33	-	6.25	-	133.95	-	3.05	-	11.16
	50	-	165.58	-	6.40	-	158.82	-	3.03	-	12.35
	60	-	155.83	-	6.70	-	162.88	-	2.79	-	10.35
Aydın	20	209.68	131.05	10.60	14.53	400.63 ab	104.63	3.48	2.80	15.35	10.97
	30	210.93	128.35	10.68	12.68	388.85 a-c	81.50	3.55	2.83	14.78	10.13
	40	211.33	131.30	10.75	17.45	393.25 ab	118.85	3.55	2.95	14.90	11.38
	50	217.20	129.45	10.53	14.85	406.30 a	117.63	3.45	3.03	15.48	10.93
	60	206.10	118.88	10.58	14.38	383.85 a-c	119.90	3.45	2.85	15.50	11.53
Eskişehir	20	-	155.13	-	6.93	-	87.76	-	3.88	-	12.33
	30	-	140.13	-	5.68	-	77.80	-	3.85		13.60
	40	-	138.00	-	5.73	-	82.63	-	3.92		12.11
	50	-	150.88	-	6.00	-	80.73	-	3.90		12.49
	60	-	143.25	-	6.40	-	91.95	-	3.80		11.74
Isparta	20	-	118.88	-	4.45	-	72.58	-	3.60		12.23
	30	-	135.33	-	5.73	-	95.70	-	3.61		13.10
	40	-	126.68	-	6.10	-	89.80	-	3.71	-	13.60
	50	-	138.30	-	6.08	-	105.98	-	3.86	-	14.38
	60	-	126.73	-	6.33	-	113.70	-	3.90	-	14.08
Tekirdağ	20	188.50	152.75	7.50	8.00	351.00 b-e	383.00	3.15	3.48	11.50	11.50
	30	211.00	151.50	7.75	7.25	317.50 d-g	380.00	3.45	3.53	10.25	10.75
	40	214.25	153.25	7.75	7.50	351.50 b-e	381.75	3.35	3.60	10.75	10.50
	50	214.50	151.75	7.25	7.75	337.00 c-f	379.00	3.38	3.53	11.75	11.50
	60	199.25	153.50	7.75	7.75	352.50 b-d	380.00	3.05	3.50	11.00	11.00
Tokat	20	125.48	179.95	7.28	6.73	98.90 j	242.43	2.18	2.79	9.98	12.20
	30	123.43	183.70	6.93	6.30	90.70 j	233.95	2.23	2.68	10.60	13.38
	40	121.30	182.90	7.45	6.58	94.95 j	207.60	2.18	2.65	9.93	13.58
	50	120.73	184.28	7.35	4.78	91.48 j	200.18	2.10	2.72	10.55	14.15
	60	115.60	171.15	7.03	5.63	80.35 j	172.20	2.23	2.76	9.63	11.73
Şanlıurfa	20	219.90	244.53	7.80	8.70	267.33 gh	232.15	2.58	2.65	12.85	12.65
	30	221.95	235.90	9.25	6.35	285.83 f-h	167.63	2.73	2.73	11.55	11.80
	40	215.23	231.13	8.03	6.60	206.25 i	189.78	2.48	2.55	12.10	12.80
	50	219.88	228.80	7.28	6.53	300.25 e-h	168.25	2.63	2.70	11.55	12.55
	60	217.88	239.45	7.30	7.15	251.20 hi	166.75	2.70	2.68	11.70	12.78
F value$_{LxR,S,}$		1.00	1.24	1.61	1.35	2.37*	1.48	1.35	1.28	1.47	1.48
Years		189.20 a	174.18 b	8.30 b	8.87 a	272.48 a	221.36 b	2.89	2.91	12.08	11.89
F value$_{Year}$		76.01**		4.74**		146.93**		0.16		1.72	
Location	Ankara	-	156.40 c	-	6.17 c	-	143.96 c	-	2.93 d	-	10.97 c
	Aydın	211.05 ab	127.81 e	10.63 a	14.78 a	394.58 a	108.50 d	3.50 a	2.89 d	15.20 a	10.90 c
	Eskişehir	-	145.48 d	-	6.15 c	-	84.17 d	-	3.87 a		12.45 b
	Isparta	-	129.18 e	-	5.74 c	-	95.55 d	-	3.74 b	-	13.48 a
	Tekirdağ	205.50 b	152.55 cd	7.60 bc	7.65 b	341.90 b	380.75 a	3.28 b	3.53 c	11.05 c	11.05 c
	Tokat	121.31 c	180.40 b	7.21 c	6.00 c	91.28 d	211.27 b	2.18 d	2.72 e	10.14 d	13.01 ab
	Şanlıurfa	218.97 a	235.96 a	7.93 b	7.07 bc	262.17 c	184.91 b	2.62 c	2.66 e	11.95 b	12.52 b
F value$_{Location}$		282.94**	242.69**	106.72**	86.38**	462.35**	198.77**	240.18**	236.13**	164.51**	20.01**
Row spacing	20	185.89	161.46	8.29	7.83	279.46	177.54	2.84	3.16	12.42	11.66 b
	30	191.83	161.60	8.65	7.15	270.72	168.64	2.99	3.15	11.79	12.06 ab
	40	190.53	159.94	8.49	8.03	261.49	172.05	2.89	3.20	11.92	12.10 ab
	50	193.08	164.15	8.10	7.48	283.76	172.94	2.88	3.25	12.33	12.71 a
	60	184.71	158.40	8.16	7.76	266.98	172.48	2.86	3.18	11.96	11.80 b
F value$_{Row\ spacing}$		1.49	1.11	1.87	1.37	1.74	0.26	1.69	2.14	2.04	4.09**
CV (%)		6.41	6.68	8.06	20.22	10.10	18.92	6.02	4.62	6.36	8.72

