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NITROGEN, YIELD AND QUALITY RELATIONSHIP IN THE RAPESEED (*Brassica napus ssp. oleifera* L.)

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ABSTRACT

The study was carried out on the field experiments of Mustafakemalpasa Vocational School, Uludag University in western Turkey in 2010-2012 years. In the trial, the potential effects of nine different nitrogen doses (0, 30, 60, 90, 120, 150, 180, 210 and 240 kg N ha^{-1}) on seed yield, yield components and quality characteristics of rapeseed were evaluated. Californium cultivar was used as plant material. Trial plots were organized according to randomized block design as with three replications. Lateral branch number attached to main stem, pod number per plant, seed number per pod, seed yield per plant, 1000-seed weight, oil yield and seed yield increased as nitrogen doses increased. Whereas, oil ratios were decreased as opposite increased of nitrogen doses. According to these results, 180 kg N ha^{-1} dose is recommended for net income.

Keywords: Rapeseed, Nitrogen doses, Yield characteristics, Oil ratio and fatty acids

1. INTRODUCTION

Rapeseed takes place in the second place among vegetable oil crops cultivation in the world in respect of production after soybean (Mortazavian and Azizi-Nia, 2014). In addition, because it is a plant blooming early in the spring, it plays a big role in beekeeping. Irregularities in oil seed production in Turkey increase the vegetable oil deficits year to year. Because vegetable oil production cannot meet the requirements in Turkey, crude oil and oil seeds are imported in increasing amounts every year. Only 40% oil consumption are met by domestic sources (Odabasi and Taskaya, 2004). On the other hand, rapeseed is in second place among oil seeds with its acreages of 33.6 million ha, 62.4 million ton production and 1856 kg ha^{-1} yield in the world after soybean (Isler, 2013). Rapeseed has 31 127 ha production area, 102 000 tons production and 3 280 kg ha^{-1} yield in Turkey according to statistics (Anonymous, 2014).

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Rapeseed grows mostly in winter in Turkey and it has 45-50% oil, 20% protein and 18% carbohydrate in its' seeds. Seeds of rapeseed has unsaturated fatty acids higher than those of the other oil seed plants. Oleic acid content of rapeseed (approximately 80 %) is as nearly higher as olive oil. Besides, seeds of rapeseed have about 20% linoleic acid which makes its edible oil quality. In addition, rapeseed oil has a high boiling point (238 ºC), and therefore it bears a good roasting peculiarity. Rapeseed oil is also rich in vit-E, Omega-3 and Omega-6 fatty acids which increase its quality (Bocianowski et al., 2012; Anonymous, 2015).

Many superior traits of rapeseed such as summer and winter varieties, short growing period, high seed and oil yields, suitability to mechanization and successfully controlling weeds make it a good oil plant (Kolsarici et al., 1990).

In the recent years, in many countries, especially in EU countries, the renewable energy resources, environment-friendly is widely being grown for bio-diesel fuel production (Shirani Rad et al., 2014). Today, 80 % of bio-diesel produced in the world belongs to rapeseed oil. That the rapeseed oil has chemical compounds most close to fuel-oil had played important role in this result (Arioglu et al., 2010).

Nitrogen fertilization increases the seed yield but decreases oil content of seed in rapeseed. However, decreases in oil ratios of seed compensates by increases in the seed yield (Dreccer et al., 2000; Schuster and Rathke, 2001; Turk et al., 2008).

Increased nitrogen rates have increased the lateral branch number of main stem, pod number per plant and seed yield in an experiment conducted by Yan et al. (2010). Elewa et al. (2014) examined how the fatty acids were affected by increasing nitrogen rates and they determined that the contents of palmitic acid, oleic acid and erusic acid increased slightly, but that the content of stearic and linolenic acids decreased and that the contents of linoleic acid did not change.

The aim of this research is to reveal effects of increased nitrogen doses on yield and quality of the rapeseed.

2. MATERIALS AND METHODS

This research was conducted on the trial field of Mustafakemalpasa Vocational School, Uludag University (40°02′ North latitude and 28°23′ East longitude) in 2010-2012 years. Experimental area is plain and altitude is 25 m.

