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Effect of integrated nutrient management on growth and yield of irrigated linseed (*Linum usitatissimum* L.)

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Abstract
A field experiment was conducted during *rabi* season of 2020-21 at Experimental Farm, Oilseeds Research Station, Latur to determine the effect of integrated nutrient management (INM) on growth and yield of linseed on vertisols soil order. The experiment was laid out Randomized Block Design with seven treatments, replicated thrice. The result of the study revealed that significantly higher growth attributes *viz*. plant height, no. of branches per plant, total dry matter per plant at 30, 45, 60, 75, 90 DAS and at harvest, plant spread at 45, 60, 75, 90 DAS and at harvest, and mean days required for 50 per cent flowering and yield attributes like no. of capsules per plant (85.96), weight of capsule per plant (5.48g), no. of seed per capsules (9.25), weight of seed per plant (3.68g), test weight (9.24g), seed yield (1757 kg ha^{-1}), straw yield (2690 kg ha^{-1}), biological yield (4447 kg/ha) and harvest index (39.50%) was observed with the application of RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} (T_6).

Keywords: Linseed, vertisols, INM, FYM, vermicompost

Introduction
Linseed (*Linum usitatissimum* L.) is an important *rabi* oilseed crop belongs to the family Linaceae (Burako, 2010; Bremer *et al*., 2009) [3, 2]. The area under cultivation of linseed crop is increasing recently but no work in agronomic aspect of linseed has been done. The national average productivity of linseed is very low as compared to that of world average. Low productivity of the linseed may be ascribed to many reasons, but inadequate and imbalanced nutrition are the major factor. To enhance the productivity of the linseed, use of balanced nutrition by the application of chemical fertilizer, along with organic manure is of great importance. Integration of inorganic fertilizer with organic manure will not only help to sustain the crop productivity but also effective for keeping good soil health and hastening the nutrient use efficiency (Verma *et al*. 2005) [23].
The oil is high in linolenic acid (>66%) and is excellent dying oil. As a consequence, it is used to produce paints, oil cloth, varnish, pad-ink, printed ink and linoleum, among other things. Linseed oil is high in omega-3 fatty acids (58%), especially alpha-linoleic acid, which has been shown to reduce the risk of heart disease, inflammatory disease, arthritis and a number of other health problems. It also includes lignins, a kind of chemical that helps prevent cancer. (Hasler, 2001; Vaisey Genser and Morris, 2003; Singh *et al*., 2018; Matheson, 1976) [11, 22, 20].
In recent years, chemical fertilizers have played a significant role in providing nutrients for intensive crop production which resulted into green revolution in country. But increased use of chemical fertilizers in an unbalanced manner has created problem of multiple nutrient deficiencies, diminishing soil fertility and unsustainable crop yields. As integrated nutrient management (INM) is the prescription for soil health, it is viable strategy for advocating judicious and efficient use of chemical fertilizers with matching addition of organic manures (Collins *et al*., 1992) [6].
Keeping these facts in view, the present field experiment was undertaken to find out effect of integrated nutrient management on linseed crop.

Materials and Methods
The field experiment was conducted during *rabi* season of 2020-21 at Experimental Farm, Oilseeds Research Station, Latur to find out effect of integrated nutrient management on linseed. The experiment was comprised of 7 treatments *i.e.* RDN (T_1), RDNP (T_2), RDNPS (T_3), RDNPS + FYM @ 5 t ha^{-1} (T_4), RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1}

(T_5), RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} (T_6) and Control (T_7), in randomized block design with three replication.

The soil of experimental plot was clayey in texture, well drained, moderately alkaline in reaction having pH (7.02) with chemical composition such as low in available nitrogen (231 kg ha^{-1}), very low in available phosphorus (8.57 kg ha^{-1}) and very high in available potassium (580 kg ha^{-1}).

The recommended dose of fertilizer as NPKS was 60:30:00:15 kg ha^{-1}. In experimental field well decomposed FYM and Vermicompost is applied by broadcasting and soil mixed properly according to the particular treatment required. As per treatment 15 kg S ha^{-1} and 20 kg $ZnSO_4$ ha^{-1} were applied as basal dose through bensulf and zinc sulphate monohydrate. All the treatments received a fixed dose of nitrogen and phosphorus through urea and DAP, respectively. Nitrogen applied through DAP was adjusted in the quantity of urea. The half dose of N and full dose of P_2O_5 and sulphur was applied as basal dose. Remaining half dose of N is applied as top dressing at 30 DAS. The crop variety used for sowing was LSL-93. Five irrigations were applied by using sprinkler method during different crop stages of linseed crop.

During the experiment the average temperature ranged between 17.9 – 25.1 ºC. As far as total amount of rainfall is concerned, 9.0 mm rainfalls were recorded during whole growth period. The average relative humidity ranged between 56.02-70.25 per cent.

