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Effects of Nitrogen and Plant Density on Rapeseed (*Brassica napus* L.) Yield and Yield Components in Southern Iran

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Abstract: This study was carried out to evaluate the influence of nitrogen levels (0, 50, 100 and 150 kg N ha^{-1}) and plant densities (70, 80 and 90 plants m^{-2}) on some growth parameters and yield components of the rapeseed. The experimental design was split plot with three replications during 2006-2007 and 2007-2008. Results revealed that with increasing plant density from 70 to 80 and 90 plants m^{-2}, 1000 seed weight (partial R^2 = 0.91), number of branches (partial R^2 = 0.83) and seed weight (partial R^2 = 0.94) were the most important variables contributing seed yield, respectively. As, with increasing nitrogen, variables contributing seed yield, were changed. Stepwise regression analysis showed that with increasing nitrogen from 0 to 50 and from 100 to 150 kg ha^{-1}, seed weight per main pod, pod number per branch and seed number per sub pod explained 91, 89 and 87% variations of seed yield, respectively. It means that, with increasing of nitrogen from 0 to 50 kg N ha^{-1}, the role of seed weight per main pod decreased (partial R^2 = 0.91 vs. 0.75). Pearson correlation results revealed that seed yield has positive correlation with seed weight per main pod (r = 0.89*), number of pod per branch (r = 0.93**), number of seed per main pod (r = 0.86*). According to the results, application of 150 kg N ha^{-1} and 90 plants m^{-2} for the maximum return unit area were recommended. Finally, it can be concluded that under high density and nitrogen, seed weight per sub pod was the most important variable contributing seed yield.

Key words: Rapeseed, partial R^2, stepwise regression, pearson correlation

INTRODUCTION

Rapeseed is the second edible oil resource in the world (Raymer, 2002) with high seed oil content of about 40-45% (Sovero, 1993) and the lowest saturated fatty acids 5-8% among all oilseed crops (Starner *et al.*, 1996). Nitrogen fertilizers have shown to cause substantial Rapeseed (canola) seed yield increases even in diverse and challenging con-ditions (Sieling and Christen, 1997; Šidlauskas and Tarakanovas, 2004). Nitrogen fertilizer requirements of rapeseed vary based on soil type, climate, management practices, timing of nitrogen application, crop cultivars and etc. (Ali *et al.*, 1998; Šidlauskas and Tarakanovas, 2004).

The level of nitrogen fertilization is one of the factors that condition the rate of the formation and reduction of generative organs (Kuchtová and Vašák, 2004). it is necessary to look for the relationship not only in the competition among vegetation and in the environmental conditions, but also in the competition between developing organs on the plants as such, which introduces secondary racemes into the relation (Kuchtová and Vašák, 2004). Characteristics of rapeseed such as plant height, number of branches per plant, number of pods per plant, seed yield and oil content are positively correlated with soil N level (Ahmadi and Bahrani, 2009). Rapeseed yield is also indirectly affected by N as a result of increased stem length, higher number of flowering branches, total plant weight, seeds per pod and number and weight of pods and seeds per plant (Taylor *et al.*, 1991). The significance of higher soil nutrient and particularly nitrogen availability in determining the yield quantity and quality of winter oil rapeseed has been underlined by Rathke *et al.* (2005).

Plant density in rapeseed has shown that is an important factor affecting rapeseed yield. It also governs the yield components and therefore, the yield of individual plant. A uniform distribution of plants per unit area is a prerequisite for yield stability (Diepenbrock, 2000). Consequently, optimum densities for each crop and each environment should be determined by local research.

Fathi *et al.* (2002) reported that increasing nitrogen fertilizer and plant density caused a boost in seed yield in rapeseed. The highest yield per hectare in this study resulted from 225 kg N ha^{-1} at a plant density of 90 plants per square meter. Prasad and Shakla (1991) concluded that the interaction between plant density and nitrogen fertilizer, affects rapeseed seed yield and hence, the

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optimal seed yield could be achieved by increasing plant density and nitrogen levels. The objective of this research was to study the effect of different nitrogen levels and plant densities on growth, yield and yield components of rapeseed (*Brassica napus* L.) in the region of Southern Iran, Shiraz.