Table 4 (Continue)- Effects of autumn and spring sowing, location and row spacing on morphologic characteristics of mustard

Spring sowing

Location	Row spacing (cm)	Plant height (cm)		Number of lateral branches (branch plant^{-1})		Number of pods per plant (pod plant^{-1})		Pod length (cm)		Number of seeds per pod (seed pod^{-1})	
		2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2013-14
Ankara	20	137.93	141.18	3.48 m-q	3.63 fgh	72.83 g	93.38	2.91 f-n	3.02 gh	14.09 c-g	12.81 c-i
	30	136.98	136.20	3.43 m-r	4.03 e-h	88.43 efg	89.33	2.82 f-o	3.19 fg	14.11 c-g	13.74 a-g
	40	140.65	138.58	3.18 n-r	4.20 e-h	107.63 d-g	111.30	2.71 h-o	3.16 fg	14.50 c-f	15.53 a
	50	146.03	130.50	3.61 k-p	4.63 ef	129.33 de	118.88	2.97 f-m	3.19 fg	14.78 cde	14.22 a-d
	60	143.13	131.10	4.23 j-n	4.92 de	146.20 d	137.76	2.85 f-n	3.42 d-g	15.58 bcd	14.62 abc
Aydın	20	119.25	76.30	4.93 g-m	3.73 e-h	111.90 d-g	71.48	3.13 c-i	3.85 bcd	8.65 nop	10.38 j-m
	30	117.80	82.23	4.78 h-m	4.58 ef	91.45 efg	100.18	2.85 f-n	4.13 abc	9.75 k-p	11.00 h-m
	40	119.68	90.05	5.08 g-k	4.50 efg	127.03 def	114.35	3.05 e-l	4.43 a	9.88 k-p	11.85 e-k
	50	114.98	88.98	4.58 i-n	4.40 eh	86.00 efg	138.55	3.08 d-k	4.18 abc	7.75 p	11.25 h-m
	60	117.88	81.53	5.00 g-l	3.85 eh	114.80 d-g	94.40	3.10 d-j	4.18 abc	11.50 h-l	11.50 f-l
Erzurum	20	62.30	112.33	5.89 e-i	6.03 c	21.08 h	102.50	2.59 i-o	3.47 d-g	12.00 f-k	16.04 a
	30	69.99	106.95	7.49 ncd	5.93 cd	28.48 h	99.70	2.52 j-n	3.26 fg	12.70 e-j	14.24 a-d
	40	71.61	109.40	7.84 bc	6.45 bc	25.24 h	105.98	2.34 no	3.52 d-g	11.92 g-k	14.92 abc
	50	64.14	108.90	6.35 d-g	7.28 ab	25.18 h	110.08	2.45 mno	3.51 d-g	11.93 g-k	14.49 abc
	60	73.42	103.20	6.78 b-e	6.08 c	27.28 h	115.98	2.50 k-o	3.38 d-g	12.99 e-i	13.84 a-f
Eskişehir	20	118.65	103.21	2.05 r	7.04 abc	79.88 g	113.25	3.88 ab	3.28 efg	19.65 a	9.79 klm
	30	123.00	111.29	2.05 r	7.80 a	78.85 g	102.68	3.65 a-d	3.29 efg	17.95 ab	9.03 m
	40	120.95	93.05	2.10 qr	6.36 bc	82.30 fg	66.28	3.65 a-d	3.76 cde	18.00 ab	10.70 i-m
	50	117.85	107.43	2.20 pqr	6.23 bc	82.05 fg	98.26	3.55 a-e	3.49 d-g	16.05 bc	10.93h-m
	60	126.35	107.66	2.40 o-r	6.16 bc	92.45 efg	101.51	3.58 a-e	3.41 d-g	16.55 bc	9.41 lm
Isparta	20	163.00	94.60	6.65 c-f	3.30 gh	289.43 c	35.08	2.94 f-m	3.48 d-g	13.30 d-h	10.85 h-m
	30	157.70	93.40	6.58 c-f	3.55 fgh	310.40 c	37.40	3.40 b-f	3.55 def	14.50 c-f	11.40 g-i
	40	160.00	92.43	6.73 cde	3.88 e-h	404.95 b	39.60	3.23 c-h	4.02 abc	15.03 cde	12.58 c-j
	50	156.08	90.78	8.13 b	4.55 ef	409.23 b	43.30	4.03 a	4.02 abc	16.08 bc	12.78 c-i
	60	159.58	91.68	10.20 a	4.90 de	469.53 a	45.83	4.04 a	4.26 ab	15.95 bc	13.98 a-e
Tekirdağ	20	119.25	83.75	3.75 j-o	3.25 h	81.25 fg	62.00	3.30 c-g	3.23 fg	10.50 i-o	7.00 n
	30	125.25	81.50	4.25 j-n	3.50 fgh	80.00 g	64.00	3.55 a-e	3.35 efg	9.25 l-p	6.75 n
	40	121.25	85.25	4.75 h-m	3.50 fgh	75.75 g	61.00	3.70 abc	3.30 efg	8.50 nop	6.75 n
