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The Effect of Different Rates of Nitrogen and Plant Density on Qualitative and Quantitative traits of Indian mustard

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Sahar Keivanrad, Babak Delkhosh, Amir Hossein Shirani Rad and Peiman Zandi: The Effect of Different Rates of Nitrogen and Plant Density on Qualitative and Quantitative traits of Indian mustard

ABSTRACT

To understand the effect of plant density and amounts of nitrogen fertilizer on some agronomic characteristics of Indian mustard, an experiment was laid out as a randomized complete block design with split-plot arrangement with three replications. Nitrogen fertilizer levels (0, 50, 100, 150 and 200 kg N/ha) were allotted to main plots and subplots were consisted of three levels of plant densities (80, 100 and 120 plants/ m^2). The results indicated that, plant density had a highly significant effect on plant height, seed/siliqua, siliqua/plant, seed yield, biologic yield, 1000-seed weight, oil content and oil yield (p<0.01). All tested traits (qualitative and quantitative ones) were significantly affected by nitrogen fertilizer (p<0.01). Nitrogen×plant density interaction also significantly affected all tested traits (p<0.05) except for plant height and siliqua/plant. Our findings suggest that for semi-arid zone of Takestan, Indian mustard due to its high adaptation to arid conditions can be a good option for spring rapeseed replacement.

Key words: *Brassica juncea,* plant population, nitrogen fertilizer, seed yield, oil yield, oil content.

Introduction

Indian mustard (*Brassica juncea* L.) is introduced as an oily plant, which is appropriate for zones with short seasons and less rainfall. Mustard lines consist of 38 to 40 oil-percentages and 23 to 30 protein-percentages [1]. Nitrogen and suitable density are the most important agronomic factors in *Cruciferae* family that affect growth and production [2]. Duncan [3] stated that, once the plant density increases, single plant yield decreases whereas seed yield in the unit of surface increases to the optimum level as well. For a better and uniform distribution of the plants and less competition of sources, Christensen and Drabble [4] and Chauhan *et al*. [5] as well as Singh and Verma [6] gained the highest mustard yield from narrow rows. Shaberi and Komar [7] showed that how by increasing density we would have less percentage of oil content but because of the relationship between seed yield and oil yield per unit area, increasing density give us more oil yield. Bani-Saeedi [8] stated that nitrogen by reducing flower abscission, and consequently affecting 1000-seed weight, increasing the number of siliquae per unit area and decreasing the number of seeds per siliqua, caused more seed yield per hectare. Esmaili *et al*.[9] have reported the highest crop yield after using 300 Kg /ha of urea in two splits, but Mirzashahi *et al*.[10] have found the highest yield after using 180 Kg N/ha . Reddy and Sinha [11] showed that seed yield has increased linearly by increasing nitrogen consumption and in comparison with no nitrogen consumption, the amounts of 40 and 80 Kg N/ha increased the seed yield to 49.5% and 96.5%, respectively. Optimum in-row spacing provides condition for greater light interception from early crop growth. Furthermore, it is important that the in-row spacing should be defined to accommodate the more number of plants per unit area and their arrangement. The mustard genotypes differ in their yielding ability [12]. This calls for a need to generate more information on the response of mustard to the nitrogen fertilizer and in-row spacing for greater yields in a given agro-climatic conditions.

Keeping in view the importance of plant density and nitrogen fertilizer, the present study was conducted to find out optimum plant population and appropriate level of nitrogen for obtaining higher quality and quantity yield of Mustard under the agro-ecological conditions of Takestan, Iran.

