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Yield and yield attributes of linseed (*Linum usitatissimum*) as influence by sowing methods x varieties and fertilizer levels grown after rice in Alfisols of Chhattisgarh plain

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Abstract
Ph.D research on “Agro-resource management studies on growth, yield, quality and economics of linseed (*Linum usitatissimum* Linn.) grown after rice in Alfisols of Chhattisgarh plains” was conducted during *rabi* seasons of 2009-10 and 2010-11 at Research cum Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur with the specific objectives to study the interaction effect of sowing methods and fertilizer management on growth, yield, nutrient uptake, oil content and economics of linseed varieties. Two different experiments on linseed crop were undertaken during two consecutive *rabi* seasons of 2009-10 and 2010-11. The experiment was sown on 26th November, 2010 and harvested on 24th March, 2011. Based on 2 years experimentation it is concluded that treatment line sowing x RLC-92 (S_1V_1) registered significantly oil content as well as maximum oil yield. Among the fertilizer levels, maximum oil yield was obtained under 50% more RDF (F_2) followed by RDF + S (F_1) during both the years and on mean basis.

Keywords: linseed, capsule, management

Introduction
The genotypes express variation under different environments, particularly with yield and yield attributing characters in linseed. Thus, environment plays an important role in its production. The low yield of linseed is characterized mainly due to lack of high yielding genotypes, further lack of response to better conditions and the instability in yield of linseed due to varying environment are also of great concern. Stability in performance is most desirable character of a genotype to be released as a variety for wide adoption. Information on stability of linseed genotypes prior to their recommendation for cultivation is very necessary.
Linseed is grown after rice on marginal and sub-marginal lands with low or no-fertilizers, mostly under rainfed both as relay cropping “*utera*” in paddy fallow and as upland in unbunded fields. In *utera* cultivation, most of the farmers use broadcasting method of sowing without fertilizer application, resulting in poor soil seed moisture content and seed may not get proper germination with decreases plant growth. So, there is urgent need to find out efficient method of sowing for optimum stand establishment and higher production and productivity of the crop.
Keeping above facts in view and considering the benefits and increased popularity of linseed, Ph.D research entitled “Agro-resource management studies on growth, yield, quality and economics of linseed (*Linum usitatissimum* Linn.) grown after rice in Alfisols of Chhattisgarh plains” was conducted during *rabi* seasons of 2009-10 and 2010-11 at Research cum Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur with the following specific objectives: To study the interaction effect of sowing methods and fertilizer management on growth, yield, nutrient uptake, oil content and economics of linseed varieties.

Materials and Methods
Location and Experimental Site
The location of the experimental site was Research cum Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) located at 21°4' N latitude and 81°39' E

longitude with an altitude of 298 metre above mean sea level having sub tropical humid climate.

Climate Conditions

The climate of Raipur region is sub humid with hot and dry summer and mild winter. It comes under the Chhattisgarh plains agro- climatic sub zone of seventh agro climatic region of India i.e. eastern plateau and hills. The average annual rainfall is about 1320 mm of which about 88 % is received during a span of four months i.e. between June to September. The rainfall is largely contributed by south-west monsoon. The maximum temperature raises up to 45°C during summer and minimum temperature falls to 5-6 °C during winter season. The relative humidity reaches maximum 93 % and minimum 41 % in August and March, respectively.

Treatment Details

Two different experiments on linseed crop were undertaken during two consecutive *rabi* seasons of 2009-10 and 2010-11. The experiment treatments were divided into main plots and sub plots in split plot design with three replications. Treatments comprised of three sowing methods with two varieties viz., broadcast x RLC-92 (S_0V_1), line sowing x RLC-92 (S_1V_1), criss-cross x RLC-92 (S_2V_1), broadcast x Deepika (S_0V_2), line sowing x Deepika (S_1V_2), criss-cross x Deepika (S_2V_2) as main plot treatment and three fertilizer levels viz. RDF (F_0), RDF + S (F_1) and 50% more of RDF (F_2) as sub plot treatment. The experiment was sown on 26th November, 2010 and harvested on 24th March, 2011.

Number of capsules plant^{-1}

Total number of capsules were recorded from five randomly tagged plants and mean was worked out by dividing the total number of capsules by five and used for statistical analysis.

Number of seeds capsule^{-1}

Ten capsules were selected from the bunch of five tagged plants, number of seeds were counted and average was worked out.

1000-seed weight (g)

Same quantity of the harvested grains from each net plot was dried in an oven at 60°C for 20-24 hours to get constant weight. One thousand seeds were taken from produce of each treatment, weigh and expressed as 1000 - seed weight in grams. The seeds were weighed on electronic balance.

