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Production Potential of Linseed *(Linum usitatissimum* L.*)* Under Different Crop Sequences and Nitrogen Application in Rainfed Conditions

Munish Kumar
Dept. of Soil Conservation & Water Management, C.S. Azad University of Agriculture & Technology, Kanpur-208002, India
e-mail: munish.csa@gmail.com

Ram Tirth
Department of Soil Conservation & Water Management, C.S. Azad University of Agriculture & Technology, Kanpur-208002, India

S.K.Uttam
Department of Soil Conservation & Water Management, C.S. Azad University of Agriculture & Technology, Kanpur-208002, India

Kaushal Kumar
Department of Soil Conservation & Water Management, C.S. Azad University of Agriculture & Technology, Kanpur-208002, India

G.S.Parihar
Department of Soil Conservation & Water Management, C.S. Azad University of Agriculture & Technology, Kanpur-208002, India

Abstract: **An experiment was conducted during 2006-07 and 2007-08 at C.S. Azad University of Agriculture and Technology, Kanpur to evaluate the response of rainfed linseed (*Linum usitatissimum* L.) to nitrogen levels in different double crop sequences. Linseed was grown in sequence with cowpea, blackgram, greengram, sorghum (fodder) and maize along with fallow and supplied with 20, 40, 60 and 80 kg N ha^{-1}. The results revealed that the yield of linseed grown after greengram showed significantly the highest seed yield (10.46 q ha^{-1}) as compared to other treatments on pooled basis. Moreover, the primary (9.7) and secondary (25.9) roots plant^{-1}, moisture use efficiency (7.6 kg seed ha^{-1}mm^{-1} water), net return (Rs 20273 ha^{-1}) and benefit: cost ratio (3.08) were also found to be the highest. Application of 80 kg N ha^{-1}, the total moisture use, moisture use efficiency, seed yield, net return and benefit: cost ratio (BCR) were higher.**

Keywords: **Crop Sequence, Linseed, Nitrogen, Moisture Use Efficiency, Yield.**

1. Introduction

Linseed (*Linum usitatissimum* L.) is an important oilseed crop next to mustard, grown mostly under rainfed situation in the country. In India, linseed is grown in an area of 5.26 lakh ha with annual production of 167 thousand tones, having the productivity of only 382 kg ha^{-1} (Rao, 2008). It is generally grown in mono-cropping system either in pure or mixed stands, but the result of researches has shown that double cropping of linseed with short duration *kharif* crop is always better than mono-cropping in respect of both production and economic returns. Suitability of preceding *kharif* crops differs under varied situations, linseed is seldomly fertilized, while it responds well to fertilizers particularly nitrogen even in rainfed condition. The linseed productivity suffers due to poor inputs and moisture management. The yield of linseed can be increased by more than 100% over the prevailing management practices under rainfed condition with fertilizer, weed control as well as plant protection. The reasons for low yield of linseed in dryland conditions are poor soil fertility, inadequate use of fertilizer and traditional crop management practices. In this respect, fertilization is the most important crop management techniques known to affect seed yield (Dordas, 2010; Verma and Singh 1998; Meena *et al.,* 2011). In dryland regions, fertility status mainly nitrogen, soil moisture, plant population, interculture operation like hoeing and weeding are the key factors that decides crop yielding and quality (Singh *et al*., 2000). Hence, the use of optimum nitrogen dose as per preceding *kharif* crop may be helpful in increasing the productivity of linseed crop. Therefore, present investigation is carried out on suitability of *kharif* crops to be grown in sequence with linseed and to work out with the optimum dose of nitrogen for linseed under different crop sequences.