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Table 1. Some soil properties of the experimental field (2010-2012).

Properties	Value
Total N (%)	0.20
Available P (P_2O_5 – kg ha^{-1})	81.00
Exchangeable K (K_2O – kg ha^{-1})	1394.98
Organic matter (%)	1.90
pH (saturation)	7.80
EC (1:2.5 – dS m^{-1})	0.48

Soils of experimental area were alkaline, limed in medium level, salt-free, medium in organic matter and rich in potassium. Profile examination of soil at 1.5 m depth indicated that there was no drainage problem. Some characteristics of soil at 0–30 cm soil depth in the trial field are presented in Table 1.

Table 2. Mean air temperature and total monthly precipitation in 2010–2012 and long-year (LY) (1930–2012) at Mustafakemalpasa, Bursa.

Months	Precipitation (mm)				Air Temperature (°C)			
	2010	2011	2012	LY	2010	2011	2012	LY
January	-	63.6	100.4	86.3	-	5.9	3.5	5.3
February	-	14.9	109.0	72.3	-	6.5	3.8	6.2
March	-	58.8	76.6	69.8	-	8.6	7.4	8.4
April	-	67.6	75.4	64.0	-	10.9	15.3	12.9
May	-	25.2	76.8	43.3	-	16.6	18.3	17.6
June	-	11.6	3.4	32.6	-	21.8	23.9	22.2
July	-	5.2	6.0	16.6	-	25.8	26.5	24.6
August	-	-	-	15.8	-	-	-	24.2
September	-	-	-	38.7	-	-	-	20.1
October	386.4	92.0	-	68.1	15.3	15.3	13.5	15.3
November	23.3	1.2	-	78.9	16.0	16.0	7.1	10.7
December	130.9	110.4	-	106.0	10.2	10.2	7.9	7.4

Rainfall in experimental years was close to those of long years except that of first month of first year (2010). The amount of the precipitation in the first month was too high (386.4 mm). Monthly temperatures of experimental years were realized mostly similar to those of long years (Table 2).

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In the experiment, Californium variety of winter rapeseed (*Brassica napus ssp. oleifera* L.) was used as plant material. Sizes of each plot were 2.5 m wide and 5 m length. Four rows were sown in each plot with 50 cm row spacing. Space within rows was 15 cm. The numbers of plants in each plot was approximately 135.Preplant crop was sunflower. Before sowing, the field was tilled by furrow at 20 cm depth. After that, disc-harrow and harrow were used to prepare the soil for sowing.

Sowings were realized at 22.10.2010 in the first year and at 25.10.2011 in the second year. The nitrogen fertilizer doses examined in the experiment were 0, 30, 60, 90, 120, 150, 180, 210 and 240 kg ha^{-1}. Half of nitrogen rates were applied during sowing time and second half at mid-March. Urea of 46% was used as nitrogen fertilizer. Weed control was done by hand hoe and straggle against Aphid by using Cypermethrin compound. Harvests were made at first week of July in both years.

Oil ratios of seeds were analyzed by Soxhlet aparatus on both year samples. For fatty acids analysis, the seeds of two years have been combined over replications and new samples were analyzed as three replications by using gas chromatography aparatus. Oil ratios and fatty acid composition were determined in the laboratory of the Sila Oil Factory, which is located in the town of Karacabey, Bursa Province

An economic analysis was applied to the results of this study based on investment, operation and production costs (Kuscu et al., 2014). The cost of urea fertilizer (46%) for each nitrogen treatment was calculated by multiplying the sale price of urea fertilizer and the amount of commercial fertilizer urea required for the rapeseed crop. All other production costs including labor (installation, irrigation, planting, weed control, cultivation, fertilizer application, spraying and harvesting), land preparation, seeds, fertilizers, chemicals (insecticides and pesticides) and other cultural applications were assumed constant across all nitrogen treatments. Polls and personal interviews were conducted with farmers to obtain information that would specify the crop management procedures. To calculate the total cost of rapeseed production for 1 year, the sum of the crop production costs and urea fertilizer costs were considered.