The harvest index is the ratio of economic yield to the biological yield (Donald and Hamblin, 1976) [8].

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \text{ X } 100$$

The data regarding growth characters, yield attributes and yield were analysed with statistical analysis and significance of treatments were tested with the help of 'F' test (Cochran and Cox 1967) [5].

Results and Discussion

Growth parameter

The data regarding growth characters *viz.* plant height, plant spread, number of branches, total dry matter of crop plant and mean number of days required for 50 per cent flowering depicted in Table 1, and Table 2, respectively. The data regarding growth clearly shows remarkable effect on growth parameters under different combination has shown significant result with application of RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} (T_6).

The data presented in Table 1 shows that the highest plant height of linseed (34.94 cm) was recorded in RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} (T_6), followed by RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} (T_5) and the minimum plant height was recorded in control (T_7) with mean value of 27.20 cm. Similar result reported by Gokhale *et al*., (2008) [9], Malik *et al*., (2008) [15], Singh *et al*., (2013) [19], and Patel *et al.* (2017) [18].

It is evident from Table 1 that the highest number of branches of linseed (8.94) were recorded in RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} (T_6), followed by RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} (T_5) and the minimum number of branches of linseed were recorded in control (T_7) with mean value of 5.07. This may be due to the better establishment of plants under this treatment as compared to other remaining treatments and it might be also due to improvement in nutrient availability particularly those of vermicompost and $ZnSO_4$. These results are in conformity with Malik *et al*., (2008) [15], Khajani *et al*., (2012) [12], Singh *et al*. (2013) [19] and Gupta *et al*., (2017) [10].

The data presented in Table 2 shows that the maximum plant spread of linseed (20.54 cm) was noted with the application of RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} (T_6), followed by RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} (T_5) and the minimum plant spread of linseed crop was recorded in control (T_7) with mean value of 13.75 cm. Application of organic manures along with N.P, and S enhanced crop growth and crop productivity. These results are in conformity with the Kumar *et al*. (2007) [13] and Dohat *et al*. (2015) [7].

As depicted in Table 2 the maximum total dry matter accumulation of linseed (9.45 g) was produced with the application of RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} (T_6), followed by RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} (T_5) and the minimum total dry matter accumulation of linseed was recorded in control (T_7) with mean value of 5.29 g. The increase in dry matter due to application of FYM and vermicompost along with N, P and S could be attributed to enhance plant height, number of branches and photosynthetic accumulation. Similar result were reported by Gokhale *et al*. (2008) [9], Malik *et al*. (2008) [15], Singh *et al*. (2013) [19] and Patel *et al*. (2017) [18].

The data presented in Table 2 shows that the minimum number of days required for 50 per cent flowering (35.33) were recorded with the application of RDNPS in combination with FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} (T_6). Similar results were recorded by Lawania *et al.* (2017) [14] and Bainade *et al.* (2019) [1].

Yield and yield attribute

The data regarding yield and yield attributing character *viz.* no. of capsules per plant, weight of capsule per plant, no. of seed per capsules, weight of seed per plant, test weight, seed yield, straw yield, biological yield and harvest index depicted in Table 3, respectively. As depicted in Table 3 the maximum number of capsules plant^{-1} (85.96), weight of capsules plant^{-1} (5.48 g), number of seed capsules^{-1} (9.25), weight of seed plant^{-1} (3.68) and test weight (8.52 g) were recorded with the application of RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} (T_6), followed by RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} (T_5) and RDNPS + FYM @ 5 t ha^{-1} (T_4). The use of organic manure consequently had more yield attributing characters has also been reported by Malik *et al*. (2008) [15], Singh *et al*. (2013) [19] and Patel *et al*. (2017) [18].

The data presented in Table 3 shows that the highest seed yield (1757 kg ha^{-1}), straw yield (2690 kg ha^{-1}), biological yield (4447 kg ha^{-1}) and harvest index (39.50%) of linseed were recorded with the application of RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} (T_6), followed by (T_5) i.e. RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} and RDNPS + FYM @ 5 t ha^{-1} (T_4). Which ultimately increased the yield due to increase in all the growth and yield attributes. The better partitioning of source to sink might have led to higher yield attributes, which finally resulted in higher seed yield of linseed. The result of present investigation is in line with those of Choudhary *et al.* (2016) [4], Minz *et al*. (2017) [17] and Tiwari *et al*. (2018) [21].

