The Bioscan 11(2): 1339-1343, 2016 (Supplement on Agronomy)
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.com

EFFECT OF NPK LEVELS AND BIOFERTILIZERS ON QUALITY PARAMETERS AND SEED YIELD OF LINSEED (*LINUM USITATISSIMUM* L.) VARIETIES UNDER IRRIGATED CONDITION

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KEYWORDS
Biofertilizers
Linseed
NPK levels
Oil quality
Yields

Received on :
18.02.2016

Accepted on :
22.05.2016

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ABSTRACT
A field experiment was conducted at Banaras Hindu University, Varanasi with treatment combinations of three NPK levels (50-30-20; 75-45-40 and 100-60-60 kg NPK/ha) in main plots and three levels of biofertilizers [*Azotobacter*, phosphate solubilizing bacteria (PSB) and combination of the both] in sub plots replicated in the thrice under split plot design. Results revealed that growth parameters, yield attributes and seed and stover yields were significantly higher under medium level of fertility (75-45-40 kg NPK/ha) as compared to low and higher level of fertility. The magnitude of increase in seed yield under medium over low and high levels of fertility was 22.4 and 13%, respectively. The maximum oil content (40%) and total NPK removal was observed under 50-30-20 kg and 75-45-40 kg NPK/ha, respectively. The iodine value which indicates the degree of unsaturation was decreased with either of increasing levels of NPK form 50-30-20 to 100-60-60 kg/ha or dual inoculation of seed with *Azotobactor* and PSB. The interaction effect indicated that the maximum seed yield (1318 kg/ha) and net return (38.92×10^3 Rs/ha) were observed from 'Sweta' variety of linseed fertilized by 75-45-40 kg NPK/ha along with dual inoculation of seed with *Azotobacter* and PSB grown under irrigated condition.

INTRODUCTION

Among the different oilseeds crops grown in country, linseed (*Linum usitatissimum* L.) is considered the most important oilseed crop of India and stands next to rapeseed-mustard in winter season (*Rabi*) oilseed crop in area and production. Linseed is an important industrial and edible oil and fiber producing crop. It also being as medicinal plant is rich in oil (41%), protein (20%), dietary fiber (28%), contains 7.7% moisture and 3.3% ashes. It has a high percentage of essential fatty acids, 75% polyunsaturated fatty acids, 57% alphalinolenic acid, which is an omega-3 fatty acid, and 16% linoleic acid, which is an omega-6 fatty acid (Morris, 2005). Essential fatty acids play a role in cell membrane synthesis by making them flexible. They are also precursors for eicosanoids and prostaglandins, a group of metabolites that affect several biological processes such as platelet aggregation, blood clotting and blood vessel contraction (Lee and Lip, 2003). Further, the nutrient requirement of linseed is very high for almost all the essential minerals which are to be supplied in sufficient quantities and balanced proportion to harvest genetic potential of the crop. Most of the Indian soils are deficient in nitrogen and medium in available phosphorus and potassium. Among the different practices to obtain higher crop yield with suitable agro technique under different agro-climatic zone, application of suitable NPK levels, biofertilizers and selection of high yielding varieties are the major applied research thrust. The production potentiality of linseed has tremendous potential to increase productivity per unit area by using high yielding cultivars (El-Nagdy *et al.,* 2010). With increase in price of fertilizers and lack of availability of organic manures give an alternative option to curtain down the fertilizer dose through the application of biofertilzers without reducing the yield of crop. The crop mostly grown under rainfed condition and its seed yield is highly related to fertilization (Berti *et al.*, 2009) and irrigation (Bandyopadhyay *et al*., 2008) while with increase in irrigated area in most parts of the country including eastern Uttar Pradesh it becomes dictatorial to workout response of linseed varieties to nutrients under irrigated condition. The objectives of the work were to study the effect of N, P, K levels and biofertilizers on yield, quality and profitability of linseed varieties.

