Agronomic Study of Fenugreek Grown under Different In-Row Spacing and Nitrogen Levels in a Paddy Field of Iran

1Peiman Zandi, 1Amir Hossein Shirani Rad and 2Leila Bazkar-Khatibani

1Department of Agronomy, Faculty of Agriculture, Islamic Azad University, Takestan Branch, Iran
2Department of Agronomy and Plant Breeding, Mazandaran University, Sari, Iran

Abstract: The objective of this study was to evaluate the effects of different levels of nitrogen and plant density on yield and yield components of Fenugreek. This study was conducted at Guilan region (Iran) in a Paddy field during 2008-2009 cropping season. The experiment was carried out using split plots based on randomized complete block design with 4 replications. Four levels of nitrogen (0, 25, 50 and 75 kg N ha⁻¹) as the main factor and four levels of plant density (60, 80, 100 and 120 plants m⁻²) as sub-plots were investigated. Result indicated that nitrogen fertilizer effect was significant on number of pods per branch, number of pods per plant, seed yield and biological yield. Plant density significantly affected biological yield (p<0.05). The highest seed yield (1468 kg ha⁻¹) was produced by using 75 kg N ha⁻¹. There was positive and significant correlation between seed yield and biological yield. According to mean comparisons of simple effects, the highest biological yield belonged to 75 kg N ha⁻¹ and 120 plants m⁻², respectively.

Key words: Trigonella foenum-graecum L. · Nitrogen fertilizer · Plant density · Yield

INTRODUCTION

Fenugreek (Trigonella foenum-graecum L) is an annual, self pollinating, legume crop, believed to be native to the Mediterranean region but now, is widely cultivated in India and other parts of the World [1]. Fenugreek seed is used in foods as a spice, in artificial flavoring of maple syrup, as a condiment and, in the production of steroid and other hormones for the pharmaceutical industry [2]. Fenugreek is a dryland crop but responds well to minimum application of irrigation [1,3], can be a very useful legume crop for incorporation into short-term rotation [4].

Using nitrogen in fenugreek leads to growth increase, deferred maturation, producing good leaves, developed stem and the plants’ luxuriant dark-green color which indicates a desired growth. Also, plant density on the row and within the rows affects the yield and is controlled by the seed rate [5].

Results from fenugreek cultivation after harvesting rice in Mazandaran province (North of Iran) showed that upon using nitrogen fertilizer in the form of 100 kg ha⁻¹ urea, the highest yield was obtained [6]. Rathore and Manohar [7] found that in a winter crop of fenugreek on loamy sand soils, seed and forage yields were higher with 20 kg N ha⁻¹ and 50 kg P ha⁻¹. Thapa and Maity [8] reported that applying 50 kg N ha⁻¹ could be effective in increasing the yield. Billaud and Adrian [9] suggested using 60 kg N ha⁻¹ and 40 kg K₂O ha⁻¹ for fenugreek cultivation. Duke [10] recommended fenugreek plants be spaced in rows 45 cm apart, 8cm for in-row spacing and 22.5 kg seed ha⁻¹ rate to be broadcast, while Yadav et al. [11] suggested 30 cm spacing, within the rows for sowing. Also, Chaudhary [12] suggested fenugreek to be sown using 25 kg seed ha⁻¹.

Optimal use of rice paddies and double cropping after harvesting rice is of great significance here and winter cultivation of fenugreek, when rice growers especially in the northern provinces of Iran are free from agricultural activities could be an appropriate strategy.

The aim of this research was to investigate the effect of various rates of nitrogen fertilizer as well as effect of planting density on yield and yield components of fenugreek in Paddy fields.
MATERIALS AND METHODS

This study was conducted under rainfed condition after rice harvest in one of the rice paddies at Guilan province (North of Iran) in 1st of November during 2009-2010 cropping season. The site is located at latitude of 37°16’N, longitude of 49°26’E and 11 meters above the sea level, in temperate climate. The soil type was loamy with pH 4.46 and EC 1.05 ds/m.