All the data obtained from trial were subjected to analyses of variance for each trait using SPSS Statistical Program (IBM® SPSS® Statistics, Version 20, Copyright 1989, 2011 SPSS Inc.). Differences between the means were evaluated at0.05 probability level using Duncan's multiple range tests.

3. RESULTS AND DISCUSSION

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According to the results of single and combined years, the different doses of nitrogen fertilizer made significant effect on all characters examined. All characters with exception of 1000-seed weight and oil ratio were significantly affected by years. The effect of year x nitrogen interaction on seed yield per plant and seed yield per hectare were found statistically significant.

3.1. Lateral Branch Numbers Attached to Main Stem

Average results of numbers of lateral branches have been affected by nitrogen applications and they increased as the levels of nitrogen increased. The 120 kg ha^{-1} and higher levels of nitrogen doses produced lateral branches changing between 9.9 and 9.8 number per plant which were in the same statistical group. The number of lateral branches of main stem was the lowest value at unfertilized plots. Differences among the numbers of lateral branches of main stem were not significant between years (Table 3).

The positive effects of increasing nitrogen doses on number of lateral branches of main stem were reported by many other researchers (Ahmadi, 2010; Cai Kang et al., 2011; Ahmad et al., 2011 and Meena et al., 2013).

3.2. Number of Pod per Plant

The number of pod per plant is an important yield component in rapeseed. Higher nitrogen doses such as 180, 210 and 240 kg ha^{-1} yielded the highest numbers of pod per plant in the same statistical group (416.8, 432.3 and 439.3 number pod/plant, respectively).

As a result, the effects of increasing nitrogen doses were in the direction of increasing pod number per plant. For this reason, the least value of pod number per plant was obtained at plots not fertilized with nitrogen. Pod number per plant in 2011 (343.3 pods/plant) was higher than in 2012 (312.1 pods/plant) (Table 3).

A lot of researchers have reported that the increasing doses of nitrogen fertilizer increased the numbers of pod per plant (Ozer, 2003; El-Nakhlawy and Bakhashwain, 2009; Ahmad et al., 2011; Khorshidi et al., 2013 and Meena et al., 2013). Our results are more or less in accord with results above given.

3.3. Seed Number per Pod

Average values of seed number per pod varied between 20.8 and 29.3. In general, all of the doses of nitrogen increased the seed number per pod when compared with unfertilized condition. The highest seed numbers per pod were obtained at 210, 180 and 240 kg ha^{-1} nitrogen treatments located in the same group (Table 4). On the other hand, so many researchers have reported that

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the increasing doses of nitrogen fertilizers progressively increased seed numbers per pod which these results are closely similar to our findings (Cheema et al., 2001; Ahmadi, 2010 and Khorshidi et al., 2013).

Table 3. The Results of branch number attached to main stem and number of pod per plant

Nitrogen Doses ($kgha^{-1}$)	Lateral Branch Number Attached to Main Stem (number)			Number of Pod per Plant		
	2010-2011	2011-2012	Average	2010-2011	2011-2012	Average
0	5.6^{d*}	5.3^{d}	5.5^{e}	138.3^{e}	182.6^{e}	160.5^{e}
30	7.3^{c}	6.6^{c}	7.0^{d}	237.3^{d}	229.0^{d}	233.1^{d}
60	8.6^{ab}	7.6^{bc}	8.1^{c}	242.3^{d}	247.0^{d}	244.6^{d}
90	8.6^{ab}	8.6^{ab}	8.6^{bc}	322.0^{cd}	286.0^{c}	304.0^{c}
120	9.3^{a}	8.6^{ab}	9.0^{ab}	362.6^{bc}	306.3^{c}	334.5^{bc}
150	9.6^{a}	9.3^{a}	9.5^{a}	371.3^{bc}	338.6^{b}	355.0^{b}
180	9.6^{a}	9.6^{a}	9.6^{a}	438.6^{ab}	395.0^{a}	416.8^{a}
210	10.0^{a}	9.6^{a}	9.8^{a}	453.6^{ab}	411.0^{a}	432.3^{a}
240	10.0^{a}	9.6^{a}	9.8^{a}	471.6^{a}	407.0^{a}	439.3^{a}
Year Ave.	8.8	8.4		343.5^{A}	312.1^{B}	
			Significance status			
Year (Y)	-	-	ns	-	-	*
Nitrogen (N)	*	*	*	*	*	*
Y x N	-	-	ns	-	-	ns

*: Means shown by the different letters within a column are statistically different at 0.01 level, ns: non-significant.

