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Full Length Research Paper

Influence of different levels of nitrogen, phosphorus and potassium on yield and yield components of flax seed oil (*Linum usitatissimum* L.) variety Lirina

Fataneh Parhizkar khajani[1]*, Hamid Irannezhad[1], Majid Majidian[2] and Hussein Oraki[3]

[1]Department of Agronomy and Plant Breeding Science, College of Abouraihan, University of Tehran, Tehran, Iran.
[2]Department of Agronomy and Plant Breeding, Faculty of Agriculture, University of Guilan, Rasht, Iran.
[3]Department of Agronomy, College of Agriculture, Tarbiat Modares University, Tehran, Iran.

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In order to study the effect of different levels of nitrogen, phosphorus and potassium on the quantitative characteristics of oil flax seed oil an experiment was conducted in agricultural research farm Abouraihan Tehran University, at 2009. The experiment was designed as factorial based on randomize complete block (RCB) with three replications. Different levels of nitrogen fertilizer consisted of three levels (N_1=30, N_2=60, N_3=90 kg.ha^{-1}) and three levels of phosphorus fertilizer (P_1=40, P_2=80, P_3=120 kg.ha^{-1}) and three levels of potassium (K_1=40, K_2=80, K_3=120 kg.ha^{-1}), were applied respectively. Traits, branch number, capsules number, number of seeds per capsule, weight of 1000 seed and seed yield was studied in this experiment. The results showed that 90, 120, 80 kg.ha^{-1} of nitrogen, phosphorus and potassium significantly increased the branches number, capsules number and seed yield. Based on the results mean grain yield was obtained (2384.28 kg.ha^{-1}0).

Key words: Nitrogen, phosphorus, potassium, seed yield, flax.

INTRODUCTION

Flax (*Linum usitatissimum* L.) and linseed for seed production have emerged as an alternative crop species that allow increased diversification of cropping systems in temperate environments. However, in many regions dominated by winter wheat (*Triticum aestivum* L. and *Triticum turgidum* sub. durum), the acceptance and production of another crop requires that there is an important agronomic benefit to the cropping system and also that the farmers' economic position will be improved. Linseed is an important source of essential fatty acids for human diets (Millis, 2002) and has several human health benefits (Millis, 2002). Thus, there is growing interest in linseed for food, feed, and industrial products and more attention is now being given to meeting the growing demand for this crop.

Further, the few reports on the effects of phosphorus (P) supply on yield components are conflicting, with some results showing an increase in the numbers of capsules per plant and seeds per capsule (Pande et al., 1970), and other results showing no change (Hamdi et al., 1971) or a decrease in these yield components with increasing P supply (Sinha and Saxena, 1965). There is also evidence which indicates that nitrogen (N) supply influences the response of some yield components of linseed to P (Sinha and Saxena, 1965; Pande et al., 1970).

As an enzyme activator, potassium has been implicated in over 60 enzymatic reactions, which are involved in many processes in the plant such as photosynthesis, respiration, carbohydrate metabolism, translocation and protein synthesis (Dong et al., 2004). Potassium also plays an important role in the maintenance of osmotic potential and water uptake during fiber development, and a shortage will result in poorer fiber quality and lowered yields (Oosterhuis, 2001). Lewis et al. (1991) conducted field experiments on sunflower at seven different sites in South Australia and found that the seed yield responses were significant to phosphorus at two sites and at another two sites, the seed yields were increased by potassium addition. Plant height, leaf area per plant, stalk yield, number of grains

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*Corresponding author: fatanehparhizkar19@yahoo.com.

Table 1. Soil characteristics of experimental site.

