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Effect of agro-input management practices on yield of linseed (*Linum usitatissimum* L.) under vertisols of Chhattisgarh, India

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Abstract: A field experiment was conducted to study the effect of agro-input management practices on yield of linseed (*Linum usitatissimum* L.) at the Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, (C.G.) during Rabi 2015-16. Different agro input management practices had significant (P=0.05) effect on growth, yield attributes and yield of linseed. However, seed rates did not give significant influence on seed yield. Whereas, application of RDF + FYM placement in rows @ 5 t ha-1 (N3) recorded significantly (P=0.05) higher growth parameters viz. plant height (88.44 cm), primary branches plant-1 (3.83), secondary branches plant-1 (23.39), dry matter accumulation (6.76 g plant-1) and yield attributes viz. capsules plant-1 (30.86), seeds capsule-1 (7.63), seeds plant-1 (235.32), seed yield (2100 kg ha-1) and stover yield (4885 kg ha-1). In case of foliar spray, application of 2 % urea at 15, 40, 65 and 90 DAS (F3) gave significantly higher growth parameters viz. plant height (88.37 cm), primary branches plant-1(3.82), secondary branches plant^{-1} (23.68), dry matter accumulation (6.59 g plant^{-1}) and yield attributes *viz.* capsules plant^{-1}(31.74), seeds capsule^{-1}(7.63), seeds plant^{-1} (241.38), seed yield (2089 kg ha^{-1}) and stover yield (4772 kg ha^{-1}). Interaction among seed rate 30 kg ha^{-1} (S_2) X RDF 60:30:30 N: P: K kg ha^{-1} (N_1) with foliar application of 2 % urea at 15, 40, 65 and 90 DAS (F_3) (S_2 XN_1X F_3) recorded the highest benefit-cost ratio (4.39). Line placement of FYM was better than broadcasting in terms of seed yield; and foliar application of urea was economical than Nitrobenzene.

Keywords: Economics, FYM, linseed, Yield attributes, Yield

INTRODUCTION

Linseed **(***Linumusitatissimum* L.) is highly nutritious, unique (best herbal source of omega-3 fatty acids) and emerging among oilseeds for its technical grade vegetable oil and good quality fibre producing ability. At present, the demand and supply of edible oil is 18.94 and 10.08 million tons, respectively. The gap in demand and supply is about 47 % *i.e*. 8.86 million tons being filled by import of edible oil (Anonymous, 2015). ISOR (2015) has projected the demand for the year 2020 and 2050 is 14.57 and 24.10 kg year^{-1} respectively. Chhattisgarh is one of the important linseed growing state of India, where it is cultivated in about 0.026 million hectare area with a production of 0.011 million tones but its productivity is low in Chhattisgarh (423 kg ha^{-1}) and national (498 kg ha^{-1}) compared to global (877 kg ha^{-1}) productivity (Anonymous, 2015). Chhattisgarh having third highest yield gap between improved technology and farmer's practice in irrigated condition is found after Uttar Pradesh and Himachal Pradesh (Singh *et al*., 2015). The major reason for low productivity of linseed may be due to adoption of primitive sowing method like *Utera* and farmers having poor knowledge with regards to INM and perpetual scarcity of basic agro-inputs like improved seed, fertilizers etc. Among the agro-techniques, judicious application of seed rates, nutrients, particularly the nitrogen, phosphorus and potash play the important role for increasing linseed productivity (Singh *et al*., 2013). There is a need to improve nutrient supply system in terms of integrated nutrient management involving the use of chemical fertilizers in conjunction with foliar application of nutrients to the plants has been successfully used in correction of nutrient deficiency, and quickly counter a mineral unbalance that would inhibit plant metabolism. Nitrobenzene is a combination of nitrogen and plants growth regulators that act as a plant energizer, flowering stimulant and yield booster (Aziz and Miah, 2009). Therefore, it is necessary to quantify the judicious agro input for optimization of linseed **(***L.usitatissimum* L.) productivity with sustainable manner.