MATERIALS AND METHODS

The field experiment was laid down during winter season (*Rabi*) of 2012-13 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi is situated at 25°18′ N latitudes, 83°03′ E longitude and at an altitude of 128.93 meters above the mean sea level in the north-eastern plains zone. The soil was sandy loam in texture, neutral in reaction (7.27%), low in organic carbon (0.42%) and available nitrogen (204.7 kg N/ha) and medium in available phosphors (22.5 kg P_2O_5/ha) and available potassium (198.4 kg K_2O/ha). The experiment was laid out in a split plot design with treatment combinations of three NPK levels (50-30-20, 75-45-40 and 100-60-60 kg NPK/ha) and two varieties

(Shubhra and Sweta) in main plots and three levels of biofertilizers [*Azotobacter*, phosphate solubilizing bacteria (PSB) and combination of the both] in sub plots replicated in thrice. Full dose of phosphorus and potassium and half dose of nitrogen as per treatments in the form of di-ammonium phosphate (18% N and 46% P_2O_5), muriate of potash (60% K_2O) and urea (46% N) was applied below the seeds at time of sowing of crop, respectively. Remaining half dose of nitrogen was divided into two equal parts as per treatment and applied as top dressing in the form of urea after one and two months of sowing, respectively. Seed of the linseed varieties were treated with *Azotobacter chroococcum* (HUAZ-1) and PSB [*Bacillus aeruginosa* (BHUPSB-01)] as per treatment and same manually by using a seed rate of 30 kg/ha on the 24th November, 2012 in the fertilized row, at row spacing of 25 cm and plant spacing at 10 cm was maintained by thinning 15 days after germination.

The observations recorded were plant growth parameters, yield attributes, seed yield, oil content, nutrient removal and economics. The oil content in seed was estimated with the help of Soxhlet's apparatus using petroleum ether as extractant (Sankaran, 1966). The iodine value was estimated by method described by Horowitz (1975). Seed and stover samples were dried, processed and analysed for their total N content by micro-Kjeldahl's and P was estimated by Vanadomolybdo-phosphoric acid-yellow colour method. Nutrient removal was estimated by multiplying the content with the oven-dry weight of biological yield. The economics was calculated by considering the market price of linseed and cost of cultivation. The weekly mean maximum and minimum temperature during the experimentation ranged from 16.5° to 37.9°C and 7.2 to 21.7°C, respectively. The total rainfall received during the crop growth was 46.2 mm.

RESULTS AND DISCUSSION

Data on growth parameters exhibited that NPK levels significantly affected plant height, primary and secondary branches, dry matter accumulation/plant (Table 1). The maximum plant height (71.5 cm), primary branches (4.88/plant), secondary branches (23.8/plant), dry matter accumulation (7.85 g/plant) were observed in linseed at medium fertility levels of 75-45-40 kg NPK/ha whereas lower (50-30-20 kg NPK/ha) and high fertility level (100-60-60 kg NPK/ha) being at par with each other recorded diminishing trends in values of the growth parameters. This might be possible because balance application and tissue differentiation, which ultimately increase the plant height and branching in plant. These results were corroborated with the finding of Karwasra *et al*. (2006) and Meena *et al*. (2011). Further, increased supply of phosphorus along with nitrogen and potassium might have improved the energy use efficiency of plants resulting in increased branching and vigorous growth at medium levels of NPK application. Kalita *et al*. (2005) and Saxena *et al*. (2005) also reported similar trend in plant growth of linseed with increasing levels of NPK levels.

The increased foliage, in turn might have accelerated the photosynthetic activity in plants producing more plant food material leading thereby to healthy growth. Thus, maximum dry matter accumulation was associated at the medium fertility level. However, increase in levels of NPK significantly delayed maturity of the crops. This might be due to prolonged vegetative phase of crops under higher supply of nutrients. The application of 75-45-40kg NPK/ ha exhibited more capsules/plant (40.5), seeds/capsules (9.42), and 1000-seed weight (7.47g) as compared to 50-30-20 and 100-60-60 kg NPK/ha. The tissue differentiation caused by nitrogen and phosphorus application resulted into greater production of flowers which later develops into capsules. However, application of 50-30-20 and 75-45-40 kg NPK/ ha remained at par with each other in respect of 1000-seed weight. The findings of the present investigation are similar to those reported earlier and fall in line with the general response elsewhere (Kalita *et al*., 2005; Singh *et al.,* 2013).