2. Materials and Methods

A field experiment was conducted at Soil Conservation and Water Management Research Farm, C.S. Azad University of Agriculture and Technology, Kanpur during 2006-07 and 2007-08 under rainfed conditions of central part of Uttar Pradesh. The soil of experimental plot was sandy loam having pH 7.8, 0.36 % organic carbon, available nitrogen, phosphorus and potassium was 180.60, 16.70 and 154 kg ha^{-1}, respectively. The annual average rainfall of Kanpur is about 877 mm, the most of which is generally received in July to September months, with occasional showers during winter months. Whether *Kharif* crops received 406.3 and 474.8 mm rains, while linseed received only 45.7 and 4.6 mm rains during 2006-07 and 2007-08, respectively. The experiment was laid out in split plot design replicated three times. The gross and net plot size were 3.6 x 3.0 and 2.6x 2.50 m, respectively. The main plot treatments were comprised six linseed based crop sequences viz., (i) fallow-linseed (ii) cowpea-linseed (iii) blackgram-linseed (iv) greengram-linseed (v) sorghum(fodder)-linseed and (vi) maize-linseed and in sub-plots four levels of nitrogen applied through inorganic fertilizers in linseed *i.e.* (i) 20 (ii) 40 (iii) 60 and (iv) 80 kg ha^{-1}. The promising crop varieties were used *Cv. Pusa Komal* of cowpea, *Cv. Shekhar* of blackgram, *Cv. Samrat* of greengram, *Cv. Bundela* of sorghum, *Cv. Azad Uttam* of maize and *Cv. Padmini* of linseed. Full dose of N as per treatment and uniform dose of 40 kg ha^{-1} each of P_2O_5 and K_2O were applied in linseed crop at sowing as basal placement through DAP, Urea and MOP. Sowing of linseed crop was done on November 10, 2006 and November 26, 2007.

Root studies were made at harvest by selecting three plants at random from each net plot. The roots were freed with a fine jet of water spray so that the delicate rootlets were not broken. Observations were made on root depth and number of roots $plant^{-1}$. Studies on root development and moisture use were made in one replication only.

Moisture Use and Moisture Use Efficiency

The soil moisture was determined gravimetrically using a screw auger at sowing, during crop growth at regular interval and harvest at various soil layers viz., 0-25, 25-50, 50-75 and 75-100 cm soil depth from each plot in one replication. These soil samples were transferred to air-tight moisture boxes and then fresh weight was determined immediately. For complete drying the samples were kept in an oven at 105^0C for 24 hours and reweighed. Moisture percentage was calculated by employing the following formula:

$$Moisture(\%) = \frac{Fresh\ weight\ of\ soil(g) - oven\ dry\ weight\ of\ soil(g)}{oven\ dry\ weight\ of\ soil(g)} \times 100$$

Value of soil moisture percentage was converted into depth of water by the following formula:

$$Water\ depth\ (cm) = \frac{Moisture(\%) \times BD(Mg\ m^{-3}) \times Depthof\ soil\ layer(mm)}{100}$$

Soil moisture data were used to determine the moisture use which was calculated by using following formula:

$$Moistureuse(mm) = [soil\ moisture(mm) at\ the\ time\ of\ sowing - soil\ moisture(mm) at\ the\ time\ of\ crop\ harvest] + effective\ rainfall\ (mm)$$

The moisture use efficiency in terms of seed production per unit of water consumed was estimated for different treatment plots with the equation suggested by Viets (1962).

MUE = Y / E T

Where,

MUE = Moisture use efficiency (kg seed ha^{-1} mm^{-1} water)

Y = Seed yield (kg ha^{-1})

ET = Total evapotranspiration (mm)

The economics of different treatments was calculated by taking in to account the prevailing market price of inputs and outputs. The net profit was calculated by deducting the total cost of cultivation from gross return of each corresponding treatment while benefit: cost ratio is the ratio of gross return to total cost of cultivation.

3. Results and Discussion

Growth and Yield Attributes

All growth and yield attributes except seeds $capsule^{-1}$ were recorded highest under greengram-linseed sequence closely followed by blackgram-linseed sequence. Lowest values of all characters were recorded under sorghum-linseed sequence. However, significance of crop sequence varied in different characters. Numbers of branches $plant^{-1}$ and dry weight $plant^{-1}$ were recorded significantly maximum in greengram-linseed sequence while in case of other characters, blackgram-linseed sequence also remained at par. Number of seeds $capsule^{-1}$ was found maximum in cowpea-linseed sequence but blackgram-linseed sequence also produced seeds $capsule^{-1}$ at par with cowpea-linseed sequence. Plant height was measured significantly, lower in sorghum-linseed and maize-linseed sequences, but all other sequences being at par produced significantly taller plants (Table 1). In general, growth and yield attributes of linseed attained higher values when grown in sequence with pulses or fallow as compared to cereals-linseed sequences. Better performance of linseed in pulses sequence might be due to improvement in soil properties which benefited succeeding linseed crop on respect to utilization of nutrients and soil moisture. Saha *et al.* (1999) also reported that linseed produced significantly more number of branches $plant^{-1}$, number of capsules $plant^{-1}$ and 1000-seed weight when grown after blackgram.