In this experiment, nitrogen fertilizer (Urea) as the main factor including four rates of pure nitrogen (N$_1$=0, N$_2$=25, N$_3$=50 and N$_4$=75 kg ha$^{-1}$) and plant density as the minor factor at four levels (D$_1$=60, D$_2$=80, D$_3$=100 and D$_4$=120 plants m$^{-2}$) were studied as a split plots based on randomized complete block design (RCBD) with four replications. Each experimental plot comprised 8 lines of 4 m long, with a line spacing of 30 cm.

After tillage, disk, land leveling and implementing the plan on the experimental field, the seeds that were soaked 24 hours prior to sowing, were broadcasted two times at the given density in continuous rows with the distance of 30 cm between rows. Then, with the same density, they were thinned in two stages. Nitrogen fertilizer was used in two splits. The first application (1/3 of the total rate) was made as the starter fertilizer at the time of sowing and the second application (2/3 of the total rate) was made as topdressing, one month after sowing and before the formation of nodules on the roots. Based on soil test results, 100 kg ha$^{-1}$ of triple super phosphate were distributed as a basal dressing for all treatments. With consideration of precipitations in Guilan province, which supply the water requirement of double cropping products, water requirement was also met through rainfall. Hand hoeing was carried out during the growth period. Any symptom of pests and diseases did not observe during the study.

Almost 10 days before maturity, ten random samples were selected from each experimental unit and their yield-related traits (i.e. number of pods per stem, number of pods per branches, number of pods per plant, pod length and number of seeds per pod) were measured. At full maturation stage, in order to estimate seed yield, biological yield and 1000-seed weight, a final harvesting from a 2.5m$^2$ area in the middle of each plot was done in June, 2010. The crop was harvested manually in each plot separately and tied into bundles. The bundles were left in the field for drying until constant weight. The sun-dried bundles were weighed by scale to determine total biomass plot$^{-1}$ (at the given area) and converted into kg ha$^{-1}$.

The bundles were manually thresher to record seed yield (kg ha$^{-1}$). Seeds were additionally dried until 10% of moisture and subsequently yield was determined.

Four samples of 100 seeds were taken from each seed lot of the experimental units and then weighed. Their average multiplied by 10 (seeds ×10) recorded 1000 seed weight (g). Economic yield divided by biological yield multiplied with 100 gave harvest index in percent. Productivity index (PI) was determined from the following relationship given by daneshian [13]:

\[ PI = \frac{\text{Reproductive organs weight}}{\text{biological yield}} \times 100 \]

The data so collected were analyzed statistically with MSTATC software, by using Fisher's analysis of variance technique. Duncan’s Multiple Range Test (DMRT) was applied to compare means of each trait at 5% probability. Correlation coefficients were computed using “SPSS ver. 18.0” for Windows 7 following the methods of Steel and Torrie [14]. The clustering was based on the squared Euclidean distance. And to build dendrogram using Ward's hierarchical clustering method which involves an agglomerative clustering algorithm.

RESULTS AND DISCUSSION

The results in Table 1 revealed that, pod length and number of pods per stem were not significantly affected by difference among applied densities, nitrogen levels and interaction thereof. Since number of seeds per pod is usually more controlled by the plant genotype than by natural factor which is due to the number of ovules being constant, it could be concluded that pod length is influenced by genetic factors and is less affected by environmental conditions.

The effect of nitrogen fertilizer on number of pods per branches, showed a highly significant difference (P<0.01) (Table 1). Application of 25kg N ha$^{-1}$ with 26.32 pods per branches had the highest number of pods, which was statistically at par with 50 and 75 kg N ha$^{-1}$.