The seed and stover yield of linseed significantly increased with incremental in levels of NPK up to 75-45-40 kg/ ha there after it was significantly decreased. The magnitude of increase in seed and stover yield under 75-45-40 kg NPK over 50-30-20 kg NPK/ ha was 22.4 and 18.4 per cent, respectively. Increase in seed yield with increasing NPK levels has also

Table 1: Growth parameters, yield attributes, yield and removal of nutrient by linseed varieties as influenced by NPK levels and biofertilizers

Treatments	Plant height (cm)	Primary branches /plant	Secondary branches /plant	Dry matter acc. (g/plant)	Days to maturity (days)	Capsules / plant	Seeds/ capsule	1000 seeds weight (g)	Seed yield (kg/ ha)	Stover yield (kg/ ha)	Total removal (seed + stover)(kg/ ha) Nitrogen	Phosphorus	Potassium
NPK levels (kg/ ha) (3)													
50-30-20	67.9	4.01	19.2	7.03	108.1	36.9	9.07	7.33	1011	1872	44.4	9.38	22.7
75-45-40	71.5	4.88	23.8	7.85	111.4	40.5	9.42	7.47	1237	2216	55.0	11.51	24.4
100-60-60	69.0	4.18	21.1	7.30	114.3	38.4	9.01	7.16	1095	2077	48.6	10.24	25.3
SEm±	0.87	0.18	0.67	0.12	0.49	0.99	0.12	0.08	38	44	1.58	0.37	0.39
CD (p = 0.05)	2.63	0.58	2.08	0.36	1.43	2.89	0.36	0.24	121	139	4.60	1.07	1.13
Varieties (2)													
Shubhra	68.0	4.07	20.5	7.15	109.1	35.5	9.03	7.24	1041	1944	47.2	9.61	23.2
Sweta	70.9	4.64	22.2	7.50	117.4	40.7	9.40	7.40	1188	2166	52.9	11.14	26.5
SEm±	0.76	0.15	0.58	0.11	0.40	0.68	0.11	0.05	38	43	1.43	0.34	0.36
CD (P = 0.05)	2.34	0.47	1.70	0.33	1.24	2.13	0.34	0.17	118	134	4.50	1.06	1.11
Biofertilizers (3)													
Azotobacter	67.9	4.03	20.0	7.12	112.2	37.4	9.07	7.22	1002	1900	44.1	9.3	22.9
PSB	68.4	4.11	21.2	7.24	113.0	37.7	9.08	7.24	1086	2004	48.0	10.1	24.5
Azotobacter + PSB	72.0	4.92	22.9	7.62	114.6	40.7	9.50	7.51	1254	2261	55.8	11.73	28.0
SEm±	0.65	0.12	0.51	0.09	0.28	0.55	0.08	0.04	33	35	1.17	0.27	0.30
CD (p = 0.05)	1.90	0.35	1.60	0.29	0.88	1.74	0.25	0.13	96	111	3.67	0.87	0.94

Table 2: Oil and protein content and their yield and iodine value of linseed varieties as influenced by NPK levels and biofertilizers