MATERIALS AND METHODS

Study area: The field experiment was conducted during Rabi season of 2015-16 at the Instructional *cum* Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (21^{o}4′N latitude, 81^{o}35′ E longitude and

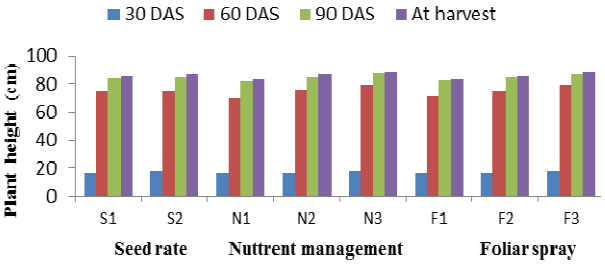

Fig. 1. *Plant height (cm) of linseed as influenced by seed rate, nutrient management and foliar spray.*

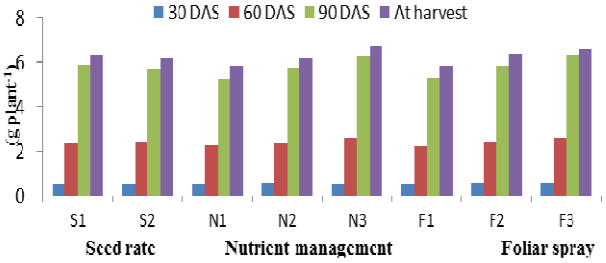

Fig. 2. *Dry matter accumulation (g plant^{-1}) of linseed as influenced by seed rate, nutrient management and foliar spray.*

290.20 meter above mean sea level) under Chhattisgarh plains (Agro climatic zones of India). The soil was clayey in texture having 0.50 % organic carbon, 6.68 pH, 0.18 Electrical Conductivity (EC) and had 226 kg ha^{-1} available N, 12.64 kg ha^{-1}available P and 367 kg ha^{-1} available K. During the investigation, cumulative rainfall 16.1 mm was received, while average minimum and maximum temperature, morning and evening relative humidity, evaporation and sunshine *viz.* 15.5 ^{0}C, 30.4 ^{0}C, 83.4 %, 36.8 %, 3.3 mm and 6.0 hours, respectively.

Treatments detail: The experiment was laid out in factorial randomized block design with three replications and eighteen treatments. The treatment consisted of two seed rate *viz.* 25 kg ha^{-1} (S_1), 30 kg ha^{-1} (S_2), three nutrient managements *viz.* RDF (Recommended dose of fertilizers) 60:30:30 N, P_2O_5 & K_2O kg ha^{-1} (N_1), RDF + Incorporation of FYM (Farm yard manure) @ 5 t ha^{-1} (N_2), RDF + FYM placement in rows @ 5 t ha^{-1} (N_3) and three foliar spray, water spray at 15, 40, 65 and 90 DAS (F_1), foliar spray of Nitrobenzene @ 0.06 % at 15, 40, 65 and 90 DAS (days after sowing) (F_2) and foliar spray of 2 % urea at 15, 40, 65 and 90 DAS (F_3).

Crop management: Linseed (cv: *RLC-92*) was planted on 22nd November, 2015 and were harvested on 12th March, 2016. All the recommended agronomic management practices were followed except for the treatments.

Statistical analysis: Standard procedure was adopted for recording the data on various growth and yield parameters. Data collected were statistically analyses by the procedure suggested by Gomez and Gomez (1984).

Table 1. Plant height at harvest and yield attributing characters of linseed as influenced by different treatments.

Treatment	Plant height at harvest (cm)	Primary branches (no.)	Secondary branches (no.)	Dry matter at harvest (g plant^{-1})	Capsules plant^{-1} (no.)	Seeds capsule^{-1} (no.)	Seeds plant^{-1} (no.)	Test weight (g)	Seed yield (kg ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Benefit: cost Ratio
Seed rate													
S_1	85.63	3.70	21.96	6.32	28.61	7.46	215.00	7.24	1934	22647	85550	62903	3.79
S_2	86.43	3.63	21.66	6.22	26.80	7.40	198.45	7.18	1971	22947	87236	64288	3.82
SE m±	0.83	0.4	0.22	0.07	0.81	0.07	6.22	0.07	21.11	-	881	881	0.04
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	NS
Nutrient Management													
N_1	83.24	3.52	20.07	5.82	23.30	7.28	169.81	7.09	1794	19997	79325	59328	3.98
N_2	86.41	3.65	21.97	6.24	28.96	7.38	215.04	7.20	1963	23897	86808	62911	3.64
N_3	88.44	3.83	23.29	6.76	30.86	7.63	235.32	7.34	2100	24497	93045	68548	3.81
SE m±	1.01	0.4	0.27	0.09	1.00	0.08	7.62	0.08	25.85	-	1079	1079	0.05
CD (P=0.05)	2.93	0.13	0.79	0.27	2.88	0.25	21.97	NS	74.48	-	3108	3108	0.14
Foliar spray													
F_1	83.63	3.48	19.95	5.83	21.48	7.20	155.12	7.03	1806	21728	79891	58163	3.69
F_2	86.10	3.60	21.81	6.39	29.91	7.46	223.69	7.28	1961	24653	86775	62122	3.53
F_3	88.37	3.82	23.68	6.59	31.74	7.63	241.38	7.32	2089	22012	92514	70502	4.21
SE m±	1.01	0.4	0.27	0.09	1.00	0.08	7.62	0.08	25.85	-	1079	1079	0.05
CD (P=0.05)	2.93	0.13	0.79	0.27	2.88	0.25	21.97	NS	74.48	-	3108	3108	0.14