Materials and Methods

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This study was conducted at research farm of Islamic Azad University, Takestan branch, Iran in 2009-2010cropping season. The site is located at 36° 18´ N latitude, 49°57´ E longitude and 1314 m above the sea level. During the research period annual mean minimum and maximum temperature and annual precipitation was 8.2 °C, 38.7 °C and 312 mm, respectively. The soil texture was clay-loam with 1.33 EC (ds/m) and pH 8.7 (0-30 cm soil depth). The experimental design was a randomized complete block in a split plot arrangement with three replications. Sub-plots were consisted of three levels of plant density including 80, 100 and 120 plants per m^2. Five levels of nitrogen fertilizer in the form of urea (0, 50, 100, 150 and 200 Kg N/ha) were allotted to main plots in three splits (50% at the sowing stage, 25% at the stem formation stage and 25% at the pollination stage). Each sub-plot was about 4 × 2.5 m with two planting lines and 30 cm row spacing. Based on result of test soil, the amount of phosphorus and potassium as a basal dressing was 75 Kg P /ha from source of triple super phosphate and 75 Kg K/ha from potassium sulphate source. Sowing patterns was based on furrow and Ridge system with blank lists of 2 cm depth. The plants were thinned at two stages during 3-4 true leaf stage. Hand weeding was also done in three stages. The final harvest was done manually with use of sickle, 5 cm distance from ground level. To determine yield components from completely harvested plants, five plants per each sub-plot were chosen randomly, and the plant height and number of siliquae per plant were measured.

To find out the number of seeds per siliqua from each sub-plot, 30 siliquae were chosen randomly and after counting number of available seeds, the number of seeds per siliqua was determined for each experimental unit. In order to estimate the seed yield, oil yield, 1000-seed weight, biologic yield and harvest index, a final harvesting from a 3.6 square meter area was done manually. In the other hand, plants were cut from the surface and placed in open air for a week to reach 12% moisture content, then the total plant weight as a biologic yield was computed and expressed as kg/ha. Treshing was done by using Treshing machine (combine) and the seeds were weighed by precision scale, then the seed yield was studied based on kg/ha. In order to find 1000-seed weight, eight samples with 1000 seeds from each experimental plot were chosen randomly and then weighed. Their average recorded 1000-seed weight (g). The harvest index for mustard was worked out as indicated below:

[13]

$$\text{Harvest index}(\%) = \frac{\text{Seed yield}}{\text{Biologic yield}} \times 100 \quad (1)$$

The seed oil percentage (oil content) was determined using carbon Tetrachloride solvent with the Soxhlet apparatus at the laboratory of Takestan branch, Islamic azad university, Iran. In term of seed extraction fresh siliqua were collected and seeds were separated. Then they were dried and subjected to hot solvent extraction in a soxhlet apparatus using carbon tetrachloride in 1:1 ratio, at a temperature range of 70-100°c. Oil yield per unit area was calculated by using following formula:

$$\text{Oil yield (kg/ha)} = \frac{\text{Seed oil content (\%)} \times \text{Seed yield (kg/ha)}}{100} \quad (2)$$

All data were analyzed statistically with MSTATC software, by using Fisher's analysis of variance (ANOVA) and the differences of means across treatments were compared by Duncan's Multiple Range Test at the probability level of 0.05.

Results and Discussion

Plant height:

A highly significant (p<0.01) effect of plant density and rate of nitrogen application on Indian mustard plant height (PH)at maturity was observed in this study,while the interaction effect for nitrogen rate × plant density was not significant for plant height (Table 1). Significantly, taller plants (115.2 cm) were observed in a density of 120 plants/m^2 (Table 2).This was mainly due to higher plant population in closer spacing. Inversely, based on Table 2, the reduction in plant height from 115.2 to 102.7cm was significant as the plant population decreased from D_3 to D_1. This might be attributed to reduction in magnitude of competition for light at wider spacing as compared to closer spacing. Our observations are in conformity with the results reported by Rana and Pachauri [14]. Comparison of nitrogen levels indicates that the highest plant height (139.5 cm) was obtained from plants received 200 kg N per ha; and this significantly differed from other levels. The minimum plant height (74.97 cm) was recorded in plants received no nitrogen (0 kg N/ ha) (Table 2). This indicates that application of nitrogen had increased the plant height. These results are in accordance with the findings of Majnoun-Hosseini *et al*. [15].