Treatment	Seed protein content (%)	Seed protein yield (kg/ ha)	Oil content (%)	Oil yield (kg/ ha)	Iodine value
NPK levels (kg/ ha)					
50-30-20	18.62	188.2	40.05	403.5	181.2
75-45-40	19.12	236.5	39.88	497.2	175.5
100-60-60	18.82	206.1	39.24	430.8	170.6
SEm ±	0.08	9.7	0.07	20.1	1.28
CD (p=0.05)	0.27	30.0	0.22	60.0	4.21
Varieties					
'Shubhra'	18.61	193.7	39.01	414.5	183.5
'Sweta'	19.10	227.0	40.79	477.6	174.4
SEm ±	0.07	9.1	0.06	18.1	1.18
CD (p=0.05)	0.25	27.0	0.20	56.0	3.52
Biofertilizers					
Azotobacter	18.70	187.4	39.73	398.7	176.6
PSB	18.75	203.6	39.71	432.5	175.2
Azotobacter + PSB	19.12	239.8	40.25	506.4	172.4
SEm ±	0.07	7.0	0.05	16.2	0.87
CD (p=0.05)	0.23	22.0	0.16	49.3	2.70

Table 3: Interaction effect of NPK levels and biofertilizers on seed yield and economics of linseed varieties

Treatment	Seed yield (kg/ ha)	Net return (x10^3 Rs/ ha)	Benefit: cost ratio
$F_1V_1B_1$	1037	26.80	1.40
$F_1V_1B_2$	1049	27.80	1.46
$F_1V_1B_3$	1074	29.22	1.53
$F_1V_2B_1$	1110	30.98	1.62
$F_1V_2B_2$	1167	32.97	1.73
$F_1V_2B_3$	1171	34.78	1.82
$F_2V_1B_1$	1110	29.07	1.40
$F_2V_1B_2$	1120	31.21	1.50
$F_2V_1B_3$	1199	34.21	1.65
$F_2V_2B_1$	1264	35.42	1.71
$F_2V_2B_2$	1252	35.70	1.72
$F_2V_2B_3$	1318	38.92	1.88
$F_3V_1B_1$	1147	28.98	1.28
$F_3V_1B_2$	1143	28.35	1.26
$F_3V_1B_3$	1248	33.40	1.48
$F_3V_2B_1$	1172	30.64	1.36
$F_3V_2B_2$	1172	30.52	1.35
$F_3V_2B_3$	1192	32.23	1.43
SEm ±	20.2	0.52	0.026
CD (p=0.05)	59.7	1.61	0.077
F_1: 50-30-20 (kg N, P, K/ ha)		V_1: 'Shubhra'	B_1: *Azotobacter*
F_2: 75-45-40 (kg N, P, K/ ha)		V_2: 'Sweta'	B_2: PSB
F_3: 100-60-60 (kg N, P, K/ ha)			B_3: *Azotobacter* + PSB

been reported by Dwivedi *et al*. (2000), Banerjee *et al*. (2001) and Kushawaha *et al*. (2006). The reduction in oil content at higher supply on nitrogen appears, due to conversion of more carbohydrates into protein and thus the amount of synthesized carbohydrates, left for conversion into fats are relatively low as compared to other low nitrogen treated plants. Many workers in the past have reported similar results (Patidar and Lal, 1992; Reddaih *et al*., 1993; Singh *et al*., 2010).

Moreover, the higher yield at medium fertility levels might have been due to reduced premature drops of flowers and young capsules. The nitrogen, phosphorus and potassium removal by seed and stover significantly increased with increase in level of fertility up to 75-45-40 kg NPK/ ha and thereafter it was increased except removal of potassium.The seed oil content and oil yield was significantly influenced by different levels of NPK. The maximum oil content was obtained with lowest dose of NPK level while progressive increase in oil yield was obtained with successive increment of NPK up to the medium level but remained at par with the highest fertility level. Seed yield appeared to be directly related with oil yield. Sune *et al*. (2006) also obtained higher oil recovery with increasing levels of NPK application. The reduction in oil yield at high and low levels of NPK can be due to a reduction in the biosynthesis of fatty acids, as a result of lower ATP available for the high energy needs of fatty acid synthesis (Taiz and Zeiger, 2002). The seed protein content and protein yield were significantly influenced by different levels of NPK (Table 2) and the maximum value was observed with 75-45-40 kg NPK/ ha. Meena *et al*. (2011) found increase in seed protein content and protein yield of 'Garima' variety with graded levels of NPKS. The iodine value indicates the degree of unsaturation was significantly decreased with increasing levels NPK form 50-30-20 to 100-60-60 kg/ ha. Singh *et al*. (2013) observed almost similar of the findings in either of 'Garima' or 'Shekhar' variety of linseed.