Growth and yield attributes increased with increasing levels of nitrogen up to 80 kg ha^{-1} but margin of increase beyond 60 kg ha^{-1} was not found significant in any case. It might be due to increase in photosynthesis rate and metabolic activities which resulted in more accumulation and translocation of assimilate from source to sink. Karwasra *et al.* (2006) found that seeds $capsules^{-1}$, test weight and seed yield responded significantly up to 60 kg N ha^{-1}, while capsules $plant^{-1}$ showed significant increase up to 90 kg N ha^{-1}. According to Dubey (2001) nitrogen application influences significantly the capsules $plant^{-1}$ and seeds $capsule^{-1}$ up to 50 kg ha^{-1} under rainfed condition.

Linseed Yields

Seed and stover yields of linseed were produced significantly highest in greengram-linseed sequence. It was followed by the yield under blackgram- linseed, cowpea-linseed and fallow-linseed sequences. The sequence of sorghum-linseed and maize-linseed produced significantly lower yield of linseed than all other sequences. On pooled basis, the seed yield of linseed accrued in greengram-linseed sequence was 5.3, 8.7, 13.20 35.5, and 42.9 % higher than the seed yield in blackgram-linseed, cowpea-linseed and fallow-linseed sequences, respectively. In general, linseed yield was much higher in sequences with pulses or fallow than with cereals attributed to growth and yield attributes which also behaved in similar manner. Higher linseed yield grown after pulses than cereals have also been reported by Saha *et al.* (1999) and Chaubey *et al.* (2004).

The increasing rates of N application increased seed and stover yields of linseed significantly up to 60 and 80 kg ha^{-1}, respectively. Increases in seed yield are attributed to yield attributes particularly seed weight plant^{-1}, while the stover yield was attributed to growth characters particularly branches plant^{-1}. The proper supply of nitrogen may increase the assimilation rate and the translocation of assimilates from source to sink, their yield attributes and seed yield with increase in N application up to an optimum level. Seed yield increased significantly up to application of 60:30:30:30 NPKS kg ha^{-1} in linseed crop (Meena *et al.,* 2011).

Seed and stover yields of linseed were also influenced significantly by interaction effect of crop sequences and N levels (Table 3). Seed and stover yields of linseed responded significantly up to 40 kg N ha^{-1} when grown in sequences with pulses, but in other sequences with cereals or fallow, yield response was found significant up to 60 kg N ha^{-1}. These effects are attributed mainly due to seed weight plant^{-1} which also responded to nitrogen in similar manner. The reason may be explained that preceding pulse crops left more nitrogen in soil than cereals, which was utilized by succeeding linseed crop, thus N requirement reduced. Verma (1999) reported that toria grown after different *kharif* crops and supplied with 0, 45 and 90 kg N ha^{-1} and found yield response of toria was significant up to 90 kg N ha^{-1} when grown after blackgram, while response was significant only up to 45 kg N ha^{-1} when grown after fallow, greengram, cowpea, green manure or maize.

Root Development

Linseed in sequence after sorghum produced maximum root depth followed by maize but number of primary and secondary roots plant^{-1} were maximum in greengram-linseed sequence (Table 4). Root development increased with increasing levels of N up to 80 kg ha^{-1}. It might be due to better establishment of crop plants in earlier stage at increased level of N. The higher amount of N increases the water demand of plants, thus in search of water, root development in soil was more at higher application of N level. Shukla *et al*. (1996) observed that the N application of 80 kg ha^{-1} increased the root development over lower N doses.