Physiochemical properties results	Results
Soil texture	Loam
Sand (%)	36
Silt (%)	39
Clay (%)	25
Saturation percentage	33
Organic matter (%)	1.1
NH_4–N (mg/kg dry soil)	0.11
Available phosphorus (mg/kg of dry soil)	3.1
Potassium (mg/kg of dry soil)	245
Calcium (mg/kg of dry soil)	62.81
Soil pH	7.62
Electrical conductivity (dSm^{-1})	1.8

per head, seed yield, and oil content increased significantly with increase in potassium K levels (Ayub et al., 1999). Increases in P levels had no significant effects on sunflower grain oil concentration, but increased grain yield and N content as compared to the control (Muralidharudu et al., 2003). Higher P levels increased the yield and nitrogen use efficiency (Zubillaga et al., 2002). Sunflower grain yield increased significantly by P application as compared to the control (Sarkar et al., 1995). In order to produce an economically viable crop, producers need to understand how different agronomic practices will affect flaxseed yield.

One of the most important agronomic practices for linseed production is N fertilization as there is positive response to N, but the overall response is less than that seen in crops like wheat, barley or oilseed rape (Grant et al., 1999; Lafond, 1993; Hocking and Pinkerton, 1991; Nuttall and Malhi, 1991; Bailey and Grant, 1989). In linseed, added nitrogen increases seed yield by increasing the number of capsules per plant and capsules per m^2, and the number of seeds per plant (Hocking and Pinkerton, 1991, 1993; Diepenbrock and Porksen, 1992; Bailey and Grant, 1989; Nuttall and Malhi, 1991; Dybing, 1964; Beech and Norman, 1968).

The application of essential plant nutrients in optimum quantity and right proportion is the key to increased and sustained crop production (Cisse and Amar, 2000). Studies on the effects of combined nitrogen, phosphorus and potassium fertilization on oil flax seed yield and yield components are scanty. Keeping in view the importance of combined nitrogen, phosphorus and potassium application to oil flax, therefore, this study was carried out with an objective to find out the best N + P + K combination to increase oil flax grain yield.

MATERIALS AND METHODS

A field experiment on oil flax was performed at agricultural research farm Aboureihan, University of Tehran, at 2009. The experimental design was a factorial design in randomize complete block (RCB) with three replications. Factors in this experiment were, different levels of nitrogen consisted of three levels (N_1=30, N_2=60, N_3=90 kg ha^{-1}) and three levels of phosphorus (P_1=40, P_2=80, P 3=120 kg ha^{-1}) and three levels of potassium (K_1=40, K_2=80, K_3=120 kg ha^{-1}), respectively. The soil used was loam. The soil texture was determined with the hygrometer method (Dewis and Freitas, 1970). The physiochemical characteristics are presented in Table 1. Electrical conductivity, pH and ions of saturation extract were determined according to Jackson (1962). The available phosphorous was determined from saturated paste extract (Olsen and Sommers, 1982). The ammonium was estimated by acid digested material (Bremner and Mulvaney, 1982) and organic matter through sulphuric acid using the Walkley–Black method (Sahrawat, 1982). The plot size was 5 × 2 m, comprising of six rows, 4 m long with 30 cm distance between the rows. All the P and K fertilizers were applied at the time of seedbed preparation. Nitrogen was applied in two equal splits, that is, 50% at sowing and 50% at the time of the vegetative stages. All other agronomic practices including irrigation, weeding and hoeing were carried out uniformly for all the experimental plots. At maturity, the yield components such as branch number, number of capsules per plant, number of seeds per capsule, and weight of 1000 seed were determined by measuring the branch number and number of capsules and seeds from 20 plants per plot. Thousand grain weights were obtained by weighing 1000 grains using an electronic balance. Analysis of variance of the data from each attribute was computed using the SAS statistical software (SAS Institute, 2000). The Duncan's new multiple range test at 5% level of probability was used to test the differences among mean values (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Statistical analysis revealed that different levels of N and P as well as their interaction (N × P) had significant effects on grain yield. The highest grain yield (2290.79 kg ha^{-1}) was obtained with 90 kg N ha^{-1}, whereas the lowest grain yield (979.8 kg ha^{-1}) was obtained when N was 30 kg N ha^{-1} (Table 3). Among the P levels, the highest rate (120 kg P ha^{-1}) had the highest grain yield (1850.99 kg

Table 2. Analysis of variance of various parameters that were measured in this study that were affected by fertilization treatment in oil flax of varieties Lirina.