The varieties showed significant differences for growth parameters and yield attributes (Table 1). On an average, 'Sweta' variety of linseed had superiority in growth parameters *viz*., plant height, primary branches/plant, secondary branches/ plant, dry matter accumulation/plant over 'Shubhra'. The marked variation in growth could be ascribed on account of their genetic capabilities to exploit available resources for their growth and development. Linseed variety 'Sweta' exhibited more number of days to maturity (117.4 days) as compared to 'Shubhra' (109.1 days). The yield attributes like capsules/plant, seeds/capsule, 1000-seed weight were significantly more in 'Sweta' over 'Shubhra' and the magnitude of increase was 14.5, 1.1 and 2.2 per cent, respectively. Therefore, seed and stover yield of 'Sweta' were significantly increased. Similar finding was reported by Dubey *et al*. (2001). In between two varieties, higher N, P and K removal by seed and stover were recorded by 'Sweta'. Variety 'Sweta' exhibited the highest seed protein content and their yield over 'Shubhra'. Further, significantly higher oil content (40.8%) and oil yield (477.6 kg/ha) were found by cultivar 'Sweta' as compared to 'Shubhra'. The iodine value was lower in 'Sweta' (174.4) than 'Shubhra' (183.5).

Seed inoculation with *Azotobacter* and PSB had significant effect on growth parameters (Table 1). The maximum plant height, primary branches/plant, secondary branches/plant and dry matter accumulation were recorded with dual inoculation of *Azotobacter* and PSB was significantly superior over *Azotobacter* and PS in respect of *Azotobacter* and PSB alone. Under dual inoculation treatments, plant synthesized more photosynthates and the storage organs (seed) were better developed. Further, PSB inoculation enhanced the availability of phosphorus and favour better root growth which in turn enables plant to assimilate more atmospheric nitrogen resulting in higher seed and stover yields. Similar results were also observed by Dalal and Nandkar (2010) in pigeon pea. The NPK removal by seed and stover were maximum under dual inoculation of seed with *Azotobacter* + PSB. It was due to higher dry matter accumulation and nitrogenase activity under *Azotobacter* inoculation which beneficially improved bacterial population in rhizosphere which in turn improved N-content in seed and stover and N-removal by seed and stover. Further, due to PSB solubilizing activity of fixed phosphorus in soil, increased the phosphorus availability which in turn resulted in increased build-up of P-content in seed and stover and P-removed by the linseed. The protein content in seed treated with dual inoculation of *Azotobacter* and PSB was 19.12% more whereas it was 18.7 and 18.75% in seed inoculated separately with *Azotobacter* and PSB, respectively.

When all factors were taken together *i.e*. NPK, variety and biofertilizer inoculation, the application of 75-45-40 kg NPK/ ha under dual inoculation of *Azotobacter* + PSB with linseed variety 'Sweta' resulted in the highest grain yield (1318 kg/ ha), net return (38.92×10^3 Rs/ha) and benefit: cost ratio (1.88) closely followed by the application of 50-30-20 kg NPK/ ha along with *Azotobacter* + PSB under same variety (Table 3). Singh *et al*. (2013) also recorded similar trend in linseed under irrigated condition.

Thus, it may be concluded that linseed variety 'Sweta' should be supplemented with 75-45-40 kg NPK/ha and seed inoculated both with *Azotobacter* and phosphate solubilizing bacteria for achieving maximum yield and net return under irrigated condition of eastern Uttar Pradesh.

ACKNOWLEDGEMET

Studentship support, provided by Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi to conduct present research work as part of M.Sc. (Ag.) thesis, is duly acknowledged.

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