Table 2. Correlation coefficients of seed yield of linseed crop with respect to growth parameter and yield attributes.

	SY	PH	NPB	NSB	DMAP	NCPP	NSPC	NSPP	TSW
SY	1.000**	0.998**	0.942**	0.982**	0.971**	0.933**	0.950**	0.930**	0.927**
PH		1.000**	0.932**	0.977**	0.958**	0.923**	0.933**	0.921**	0.909**
NPB			1.000**	0.970**	0.936**	0.903**	0.962**	0.898**	0.902**
NSB				1.000**	0.963**	0.962**	0.970**	0.958**	0.944**
DMAP					1.000**	0.953**	0.970**	0.952**	0.974**
NCPP						1.000**	0.952**	0.999**	0.985**
NSPC							1.000**	0.946**	0.971**
NSPP								1.000**	0.983**
TSW									1.000**

Where: SY= Seed yield; PH= Plant height; NPB= No. of Primary branches per plant; NSB= No. of secondary branches per plant; DMAP= Dry matter accumulation per plant; NCPP= No. of capsules per plant; NSPC= No. of seeds per capsules; NSPP= No. of seeds per plant; TSW= Thousand seed weight (g),*, ** *indicates significant at 5 % and 1 % probability level respectively*

RESULTS AND DISCUSSION

Growth, yield attributing characters and yield of linseed: The seed yield, ultimate result of various interacting growth, development and yield contributing character. The data shown in Table 1 and Fig. 1 and Fig. 2 revealed that growth, yield attributing character and yield were significantly (P=0.05) affected due to nutrient management and foliar spray. Between seed rates, no significant difference was observed on growth, and yield of linseed. Among nutrient management, the application of recommended dose of fertilizer (RDF) + FYM placement in rows @ 5 t ha^{-1} (N_3) gave significantly plant height (88.44 cm), primary branches $plant^{-1}$ (3.83), secondary branch $plant^{-1}$ (23.29), dry matter accumulation g $plant^{-1}$ (6.76), capsules $plant^{-1}$ (30.86), seeds $capsule^{-1}$ (7.63), seeds $plant^{-1}$ (235.32), test weight (7.34) and seed yield (2100 kg ha^{-1}). However, plant height at harvest, capsules $plant^{-1}$, seeds $capsule^{-1}$ and seeds $plant^{-1}$ was found at par with the same treatment. The lowest seed yield was recorded with application of RDF (1794kg ha^{-1}). It is possible due to the application of RDF + FYM placement in rows @ 5 t ha^{-1}due to that NPK application along with FYM placement with rows, application of FYM to linseed improving the overall fertility status of the soil, vigorous plant growth might have produced more photosynthetic. Efficient partitioning of accumulated photosynthesis, enhanced yield attributes which ultimately positive reflection in the seed yield. Similar observations were noted by Delesa and Choferie (2015) in linseed (*Linumusitatissimum* L.) crop. The similar result has been reported by Khare *et al.* (1996) and revealed that the increment in yield attributing characters of linseed with the application of major nutrient and secondary nutrient (S). In case of the foliar spray, of nitrobenzene is a combination of nitrogen and plants growth regulators that act as a plant energizer, flowering stimulant and yield booster (Aziz and Miah, 2009). Nitrobenzene produce best result in combination with plants growth regulators, which have capacity to increase to flowering in plants and also prevent flower shedding due to more number of flower, it increase the yield by considerable ratio with better quality. The application of 2 % urea at 15, 40, 65 and 90 DAS (F_3) recorded significantly highest plant height (88.37cm), primary branches $plant^{-1}$ (3.82), secondary branch $plant^{-1}$ (23.68), dry matter accumulation g $plant^{-1}$ (6.59), capsules $plant^{-1}$ (31.74), seeds $capsule^{-1}$ (7.63), seeds $plant^{-1}$ (241.38), test weight (7.32) andseed yield (2089 kg ha^{-1}). Whereas, application of water spray (F_1) gave the lowest seed yield (1806 kg ha^{-1}). However, plant height at harvest, dry matter accumulation at harvest, capsules $plant^{-1}$, seeds $capsule^{-1}$ and seeds $plant^{-1}$ was found at par with the same treatment. Physiological activities like chlorophyll content and total photosynthetic pigments in leaves were significantly (P=0.05) increased with increasing nitrogen level. Foliar nutrient application of urea remarkably improved growth traits of linseed (*Linumusitatissimum* L.) crop and similar results was also obtained by El-Kady *et al*. (2010) in sunflower (*Helianthusannus* L.) crop at Egypt.