	50	123.75	82.25	5.25 f-j	3.25 h	77.25 g	60.75	3.20 c-h	3.30 efg	8.25 op	6.50 n
	60	124.00	82.25D	3.50 l-q	3.50 fgh	74.25 g	62.50	3.33 b-g	3.30 efg	8.75 m-p	6.75 n
Tokat	20	91.53	139.85	6.15 d-h	5.88 cd	91.05 efg	138.93	2.93 f-m	3.18 fg	11.28 k-m	16.00 a
	30	77.83	153.63	6.15 d-h	6.25 bc	91.90 efg	175.40	2.68 h-o	3.41 d-g	10.50 i-o	15.30 ab
	40	82.85	137.78	6.25 d-g	6.55 bc	91.20 efg	169.50	2.80 g-o	3.09 fgh	11.28 h-m	13.15 b-h
	50	89.23	137.00	6.13 d-h	6.28 bc	90.13 efg	187.53	2.70 h-o	3.52 d-g	10.20 j-p	13.10 b-h
	60	93.08	140.55	6.28 d-g	6.23 bc	88.78 efg	197.85	2.70 h-o	3.08 fgh	10.78 h-o	14.43 abc
Şanlıurfa	20	108.45	104.13	4.28 j-m	4.23 e-h	69.58 g	59.35	2.50 k-o	2.68 hi	11.75 g-l	11.68 e-l
	30	111.25	101.73	4.35 j-m	3.90 e-h	73.70 g	52.15	2.48 l-o	2.53 i	11.00 h-n	11.50 f-l
	40	113.35	99.88	4.18 j-m	3.75 e-h	68.75 g	50.00	2.43 mno	2.33 i	11.35 h-m	11.75 e-l
	50	113.50	105.60	3.90 j-m	4.20 e-h	75.65 g	55.90	2.25 o	2.45 i	11.35 h-m	11.70 e-l
	60	109.00	107.25	4.30 j-m	4.65 fg	72.45 g	56.38	2.40 mno	2.50 i	11.55 h-l	12.08 d-k
F value$_{LxR,S,}$		0.85	43101.00	4.03**	1.78*	6.98**	11324.00	2.65**	2.70**	2.46**	1.63*
Years		116.06a	106.63b	4.98	4.20	117.59 a	93.51b	3.02 a	3.39 b	12.54a	11.91 b
F value$_{Year}$		104.57**		0.62		103.49**		3649.91**		18.73**	
Location	Ankara	140.94 b	135.51 a	3.58 f	4.28 c	108.88 b	110.13 b	2.85 c	3.19 e	14.61 b	14.18 a
	Aydın	117.92 c	83.82 d	4.87 d	4.21 c	106.24 bc	103.79 b	3.04 c	4.15 a	9.51 e	11.20 b
	Erzurum	68.29 f	108.16 b	6.87 b	6.35 a	25.45 f	106.85 b	2.48 d	3.43 cd	12.31 c	14.70 a
	Eskişehir	121.36 c	104.53 b	2.16 g	6.72 a	83.11 de	96.40 b	3.66 a	3.45 c	17.64 a	9.97 c
	Isparta	159.27 a	92.58 c	7.66 a	4.04 c	376.71 a	40.24 d	3.53 ab	3.86 b	14.97 b	12.32 b
	Tekirdağ	122.70 c	83.00 d	4.30 e	3.40 d	77.70 de	62.05 c	3.42 b	3.30 cde	9.05 e	6.75 d
	Tokat	86.90 e	141.76 a	6.19 c	6.24 a	90.61 cd	173.84 a	2.55 d	3.25 de	10.81 d	14.40 a
	Şanlıurfa	111.11 d	103.72 b	4.20 e	4.15 b	72.03 e	54.76 cd	2.41 d	2.50 f	11.40 cd	11.74 b
F value$_{Location}$		249.87**	120.67**	139.90**	64.69**	533.68**	57.08**	61.63**	99.15**	124.02**	73.49**
Row spacing	20	115.04	106.92	4.65 b	4.63	102.12 b	84.49 b	6.14	3.27 b	12.65	11.82
	30	114.97	108.36	4.88 ab	4.94	105.40 b	90.10 ab	6.17	3.34 ab	12.47	11.62
	40	116.29	105.80	5.01 ab	4.90	122.86 ab	89.75 ab	6.03	3.45 a	12.56	12.15
	50	115.69	106.43	5.02 ab	5.10	121.85 a	101.66 a	6.36	3.46 a	12.05	11.87
	60	118.30	105.65	5.34 a	5.04	135.72 a	101.52 a	6.26	3.44 a	12.96	12.07
F value$_{Row\ spacing}$		0.91	0.48	4.23**	2.01	13.99**	3.08*	0.38	0.38	4.55**	2.43
CV (%)		6.97	8.36	13.82	14.55	17.76	26.59	8.98	6.48	9.53	11.74

*, P<0.05; **, P<0.01 significantly different according to the Duncan. Data was the means of 4 replications

Table 5- Effects of autumn and spring sowing, location and row spacing on morphologic characteristics of mustard