The lowest number of pods per branches (18.23) was recorded for the nitrogen application of 0 kg N ha$^{-1}$; therefore, in the Duncan grouping method it was placed in a separate statistical group (Table 2). The effect of plant density and the interaction effect of nitrogen × plant density were not significantly effective in this trait (Table 1).
In this experiment, number of pods per plant was significantly affected by nitrogen fertilizer (p<0.01), whereas plant density and interactions between plant density and nitrogen showed not-significant effects (Table 1). Means comparison of nitrogen rates using Duncan test at the probability level of 5% showed that 25 kg N ha⁻¹ produced the highest number of pods per plant (45.39) and based on the Duncan grouping method it was placed in the first group which was statistically at par with the 50 kg N ha⁻¹. Also, the control treatment (N₅) had the least number of pods per plant (35.17) (Table 2). Generally, this trait is one of the most important components of yield and in cases of affecting any factor, seed yield will be directly affected. It is also quite effective in increasing the number of seeds per plant relative to the number of seeds per pod. By increasing the duration of the vegetative growth and dry matter accumulation, nitrogen fertilizer caused more flowers to be formed in branches through the crop growth rate (CGR) and finally led to more pods in branches. Apparently, assimilate materials produced by the plant during the maturity period (since Anthesis till physiological maturity) compared with those produced in the main stem caused more flowers in branches and eventually more pods to be produced. In the research conducted by Bismillah Khan et al. [15], it was concluded that density did not have any significant effect on the number of pods per plant. Also, Khadem Hamzeh et al. [16] reported that as the density increased, the number of pods per single plant decreased; however, it increased per unit area.

The results in Table 1 indicated that, number of seeds per pod and 1000-seed weight were not significantly affected by different planting density, nitrogen levels and interaction thereof. In their experiment, Ghurbardi and Taberi-Mazendarani [17] concluded that environmental factor was less effective in changing the number of seeds per pod and that it was more influenced genetically.
Moreover, 1000-seed weight is considered as one of the genetic characteristics of a cultivar which is less affected by environmental factors such as light, moisture and temperature [18]. Fenugreek seed yield was affected significantly (P<0.05) by Nitrogen rates (Table 1). Maximum seed yield (1468kg ha$^{-1}$) was obtained from 75 kg N ha$^{-1}$, which was statistically at par with 50 kg N ha$^{-1}$ (1464kg ha$^{-1}$). Nitrogen application at the rate of 0 kg N ha$^{-1}$ produced the lowest seed yield (1301 kg ha$^{-1}$), but statistically at par with 25 kg N ha$^{-1}$ (1332kg ha$^{-1}$) (Table 2). Both 75 kg N ha$^{-1}$ and 50 kg N ha$^{-1}$ were statistically superior to other two nitrogen levels. It may be due to the reason that nitrogen fertilizer aids in seed development in legumes. Venna et al. [19] along with Deteroja et al. [20] found that using organic and inorganic fertilizers such as nitrogenous and phosphorus ones were effective in increasing fenugreek yield. Differences among densities and interaction between densities and nitrogen levels did not affect significantly (p<0.05) seed yield of Fenugreek (Table 1). Usually, plant density is one of the most effective agronomic factors for determining the yield which is in itself affected by cultivar and climatic conditions. Bothe et al. [21] reported that plant density did not have any significant effect on the plant's yield, while Glamočlija et al. [22], Singh et al. [23] and Gowda et al. [24] obtained contradictory results. The differences in results might be due to differences in environmental conditions under which these experiments were conducted.