MATERIALS AND METHODS

This research was conducted in a silty clay loam soil at the Experimental Research Center (Badjgah), Shiraz University (52° 46 E, 29° 50 N and 1810 m) in two growing seasons (2006-2008). The experimental design was split plot with three replications. The treatments consisted of N fertilizer in four levels (N1 = 0, N2 = 50, N3 = 100 and N4 = 150 kg N ha^{-1}) as main plots and plant density in three levels (D1 = 70, D = 80 and D3 = 90 plants m^{-2}) as sub plots. Data on monthly average temperature and rainfall for 2 years of study and 30 years means of the region as well as some properties of soil are shown in Table 1 and 2. Land preparation practices included plowing, disking and ridging plots (sized 4 by 4 m). Weeds were controlled by Triflouralin (2 L ha^{-1}) that was applied prior to planting and incorporated into soil by disking. Nitrogen was supplied from urea and added to plots in two periods (½ at planting time and ½ at stem elongation stage). The seeds of rapeseed cv Talayeh were sown in plots by Pneumatic grain drill (model Accord, Germany) in late September in both years. To reach exact plant density plant thinning was performed at 5 leaf growth stage. Some traits such as seed yield (g m^{-2}), biomass (g m^{-2}), Pod Number in Main Stem (PNMS), Pod Number in Sub Stem (PNSS), Seed Weight (g) per Main Pod (SWMP) and sub pod (SWSP), 1000 seed weight (g) (MKW) and Branch Number (BN) per plant were measured by randomly selecting ten plants in each plot. The experimental data were analyzed using the SAS (version 9.1) system (SAS Institute, 1996). Where analysis of variance showed significant treatment effect, LSD Test was used to compare the means at $p<0.05$. Additionally, 2 years data were combined and no significant differences were observed in this regard, so the values in the tables are representative data for combination of 2 years.

RESULTS AND DISCUSSION

Branch numbers: Results indicated that nitrogen levels and plant densities had significant effects on branch number (Table 3 and 4). Nitrogen application in the rate of 150 kg ha^{-1} produced the highest branch number (7.1) and control produced the lowest (3.7) ones (Table 3). Increasing in BN with increasing of nitrogen levels were observed by Patll *et al*. (1996) for rapeseed cultivars.

Number of branches significantly varied with plant densities. The maximum (6.5) and minimum (5.1) number of branches were observed for 70 and 80 plants m^{-2}, respectively (Table 4). Rapeseed typically gives similar yields over a wide range of sowing rates (Nuttall *et al*., 1992). However, plants at higher density are thinner and carry fewer branches and have smaller crop growth rates and net assimilation rates (Morrison *et al*., 1990; Šidlauskas and Tarakanovas, 2004).

The nitrogen and plant density interaction showed that the most branch number (8.3) was recorded in 150 kg ha^{-1} nitrogen application rate and 70 plants m^{-2} (Table 5). Similar results have been observed by Patll *et al*. (1996).

Table 1: Monthly average temperature and rainfall values during the years of experiment and 30-year means at Agricultural Research Center (Badjgah), Shiraz, Iran

	Rainfall (mm)			Temperature (°C)		
Months	2006-2007	2007-2008	1975-2005	2006-2007	2007-2008	1975-2005
Sep-Oct	0.00	0.00	1.80	16.70	15.70	15.30
Oct-Nov	0.00	0.00	25.90	12.30	11.30	9.90
Nov-Dec	82.00	18.00	82.00	2.60	6.60	5.80
Dec-Jan	50.50	76.00	98.30	0.38	1.40	3.40
Jan-Feb	82.50	29.50	87.50	4.50	3.70	3.50
Feb- Mar	35.00	0.00	66.70	7.40	8.90	6.90
Mar-Apr	138.50	3.50	43.90	11.50	14.00	10.90
Apr-May	3.00	0.00	13.60	17.30	17.90	15.70
May-Jun	0.00	0.00	0.80	22.00	22.40	20.20
Jun- Jul	2.50	0.00	0.30	25.10	25.80	23.76
Jul-Aug	0.00	0.00	0.50	24.10	24.70	23.72
Aug-Sep	0.00	0.00	0.40	21.20	21.00	20.40
Total	394.00	127.00	421.70	-	-	-