Fall sowing

Location	*Row spacing (cm)*	*Thousand-seed weight (g)*		*Seed yield (kg ha^{-1})*		*Crude oil percentage (%)*		*Crude oil yield (kg ha^{-1})*	
		2013-14	*2014-15*	*2013-14*	*2014-15*	*2013-14*	*2014-15*	*2013-14*	*2014-15*
Ankara	20	-	3.77 d-h	-	3074.8 e	-	26.08	-	802.0 f
	30	-	3.93 c-f	-	3225.5 d	-	26.21	-	847.8 e
	40	-	3.98 cde	-	3096.6 e	-	25.17	-	782.7 g
	50	-	3.86 c-g	-	2701.7 f	-	23.63	-	641.8 i
	60	-	3.97 c-f	-	2711.7 f	-	25.39	-	688.5 h
Aydın	20	2.65	3.01 k-n	1661.8 b-d	691.5 v	21.16 e-g	21.02	352.9 b-d	145.2 u
	30	2.75	3.63 e-i	1962.5 ab	922.8 qrs	19.82 fg	18.07	398.6 a-c	165.9 t
	40	2.68	3.47 g-j	1811.3 a-c	970.0 pq	19.07 g	18.88	345.2 cd	184.5 s
	50	2.66	3.73 e-h	1960.3 ab	848.0 tu	24.79 c-f	20.49	483.9 a	177.5 st
	60	2.65	3.17 j-m	2081.3 a	1057.3 o	22.52 d-g	19.25	469.1 ab	207.9 r
Eskişehir	20	-	3.54 e-j	-	1376.7 j	-	26.14	-	362.8 l
	30	-	3.48 g-j	-	1267.5 l	-	24.16	-	306.6 n
	40	-	3.45 g-k	-	1207.1 m	-	24.37	-	290.2 o
	50	-	3.35 h-k	-	1002.7 p	-	24.23	-	239.5 q
	60	-	3.28 i-l	-	924.2 qrs	-	26.56	-	244.2 q
Isparta	20	-	3.93 c-f	-	1128.3 n	-	27.49	-	310.2 n
	30	-	4.18cd	-	1328.0 k	-	27.44	-	364.1 l
	40	-	4.28 bc	-	958.8 pqr	-	27.07	-	259.4 p
	50	-	4.60 ab	-	980.5 p	-	28.25	-	277.0 o
	60	-	4.70 a	-	894.0 st	-	28.27	-	252.9 pq
Tekirdağ	20	3.50	3.53 f-j	1080.0 e-h	1137.5 n	31.86 a	29.33	345.3 cd	330.8 m
	30	3.38	3.53 f-j	876.7 g-j	916.7 rs	30.35 ab	24.12	263.0 d-f	221.2 r
	40	3.55	3.58 e-j	985.7 f-I	1007.5 p	28.60 a-c	24.74	281.9 c-f	247.0 pq
	50	3.40	3.45 g-j	733.3 h-j	830.0 u	27.62 a-d	25.39	204.4 e-g	211.9 r
	60	3.58	3.55 e-j	723.3 h-j	801.7 u	25.54 b-e	26.44	184.9 fg	212.7 r
Tokat	20	2.80	2.65 nop	639.8 ij	3219.9 d	27.91 a-d	26.98	176.8 fg	867.7 d
	30	2.90	2.68 nop	513.3 j	3754.9 b	26.25 b-e	24.26	133.3 g	910.1 c
	40	2.83	2.80 mno	611.0 ij	3492.2 c	29.01 a-c	24.07	176.7 fg	841.6 e
	50	2.90	2.87 lmn	1076.0 e-h	3929.2 a	30.11 a-c	26.62	323.8 c-e	1048.1 b
	60	2.95	2.99 k-n	846.8 g-j	3975.0 a	24.87 c-f	26.64	210.7 e-g	1066.8 a
Şanlıurfa	20	2.21	2.38 pq	1473.5 c	1614.3 g	24.76 c-f	25.41	362.5 b-d	410.1 j
	30	2.32	2.23 q	1235.0 e-g	1516.8 h	21.73 e-g	23.61	268.4 d-f	357.9 l
	40	2.34	2.40 opq	1322.3 def	1439.0 i	22.14 e-g	25.68	293.0 c-f	368.3 l
	50	2.30	2.37 pq	1163.8 e-g	1452.5 i	21.39 e-g	26.64	248.0 d-g	388.1 k
	60	2.24	2.04 q	1351.5 def	1454.0 i	21.08 e-g	25.19	286.8 c-f	367.0l
F value$_{LxR,S}$		1.27	1.88*	3.17**	2.31**	1.95*	0.77	4.40**	1.77*
Years		2.83 b	2.98a	1205.4 b	1751.5 a	25.03 a	24.14 b	290.5 b	436.5 a
F value$_{Year}$		23.59**		228.38**		4.49*		133.36**	
Location	Ankara	-	3.89 b	-	2962.1 b	-	25.29 b	-	752.5 b
	Aydın	2.68 c	3.33 c	1895.4 a	897.9 g	21.47 b	19.54 c	409.9 a	176.2 f
	Eskişehir	-	3.42 c	-	1155.6 d	-	25.09 b	-	288.6 d
	Isparta	-	4.34 a	-	1057.9 e	-	27.71 a	-	292.7 d
	Tekirdağ	3.48 a	3.53 c	879.8 c	938.6 f	28.79 a	26.01 ab	255.0 bc	244.7 e
	Tokat	2.88 b	2.80 d	737.4 c	3674.2 a	27.63 a	25.71 ab	204.3 c	946.9 a
	Şanlıurfa	2.28 d	2.28 e	1309.2 b	1495.3 c	22.22 b	25.31 b	291.7 b	378.3 c
F value$_{Location}$		347.32**	133.44**	118.81**	3362.6**	33.15**	27.70**	373.2**	1859.5**
Row spacing	20	2.79	3.26	1213.7	1749.0	26.42 a	26.06 a	180.2	461.3
	30	2.84	3.38	1146.9	1847.4	24.54 c	23.98 c	152.9	453.4
	40	2.85	3.42	1182.5	1738.7	24.70 bc	24.28 bc	160.0	424.8
	50	2.81	3.41	1233.3	1677.8	25.98 abc	25.04 abc	173.5	426.2
	60	2.85	3.38	1250.7	1688.3	23.50 ab	25.39 ab	161.8	434.3
F value$_{Row\ spacing}$		0.76	1.77	0.60	1.88	2.64*	3.47*	1.80	0.83
CV (%)		4.24	7.77	17.71	14.97	11.54	9.57	22.02	21.75