Furthermore, Nitrogen application had a significant effect on the biological yield (P<0.05) while the interaction effect for nitrogen rate × plant density on the biological yield was not significant (Table 1). Mean comparisons of nitrogen rates using Duncan's test (p<0.05) indicated that the highest biological yield (6336 kg ha$^{-1}$) was obtained using 75 kg N ha$^{-1}$ which was at par with 50 kg N ha$^{-1}$). On the other hand, the lowest biological yield (5567 kg ha$^{-1}$) was that of the control treatment (N₀) and was in turn at par with 25 and 50 kg N ha$^{-1}$; thus, it was placed in the same statistical group as those (Table 2). Effect of N(nitrogen) on yield attributes of Fenugreek has been observed earlier [25, 26]. According to the results in Table 1, a highly significant (P<0.01) effect of plant density on biological yield at the full maturity stage was observed in this study (Table 1). The highest biological yield (6227 kg ha$^{-1}$) was obtained from 120 plants m$^{-2}$. In relation to biological yield, application of 80 plants m$^{-2}$ (5853 kg ha$^{-1}$) 100 plants m$^{-2}$ (6111 kg ha$^{-1}$) and 120 plants m$^{-2}$ were statistically at par with each other. Also, the lowest biological yield (5402 kg ha$^{-1}$) was obtained using 60 plant's m$^{-2}$ (D₀), so it was put in a separate statistical group (Table 2). With regards to the effect of different nitrogen rates and plant density on the agronomic traits and also the development of shoots, Toghaei et al. [27] showed that, increased vegetative growth and developed shoots, were followed by increased biological yield as a result of more nitrogen application. Also, Foraw and Elsheikh [28] in their study found that N-fertilization significantly increased the dry matter production and plant nitrogen content.

Since the highest biological yield was obtained upon using 75 kg N ha$^{-1}$, it seemed that application of higher dosage of nitrogen fertilizer as a nutritional condition was accompanied by the increase of the total dry matter (TDM) in this treatment. Our results indicated that as the density increased from 60 up to120 plant's m$^{-2}$, the biological yield increased as well. Hence, it could be said that as the plant density increased, competition for growth requirement factors [which includes adequate space for growth and development of shoots and roots (planting geometry), sufficient light, nutrients and water requirements] increased and as a result, single plants showed less growth and development. Therefore, due to increase number of plants per unit area despite the reduced growth and development of each plant (reduced total dry weight of a single plant), the biological yield per square meters increased.

As regards harvest index (Table 1), Effect of N (nitrogen), D (plant density) and the interaction effect of N×D was not significant.

Usually, harvest index is a sustainable parameter for a cultivar and its substantial differences result from the environmental conditions during a plant's growth period [29]. Higher seed yields are normally obtained from plants with more dry weights. But in general, the increase of the said yield is more a result of increased harvest index than the biomass increase [30]. In the present study, we found that, due to the growth increase of the plant's superior organs (Shoots), the growth of vegetative organs and reproductive ones were proportional with specified rate, what meant that seed production of fenugreek was a function of vegetative growth.

Finally, based on obtained results in Table 1, Productivity index did not significantly affected by all studied treatments and their interactions. In fact, a ratio of the biological yield which forms the weight of reproductive organs is called productivity index. In other words, Productivity index (PI), indicates the level of photosynthesis materials allocated to reproductive organs. The actual “PI” is calculated by the ratio of pod weight to the maximum plant weight during its growth period [13].
Table 3: Phenotypic correlation coefficients among 10 fenugreek characters grown under rain fed condition.

<table>
<thead>
<tr>
<th>Traits</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Pod length</td>
<td>.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2: Pod stem -1</td>
<td>.190**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3: Pod branches -1</td>
<td>.179**</td>
<td>.492**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4: Pod plant -1</td>
<td>-.174**</td>
<td>.682**</td>
<td>.972**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5: Seed pod -1</td>
<td>.124**</td>
<td>.183**</td>
<td>.156**</td>
<td>.082**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6: 1000 seed weight</td>
<td>.423**</td>
<td>.152**</td>
<td>-.261**</td>
<td>-.178**</td>
<td>.250**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7: Seed yield</td>
<td>-.098**</td>
<td>.071**</td>
<td>.172**</td>
<td>.125**</td>
<td>.453**</td>
<td>.259**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8: Biological yield</td>
<td>.207**</td>
<td>.105**</td>
<td>.506*</td>
<td>.453**</td>
<td>.425**</td>
<td>.134**</td>
<td>.638**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9: Harvest index</td>
<td>-.382**</td>
<td>-.231**</td>
<td>-.367**</td>
<td>-.371**</td>
<td>.043**</td>
<td>.171**</td>
<td>.476**</td>
<td>-.366**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>110: Productivity index</td>
<td>-.070**</td>
<td>.118**</td>
<td>-.047**</td>
<td>-.007**</td>
<td>-.395**</td>
<td>.083**</td>
<td>-.009**</td>
<td>-.547**</td>
<td>.619*</td>
<td>1</td>
</tr>
</tbody>
</table>