3.4. 1000-Seed Weight

1000-seed weight has been affected significantly by all levels except 30 kg ha^{-1} nitrogen dose, but the differences of effects of nitrogen levels have not been so great. As a matter of fact, plots treated with 150, 180, 210 and 240 kg ha^{-1} nitrogen doses have produced 1000-seed weights being statistically in the same group. The effects of years on 1000-seed weight were insignificant (Table 4).

The findings of many researchers indicated that different doses of nitrogen fertilizer increased 1000-seed weight, but the effects of nitrogen levels on 1000-seed weight have been found close

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to each other (Cheema et al., 2001; Ozer, 2003; El-Nakhlawy and Bakhashwain, 2009; Khorshidi et al., 2013).

Table 4. The results of seed number per pod and 1000-seed weight

Nitrogen Doses ($kgha^{-1}$)	Seed Number per Pod			1000-Seed Weight (g)		
	2010-2011	2011-2012	Average	2010-2011	2011-2012	Average
0	22.0^{d*}	19.6^{f}	20.8^{e}	4.1^{d}	4.0^{d}	4.1^{d}
30	23.6^{d}	22.0^{e}	22.8^{d}	4.1^{d}	4.0^{d}	4.1^{d}
60	25.6^{c}	22.0^{e}	23.8^{d}	4.5^{cd}	4.3^{cd}	4.4^{c}
90	27.6^{b}	24.6^{d}	26.1^{c}	4.6c	4.5^{bc}	4.5^{ab}
120	28.6^{ab}	26.6^{bc}	27.6^{b}	4.7^{bc}	4.7^{ab}	4.7^{b}
150	29.3^{ab}	26.3^{c}	27.8^{b}	5.0^{ab}	5.0^{a}	5.0^{a}
180	30.3^{a}	27.3^{abc}	28.8^{ab}	5.1^{a}	5.1^{a}	5.1^{a}
210	30.0^{a}	28.6^{ab}	29.3^{a}	5.1^{a}	5.1^{a}	5.1^{a}
240	29.0^{ab}	28.0^{a}	28.5^{ab}	5.2^{a}	5.1^{a}	5.2^{a}
Year Ave.	27.3^{A}	25.0^{B}		4.8	4.7	
			Significance status			
Year (Y)	-	-	*	-	-	ns
Nitrogen (N)	*	*	*	*	*	*
Y x N	-	-	ns	-	-	ns

*: Means shown by the different letters within a column are statistically different at 0.01 level, ns: non-significant

3.5. Seed Yield per Plant

All of nitrogen doses increased seed yields per plant as compared to those of unfertilized plots. Some differences among nitrogen treatments were found significant and the highest value was determined at 210 kg ha^{-1} N level (39.4 g/plant). 240 and 180 kg ha^{-1} N applications followed this value (39.1 and 37.7 g/plant). Seed yields of check plots and plots treated with 30 kg ha^{-1} N were the lowest and present in the same group. There were no differences between seed yields per plant of two years (Table 5). The increased rates of nitrogen fertilizer were increased seed yields per plant (Cheema et al., 2001; Meena et al., 2013).