Correlation analysis: The correlation coefficients of seed yield with plant height (0.998), number of primary branches $plant^{-1}$ (0.942), number of secondary branches $plant^{-1}$ (0.982), dry matter accumulation $plant^{-1}$ (0.971), capsules $plant^{-1}$ (0.933), seeds $capsule^{-1}$ (0.950), seeds $plant^{-1}$ (0.930) and 1000 seeds weight (0.927) by linseed were significant at 1 % level of significance (Table 2). All these characters, showed positive associations with seed yield. These findings are similar to Mirshekari *et al*. (2012) which was found that the correlation coefficient of seed yield was highly significant and positive correlated with plant height, number of primary branches$plant^{-1}$, capsules $plant^{-1}$, seeds $capsule^{-1}$ and thousand seed weight in linseed (*L. usitatissimum* L.) crop at Iran.

Interaction analysis of seed yield: Interaction effects of seed rates, nutrient managements and foliar spray on seed yield were found significant and data are presented in Table 3. The interaction of application of seed rate 30 kg ha^{-1} (S_2), RDF + FYM placement in rows @ 5 t ha^{-1} (N_3) with foliar application of 2 % urea at 15, 40, 65 and 90 DAS (F_3) recorded significantly (P=0.05) highest seedyield (2344 kg ha^{-1}) than

Table 3. Interaction effect of seed rate, nutrients and foliar spray on seed yield of linseed.

Treatment		Seed yield (kg ha^{-1})			
		Foliar spray			
		F1	F2	F3	Mean
Seed rate X Nutrient management					
S_1 X N_1	25 kg ha^{-1} X RDF (60:30:30 N:P:K kg ha^{-1})	1533	1881	1838	1751
S_1 X N_2	25 kg ha^{-1} X RDF + Incorporation of FYM	1880	1927	2035	1948
S_1 X N_3	25 kg ha^{-1} X RDF + FYM placement in rows	1910	2091	2306	2102
S_2 X N_1	30 kg ha^{-1} X RDF (60:30:30 N:P:K kg ha^{-1})	1858	1731	1923	1837
S_2 X N_2	30 kg ha^{-1} X RDF + Incorporation of FYM	1820	2028	2089	1979
S_2 X N_3	30 kg ha^{-1} X RDF + FYM placement in rows	1836	2107	2344	2096
Mean		1806	1961	2089	
SE m±				63.33	
CD (P=0.05)				182.44	

Table 4. Interaction effect of seed rate, nutrients and foliar spray on benefit: cost ratio of linseed.

Treatment		Benefit: cost ratio			
		Foliar spray			
		F1	F2	F3	Mean
Seed rate X Nutrient management					
S_1 X N_1	25 kg ha^{-1} X RDF (60:30:30 N:P:K kg ha^{-1})	3.62	3.82	4.27	3.91
S_1 X N_2	25 kg ha^{-1} X RDF + Incorporation of FYM	3.66	3.33	3.92	3.64
S_1 X N_3	25 kg ha^{-1} X RDF + FYM placement in rows	3.63	3.53	4.34	3.83
S_2 X N_1	30 kg ha^{-1} X RDF (60:30:30 N:P:K kg ha^{-1})	4.29	3.48	4.39	4.06
S_2 X N_2	30 kg ha^{-1} X RDF + Incorporation of FYM	3.51	3.46	3.97	3.65
S_2 X N_3	30 kg ha^{-1} X RDF + FYM placement in rows	3.45	3.53	4.36	3.78
Mean		3.69	3.53	4.21	
SE m±				0.12	
CD (P=0.05)				0.35	

other treatments. But it was found at par to interaction between applications of seed rate 25 kg ha^{-1} (S_1) X application of RDF + FYM placement in rows @ 5 t ha^{-1} (N_3) X foliar application of 2 % urea at 15, 40, 65 and 90 DAS(F_3) (S_1 XN_3 X F_3). The lowest seedyield (1533 kg ha^{-1}) was noted underapplications of seed rate 25 kg ha^{-1} (S_1) XRDF 60:30:30 N:P:K kg ha^{-1} (N_1) X water spray (F_1) (S_1 X N_1 X F_1).