Table 1: Mean plant height (cm) and Number of branches plant^{-1} of linseed as influenced by different treatments at various growth stages of crop

Treatments	Mean plant height (DAS)						Number of branches plant^{-1} (DAS)					
	30	45	60	75	90	At harvest	30	45	60	75	90	At harvest
T_1: RDN	12.86	21.81	25.18	27.06	27.92	27.92	2.40	4.94	5.44	5.68	6.54	6.54
T_2: RDNP	13.35	23.33	25.96	28.04	28.93	28.93	2.52	5.10	5.56	6.02	7.01	7.01
T_3: RDNPS	13.71	24.70	26.26	29.06	29.81	29.81	2.64	5.41	5.83	6.24	7.34	7.34
T_4: RDNPS + FYM @ 5 t ha^{-1}	14.80	25.40	27.46	30.45	31.50	31.50	2.79	5.67	6.50	7.09	7.98	7.98
T_5: RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1}	15.79	26.46	28.74	31.26	32.17	32.17	2.82	5.81	6.67	7.34	8.21	8.21
T_6: RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1}	16.45	27.36	30.08	33.81	34.94	34.94	3.04	6.41	7.06	7.86	8.94	8.94
T_7: Control	11.45	19.27	23.80	25.56	27.20	27.20	2.04	3.98	4.31	4.94	5.07	5.07
SE +	0.50	0.86	0.96	1.05	1.28	1.28	0.11	0.29	0.26	0.31	0.27	0.27
C.D. at 5%	NS	2.40	2.66	2.91	3.55	3.55	NS	0.81	0.73	0.87	0.39	0.39
General Mean	14.06	24.05	26.78	29.22	30.35	30.35	2.61	5.33	5.91	6.45	7.30	7.30

Table 2: Mean total spread (cm) plant^{-1} and mean total dry matter accumulation (g) of linseed as influenced by different treatments at various growth stages of crop.

Treatments	Mean total spread (DAS)					Mean total dry matter accumulation (DAS)						Days after 50% flowering
	45	60	75	90	At harvest	30	45	60	75	90	At harvest	
T_1: RDN	11.84	13.66	14.56	15.28	15.28	0.25	1.19	3.95	5.03	6.30	6.30	38.33
T_2: RDNP	12.62	14.17	15.63	16.69	16.69	0.26	1.48	4.09	5.46	6.72	6.72	38.00
T_3: RDNPS	12.98	14.88	15.93	17.81	17.81	0.28	1.77	4.42	5.95	7.37	7.37	37.33
T_4: RDNPS + FYM @ 5 t ha^{-1}	13.94	15.80	16.90	18.82	18.82	0.49	2.43	5.80	6.78	8.76	8.76	36.66
T_5: RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1}	14.32	16.07	17.34	19.03	19.03	0.53	2.52	5.98	6.93	8.92	8.92	36.00
T_6: RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1}	15.23	17.24	18.45	20.54	20.54	0.58	2.65	6.25	7.35	9.45	9.45	35.33
T_7: Control	10.08	11.38	13.20	13.75	13.75	0.21	1.01	2.93	4.06	5.29	5.29	39.00
SE +	0.48	0.57	0.57	0.68	0.68	0.01	0.09	0.18	0.24	0.28	0.28	1.48
C.D. at 5%	1.34	1.58	1.58	1.89	1.89	NS	0.26	0.51	0.66	0.80	0.80	NS
General Mean	13.00	14.74	16.00	17.41	17.41	0.37	1.86	4.77	5.93	7.54	7.54	37.24

Table 3: Yield and yield attributes of linseed as influenced by different treatments.

Treatments	No. of capsules plant^{-1}	Wt. of capsules plant^{-1} (g)	No. of seeds capsules^{-1}	Wt. of seed plant^{-1} (g)	Test weight (g)	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	HI (%)
T_1: RDN	65.42	4.04	7.09	2.68	8.15	1092	2135	3227	33.83
T_2: RDNP	75.13	4.23	7.15	2.81	8.41	1154	2215	3369	34.25
T_3: RDNPS	77.50	4.87	7.48	2.97	8.64	1202	2265	3467	34.66
T_4: RDNPS + FYM @ 5 t ha^{-1}	79.37	5.19	7.89	3.34	8.92	1304	2345	3649	35.73
T_5: RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1}	83.06	5.37	8.81	3.47	9.07	1668	2630	4298	38.80
T_6: RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1}	85.96	5.48	9.25	3.68	9.24	1757	2690	4447	39.50
T_7: Control	57.52	2.94	6.94	1.96	7.20	988	2087	3075	32.13
SE +	2.94	0.20	0.41	0.14	0.32	54	102	153	1.35
C.D. at 5%	8.15	0.57	NS	0.39	NS	148	284	423	NS
General Mean	74.85	4.59	7.80	2.98	8.52	1310	2338	3647	36.60

Conclusion

From the results of the present investigation summarized above it may be concluded that, integration of RDNPS + FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} (T_6) is utmost beneficial and essential to get highest growth and yield attributing characters, seed yield and productivity of linseed.

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