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Influence of Fertilizer Levels and Biofertilizers on Growth and Yield of Linseed (*Linum usitatissimum* L.) Under Rainfed Condition of South Gujarat

Bharat Bhanwariya[1], Manohar Ram[2], Narendra Kumawat[2]* and Rakesh Kumar[2]
[1]N.M. College of Agriculture, Navsari Agricultural University, Navsari
[2]Institute of Agricultural Sciences, Banaras Hindu University, Varanasi -221 005

A field experiment consisting of twelve treatments was conducted for two consecutive years (2010-11 and 2011-12) in factorial randomized block design with three replications at Navsari to study the influence of fertilizer levels and biofertilizers on growth and yield of linseed (*Linum usitatissimum* L.) under rainfed condition of south Gujarat. The treatments consisted of three fertilizer levels, *viz.* 100% RDF, 75% RDF and 50% RDF and four biofertilizers *viz.* *Azotobacter*, PSB, *Azotobacter* + PSB and control. Higher values of growth and yield parameters, seed and stover yield were recorded with 100% RDF. Fertilizer level of 100% RDF also recorded significantly higher N and P content in seed and straw and their uptake and oil yield followed by 75% RDF and the lowest under 50% RDF. The results indicated that higher growth, yield attributes and yields, N and P uptake and oil yield were recorded with dual seed inoculation (*Azotobacter*+PSB). Higher values of gross return, net return and B:C ratio were found with the combination of 75% RDF+ *Azotobacter* + PSB (F_1B_3). +

Key words: Linseed, RDF, *Azotobacter,* PSB, seed yield, oil yield and net return.

Linseed (*Linum usitatissimum* L.) is a valuable non-edible oil seed crop which contains 33-45% oil and 24% crude protein and is one of the oldest commercial oilseed plant used for various purposes. In India, it is cultivated in about 0.53 m ha with the production of 0.21 m tones with an average productivity of 403 kg/ha (Anonymous, 2011). Nitrogen and phosphorus are the most important elements as well as expensive input in crop production. An adequate supply of these nutrients is closely associated with growth and development of plant. Nitrogen plays an important role in synthesis of chlorophyll, amino acids and other organic compounds which contribute to the building units of proteins in the plant system. Phosphorus is an important constituent of major biological products in plants itself and plays a key role in the balanced nutrition of the crops. However, the importance of microbial inoculation in soil nutrients cycling and their role in plant nutrition has been realized for a long time. Recently attempts have been made to identify specialized group of soil microorganisms that will allow plant to absorb P from sources that are otherwise less available *viz*. mineral rocks, phosphate rock (Srivastava and Ahlawat, 1995).

Azotobacter has been found promising to improve nitrogen status of soil and crop yield due to their capacity to fix atmospheric nitrogen. In addition, it also secretes growth -promoting substance like gibberellins, IAA etc. Phosphorus solublizing bacteria (PSB) become a source of P to plants upon its release from their cells. PSB reduce the P fertilizer application by 50% without any significant reduction of crop yield (Jilani *et al*., 2007 and Yazdani *et al.,* 2009). It infers that PSB inoculants hold great prospects for sustaining crop production with optimized P fertilization. Among the soil bacterial communities, phosphate solubilization is the result of combined effect of pH decrease and organic acids production (Fankem *et al.,* 2006). The use of PSB enhanced the availability of phosphorus in soil and its uptake by plants (De and Singh, 2010). Keeping the above things in view the present experiment was planned to assess the influence of fertilizer levels and biofertilizers on growth and yield of linseed under rainfed condition of south Gujarat.