Table 2: Some physical and chemical properties of experimental site soil

Clay	Silt	Sand	OM	Cu	Mn	Zn	Fe	P			
(%)				(ppm)					N (%)	Ec (μmos sec^{-1})	pH
18	60.72	21.28	2.85	2.48	6.75	2.31	6.4	21.8	0.091	2.61	7.83

Table 3: Effects of nitrogen on growth, yield and yield components of rapeseed

Treatments	Biomass (g m^{-2})	Seed yield (g m^{-2})	H.I.(%)	SWMP	SWSP	PNMS	PNSS	TSNMP	TSNSP	MKW (g)	BN
N1	454.44	181.90	40.64	0.80	1.50	16.7	19.30	194.80	376.20	4.2	3.70
N2	675.70	313.40	46.46	1.50	2.60	40.7	41.44	292.23	532.50	5.0	5.40
N3	736.00	373.40	50.67	1.60	3.10	49.7	52.60	320.80	617.51	5.0	6.40
N4	796.20	426.10	53.22	1.70	3.60	72.2	81.67	330.90	700.90	5.1	7.10
LSD (5%)	20.30	8.57	2.50	0.19	0.35	11.8	13.90	38.90	81.10	0.3	0.89

N1: 0 kg N ha^{-1}, N2: 50 kg N ha^{-1}, N3: 100 kg N ha^{-1}, N4: 150 kg N ha^{-1}, H.I.: Harvest Index, SWMP: Seed weight per main pod, SWSP: Seed weight per sub pod, PNMS: Pod number per main stem, PNSS: Pod number per sub stem, TSNMP: Total seed number per main pod, TSNSP: Total seed number per sub pod, MKW: 1000 seed weight, BN: Branch number

Table 4: Effects of density on growth, yield and yield components of rapeseed

Treatments	Biomass (g m^{-2})	Seed yield (g m^{-2})	H.I. (%)	SWMP	SWSP	PNMS	PNSS	TSNMP	TSNSP	MKW (g)	BN
D1	582.54	275.83	47.00	1.70	3.20	52.0	78.17	335.7	673.9	5.00	6.50
D2	670.83	331.20	47.85	1.40	2.70	45.8	35.80	295.2	553.6	4.80	5.40
D3	743.42	364.70	48.46	1.10	2.20	36.7	25.92	223.1	442.8	4.70	5.10
LSD (5%)	17.30	12.00	2.40	0.09	0.17	4.80	7.70	23.3	44.7	0.14	0.54

D1: 70 plant m^{-2}, D2: 80 plant m^{-2} , D3: 90 plant m^{-2}; H.I.: Harvest Index, SWMP: Seed weight per main pod, SWSP: Seed weight per sub pod, PNMS: Pod number per main stem, PNSS: Pod number per sub stem, TSNMP: Total seed number per main pod, TSNSP: Total seed number per sub pod, MKW: 1000 seed weight, BN: Branch number

Table 5: Interaction effects of nitrogen and plant density on growth, yield and yield components of rapeseed

Treatments	Biomass (g m^{-2})	Seed yield (g m^{-2})	H.I.(%)	SWMP	SWSP	PNMS	PNSS	TSNMP	TSNSP	MKW (g)	BN
N1											
D1	346.7	157.3	45.40	0.50	1.90	15.0	30	112	464	4.10	4.50
D2	483.3	188.3	38.99	0.90	1.50	18.0	15	244	405	3.80	3.60
D3	533.0	200.0	37.54	1.00	1.20	17.0	13	229	259	4.60	3.00
N2											
D1	635.3	276.7	43.58	1.10	3.00	33.0	63	237	669	4.50	5.60
D2	667.6	331.3	49.63	1.60	2.80	41.0	37	296	520	5.40	5.30
D3	724.6	333.7	46.16	1.80	2.10	48.0	25	344	408	5.20	5.20
N3											
D1	642.0	310.0	48.24	1.30	3.80	41.0	94	268	726	5.20	7.30
D2	743.0	393.3	52.90	1.60	2.90	50.0	35	324	587	4.90	6.50
D3	821.6	417.0	50.85	1.90	2.70	58.0	29	370	540	5.00	5.30
N4											
D1	705.3	358.0	50.77	1.40	4.20	58.0	141	275	836	5.10	8.30
D2	788.6	411.7	52.32	1.60	3.50	75.0	36	317	702	4.90	6.90
D3	894.0a	508.3	56.89	2.10	2.90	83.0	67	400	564	5.30	6.00
LSD (5%)	35.1	21.9	4.29	0.22	0.35	9.6	15	47	89	0.25	0.95