Table 5 (Continue)- Effects of autumn and spring sowing, location and row spacing on morphologic characteristics of mustard

Spring sowing									
Location	*Row spacing (cm)*	*Thousand-seed weight (g)*		*Seed yield (kg ha^{-1})*		*Crude oil percentage (%)*		*Crude oil yield (kg ha^{-1})*	
		2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Ankara	20	2.62	0.83 l	1907.8 d	660.0	20.21	21.79	387.0 b	143.2
	30	2.48	1.06 i-l	1831.9 e	585.4	18.73	19.82	343.0 d	115.4
	40	2.64	1.29 hi	1687.5 f	575.3	18.63	18.92	318.6 e	108.8
	50	2.64	1.4 1h	2017.0 c	602.7	19.66	20.19	395.9 a	120.9
	60	2.60	1.36 h	2056.8 b	538.5	18.64	18.87	373.1 c	99.6
Aydın	20	1.03	1.03 i-l	444.5 p	206.8	14.06	12.97	62.4 n	30.3
	30	1.00	1.00 i-l	330.8 r	146.0	12.97	12.45	42.5 o	19.1
	40	0.90	0.90 kl	347.8 qr	155.5	12.75	12.81	45.1 o	21.2
	50	0.96	0.96j kl	240.5 u	201.0	11.29	12.09	27.4 q	27.4
	60	0.95	0.95 jkl	283.5 t	133.0	10.98	13.01	31.0 pq	17.9
Erzurum	20	1.25	3.02 def	86.0 z	631.7	8.12	14.36	7.0 s	91.1
	30	1.49	3.05 de	126.2 yz	624.2	7.69	12.90	9.8 rs	80.8
	40	1.40	3.08 de	103.7 z	626.2	8.15	13.03	8.5 rs	80.9
	50	1.28	2.99 def	70.2 z	600.0	7.49	13.28	5.3 s	79.0
	60	1.30	3.01 def	92.4 z	577.8	7.94	12.61	7.4 s	73.1
Eskişehir	20	2.34	3.48 ab	2178.3 a	284.0	17.65	23.01	391.4 ab	65.1
	30	2.36	3.68 a	1587.0 g	295.4	17.38	22.50	277.5 f	65.8
	40	2.18	3.41 abc	1444.8 i	252.5	15.49	22.80	223.7 h	56.8
	50	2.49	3.23 bcd	1482.3 h	215.7	16.14	22.68	239.6 g	48.6
	60	2.40	3.22 bcd	1462.3 hi	163.2	16.30	22.35	238.4 g	36.7
Isparta	20	2.36	2.83 efg	890.0 k	553.0	26.44	23.03	2353 g	127.6
	30	2.27	3.10 de	768.9 m	574.0	24.77	22.15	190.9 j	128.5
	40	2.43	3.13 cde	957.5 j	473.3	24.54	21.77	234.5 g	103.5
	50	2.40	3.08 de	793.3 l	360.3	26.03	22.97	206.0 i	83.6
	60	2.48	3.15 cd	788.3 lm	346.0	22.90	21.05	179.4 k	73.0
Tekirdağ	20	3.25	3.18 cd	523.3 n	64.7	11.72	14.49	107.6 l	6.8
	30	3.25	3.23 bcd	474.2 o	82.8	9.37	12.14	94.7 m	10.2
	40	3.28	3.23 bcd	526.8 n	55.5	12.22	13.47	92.2 m	7.7
	50	3.25	3.15 cd	357.5 q	45.2	10.40	14.86	66.1 n	6.4
	60	3.33	3.20 bcd	308.3 s	59.3	13.63	14.01	61.5 n	8.4
Tokat	20	1.48	2.55 g	218.3 v	2833.7	6.10	20.23	25.8 q	576.1
	30	1.20	2.70 g	152.5 wx	2862.3	8.92	17.37	14.3 r	496.4
	40	1.40	2.74 fg	294.0 st	2676.5	6.00	18.46	35.8 p	493.3
	50	1.40	2.73 fg	253.5 u	2577.5	5.59	18.98	27.0 q	486.9
	60	1.40	2.70 g	305.5 st	2594.5	7.02	18.32	41.6 o	477.3
Şanlıurfa	20	0.72	1.23 hij	137.0 xy	319.5	20.86	14.81	8.2 rs	74.8
	30	0.72	1.16 h-k	104.8 z	311.5	20.12	14.39	8.9 rs	62.5
	40	0.67	1.12 h-l	162.5 w	255.8	18.13	13.80	10.0 rs	54.9
	50	0.76	1.12 h-l	109.8 z	278.3	19.53	14.58	7.3 s	62.6
	60	0.73	1.12 h-l	119.5 yz	293.0	19.71	14.81	8.5 rs	66.0
F value$_{LxR,S,}$		1.44	2.35**	4.95**	0.82	0.74	0.33	1.85*	0.75
Years		1.88b	2.33a	700.7 a	641.7 b	14.87 b	18.14 a	127.2 a	119.7 b
F value$_{Year}$		967.65**		21.62**		188.46**		5.20*	
Location	Ankara	2.60 b	1.19 e	1900.2 a	592.4 c	19.07 b	19.92 b	363.5 a	117.6 b
	Aydın	0.97 e	0.97 f	329.4 e	168.5 g	12.41 d	12.62 c	41.7 e	23.2 g
	Erzurum	1.34 d	3.03 c	95.7 h	612.0 b	7.88 e	13.24 c	7.6 g	81.0 d
	Eskişehir	2.35 c	3.41 a	1630.9 b	241.6 f	16.59 c	22.67 a	274.1 b	54.6 f
	Isparta	2.39 c	3.06 c	839.6 c	461.3 d	24.94 a	22.20 a	209.2 c	103.2 c
	Tekirdağ	3.27 a	3.20 b	438.0 d	57.5 h	19.67 b	13.80 c	84.4 d	7.9 h
	Tokat	1.38 g	2.68 d	244.8 f	2708.9 a	11.47 d	18.67 b	28.9 f	506.0 a
	Şanlıurfa	0.72 f	1.15 e	126.7g	291.6 e	6.93 e	22.03 a	8.6 g	64.2 e
F value$_{Location}$		909.84**	1133.37**	699.85**	1082.39**	118.95**	68.65**	226.68**	437.51**
Row spacing	20	1.88	2.27 b	798.1 a	691.7 a	15.64	19.18 a	15.31 a	13.94 a
	30	1.85	2.37 a	672.0 b	684.8 ab	14.99	17.37 b	12.27 b	12.23 ab
	40	1.86	2.36 a	690.6 b	633.8 abc	14.49	17.86 b	12.10 b	11.59 b
	50	1.90	2.33 ab	665.5 b	610.1 bc	14.64	18.45 ab	12.18 b	11.44 b
	60	1.90	2.34 a	677.1 b	588.2 c	14.58	17.85 b	11.76 b	10.65 b
F value$_{Row\ spacing}$		0.74	0.91	6.97**	4.87**	42614.00	2.86*	4.10**	4.15**
CV (%)		7.10	5.93	16.90	16.89	17.27	12.77	31.98	28.66