Number of seeds per siliqua:

Data revealed that, number of seeds per siliqua was significantly affected by the nitrogen levels applied, plant densities and interaction thereof (Table1) .Since the interaction effect of N rate × plant density was significant; mean values for each treatment combination are presented in Table 3. Comparison of means of interaction (nitrogen levels × planting densities) indicate that the maximum number of seeds per siliqua (17.80) was recorded in the combinations of highest nitrogen level (200 kg N/ha) with lower plant densities (80 plants/m^2)

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followed by the combinations of similar nitrogen level with higher plant density (100 plants/m^2). The minimum seed number per siliqua (10.70) was recorded in combinations of no nitrogen application with the highest planting density (Table 3) confirming the supremacy of the highest nitrogen level on seed number per plant. This fact implies that, in lower densities, due to lesser competition between the plants and also the existence of sufficient light as a potent source for increasing biomass, the numbers of seeds per siliqua were increased. Considering the Table 3, it can be concluded, at each level of nitrogen consumption with increase in density, the number of seeds per siliqua were increased which demonstrates, the fertility can be achieved best in lower densities. In low densities, in addition to the number of seeds per siliqua, the number of siliquae per plant is also increased as compared to high densities, which represents high flexibility of Indian mustard to the plant density changes. It means, if the number of plants per unit area decreased, the remaining plants by preventing flower and siliqua abscission and more seed production per siliqua are able to compensate it to some extent. These results are in agreement with the findings of Kazemeini *et al*. [16] and Siadat *et al*. [17].

Table1: The mean squares of ANOVA for plant height (PH), seed/siliqua (S/S), siliqua/plant(S/P), seed yield(S Y), biologic yield (B Y), 1000-seed weight (1000 S W), harvest index (H I), oil content (O C) and oil yield (O Y) in variance analysis of 2009–2010 data.

S.O.V	df	PH	S/S	S/P	S Y	B Y	1000 SW	HI	O C	O Y
R	2	221.109**	5.882**	185.486**	323572.9**	2013203.27**	2.323**	4.981ns	2.288ns	68194.16**
N	4	5478.845**	59.361**	4707.855**	4393382**	103503272.7**	11.813**	134.76**	22.88**	631561.58**
E_a	8	3.440	0.181	4.746	23255.53	135251.517	0.039	3.395	0.339	4669.29
D	2	604.178**	6..278**	637.946**	205778.6**	3882800.6**	1.184**	0.146 ns	6.164**	55461.36**
N D	8	10.568 ns	0.063*	5. 549 ns	4524.35*	72126.6*	0.029*	1.246*	0.13*	830.24*
E	20	4. 403	0.112	3.070	10.72	92312.267	0.036	2.638	0.213	2004.13
CV (%)		1.92	2.35	2.19	4.77	3.51	4.81	6.56	1.13	5.25

**$p < 0.01$; *$p < 0.05$; ns – $p > 0.05$. R – replication effect; N – nitrogen fertilizer effect; D – plant density effect; N D represent interaction terms between the treatment factors.

Number of siliquae per plant:

The number of siliquae per plant of Indian mustard was affected highly significantly ($p<0.01$) by the plant densities and nitrogen rates, while the interaction effect of nitrogen × plant density was not significant (Table 1).

Maximum siliqua number per plant (108.60) was obtained in plots that received 200 kg N/ha. The minimum number of siliquae per plant (50.10) produced in control plots (no nitrogen application). In fact, the increase in number of siliquae per plant due to more nitrogen consumption emphasizes the existence of source limitation, which results in competition between plants, and different parts of each plant for receiving assimilates. This competition brings forth the abscission of flower and (newborn) fresh siliquae. Hence, with increase in nitrogen consumption, the abscission intensity decreased. Therefore, there is a huge/ remarkable difference between the highest and lowest level of nitrogen consumption regarding the number of siliquae per plant. The same results obtained by other experiments on this family (Brassicaceae) [17,18,19]. Plant population of 80 plants/m^2 recorded significantly higher siliqua number per plant (86.70) as compared to 120 plants/m^2 which caused the lowest siliqua number per plant (73.68) (Table 2). This was due to the reason that, with increase in density the number of siliquae, which were produced solely by each plant, will decrease due to low space and more competition [20].