Materials and Methods

Field experiments were conducted during *rabi* 2010-11 and 2011-12 at N.M. College of Agriculture, Navsari Agricultural University, Navsari in factorial randomized block design with three replications. The soil was deep black in texture with pH 7.8, organic carbon 0.51%, low in available nitrogen (175.0 kg/ha), high in available phosphorus (30.9 kg P_2O_5/ha) and available potassium (352 kg K_2O/ ha) content. The treatments comprised of three fertility levels *viz.* 100% RDF @ 100 kg N + 50 kg P_2O_5/ha (F_1), 75% RDF @ 75 kg N + 37.5 kg P_2O_5/ha (F_2) and 50% RDF @ 50 kg N + 25 kg P_2O_5/ha (F_3) and biofertilizers *viz.* *Azotobacter* (B_1), PSB (B_2) *Azotobacter* + PSB (B_3) and control (B_4), totalling 12

*Corresponding author email: kumawatandy@gmail.com

treatment combinations.Recommend dose of fertilizer (RDF) was applied as per treatment through DAP and urea as a basal dose. The biometrical observations on crop growth parameters and yield were recorded. The representative samples of seed and stover were utilized for N and P estimation (%). The uptake of N and P at harvest in seed and straw was estimated in kg/ha.

Results and Discussion

Effect of fertilizer levels

Application of 100% RDF recorded the maximum plant height (Table 1). This kind of behavior could be explained on the basis of role of N and P in plant system. Nitrogen being an essential part of nucleic acid and protein which are very important in promoting the growth. Similarly, initial stage phosphorus helped in promoting root growth and better establishment of crop. The greater uptake of nutrients might have increased the photosynthetic and carbohydrate synthesis and then translocation to different parts for promoting meristematic development in potential apical buds and intercalary meristem which ultimately increased root and shoot development in terms of all the growth parameters. Significantly higher number of primary branches/ plant was recorded with 100% RDF. This might be owing to efficient utilization of nutrients which helped in better and vigorous vegetative growth. These results are in conformity with those reported by Meena *et al*. (2011).

Table 1. Growth, yield attributes and yields of linseed as influenced by fertilizer levels and biofertilizers (Pooled data of 2 years)

Treatment	Plant height (cm)	No. of primary branches/ plant	Days to 50% flowering	No. of capsules/ plant	No. of seeds/ capsule	Weight of seeds /plant (g)	Test weight (g)	Seed yield (q/ha)	Stover yield (q/ha)	Harvest index (%)
Chemical fertilizer										
100% RDF	56.94	6.56	54.00	45.69	6.80	1.83	6.50	9.51	16.06	37.14
75% RDF	52.19	6.17	53.00	43.31	6.37	1.79	6.16	8.92	14.97	37.45
50% RDF	49.69	5.97	51.00	40.44	6.18	1.59	5.99	8.38	14.48	36.68
S.Em. ±	1.53	0.16	1.24	1.38	0.18	0.05	0.19	0.12	0.20	0.98
C.D at 5%	4.40	0.45	NS	3.96	NS	0.13	NS	0.35	0.59	NS
Biofertilizers										
Azotobacter	52.00	6.05	52.08	41.92	6.41	1.70	6.03	8.64	14.66	37.10
PSB	53.75	6.22	53.00	43.83	6.50	1.88	6.45	9.21	15.80	36.81
Azotobacter + PSB	56.67	6.68	54.50	46.67	6.78	1.93	6.53	9.64	15.99	37.73
No biofertilizers	49.33	5.98	51.08	40.17	6.10	1.44	5.85	8.26	14.24	36.73
S.Em. ±	1.77	0.18	1.43	1.59	0.21	0.05	0.22	0.14	0.23	1.14
C.D. (P=0.05)	5.08	0.52	NS	4.58	NS	0.15	NS	0.40	0.68	NS

In relation to yield attributes of linseed, fertilizer application at 100% RDF recorded higher no. of capsules/plant and seed weight/plant but no. of capsule and seed weight/plant were statistically at par with 75% RDF. Seed and stover yield (Table 1) of linseed were significantly influenced by various levels of fertilizers. Higher seed and stover yield were recorded with application of 100% RDF followed by 75% RDF. The increase in seed yield might be due to remarkable improvement in the yield attributes *viz.* no. of capsules/plant, no. of seeds/ capsule and seeds weight/plant. Fertilizer application also had profound effect of stover yield which might be due to the higher plant height and number of primary branches/plant. Similar results were also reported by Gokhale *et al*. (2008).