Moisture Use (MU) and Moisture Use Efficiency (MUE)

MU in linseed was recorded maximum when grown after cowpea followed by after greengram, while minimum when grown after sorghum (Table 4). It may be associated with the availability of soil moisture and rooting pattern of crop. At the time of linseed sowing, initial soil moisture was maximum in the plots vacated by cowpea followed by greengram. Thus, linseed crop availed this moisture and increased WU than other crops. On the other hand, in the plots vacated by sorghum, initial moisture was minimum and root development of linseed was also minimum after sorghum. MUE of linseed was calculated highest when grown after greengram followed by blackgram. It was attributed to maximum seed yield of linseed after greengram and normal MU which indicates about efficient use of moisture by linseed grown after greengram. Dutta *et al.* (1995) observed that consumptive use of water increased with increasing levels of N up to 80 kg ha^{-1} where, maximum of 207.91 mm water was consumed by linseed crop. Moisture use efficiency also increased with increasing N levels, but up to the application of 60 kg ha^{-1} beyond which it decreased at 80 kg ha^{-1}. MU and MUE both increased at higher rates of N application up to 80 kg ha^{-1} level. Increase in MU might be to meet the water requirement of crop plants for their better growth and development by using higher amounts of nutrients from the soil. Increased MUE with increasing rates of N was attributed to increased seed yield which also increased with each increase in N level. Meena *et al.* (2011) noted that the MUE increased with increasing fertility levels and it was maximum with application of 60:30:30:30 NPKS kg ha^{-1} in linseed crop.

Economics

Gross income, net profit and benefit: cost ratio from linseed crop were recorded significantly maximum when grown after greengram and followed by after blackgram, cowpea and fallow (Table 4). These are attributed to higher seed and stover yields under same treatments (Table 2). Gross income was directly associated with seed and stover yields. Higher return from linseed grown after pulses than after cereals or fallow has also been reported by Chaubey *et al.* (2004). The economic parameters of linseed showed significant increase with increasing levels of N up to 60 kg ha^{-1}. These higher values of economic parameters are attributed to seed and stover yields of linseed which also responded to higher N levels. Though, cost of cultivation also increased at increased level of N but increase in income was much higher than the cost involved in N, which not only compensated the cost of N but increased the profit of linseed. Increase in net return and benefit: cost ratio due to increased levels of N has also been reported by Chaubey *et al.* (2004) and Karwasra *et al.* (2006).

4. Conclusions

It is concluded from the study that linseed variety "*Padmini*" grown in sequence with greengram-linseed and fertilized with 60 kg N ha^{-1} were found to be the best practice and achieve maximum root development, MUE, yield, net profit and benefit: cost ratio under rainfed conditions in central Uttar Pradesh.

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Table: 1 Growth and yield attributes of linseed as influenced by crop sequences and nitrogen levels (pooled 2 yrs.)

Treatments	Plant height (cm)	No. of branches plant^{-1}	Dry wt. plant^{-1} (g)	No. of capsules plant^{-1}	No. of seeds capsule^{-1}	Seed wt. plant^{-1} (g)	1000-seed wt. (g)
Crop sequences							
Fallow-linseed	65.78	15.53	7.60	56.42	4.90	2.026	9.03
Cowpea-linseed	65.53	15.32	7.85	55.93	5.04	2.083	8.77
Blackgram-linseed	66.53	16.66	8.06	62.03	4.90	2.226	9.15
Greengram-linseed	67.08	17.47	8.48	63.93	4.86	2.294	9.24
Sorghum(fodder)-linseed	63.64	13.54	6.07	50.79	4.87	1.663	8.37
Maize-linseed	64.19	14.39	6.42	53.66	4.79	1.709	8.33
SEm±	0.52	0.19	0.10	0.67	0.03	0.032	0.06
CD (P=0.05)	1.55	0.56	0.30	1.99	0.08	0.093	0.18
Nitrogen levels (kg ha^{-1})							
20	62.97	12.12	6.19	50.77	4.72	1.639	8.55
40	65.13	15.04	7.38	57.17	4.89	1.997	8.81
60	66.45	16.84	7.94	59.95	4.96	2.159	8.95
80	67.28	17.93	8.15	60.63	5.00	2.206	8.95
SEm±	0.64	0.22	0.12	0.78	0.03	0.036	0.06
CD (P=0.05)	1.81	0.61	0.33	2.19	0.08	0.101	0.17

Table: 2 Seed and stover yields of linseed (q ha^{-1}) as influenced by crop sequences and nitrogen levels