Seed yield:

Result indicated that nitrogen application rate ($p<0.01$), plant density ($p<0.01$) and their interaction ($p<0.05$) had significant effect on seed yield (Table 1). Means comparison showed that, the most (2832 kg/ha) and least seed yield (1038 kg/ha) were produced at application doses of 200 and 0 kg N/ha, respectively (Table 2). The application of 200kg N/ha, by preventing flower and siliqua abscission, increasing the number of siliquae per unit area and affecting 1000-seed weight led to more seed yield. Present results support the previous study of Ali *et al*. [21] and Siadat *et al.* [17], who reported that use of nitrogen could increase rapeseed seed yield. Among the plant densities 80 plants/m^2 produced significantly higher seed yield (2218 kg/ha) while 100 and 120 plants/m^2 gave 2105 and 1984 kg/ ha, respectively (Table2). As a matter of fact, the high amount of seed yield in 80 plants/m^2 compared to other densities is due to, lesser inter competition and higher number of siliquae per unit area. In this level of density, by creating more suitable green canopy in the unit area, with the least inter competition, solar radiation was used effectively for producing economic yield [22, 23]. Interaction effect of nitrogen and plant density results showed that the

most seed yield (2961 kg/ha) was produced in 200 kg N/ha in case of 80 plants/m^2. Moreover, the least seed yield (952 kg/ha) was obtained in no nitrogen application in case of 120 plants/m^2. The interaction effects of applying 200 kg N/ha at each level of density (i.e., N_5D_1, N_5D_2, and N_5D_3) revealed, if plant exposed by nitrogen fertilizer effectively, it can compensate the loss made by decrease in density per square meter. Therefore, in zones with the possibility/probability of decrease in plant population, for preventing the considerable yield decrease, nitrogen fertilizer is utilized. Yousaf and Ahmad [24], Kazemeini *et al*. [16] and Fathi *et al*. [25] indicated that increasing nitrogen fertilizer and plant density caused a boost in seed yield in rapeseed.

Biologic yield:

Results in Table 1 show that, the individual effects of nitrogen and plant density were highly significant on the crop biologic yield (p<0.01). The application rate of 200 kg N/ha produced the maximum biologic yield (12840 kg/ha), followed by 150 kg N/ha which produced 11330 kg/ha biologic yield. The minimum biologic yield(4823 kg/ha) was recorded in control treatment (Table2).These results are in line with the finding of Ali *et al*.[21] who reported that biologic yield was maximum with increasing nitrogen levels. Means comparison of density levels using Duncan's test (p<0.05) indicated that the highest biological yield (9154 kg/ha) was obtained applying a density of 80 plants/m^2.On the other hand, the lowest biological yield (8136 kg/ha) was that of 120 plants/m^2. The interaction effects of nitrogen and plant densities had a significant effect on biologic yield of Indian mustard (Table 1). Among all treatments, 200 kg N/ha coupled with 80 plants/m^2 (N_5D_1) produced the highest biologic yield (13490 kg/ha) (Table 3). In this regards, Yousaf and Ahmad [24] indicated that the maximum biomass would be obtained in maximum plant density. In addition, the lowest biologic yield (4286 kg/ha) was that of the control treatment (no nitrogen application) coupled with a density of 120 plants/m^2 (N_1D_3). This fact is due to the effective role of nitrogen as a nutrient management on assimilates distribution and adjusting the effect of inter and intra plant competition [26]. Concerning the fact that 200 kg nitrogen application creates more foliage (through higher siliqua yield and stover yield) compared to the seed production (based on the obtained results of harvest index), due to plant nutrient improvement, the photosynthesis developed, which itself increases the yield [16,27].