* , ** = Significant at 5 and 1% probability, respectively. ns= Non-significant

Fig. 1: Dendrogram of 16 Treatment Combination of Iranian fenugreek using WARD’s method based on agronomic traits measured under rain fed conditions. The cluster diagram revealed two major lineage groups at linkage distance 20. Lineage ‘A’ at linkage distance 15 was further divided into two clusters (I and II). Among the lineage ‘A’, cluster I consists of 5 accessions including four treatment combinations (N1D3, N3D3, N2D4, N1D3, and N4D3). Cluster II consists of seven accessions; N1D3, N3D4, N4D2, N1D3, N4D1, N3D2 and N4D3, while lineage group ‘B’ comprises of only one cluster (III). Cluster II comprises four treatment combinations; N1D3, N3D3, N4D1, and N4D3.

In terms of this trait, it could be said that the growth of vegetative and reproductive organs had a certain ratio, i.e. the level of the allocation of assimilate materials to reproductive and vegetative physiological sinks was to a certain proportion.

Correlations: In order to study and compare correlated relationships between the evaluated traits at different nitrogen levels and plant densities, all correlation coefficients were evaluated (Table 3).

Pod lengths, number of seeds per pod and 1000-seed weight were not significantly correlated with other measured traits. However, there was a positive significant correlation between: (1) Number of pods per stem and the number of pods per plant (r=0.682**), (2) Number of pods per branches with the number of pods per plant (r=0.972**) and the biological yield (r=0.506*), (3) Harvest index and Productivity index (r=0.619*) and also (4) between seed yield and biological yield (r=0.638**).

With consideration of the fact that the biological yield made the greatest contribution to the increase of seed yield and showed a positive significant correlation with the number of pods per branches, it could be concluded that reproductive organs indirectly resulted in
the increase of seed yield. On the other hand, whatever, may be chosen for increasing seed yield, the improvement could be achieved only through biological yield. Hence it may be concluded that biological yield is the main trait which is responsible for manipulation of seed yield in fenugreek.

**Cluster Analysis:** The results of the cluster analysis (Ward's method) based on agronomic characteristics are presented in the Figure 1, the cluster diagram revealed two major groups. Groups A and B. Group A comprised of two clusters one containing 5 accessions and the other containing 7 accessions and group B consist of one cluster of only four accessions N,D,N,D,N,D,N,D.

This dendrogram shows that the accessions in one cluster are mostly identical and have less diversity.

**CONCLUSIONS**

In conclusion, we suggest that, simultaneous Application of pure nitrogen at the rate of 75kg Nha⁻¹ and a density of 120 plants m⁻² (i.e. N₃D₃) for achieving high seed and biologic yield in paddy fields is possible. Since the said treatment combination was quite related to N₃D₃, N₃D₃, N₃D₃ and N₃D₃ in the cluster analysis, applying N₃D₃, due to its less fertilizer and seed consumption would be ideal.

Application of nitrogen fertilizer can significantly improve both seed and biological yield under rain fed condition in temperate climates.

However, further confirmation of the trends seen in this experiment needs to be obtained before more specific recommendations can be made.

**ACKNOWLEDGEMENT**

The author wishes to thank the Islamic Azad University, Takestan Branch, Iran for giving all types of support in publishing this study.

**REFERENCES**