s.o.v	df	Branch number	Capsule number	Capsule number of seeds	1000 seed weight	Seed yield
Rep	2	0.02^{ns}	14.54^{*}	0.03^{ns}	0.06^{ns}	2938.97^{ns}
Nitrogen	2	29.66^{**}	1027.00^{**}	7.25^{**}	0.02^{ns}	11879052.3^{**}
Phosphorus	2	3.06^{**}	199.53^{**}	1.51^{**}	7.15^{**}	778550.85^{**}
Potassium	2	0.37^{*}	32.10^{**}	0.21^{ns}	0.42^{ns}	115344.27^{**}
N*P	4	0.51^{**}	41.19^{**}	0.26^{*}	0.2^{ns}	46214.34^{**}
N*K	4	0.09^{ns}	2.91^{ns}	0.03^{ns}	0.24^{ns}	$3784 .19^{ns}$
P*K	4	0.06^{ns}	4.40^{ns}	0.05^{ns}	0.24^{ns}	$35264 .34^{**}$
N*P*K	8	0.13^{ns}	7.50^{ns}	0.06^{ns}	0.32^{ns}	1218.14^{ns}
Error	52	0.08	3.62	0.08	0.27	8324.9
CV	----	4.12	10.92	3.92	22.12	5.4

* = $p < 0.05$, ** = $p < 0.01$, NS = non-significant.

Table 3. Effect of fertilization treatments on studied traits.

Treatments (kg.ha^{-1})	Branch number	Capsule number	Capsule number of seeds	1000 seed weight (g)	Seed yield (kg.ha^{-1})
30 N	6.10^{c}	11.85^{c}	8.05^{a}	4.28^{a}	979.8^{c}
60 N	7.43^{b}	16.4^{b}	7.55^{b}	4.34^{a}	1791.79^{b}
90 N	8.16^{a}	24.05^{a}	7.01^{c}	4.33^{a}	2290.79^{a}
40 P	6.85^{b}	14.49^{c}	7.75^{a}	4.93^{b}	1511.82^{c}
80 P	7.34^{a}	17.95^{b}	7.58^{b}	4.13^{b}	1696.57^{b}
120 P	7.49^{a}	19.85^{a}	7.28^{c}	4.90^{a}	1850.99^{a}
40 K	7.09^{b}	16.18^{b}	7.60^{a}	4.28^{a}	1611.47^{b}
80 K	7.28^{a}	17.9^{a}	7.57^{ab}	4.22^{a}	1731.35^{a}
120	7.31^{a}	18.21^{a}	7.43^{a}	4.46^{a}	1716.55^{a}

[†] Means in the same column by the same letter do not differ significantly according to the Duncan test (P = 0.05).

ha−1) and the lowest grain yield (1511.82 kg ha−1) was obtained from 40 kg P ha^{-1} (Table 3). The highest grain yield (1716.55 kg ha^{-1}) was obtained with 120 kg K ha^{-1}, whereas the lowest grain yield (1611.47 kg ha^{-1}) was obtained when K was 40 kg N ha^{-1} (Table 3). Application of N increased grain yield significantly when applied in combination with the higher P levels (120 kg P ha−1) as compared with the lowest P level (40 kg P ha−1) (Table 4). Increases in N and P levels increased grain yield in oil flax significantly as compared with 30 kg N and 40 kg P ha^{-1}. Fertilization of oil flax with higher levels of K and P might increase the uptake and effectiveness of N and other nutrients, which extended growth period (Zubillaga et al., 2002; Muralidharudu et al., 2003), increased branch number, number of capsules per plant and therefore increased grain yield. We found that application of 90:120:120 kg N:P:K ha^{-1} to oil flax produced the highest, branch number and number of capsules per plant as compared with the lowest , branch number and number of capsules per plant obtained from the 30:40:40 kg N:P:K ha^{-1}. These results are also in agreement with those of several researchers (Ayub et al., 1999). In particular, seed weight was affected by phosphorus fertilization. In contrast, other yield components, such as the number of seeds per capsule were not affected by N fertilization (Table 2).