Table 2: Means comparison of plant characteristics of Indian mustard as affected by individual effect of plant density and nitrogen fertilizer.

Treatments	PH (cm)	S/S	S/P	SY(kg/ha)	BY(kg/ha)	1000 SW(g)	HI (%)	OC (%)	OY(kg/ha)
Nitrogen Fertilizer									
N_1: 0 kg/ha	74.97e	10.78e	50.10e	1038e	4823e	2.47e	21.55c	40.80b	424d
N_2: 50 kg/ha	97.97d	12.84d	66.47d	1861d	6123d	3.27d	30.44a	43.08a	802.6c
N_3: 100 kg/ha	111.5c	14.31c	80.60c	2214c	8149c	3.9c	27.14b	40.86b	905.8b
N_4: 150 kg/ha	123.9b	15.96b	94.10b	2568b	11330b	4.77b	22.56c	40.21b	1034a
N_5: 200 kg/ha	139.5a	17.32a	108.60 a	2832a	12840a	5.3a	22.07c	38.64c	1095a
Plant Density									
D_1: 80 plants/m^2	102.7c	14.90a	86.70a	2218a	9154a	4.24a	24.67a	41.36a	912.5a
D_2: 100 plants/m^2	110.8b	14.22b	79.50b	2105b	8668b	3.92b	24.78a	40.73b	853.3b
D_3: 120 plants/m^2	115.2a	13.61c	73.68c	1984c	8136c	3.7c	24.86a	40.08c	790.9c

Values within the same column followed by the same letters are not significantly different according to Duncan's multiple range Test (p=0.05). Plant height: PH; seed/siliqua: S/S; siliqua/plant: S/P; seed yield: S Y; biologic yield: B Y; 1000-seed weight: 1000 S W; harvest index: H I; oil content: O C; oil yield: O Y.

1000-Seed weight:

According to results in Table 1, 1000-seed weight was highly significantly affected (p<0.01) by different plant densities and nitrogen levels. In this regard, Angadi *et al*. [28] contradictorily, revealed that, one thousand seed weight is the stable part of yield and not affected by plant density fluctuations. Data on Table 2 show that the 1000-seed weight increased with increasing in nitrogen application rates and decreased with increasing in plant densities. Thus, the highest and lowest values of 1000-seed weight were obtained from 80 and 120 plants/m^2, respectively. Maximum 1000-seed weight (5.3 g) was recorded at 200 kg N/ha against the minimum (2.47 g) at control. In this regard, similar results were reported by Sharma and Kumar [29]. The interaction effects of nitrogen and plant density had significant effect (p<0.05) on this trait (Table 3). The N_5D_1 interaction recorded significantly higher 1000-seed weight (5.5 g) compared to rest of the interactions. Significantly lower 1000-seed weight of 2.1 g was recorded with N_1D_3 interaction. As compared to other traits, in this experiment, 1000-seed weight changes to the levels of evaluated treatments had fewer fluctuations. Furthermore, no sharp drop is noticed in this trait, while increasing the density at each level of manure application. The optimum density strengthen the optimal use of environmental condition for the crop and it lessen the inter plant competition and results in production of appropriate

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seeds with more weight. Although, the competition between the plants intensified by increasing the plant density, but these plants by allocating more photosynthesis materials to the seed, which may be provided via remobilization of secondary materials (Translocation), prevents severe decrease in seed weight. At higher level of nitrogen application, the plants which were cultivated at high density, had lost their 1000-seed weight because of lodging. Moreover, the excessive numbers of plants, under nutrient' stress condition (no nitrogen application), causes severe inter plant competition and 1000-seed weight decline. These results are supported by Trivedi and Singh [30] and Mehmet [31].