Treatments	Seed yield (q ha^{-1})			Stover yield (q ha^{-1})		
	2006-07	2007-08	Pooled	2006-07	2007-08	Pooled
Crop sequences						
Fallow-linseed	10.02	8.45	9.24	30.27	26.33	28.25
Cowpea-linseed	10.37	8.88	9.62	30.61	27.36	28.98
Blackgram-linseed	10.66	9.20	9.93	31.19	28.33	29.76
Greengram-linseed	11.25	9.68	10.46	33.58	29.38	31.48
Sorghum (fodder)-linseed	7.89	6.76	7.32	24.23	20.39	22.31
Maize-linseed	8.28	7.16	7.72	25.15	21.55	23.35
SEm±	0.23	0.18	0.14	0.60	0.51	0.40
CD (P=0.05)	0.71	0.55	0.42	1.90	1.61	1.17
Nitrogen levels (kg ha^{-1})						
20	8.20	6.35	7.27	24.29	20.50	22.40
40	9.61	8.35	8.98	28.44	25.26	26.85
60	10.40	9.18	9.79	31.21	27.42	29.32
80	10.76	9.54	10.15	32.75	28.98	30.86
SEm±	0.25	0.18	0.16	0.64	0.54	0.42
CD (P=0.05)	0.73	0.54	0.44	1.83	1.55	1.17

Table: 3 Interaction effect of crop sequence and nitrogen on seed and stover yield (q ha^{-1}) of linseed (pooled 2 yrs.)

Crop sequences	N- levels (kg ha^{-1})				Significance
	20	40	60	80	
	Seed yield (q ha^{-1})				
Fallow-linseed	7.85	8.78	9.81	10.50	SEm±
Cowpea-linseed	7.66	9.70	10.64	10.49	N(S) 0.39
Blackgram-linseed	7.94	10.26	10.80	10.71	S(N) 0.34
Greengram-linseed	8.50	11.01	11.12	11.22	CD (P=0.05)
Sorghum (fodder)-linseed	5.63	6.73	8.04	8.89	N(S) 1.09
Maize-linseed	6.05	7.38	8.34	9.10	S(N) 0.98
	Stover yield (q ha^{-1})				
Fallow-linseed	23.74	26.66	29.77	32.83	SEm±
Cowpea-linseed	23.67	28.54	31.38	32.33	N(S) 1.02
Blackgram-linseed	24.72	30.26	31.64	32.42	S(N) 0.91
Greengram-linseed	25.87	32.67	33.52	33.86	CD (P=0.05)
Sorghum (fodder)-linseed	17.51	20.63	24.60	26.50	N(S) 2.87
Maize-linseed	18.86	22.31	24.98	27.24	S(N) 2.63

Table: 4 Root development, moisture use, moisture use efficiency and economics of linseed as influenced by crop sequences and nitrogen levels (pooled 2 yrs.)

Treatments	Root depth (cm)	Primary roots plant^{-1}	Secondary roots plant^{-1}	Moisture use (mm)	MUE (kg seed ha^{-1} mm^{-1} water)	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net profit (Rs ha^{-1})	B:C Ratio
Crop sequences									
Fallow-Linseed	28.9	8.4	22.5	137.0	6.8	9765	26533	16768	2.72
Cowpea-Linseed	28.1	8.8	23.4	140.3	6.9	9765	27621	17856	2.83
Blackgram-linseed	28.5	9.2	25.5	134.3	7.4	9765	28491	18726	2.92
Greengram-linseed	27.2	9.7	25.9	138.4	7.6	9765	30038	20273	3.08
Sorghum (fodder) - linseed	31.3	7.4	20.3	128.6	5.7	9765	21034	11269	2.15
Maize-Linseed	30.9	7.9	21.4	131.4	5.9	9765	22164	12399	2.27
SEm±	-	-	-	-	0.1	-	574	409	0.04
CD (P = 0.05)	-	-	-	-	0.3	-	1197	852	0.09
Nitrogen levels (kg ha^{-1})									
20	26.0	6.8	19.0	129.9	5.6	9430	20900	11470	2.22
40	28.7	8.1	22.3	133.2	6.8	9654	25768	16114	2.67
60	30.7	9.5	24.9	136.7	7.2	9877	28099	18222	2.84
80	31.6	9.9	26.4	140.1	7.3	10100	29154	19054	2.89
SEm±	-	-	-	-	0.1	-	655	443	0.06
CD (P=0.05)	-	-	-	-	0.3	-	1297	877	0.13