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Table 5. The results of seed yield per plant and seed yield per hectare

Nitrogen Doses (kgha^{-1})	Seed Yield per Plant (g)			Seed Yield (kg ha^{-1})		
	2010-2011	2011-2012	Average	2010-2011	2011-2012	Average
0	17.6^{e*}	25.6^{c}	21.6^{e}	2072^{d}	1325^{f}	1698^{e}
30	19.3^{e}	27.2^{c}	23.2^{e}	2411^{c}	1744^{e}	2077^{d}
60	25.0^{d}	27.9^{c}	26.4^{d}	2629^{bc}	1976^{d}	2303^{cd}
90	29.3^{c}	30.8^{b}	30.1^{c}	2637^{ab}	2392^{c}	2514^{bc}
120	33.3^{b}	31.5^{b}	32.4^{bc}	2695^{ab}	2931^{b}	2813^{ab}
150	34.6^{b}	32.5^{b}	33.6^{b}	2942^{a}	2978^{b}	2960^{a}
180	38.3^{a}	37.0^{a}	37.7^{a}	2998^{a}	3176^{a}	3104^{a}
210	40.0^{a}	38.8^{a}	39.4^{a}	3000^{a}	3279^{a}	3139^{a}
240	40.0^{a}	38.3^{a}	39.1^{a}	3028^{a}	3253^{a}	3140^{a}
Year Ave.	30.9	32.3		343.5^{A}	312.1^{B}	
Significance status						
Year (Y)	-	-	ns	-	-	*
Nitrogen (N)	*	*	*	*	*	*
Y x N	-	-	ns	-	-	ns

*: Means shown by the different letters within a column are statistically different at 0.01 level, ns: non-significant

3.6. Seed Yield (kg ha^{-1})

Seed yields of single and combined years were given in Table 5. Seed yields of combined two years have varied between 1698 and 3140 kg ha^{-1}. All of the nitrogen doses produced higher seed yields then control condition, but the effects of increasing nitrogen rates were not linear. Especially plots fertilized with higher doses of nitrogen such as 150, 180, 201 and 240 kg ha^{-1} produced statistically similar seed yields being in the same group, and the seed yields of these nitrogen doses were about 74.3-84.9% higher than untreated plots. The seed yield of 2011 (3435.0 kg ha^{-1}) was higher than that of 2012 (3121.0 kg ha^{-1}).

Our findings showed a great resemble to results of some other researchers (Basalma, 1999; Cheema et al., 2000; Karaaslan et al., 2008; Kazemeini et al., 2010; Zheljazkov et al., 2012). Some researchers obtained the highest seed yield at different rates of nitrogen fertilizer. For example, Nemeth et al. (2009) determined the highest seed yield at 250 kg ha^{-1} N; Jackson (2000) at 200 kg ha^{-1} N and Rabiee et al. (2012) at 180 kg ha^{-1} N, and these researchers have found that the higher rates of nitrogen above the maximum seed yielding level decreased seed yield. Joshi et al. (1998) reported that 60 and 90 kg ha^{-1} N applications produced 30.1% and

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28.1% higher seed yields than control plots. In this meaning, some other researchers have declared similar findings (Zhong Fen et al., 2010; Yin Shui et al., 2011; Cai Kang et al., 2011; Juan et al., 2011; Sardana and Sheoran, 2011; Rameeh, 2014).

3.7. Oil Ratio

In general, both in combined and single years increasing nitrogen levels have caused decrease in oil ratio. According to the results, the plant grown in control and 30 kg ha^{-1} N treated plots produced similarly the highest oil ratios such as 37.2 % and 36.8 %. Inevitably, the lowest values of oil contents have been obtained from plants grown with 210 and 240 kg ha^{-1} nitrogen doses. No differences were found between experimental years in respect of oil ratio of seeds (Table 6).

Table 6. The results of oil ratio and oil yield.