*, P<0.05; **, P<0.01 significantly different according to the Duncan. Data was the means of 4 replications

and yield components among locations could be derived from various years and locations which have different ecological conditions including air temperature, precipitation, agronomic practices and differences in the number of plants per unit area (Saran & Giri 1987; Shafii et al 1992; Walton et al 1999). The maximum crude oil percentage (28.79 and 27.71%, respectively) was determined at Tekirdağ during 2013-14 and at Isparta during 2014-15. The highest crude oil yield (409.9 and 946.9 kg ha^{-1}, respectively) was obtained at Aydın during 2013-14 and at Tokat during 2014-15 (Table 5). The maximum crude oil percentage was determined at Tekirdağ with 28.79% during 2013-14; at Isparta locations with 27.71% during 2014-15. Increase of seed oil content from flowering to ripening (Baydar & Yüce 1996); and the longer growth period due to early flowering could be attributed to increase in crude oil percentage (Walton et al 1999). Ripening low temperature and more rainy days prevent oil formation (Kolsarıcı & Başalma 1988). The minimum crude oil percentage was obtained (21.47% and 19.54%) at Aydın locations during both years (Table 5). The result might be due to Aydın location's soil structure as well as air temperature and precipitation. Different row spacing affect mean seed yield and its components were also examined but these were not statistically different except number of seeds per pod during 2014-15 and crude oil percentage for both years. The maximum number of seeds per pod (12.71 seed pod^{-1}) was obtained from 50-cm row spacings (Table 4). The maximum crude oil percentage (26.42 and 26.06%, respectively) was obtained from 20-cm row spacings during both years (Table 5). Crude oil percentage in 20-cm row spacing increased by approximately 12.43% compared to 60 cm row spacing during 2013-14. Similarly 20 cm row spacing showed an increased of approximately 8.67% compared to 30 cm row spacing during 2014-15. Findings of optimum number of plants per unit and uniform distribution of seeds per unit are important factors that determine yield. Kondra (1975), Morrison et al (1990), Misra & Rana (1992), Öztürk (2000), Heidari et al (2003), Kumar & Singh (2003) and Farsak (2009) agreed that seed yield is decreased by increasing row spacing; whereas, Christensen et al (1985), Pyare et al (2008) suggest that seed yield is increased by increasing row spacing. Optimum row spacing is affected by climatic and soil of ecological conditions (Kolsarıcı & Başalma 1988; Shrief et al 1990). The maximum crude oil percentage was determined at 20 cm row spacing for both years. Crude oil percentage in 20 cm increased compared to the 60 cm row spacing during 2013-14 and crude oil percentage in 20 cm row spacing increased compared to the 30 cm row spacing during 2014-15. The crude oil percentage decreased by increasing row spacing (Patel et al 2004; Kaur & Sidhu 2006). Potter et al (1999) did not find any affect of row spacing on crude oil percentage. Sra (1978), Saran & Giri (1987) and Zukalova et al (1988) reported that crude oil percentage might be affected by years and locations ecological conditions including air temperature, precipitation, and soil fertility. In general, the optimum density strengthened the optimal use of environmental condition for the crop and it reduced inter plant competition and results in production of appropriate seeds with more gain in seed weight. However, the excessive numbers of plants caused severe inter plant competition and reduction in thousand-seed weight. These results are in accordance with the findings of Mamun et al (2014) on rapeseed and mustard.