Harvest Index (%):

As regards Harvest Index (Table 1), Recorded data indicated no statistically significant difference in harvest index on the plant densities of 80,100 and 120 plants/m^2 (p>0.05). On the other hand, plant density had no effect on this trait. Harvest index (HI) was relatively stable and was not affected by population densities [32]. Whereas, Genter and Campare [33] and Danesh-Shahraki *et al*. [34] reported that plant density, significantly affected harvest index. HI was highly significantly affected (p<0.01) by nitrogen application rates. The interaction effect between plant density and nitrogen was significant (p<0.05) on this trait (Table1). The N_2D_3 interaction recorded significantly higher harvest index (30.79%) compared to over rest of the interactions. whereas it was on par with N_2D_1, N_2D_2, and N_3D_1 interactions (Table3). In density of D_3 (120 plants/m^2), due to the presence of more number of plants and more number of siliquae per unit area, the seed yield exceeds the biologic yield. On the other hand, application of 50 kg N/ha increases the amount of seed yield to biologic yield and causes the harvest index to increase. The significantly lower interactions for HI was recorded in N_1D_1 (21.16%) as compared to N_2D_1, N_2D_2, N_2D_3, N_3D_1 , N_3D_2 and N_3D_3 interactions (29.84, 30.69, 30.79, 27.99 , 27.39 and 26.04), respectively. However, N_1D_1, N_1D_2, N_1D_3, N_4D_1, N_4D_2, N_4D_3, N_5D_1, N_5D_2 and N_5D_3 interactions were on par. According to the results in Table2 and 3, in terms of decrease in this trait with increase in application of nitrogen fertilizer over 50 kg N/ha (i.e.,100,150 and 200 kg N/ha), it should be noted that when the biologic yield increases more than seed yield, it helps the harvest index to decrease. On the other hand, this was mainly due to more partitioning of dry matter into various plant parts than reproductive organs as a result of higher application of nitrogen fertilizer. These results are in accordance with the finding of earlier workers [27, 21].

Table 3: Means comparison of plant traits of Indian mustard as affected by interaction effect of different plant density and nitrogen levels. (Traits information given under Table 2)

*N×D	PH (cm)	S/S	S/P	SY(kg/ha)	BY(kg/ha)	1000 SW(g)	HI (%)	OC (%)	OY(kg/ha)
N_1D_1	65.20l	11.57i	56.40i	1126h	5322jk	2.8gh	21.16d	41.35c	465.7h
N_1D_2	76.30k	10.70j	50.40j	1035h	4861k	2.5h	21.28d	40.86cd	423.3hi
N_1D_3	83.40j	10.07k	43.50k	952h	4286l	2.1i	22.22d	40.22d	383i
N_2D_1	91.60i	13.57g	74.70g	1938fg	6487h	3.6ef	29.84ab	43.97a	852.7ef
N_2D_2	99.80h	12.90h	66.20h	1879fg	6122hi	3.3f	30.69a	42.87b	805.7fg
N_2D_3	102.5h	12.07i	58.50i	1766g	5761li	2.9g	30.79a	42.39b	749.3g
N_3D_1	106.3j	14.97e	87.40e	2376de	8485f	4.2d	27.99abc	41.38c	983cd
N_3D_2	112.7f	14.37f	78.60f	2237e	8176fg	3.8e	27.39bc	40.93cd	916.7de
N_3D_3	115.6ef	13.60g	75.80fg	2028f	7786g	3.7e	26.04c	40.28d	817.7fg
N_4D_1	118.2e	16.60c	99.40c	2689bc	11990c	5.1b	22.42d	40.93cd	1102ab
N_4D_2	125.3d	15.90d	93.90d	2553cd	11290d	4.7c	22.60d	40.38d	1031bc
N_4D_3	128.2d	15.37de	89e	2461d	10720e	4.5cd	22.93d	39.28e	967.3cd
N_5D_1	132.1c	17.80a	115.6a	2961a	13490a	5.5a	21.92d	39.12e	1159a
N_5D_2	140.1b	17.23ab	108.5b	2822ab	12900b	5.3ab	21.94d	38.59ef	1090ab
N_5D_3	146.2a	16.93bc	101.6c	2712bc	12130c	5.2ab	22.35d	38.21f	1037bc