Application of 100% RDF recorded higher N and P content and uptake by seed and stover (Table 2). Higher removal of N and P under 100% RDF might be due to enhancement of all the physiological

Table 2. Nutrient content, nutrient uptake, oil content and oil yield of linseed as influenced by fertilizer levels and biofertilizers (Pooled data of 2 years)

Treatment	N content (%)		N uptake (kg/ha)			P content (%)		P uptake (kg/ha)			Oil content (%)	Oil yield (kg/ha)
	Seed	Stover	Seed	Stover	Total	Seed	Stover	Seed	Stover	Total		
Chemical fertilizer												
100% RDF	2.48	0.81	23.60	13.10	36.70	0.62	0.34	5.91	5.41	11.32	37.11	353.57
75% RDF	2.39	0.77	21.31	11.45	32.76	0.58	0.32	5.17	4.72	9.89	37.18	331.81
50% RDF	2.17	0.71	18.19	10.27	28.46	0.56	0.28	4.67	4.09	8.76	37.28	313.11
S.Em. ±	0.08	0.02	0.89	0.41	0.97	0.01	0.01	0.20	0.18	0.24	0.47	11.08
C.D at 5%	0.22	0.05	2.56	1.18	2.78	0.04	0.03	0.57	0.53	0.69	NS	31.90
Biofertilizers												
Azotobacter	2.30	0.77	19.89	11.25	31.14	0.58	0.31	4.99	4.53	9.53	36.70	317.11
PSB	2.33	0.76	21.70	11.94	33.64	0.59	0.31	5.47	4.91	10.38	37.31	343.99
Azotobacter + PSB	2.50	0.80	24.02	12.79	36.81	0.60	0.33	5.86	5.29	11.16	38.25	368.94
No biofertilizers	2.25	0.73	18.51	10.45	28.96	0.57	0.30	4.68	4.24	8.91	36.49	301.27
S.Em. ±	0.09	0.02	1.03	0.47	1.12	0.02	0.01	0.23	0.21	0.28	0.55	12.80
C.D. (P=0.05)	NS	NS	2.95	1.36	3.21	NS	NS	0.66	0.61	0.80	NS	36.82

processes resulting from adequate supply of fertilizers. Oil yield was significantly influenced by fertilizer application. Higher oil yield was recorded with application of 100% RDF. This might be due to higher productivity in this treatment. Similar result was also reported in linseed by El-Nagdy *et al*. (2010).

Effect of biofertilizers

Among the growth attributes, plant height and no. of primary branches/plant were significantly influenced by biofertilizers. Treatment receiving dual inoculation of *Azotobacter* and PSB recorded higher values of plant height and no. of primary branches/ plant (Table 3). This might be due to the positive effect of dual inoculation to the plants by way of extra N by providing atmospheric nitrogen and rendering the insoluble phosphorus into available form. The enhanced availability of phosphorus favoured nitrogen fixation and rate of photosynthesis and consequently led to better plant height. This result is in agreement with those reported by Hussein (2007).

Table 3. Economics of linseed as influenced by fertilizer levels and biofertilizers (Pooled data of 2 years)

Treatment	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B: C ratio
100% RDF + *Azotobacter*	14710	31955	17244	1.17
100% RDF + PSB	14710	35455	20744	1.41
100% RDF + biofertilizers (PSB + *Azotobacter*)	14785	35595	20809	1.41
100% RDF + control	14635	30135	15499	1.06
75% RDF+ *Azotobacter*	14303	30940	16636	1.16
75% RDF + PSB	14303	32025	17721	1.24
75% RDF + biofertilizers (PSB + *Azotobacter*)	14378	32620	18241	1.27
75% RDF + control	14228	29295	15066	1.06
50% RDF + *Azotobacter*	13895	27825	13929	1.00
50% RDF + PSB	13895	29260	15364	1.11
50% RDF + biofertilizers (PSB+ *Azotobacter*)	13970	29470	15499	1.11
50% RDF + control	13820	27300	13479	0.98