The effect of locations and row spacing on number of pods per plant, crude oil percentage were statistically significant during 2013-14 and thousand seed weight was statistically significant during 2014-15. Seed yield and crude oil yield were statistically significant for both years. The maximum number of pods per plant (406.30 pod $plant^{-1}$) was determined at Aydın and 50-cm row spacing (Table 4). The highest crude oil percentage (31.86%) was determined at Tekirdağ and 20 cm row spacing during 2013-14 (Table 5). The maximum thousand seed weight (4.70 g) was determined at Isparta and 60 cm row spacing during 2014-15. The highest seed yield (2081.3 and 3975.0 kg ha^{-1}, respectively) was obtained at Aydın and 60 cm row spacing and at Tokat and 60 cm row spacing. The maximum crude oil yield (483.9 and 1066.8 kg ha^{-1}, respectively)

were obtained at Aydın with 50 cm row spacing and Tokat with 60 cm row spacing (Table 5).

In spring sowing, statistically significant differences were found between the two consecutive years in terms of plant height, pod length, number of seeds per pod number of pods per plant, thousand-seed weight, seed yield, crude oil percentage, crude oil yield of mustard. However, no such differences were found for number of lateral branches during both years. The seed yield (700.7 kg ha^{-1}) of the first year was higher compared to the seed yield (641.7 kg ha^{-1}) of the second year (Table 5). In spring sowing, especially mean seed yield and crude oil yield were higher during first year compared to their seed and crude oil yield during second year. This differences could have resulted from higher precipitation during the vegetative growing period of plants during the second year.

The effect of location on the seed yield and yield components was found statistically significant for both years. The maximum plant height (159.27 and 141.76 cm, respectively) was detected at Isparta during 2013-14 and at Tokat during 2014-15. The maximum number of lateral branches, number of pods per plant (7.66 and 6.35, respectively) was determined at Isparta during 2014 and at Erzurum during 2015. The highest number of pods per plant (376.71 and 173.84 pod $plant^{-1}$, respectively) was determined at Isparta during 2014 and at Tokat during 2015. The maximum pod length of 3.66 and 4.15 cm was determined at Eskişehir (2014) and at Aydın (2015) respectively. The highest number of seeds per pod of 17.64 and 14.70 was determined at Eskişehir (2014) and at Erzurum (2015) respectively (Table 3). The maximum thousand-seed weight of 3.27 and 3.41 g was determined at Tekirdağ (2014) and at Eskişehir (2015) respectively. The highest seed yield (1900.2 and 2708.9 kg ha^{-1}, respectively) at Ankara in 2014 and at Tokat in 2015. The maximum crude oil percentage (24.94 and 22.67%, respectively) was determined at Isparta in 2014 and at Eskişehir in 2015. The highest crude oil yield 363.5 and 506.0 kg ha^{-1} was detected at Ankara (2014) and at Tokat (2015) respectively (Table 5). The seed yield and its components, including plant height, number of lateral branches, number of pods per plant, pod length, number of seeds per pod, thousand-seed weight, seed yield, crude oil percentage and crude oil yield affected locations for both years. The precipitation of 69.2 and 58.6 mm during flowering at Ankara location, began and continued until May and June until the maturity of capsules after fertilization that positively affected them during 2014. Amirnia et al (2012) reported that the altitude of growth location has a significant effect on ecophisiological parameters of mustard. Erzurum had the highest altitude among locations where vegetative and generative growth showed weak. These plants were not able to complete there vegetative growth and entered generative phase at an earlier stage of growth that resulted in non development of their morphological features before generative maturity, therefore this affected complete formation of grains and yield. So the grains were quite weak and feeble. Long period of drought before flowering caused reduction in seed yield (İptaş & Kolsarıcı 1988), a longer ripening period due to earlier flowering affected seed yield positively (Walton et al 1999). The maximum crude oil percentage was determined at Isparta with 24.94% during 2014; at Eskişehir locations with 22.67% increase during 2014**.** The minimum crude oil percentage was obtained at Erzurum with 7.88% during 2014; at Aydın locations with 12.62% during 2015 (Table 5). Water stress during flowering and ripening resulted in reduction in crude oil percentage of seeds (Hocking et al 1997). From flowering to ripening increase in oil percentage of seed (Baydar & Yüce 1996) and the longer period of vegetative growth due to early flowering could be attributed to the crude oil percentage increase (Walton et al 1999); especially during ripening at low temperature and more rainy days that prevented oil formation (Kolsarıcı & Başalma 1988). The maximum crude oil yield was determined at Isparta with 363.5 kg ha^{-1} at Ankara locations during 2014; at Tokat locations with 506.0 kg ha^{-1} during 2015. The minimum crude oil yield was obtained at Erzurum with 7.6 kg ha^{-1} during 2014; at Tekirdağ locations with 7.9 kg ha^{-1} during 2015 (Table 5). According to these results, these differences among locations could be

due to the effects of growing ecological conditions including temperature, precipitation, agronomic practices (Sra 1978; Christensen et al 1985).