Values within the same column followed by the same letters are not significantly different according to Duncan's multiple range test (p= 0.05). *N×D: interaction effect

Oil content (%):

Seed oil content was highly significantly (p<0.01) affected by plant densities and different nitrogen rates (Table1). Maximum oil contents (41.36%) were recorded at lower densities (80 plants/m^2), while 120 plants/m^2 produced minimum (40.08%). similar results have been observed by Singh *et al*. [35] while Chauhan *et al*. [5] and Saleem *et al*. [27] obtained contradictory results. The differences in results might be due to differences in environmental conditions under which these experiments were conducted. Mean comparisons of nitrogen rates using Duncan's test (p<0.05) indicated that the highest oil content (43.08%) was obtained using 50 kg N/ha. On the other hand, the lowest oil content (38.64%) was that of N_5 (200 kg N/ha). According to analysis of variance (ANOVA) results, the interaction effect between plant density and nitrogen was significant (p<0.05) (Table 1). N_2D_1 interaction recorded significantly higher oil content of 43.97% compared to over rest of the interactions.

The higher oil content in this interaction was due to the fact that, regarding the oil content, it is necessary to consider the amount of applied manures. The excessive existence of nitrogen in soil, as a nutrient material, generates harmful materials in seed oil and causes its difficult extraction. This fact is highly applicable to nitrogen fertilizer and oily seeds [36]. Presence of N-compounds in seed oil complicates the procedure of oil extraction and increases the amount of undesirable materials like glucosinolates. In comparison to other nitrogen levels, application of 50 kg nitrogen by decreasing the amount of N-compounds increases the seed oil content. The results are in conformity with the findings of Mirzashahi *et al*. [10]. The significantly lower interaction for oil content was recorded in N_5D_3 interaction (38.21%) as compared to rest of the interactions except for N_5D_2, which was at par with this interaction (Table3).

Oil yield:

Finally, based on obtained results in Table 1, Oil yield was also significantly affected by plant densities ($p<0.01$), nitrogen levels ($p<0.01$) as well as interaction thereof ($p<0.05$). In this study, Oil yield followed the similar trend of seed yield (Table 2 and 3). Lesser Density of 80 plants/m^2 recorded significantly higher oil yield by 41.36 per cent (912.5 kg/ha) over higher densities (100 and 120 plants/m^2). The higher oil yield in density of 80 plants/m^2 was mainly due to; higher seed yield (Table 2). These results are in conformity with the findings of Mishra and Rana [37], Rana and Pachauri [14] and Chauhan *et al*. [5]. Furthermore, nitrogen application at the rate of 200 kg N/ha produced the highest oil yield (1095 kg/ ha), but statistically at par with 150 kg N/ha (1034 kg/ha) (Table 2). Among all combination treatments, N_1D_3 interaction has taken, lower oil yield (383 kg/ha) as compared to rest of interactions. The N_1D_2, N_1D_3 interactions were on par with each other (Table 3). The N_5D_1 interaction recorded significantly higher oil yield (1159 kg/ha) over rest of the interactions. However, it was on par with N_4D_1 and N_5D_2. The higher oil yield in N_5D_1 interaction was also attributed to higher seed yield. Thus, applying 200 kg N/ha caused nutritive improvement and increase in seed yield as affected by said treatment combination. Therefore paying special attention to nitrogen application is recommended in places that highly affected by decrease in density [7].

Conclusions:

Based on performed research and analysis of obtained results, the following can be concluded:

Among different plant densities, D_1 influenced the main yield components of Indian mustard and recognized as the best density in this experiment. For treatments fertilized with level N_5, a significant superiority was shown in estimated traits except for oil content and harvest index. N_5D_1 interaction is recommended for achieving maximum qualitative/ quantitative yield of the crop over rest of the interactions. Indian mustard due to having highly acclimation with semi-arid climates and as an early-season crop can easily act as a substitute crop for spring rapeseed cultivars. However, further confirmation of the trends seen in this experiment needs to be obtained before more specific recommendations can be made.

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