Nitrogen Doses (kgha^{-1})	Oil Ratio (%)			Oil Yield (ka ha^{-1})		
	2010-2011	2011-2012	Average	2010-2011	2011-2012	Average
0	37.3^{a*}	37.0^{a}	37.2^{a}	773.9^{d}	490.7^{f}	632.3^{e}
30	36.9^{ab}	36.7^{ab}	36.8^{ab}	891.3^{c}	641.2^{e}	766.2^{d}
60	36.5^{bc}	36.4^{ab}	36.4^{b}	959.2^{ab}	719.5^{d}	839.3^{c}
90	36.2^{bc}	36.5^{ab}	36.3^{b}	954.0^{ab}	873.1^{c}	913.5^{b}
120	36.3^{bc}	36.0^{abc}	36.1^{b}	980.6^{ab}	1055.4^{b}	1018.0^{a}
150	35.4^{cd}	35.5^{bc}	35.4^{c}	1042.1^{a}	1057.6^{b}	1049.8^{a}
180	34.8^{de}	35.4^{bc}	35.1^{cd}	1043.4^{a}	1126.7^{a}	1085.0^{a}
210	34.2^{de}	34.7^{cd}	34.4^{de}	1026.9^{a}	1139.1^{a}	1083.0^{a}
240	33.7^{f}	33.9^{d}	33.8^{e}	1021.3^{a}	1105.1^{a}	1063.2^{a}
Year Ave.	35.7	35.8		965.8^{A}	912.0^{B}	
			Significance status			
Year (Y)	-	-	ns	-	-	*
Nitrogen (N)	*	*	*	*	*	*
Y x N	-	-	ns	-	-	ns

*: Means shown by the different letters within a column are statistically different at 0.01 level, ns: non-significant

There are great discrepancies among results of different researches indicating the relationships between nitrogen application and seed oil ratio. Some researchers reported results indicating that the increasing nitrogen doses progressively decreased oil ratio in seed (Basalma, 1999; Cheema et al., 2001; Jackson, 2000; El-Nakhlawy and Bakhashwain, 2009; Zang et al., 2012). On the other hand, some researchers determined that the increasing nitrogen doses increased oil ratio of seed (Taheri et al., 2012; Rameeh, 2014). Ozturk (2010) obtained the highest oil ratio from seeds fertilized with 100 kg ha^{-1} nitrogen. In some researches, oil ratio of seed increased with increasing doses of nitrogen fertilizer up to certain point and then decreased in spite of increasing

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nitrogen levels (Cai Kang et al., 2011). Zheljazkov et al. (2012) found that there were no effects of nitrogen application on oil ratio of seed in rapeseed.

3.8. Oil Yield

According to the results of the two-year average summarized in Table 6, oil yields of grown plants in nitrogen dose of 120, 150, 180, 210 and 240 kg ha^{-1} have taken place in the same statistical group (respectively, 1018.0, 1049.8, 1085.0, 1083.0 and 1063.2 kg ha^{-1}). The lowest value was fixed at control dose the nitrogen is not applied as 632.3 kg ha^{-1}. Value of oil yield of year 2011 was significantly higher than the average value measured for the year 2012 (965.8 and 912.0 kg ha^{-1}). Findings of Ghanbari-Malidarreh (2010) and Ahmadi (2010) show similarities with the research results.

3.9. Fatty Acids

Important fatty acids such as oleic, linoleic, linolenic, palmitik, stearic and erusic acid were determined as ratios in this study. The exchange limits of fatty acids were 65.52-67.18%for oleic acid, 17.71-19.44% for linoleic acid, 6.47-6.81% for linolenic acid, 4.34-4.45%, for palmitic acid and 1.54-1.72% for stearic acid. In the study, erusic acid was not found in seeds of rapeseed, and therefore no effect of nitrogen application on erusic acid was determined (Table 7).

Effect of nitrogen applications has been found significant and different on oleic and linoleic acid ratios. The highest and the lowest oleic acid ratios were 67.18% and 65.52% and they obtained at 150 kg ha^{-1} and 240 kg ha^{-1} nitrogen doses, respectively. While the highest linoleic acid ratio (19.44%) was obtained at 240 kg ha^{-1}, the 30, 60, 150 and 210 kg ha^{-1} nitrogen doses formed in the last statistical group (respectively, 17.83, 17.87, 17.71 and 17.91%).