N1: 0 kg N ha^{-1}, N2 : 50 kg N ha^{-1}, N3 : 100 kg N ha^{-1}, N4: 150 kg N ha^{-1}, D1: 70 plant m^{-2}, D2: 80 plant m^{-2} , D3: 90 plant m^{-2}, H.I.: Harvest Index, SWMP: Seed weight per main pod, SWSP: Seed weight per sub pod, PNMS: Pod number per main stem, PNSS: Pod number per sub stem, TSNMP: Total seed number per main pod, TSNSP: Total seed number per sub pod, MKW: 1000 seed weight, BN: Branch number

Pod number per main stem: Table 3 exhibits that different nitrogen levels had highly significant effect on PNMS. Maximum PNMS (72.2) were obtained in plots that received 150 kg N ha^{-1}. The minimum PNMS (16.7) was produced in control plots. Also, plant density and interaction of nitrogen and plant density had significant effects on PNMS (Table 4 and 5). The summary of Stepwise Selection for nitrogen and plant density treatments showed in Table 4 and 5. Similar results were also reported by other researchers (Khan *et al*., 2002; Šidlauskas and Tarakanovas, 2004). They showed that pod number would be increased in nitrogen level.

Number of seeds per pod: Significant differences were recorded in number of seeds per pod included as Total Seed Number per Main Pod (TSNMP) and Total Seed umber per Sub Pod (TSNSP) among various nitrogen treatments (Table 3). Maximum TSNMP (330.9) and TSNSP (700.9) were produced at 150 kg N ha^{-1}. In different plant densities, the most TSNMP (335.7) was produced in 70 plants m^{-2} (Table 4). Increasing the plant population densities significantly enhanced TSNMP and reduced TSNSP (Table 4). These results are in agreement with the findings for soybean by Ball *et al*. (2000) and for colza by Fathi *et al*. (2002).

1000-Seed weight (MKW): Data on Table 3 show that the 1000-weight seed increased with increasing in nitrogen application rates and decreased with increasing in plant densities. Thus, the highest and lowest values of MKW were obtained from 70 and 90 plants m^{-2}, respectively (Table 4). The interaction effects of nitrogen and plant density had significant effect on MKW (Table 5). These results are supported by Trivedi and Singh (1999) and Mehmet (2008).

Harvest Index (HI): HI was significantly affected by nitrogen application rates. The highest and the lowest HI

Table 6: Summary of stepwise selection for nitrogen treatments

Treatments	Variable entered	Partial R^2	Model R^2	F-value	Pr>F
N1	Seed weight per main pod	0.9113	0.9113	71.88	<0.0001
N2	Seed weight per main pod	0.7529	0.7529	21.33	0.0024
N3	Pod No. per branch	0.8864	0.8864	54.64	0.0002
	Seed No. per main pod	0.0552	0.9416	5.68	0.0546
	Seed weight per main pod	0.0219	0.9635	3.00	0.1439
N4	Seed No. per sub pod	0.8714	0.8714	47.43	0.0002
	Seed weight per main pod	0.0549	0.9262	4.46	0.0791

N1: 0kg N ha^{-1}, N2: 50 kg N ha^{-1}, N3: 100 kg N ha^{-1}, N4: 150 kg N ha^{-1}