Economics of linseed: Between seed rates, use of 30 kg ha^{-1} (S_2) had more cost (□ 22947 ha^{-1}) towards linseed production than seed rate of 25 kg ha^{-1} (S_1) (□ 22647 ha^{-1}), this might be due to higher price with higher quantity of seed cost hence, higher cost of cultivation was observed with the application of 30 kg ha^{-1} seed rate. Among nutrient management, RDF + FYM placement in rows @ 5 t ha^{-1} (N_3) incurred more cost (□ 24497 ha^{-1}) towards linseed production followed by RDF + incorporation of FYM @ 5 t ha^{-1} (N_2) (□ 23897 ha^{-1}). It is because of higher cost of FYM and labour imposed on placement in rows. The lower cost on production (□ 19997 ha^{-1}) was recorded with the application of in RDF (N_1) treatment. The treatment RDF + FYM placement in rows (N_3) gave the highest gross return (□ 93045 ha^{-1}), net return (□ 68548 ha^{-1}) but the application of RDF 60:30:30 N: P: K kg ha^{-1} (N_1) incurred low cost of cultivation (□ 19997 ha^{-1}), which have low gross return (□ 79325 ha^{-1}), net return (□ 59328 ha^{-1}) but they gave high benefit-cost ratio (3.98). It is because due to no cost of FYM and labour imposed on it. Among the foliar spray, application of 2 % urea at 15, 40, 65 and 90 DAS (F_3) gave the highest gross return (□ 92514 ha^{-1}), net return (□ 70502 ha^{-1}) and highest benefit-cost ratio (4.21). This was followed by foliar application of 0.06 % Nitrobenzene at 15, 40, 65 and 90 DAS (F_2), gross return (□ 86775 ha^{-1}) and net return (□ 62122 ha^{-1}), but application of water spray (F_1) which had lowest gross return(□ 79891 ha^{-1}) and net return (□ 58163 ha^{-1}) and higher benefit-cost ratio (3.69) compared to foliar spray of nitrobenzene (3.53) due to high cost of nitrobenzene as compared to water spray.

Interaction of B: C Ratio: Interaction effects of seed rate, nutrient managements and foliar applicationon benefit-cost ratio were found significant (P=0.05).The interaction among seed rate 30 kg ha^{-1} (S_2) XRDF 60:30:30 N: P: K kg ha^{-1} (N_1) X application of 2 % urea at 15, 40, 65 and 90 DAS (F_3) recorded significantly highest benefit-cost ratio (4.39) (S_2X N_1X F_3) than other interactions.

Conclusion

Based on the above findings it was concluded that the application of RDF + FYM placement in rows @ 5 t ha^{-1} (N_3) recorded higher value of important growth, yield attributes and seed yield of linseed (2100 kg ha^{-1}). Among different foliar spray, application of 2 % urea at 15, 40, 65 and 90 DAS (F_3) was produced higher value of important growth, yield attributes and seed yield of linseed (2089 kg ha^{-1}) as well as accrued handsome B: C ratio (4.21). Seed yield of linseed was

recorded maximum (2344 kg ha^{-1}) when crop was sown with higher seed rate *i.e*. 30 kg ha^{-1} and applied with RDF + FYM placement in rows combined with foliar application of 2 % urea. In terms of economics the maximum Benefit: Cost ratio (4.39) was obtained with interaction among seed rate 30 kg ha^{-1} (S_2) X RDF 60:30:30 N: P: K kg ha^{-1} (N_1) X application of 2 % urea at 15, 40, 65 and 90 DAS (F_3) gave significantly highest benefit-cost ratio than others (S_2 X N_1 X F_3). Line placement of FYM was better than broadcasting in term of seed yield; and foliar application of urea was better than Nitrobenzene in terms of seed yield and net profit.

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