The effect of row spacing on the number of lateral branches was found statistically significant for 2014 year. Differences among pod length, thousand seed weight, crude oil percentage were found statistically significant for 2015. Whereas, number of pods per plant, seed yield and crude oil yield showed statistically significant during both years. The highest number of lateral branches (5.34) was obtained from the 60 cm row spacing. The maximum pod length (3.46 cm) was obtained from the 50 cm row spacing (Table 4). The maximum thousand seed weight (2.37 g) was determined in 30 cm row spacing. The highest crude oil percentage (19.18%) was determined in 20 cm row spacing (Table 5). The maximum number of pods per plant 135.72 and 101.66 pod plant^{-1} were obtained from the 60 cm and 50 cm row spacing respectively (Table 4). The highest seed yield 798.1 and 691.7 kg ha^{-1} was detected from the 20 cm row spacing respectively. The maximum crude oil yield (153.1 and 139.4 kg ha^{-1}, respectively) was obtained from the 20 cm row spacing during both years (Table 5). Different row spacings affected mean yield components but did not statistically affect number of seeds per pod, seed yield and crude oil for both years. Some research showed that seed yield decreased by increasing row spacing (Heidari et al 2003; Arif et al 2012); seed yield increased by increasing row spacing (Christensen et al 1985; Pyare et al 2008); optimum row spacing as affected by climatic and soil conditions of respective ecologies (Kolsarıcı & Başalma 1988; Shrief et al 1990). The maximum crude oil percentage was determined at 20 cm row spacing for both years. The crude oil percentage increased by increasing row spacing (Patel et al 2004; Kaur & Sidhu 2006); in another study, the number of seeds per pod and the crude oil percentage were not affected by row spacing (Angadi et al 2003). The higher seed yield implicates that such plant density facilitated maximum utilization of nutrients and increased dry matter production which ultimately enhanced seed yield, by reducing inter and intra plant competition, due to efficient nutrient uptake, during photosynthesis increased the yield (Cheema et al 2001; Mamun et al 2014). Moreover, using this plant density resulted in creation of more suitable green canopy per unit area with the least inter competition, solar radiation that effectively helped in production of economic yield (Kazemeini et al 2010).

The effects of locations and row spacing was statistically significant for number of pods per plant, seed yield and crude oil yield during 2014, and for thousand seed weight during 2015. Number of lateral branches, pod length and number of seeds per pod were significantly for both years. The highest number of pods per plant (469.53 pod plant^{-1}) was determined at Isparta and 60 cm row spacing (Table 4). The maximum seed yield (2178.3 kg ha^{-1}) was detected at Eskişehir and 20 cm row spacing. The highest crude oil yield (391.4 kg ha^{-1}) was determined in Eskişehir and 20 cm row spacing during 2014 (Table 5). The maximum thousand seed weight (3.68 g) was determined at Eskişehir and 30 cm row spacing during 2015. The highest number of lateral branches, number of pods per plant (10.20 and 7.80, respectively) was obtained at Isparta and 60 cm row spacing at Eskişehir and 30 cm row spacing. The maximum pod length (4.04 and 4.43 cm, respectively) was determined at Isparta and 60 cm row spacing and at Aydın for 40 cm row spacing. The highest number of seeds per pod (19.65 and 16.00, respectively) was determined at Eskişehir and 20 cm row spacing and at Tokat and for 20 cm row spacing for both years (Table 4).

4. Conclusions

Autumn sowing; The results could not be obtained due to cold damage at Ankara, Eskişehir and Isparta locations during 2013-14. Cold damage losses were not observed during 2014-15 as plants entered to winter at 8-10 leaves rosette stage. So autumn sowing could be also possible at Ankara, Eskişehir, and Isparta locations if plants enter winter at right time (8-10 leaves rosette stage). It was determined that autumn sowing is suitable at Aydın, Tekirdağ, Tokat and Şanlıurfa locations. Average of two years

mean, for Tokat ecological conditions showed that mustard should be sown in 50 cm row spacing, for Aydın, Tekirdağ and Şanlıurfa, mustard should be sown in 20-30 cm row spacing to obtain higher seed yield. According to the one year, Ankara, Eskişehir and Isparta ecological conditions, mustard might be sown in 20-30 cm row spacing to obtain higher seed yield. Appropriate emergence could not be achieved in spite of irrigation Erzurum ecological conditions for both years due to high coldness. In gerenal, the crude oil percentage content increased in the wider row spacings. The results of the study emphasise new studies for cold locations after screening of local populations to breed cold resistant cultivars.

Spring sowing; According to the two years mean, it is considered inappropriate for spring sowing because of low yield depending on limited rainfall at Aydın, Tekirdağ and Şanlıurfa locations and; due to differences in the amount and distribution of rainfall at Tokat. The seed yield of the second year was lower compared to the first year under high temperature and low humidity Ankara, Erzurum, Eskişehir and Isparta locations. Because of spring sowing times shortened the development period of mustard or the period of high temperature and low humidity; it is considered that spring sowing is not appropriate because of low yield at Ankara, Erzurum, Eskişehir and Isparta locations. Growing mustard at Erzurum ecological conditions is not promising in terms of seed yield and crude oil yield. In general, 20-30 cm row spacing is recommended for all ecological locations tested in this study.

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