The highest number of seeds per capsule was obtained with 30 kg N ha^{-1} and the highest number of seeds per capsule was obtained when P application was 40 kg N ha^{-1} (Table 3). This can be attributed to the fact that N level can differentially affect the yield and its component, due this fact that N can affect numerous growth processes, including organ development, fertilization, seed formation, and development. The main effect of P stress on yield components was a reduction in the number of capsules per plant (Table 3). The decrease in capsule production by P- and N-stressed plants is due to the combined effects of restricted tillering and reduced production of fruiting branches which bear the capsules.

Branch number, capsule number, seed yield increased significantly with increase in K levels. Nitrogen fertilization affected seed yield and most of the yield components.

Table 4. Effect of nitrogen treatment phosphorus interaction on studied traits.

Treatments	Branch number	Capsule number	Capsule number of seeds	1000 seed weight (g)	Seed yield (kg.ha^{-1})
N1P1	5.42^{c}	8.80^{f}	8.27^{a}	3.58^{b}	734.08^{i}
N1P2	6.27^{f}	13.14^{e}	7.99^{ab}	4.17^{b}	982.72^{h}
N1P3	6.60^{e}	13.61^{e}	7.87^{bc}	4.83^{a}	1213.60^{g}
N2P1	7.20^{d}	15.76^{d}	7.70^{cd}	4.06^{b}	1610.98^{f}
N2P2	7.47^{cd}	16.02^{d}	7.54^{ed}	4.19^{b}	1809 .3^{e}
N2P3	7.61^{c}	17.41^{cd}	7.43^{efd}	4.78^{a}	1955.08^{d}
N3P1	7.93^{b}	18.92^{c}	7.27^{ef}	3.87^{b}	2190.4^{c}
N3P2	8.27^{a}	24.68^{b}	7.22^{f}	4.03^{b}	2297.7^{b}
N3P3	8.29^{a}	28.55^{a}	6.54^{g}	5.09^{a}	2384.28^{a}

[†] Means in the same column by the same letter do not differ significantly according to the Duncan test (P = 0.05).

Nitrogen application was shown to increase seed yield (Lafond et al., 2008; Grant et al., 1999; Lafond, 1993; Diepenbrock and Porksen, 1992; Hocking and Pinkerton, 1991; Nuttall and Malhi, 1991; Bailey and Grant, 1989). In addition, Lafond (1993) reported that limited response of linseed to N application occur when high value of nitrogen observed in soil there is. In most locations, there was an increase in seed yields up to applied 90 kg N and 120 kg P ha^{-1}.

In some locations, there was also a significant decrease in seed yield at low N levels because of lodging (Grant et al., 1999). The effect of N on seed yield may be a consequence of N influence on photosynthesis, on the amount of photo-assimilates that are produced by the plant, on dry matter partitioning, and on organ development (Dordas and Sioulas, 2008, 2009; Dordas et al., 2008). The effect of N on photosynthesis may also affect the yield components (Dordas and Sioulas, 2008, 2009). The seed yield that was obtained in our experiments is much lower than has been reported in other experiments (Lafond et al., 2008; Grant et al., 1999). Although linseed requires less N and other nutrients than many other annual crops, application of N fertilizer is needed to optimize yield components such as capsules per plant and capsules per m^2 (Hocking and Pinkerton, 1991). The most important effect of N fertilization was an increase in the number of capsules per plant, which agrees with findings of other studies (Hocking and Pinkerton, 1991; Dybing, 1964). Other studies (Hocking and Pinkerton, 1991; Beech and Norman, 1968; Dybing, 1964) reported that N deficiency had no significant effect on 1000 seed weight or on the number of seeds per capsule, as was also observed in the present study.

Conclusion

Combined applications of N, K and P had positive impacts on growth, yield components, and grain yield of oil flax. The yield components were affected by N application and especially the branch number per plant and the number of capsules per plant, all of which were increased with Nitrogen, phosphorus and potassium fertilization. A combined application of 90 kg N + 120 kg P ha^{-1} could maximize the productivity of oil flax.

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