Significantly better yield attribute like no. of capsules/plant and seed weight/plant were observed with dual inoculation of *Azotobacter* and PSB, but remained statistically at par with PSB seed inoculation (Table 1). This could be owing to better growth of plant in terms of dry matter accumulation under dual inoculation and PSB alone plots. Seed and stover yield of linseed were also significantly influenced by biofertilizers. Higher seed yield was recorded with dual inoculation of *Azotobacter* and PSB. Similarly, stover yield also was recorded with dual inoculation of *Azotobacter* and PSB, which remained at par with PSB alone. The increase in seed and stover yield were attributed to improvement in no. of branches/plant and no. of capsules/plant under this treatment.

Table 4. Interaction effect of chemical fertilizer and biofertilizers on seed and stover yield of linseed (Pooled data of 2 years)

Chemical fertilizer / Biofertilizers	Seed yield (kg/ha)				Stover yield (kg/ha)			
	100% RDF	75% RDF	50% RDF	Mean	100% RDF	75% RDF	50% RDF	Mean
Azotobacter	9.27	8.53	8.11	8.64	15.57	14.30	14.11	14.66
PSB	9.80	9.14	8.70	9.21	16.90	15.61	14.90	15.80
Azotobacter +PSB	10.08	10.05	8.80	9.64	16.94	16.03	15.00	15.99
No biofertilizers	8.90	7.95	7.92	8.26	14.84	13.95	13.92	14.24
Mean	9.51	8.92	8.38	8.94	16.06	14.97	14.48	15.17
	S.Em±	C.D. (P=0.05)			S.Em±	C.D. (P=0.05)		
	0.14	0.40			0.23	0.68		

Nitrogen and phosphorus uptake by seed and stover were significantly influenced by biofertilizer treatments, while nitrogen and phosphorus content in seed and stover was found to be non-significant due to biofertilizers treatments (Table 2). Significantly higher nitrogen and phosphorus uptake by seed and stover were recorded with dual inoculation of *Azotobacter* + PSB followed by PSB alone but both were statistically at par with each other. Nutrient uptake by plant play key role for yield and nutrient content in seed and stover. Treatment receiving dual inoculation (*Azotobacter* + PSB) and PSB alone recorded higher oil yield in linseed and found significantly superior to *Azotobacter* alone and no inoculation. The higher oil yield with these treatments is attributed to higher values of oil content and seed yield.

Regarding economics, combined application of 100% RDF + biofertilizers (*Azotobacter* + PSB) recorded highest values of gross return (Rs. 35595/ ha), net return (Rs. 20809/ha) and B:C ratio (1.41) followed by 100% RDF + PSB and were on par. This could be attributed to higher grain yield with low cost input. Similar findings were also reported by El-Nagdy *et al*. (2010) and Meena *et al*. (2011).

Interaction effect

Interaction effects of chemical fertilizers with biofertilizers on seed and stover yield of linseed were significant (Table 4). It was evident from the data that application of 100% RDF combined with biofertlizers (*Azotobacter* + PSB) significantly increased seed and stover yield and it was at par with 75% RDF + biofertilizers (*Azotobacter* + PSB). In terms of percentage the seed and stover yield increased by 27.27 and 21.69% over 50% RDF with no seed inoculation. Combined application of fertilizers and biofertilizers improve the nutrient content in soil and so better utilized by crop (El-Nagdy *et al*., 2010).

Conclusion

Application of 100% RDF and seed inoculation with *Azotobacter* + PSB can be used to achieve higher yield and maximum profitability under rainfed condition of south Gujarat.

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