Table 7: Summary of stepwise selection for density treatments

Treatments	Variable entered	Partial R^2	Model R^2	F-value	Pr>F
D1	Seed weight per main pod	0.9146	0.9146	107.14	<0.0001
	Pod No. per main stem	0.0255	0.9402	3.84	0.0816
D2	Branch No.	0.8322	0.8322	49.59	<0.0001
	Seed weight per sub pod	0.0752	0.9074	7.31	0.0243
	Seed No. per main pod	0.0381	0.9455	5.59	0.0456
	Seed weight per main pod	0.0193	0.9648	3.85	0.0905
	First branch height	0.0219	0.9846	9.96	0.0160
D3	Seed weight per sub pod	0.9363	0.9363	146.96	<0.0001
	Pod No. per branch	0.0332	0.9649	9.77	0.0122
	Seed No. per main pod	0.0148	0.9843	7.56	0.0250

D1: 70 plant m^{-2}, D2: 80 plant m^{-2}, D3: 90 plant m^{-2}

values were obtained from 150 kg N ha^{-1} (53.22%) against 40.64% for the control (Table 3). Ali *et al.* (1990) reported the progressive increase in the value of harvest index when the rate of applied nitrogen increased gradually. On the other hand, plant density has no effect on harvest index (Table 4). Harvest index was relatively stable and was not affected by population densities (Ball *et al.*, 2000).

Biomass: Results in Table 3 show that the effects of nitrogen were highly significant on the crop biomass. The application rate of 150 kg N ha^{-1} produced the maximum biomass (796.2 g m^{-2}), followed by 100 kg N ha^{-1} which produced 736.0 g m^{-2} biomass (Table 3). The minimum biomass (454.44 g m^{-2}) was recorded in control treatment. These results are in line with the findings of Ali *et al.* (1990) who reported that biological yield was maximum with increasing nitrogen levels.

The interaction effects of nitrogen and plant densities had a significant effect on biomass of rapeseed (Table 5). Among all treatments, 150 kg N ha^{-1} coupled with 90 plants m^{-2} (N4 D3) produced the highest biomass (894.0 g m^{-2}). Yousaf and Ahmad (2002) indicated that the maximum biomass would be obtained in maximum plant density.

Seed yield: Result indicated that nitrogen application rate, plant density and their interaction had significant effect on seed yield (Table 5). Rapeseed seed yield varied from 454 to 796 g m^{-2}, with the highest and lowest seed yields at no nitrogen and 150 kg N ha^{-1} application rates respectively (Table 3). The difference between the lowest and the highest seed yields was 342 g m^{-2}. Present results support the previous study of Ali *et al.* (1990) who reported that use of nitrogen could increase rapeseed seed yield. Yousaf and Ahmad (2002) and Fathi *et al.* (2002) indicated that increasing nitrogen fertilizer and plant density caused a boost in seed yield in rapeseed.

Stepwise regression analysis: With increasing nitrogen, variables contributing seed yield were changed. Stepwise regression analysis showed that with increasing nitrogen from 0 to 50 and 100 to 150 kg ha^{-1}, seed weight per main pod (g), pod number per branch and seed number per sub pod explained 91, 89 and 87% variations of seed yield, respectively (Table 6). It means that, with increasing of nitrogen from 0 to 50 kg ha^{-1}, the role of seed weight per main pod increased (partial R^2 = 0.91 vs. 0.75). The results are supported by Yousaf and Ahmad (2002) and Ozer (2003). With increasing plant density from 70 to 80 and 90 plants m^{-2}, 1000 seed weight (g) (partial R^2 = 0.91), number of branches (partial R^2 = 0.83) and seed weight (partial R^2 = 0.94) were the most important variables contributing seed yield, respectively (Table 7). These results are agreement with the findings of Trivedi and Singh (1999) and Mehmet (2008). Pearson correlation results revealed that seed yield (g m^{-2}) has positive correlation with seed weight (g) per main pod (r = 0.89*), pods number per branch (r = 0.93**), seed number per main pod (r = 0.86*).

CONCLUSION

Nitrogen levels and plant densities significantly affected some important growth, yield and yield components in rapeseed. An increase in both nitrogen and plant density levels, increased harvest index, biomass and seed yield. However, number of branches and 1000 seed weight decreased when plant density increased. According to the results application of 150 kg N ha^{-1} and 90 plants m^{-2} for the maximum return unit area were recommended. Finally, it can be concluded that under high density and nitrogen conditions, seed weight per sub pods (pods in branches) was the most important variable contributing seed yield.

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