Table 7. Fatty acid rates (Averages of 2010-2012 years)

Nitrogen Doses (kg ha^{-1})	Fatty Acid rates (%)				
	Palmitic acid (C16:0)	Stearic acid (C18:0)	Oleic acid (C18:1)	Linoleic acid (C18:2)	Linolenic acid (C18:3)
0	4.34	1.68	66.77^{ab*}	18.00^{bc}	6.69
30	4.35	1.88	66.84^{ab}	17.83^{c}	6.79
60	4.39	1.69	66.81^{ab}	17.87^{c}	6.79
90	4.38	1.60	66.81^{ab}	18.13^{bc}	6.81
120	4.41	1.72	66.62^{ab}	18.15^{bc}	6.71
150	4.45	1.62	67.18^{a}	17.71^{c}	6.73

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180	4.37	1.61	66.09[bc]	19.06[ab]	6.67
210	4.41	1.54	66.93[ab]	17.91[c]	6.75
240	4.44	1.67	65.52[c]	19.44[a]	6.47
Significance status					
Nitrogen	ns	ns	*	*	ns

*: Means shown by the different letters within a column are statistically different at 0.01 level, ns: non-significant

Results reported by numerous researches have indicated resembles to our findings. However, different results were also reported. For example, Cheema et al. (2001) found that the increase of nitrogen levels increased the linoleic acid content. Some other researchers have found no effects of nitrogen fertilizer rates on fatty acid contents (Joshi et al., 1998; Elawa et al., 2014). Contents of free fatty acids of nitrogen treatment were determined as 14.23-14.88% for linoleic acid, 7.35-7.58% for linolenic acid, 2.23-2.56% for palmitic acid and 0.79-0.97% for stearic acid in the study of Joshi et al. (1998).

3.10. Economic evaluation

The results of economic evaluation based on averages of two experimental seasons are shown in Table 8. The annual total cost varied from US$ 708.3 ha^{-1} to $ 986.6 ha^{-1}. The total cost increased with increases in the levels of nitrogen. The net income was highest for the treatment 180 kg N ha^{-1}, followed by 210 and 150 kg N ha^{-1} doses. In contrast, the 0 and 30 kg N ha^{-1} doses, treatments in which the plants were nitrogen stressed during total plant growing season, produced the lowest net income. This study showed that 180 kg N ha^{-1} doses is the best nitrogen dose to obtain a higher net income.

Table 8. Economic analysis and results for the treatments.

Nitrogen doses (kg ha^{-1})	The required amount of commercial fertilizer urea (46% N) (kg ha^{-1})	Sale price of urea fertilizer (46% N) (US$ kg^{-1})	Cost of urea fertilizer ($ ha^{-1})	Crop production cost ($ ha^{-1})	Annual total cost ($ha^{-1})	Seed yield(kg ha^{-1})	Rapeseed sale price ($ kg^{-1})	Gross income per ha ($ha^{-1} year^{-1})	Net income ($ ha^{-1} year^{-1})
0	0	0.5334	0	708.3	708.3	1698.	0.465	790	82
30	65.22	0.5334	34.8	708.3	743.1	2077.	0.465	966	223
60	130.44	0.5334	69.6	708.3	777.9	2303.	0.465	1071	293
90	195.65	0.5334	104.4	708.3	812.6	2449.	0.465	1139	326
120	260.87	0.5334	139.1	708.3	847.4	2813.	0.465	1309	461
150	326.09	0.5334	173.9	708.3	882.2	2960.	0.465	1377	495
180	391.30	0.5334	208.7	708.3	917.0	3104.	0.465	1444	527
210	456.52	0.5334	243.5	708.3	951.8	3139.	0.465	1460	509

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240	521.74	0.5334	278.3	708.3	986.6	3140.	0.465	1460	474

4. CONCLUSION

The seed yield of rapeseed depends on many soil factors. The nitrogen content of soil is the one of the most important soil factors which effects seeds yield of rapeseed. In this study, large amounts of nitrogen fertilizer were used to determine the suitable level producing the highest seed yield in rapeseed. The results of experiment indicated that all of the parameters examined except that oil contents increased up to a certain nitrogen level and became stable. As a general result, 180 kg ha^{-1} nitrogen dose can be proposed for maximum oil yield production and higher net income depending on the seed yield under these experimental conditions.

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