Seed yield (q ha^{-1})

At physiological maturity, the crop harvested from each net plot. The harvested crop was air dried, threshing, winnowing and weighed. Seed yield ha^{-1} was computed from yield per plot, which was expressed in q ha^{-1}.

Stalk yield (q ha^{-1})

After harvesting of the crop, sun dried in the field and the produce was tied in to bundles. Stalk yield of plot was noted down after subtraction of seed yield from bundle weight. Then the bundle weight of the stalk (kg plot^{-1}) was taken and stalk yield is expressed in q ha^{-1}.

Biological yield (q ha^{-1})

The harvested produce of each net plot was tied in bundles separately. Stalk yield of plot was noted down after subtraction of seed yield from bundle weight. Bundle weight was recorded with the help of spring balance.

Harvest index (%)

Harvest index is the ratio of economic yield to biological yield of the crop. It was calculates by using following formula:

$$\text{HI (\%)} = \frac{\text{Grain Yield, q ha}^{-1}}{\text{Biological Yield, q ha}^{-1}} \times 100$$

Result and discussion

Yield attributes and yield

Number of seeds capsule^{-1}

The data on number of seeds capsule^{-1} as influenced by sowing methods x varieties and fertilizer levels are given in Table 1. The number of seeds capsule^{-1} was significantly influenced by sowing methods x varieties and fertilizer levels. Number of seeds capsule^{-1} was recorded significantly higher under line sowing x RLC-92 (S_1V_1) as compared to other treatments, but it was at par to line sowing x Deepika (S_1V_2) during both the years and on mean basis.

The number of seeds capsule^{-1} was significantly higher under 50% more RDF (F_2) as compared to RDF (F_0) however, it was found comparable with RDF + S (F_1) during both the years and on mean basis.

Number of capsules plant^{-1}

The data on number of capsules plant^{-1} as influenced by sowing methods x varieties and fertilizer levels are given in Table 1. The number of capsules plant^{-1} was significantly influenced by sowing methods x varieties and fertilizer levels. Significantly higher number of capsules plant^{-1} was observed under line sowing x RLC-92 (S_1V_1) as compared to other treatments, but it was at par to line sowing x Deepika (S_1V_2) during both the years and on mean basis.

In fertilizer levels, significantly higher capsules plant^{-1} was noted under 50% more RDF (F_2) than RDF (F_0) but it was at par to RDF +S (F_1) during both the years and on mean basis.

Number of capsules plant^{-1} of linseed has been varied significantly due to the interaction of methods of sowing x varieties and fertilizer levels Table 4.41. The interaction between line sowing x RLC-92 (S_1V_1) and 50% more RDF (F_2) registered significantly higher number of capsules plant^{-1} as compared to other interactions, but it was at par to interactions between Deepika sown in lines x 50 % more RDF (S_1V_2 x F_2), Deepika sown in lines x RDF + S (S_1V_2 x F_1) and RLC-92 sown in lines x RDF + S (S_1V_1 x F_1) during both the years and on the mean basis.

Significantly higher number of capsules plant^{-1} was noted under line sowing method than broadcasting. It may be due to the fact that more number of branches allowed in bearing more number of capsules plant^{-1}. The formation of more capsules plant^{-1} under regular sowing in line was also reported by Khare *et al.* (1999) [4] and highest number of panicle m^{-2} under drilling as compared to broadcasting method in wheat was also reported by Dhiman *et al.* (1997) [2].

1000-seed weight (g)

The data on 1000-seed weight of linseed as affected by sowing methods x varieties and fertilizer levels are presented in Table 1. The results revealed that significantly higher 1000-seed wei(S_1V_1) as compared to other treatments, but it was at par to line sowing x Deepika (S_1V_2) during both the years and on mean basis.

Among the fertilizer levels, treatment 50 % more RDF (F_2) registered significantly higher 1000-seed weight over RDF

(F_0), but it was at par to RDF + S (F_1) during both the years and on mean basis.

Seed yield (q ha^{-1})

The data on seed yield of linseed as influenced by sowing methods x varieties and fertilizer levels are given in Table 2. The results revealed that among sowing methods x varieties significantly higher seed yield of linseed was observed under line sowing x RLC-92 (S_1V_1) as compared to other treatments, however, it was at par to criss-cross x RLC-92 (S_2V_1) and line sowing x Deepika (S_1V_2) during both the years and on mean basis. Linseed seeded under fertilizer levels showed significant variation in seed yield. The 50% more RDF (F_2) produced significantly higher seed yield (11.53, 11.34 and 11.44 q ha^{-1} in 2009-10, 2010-11 and on mean basis, respectively) than RDF (F_0), but it was comparable to RDF + S (F_1) during both the years and on mean basis.

The seed yield of linseed varied significantly due to the interactions between sowing methods x varieties and fertilizer levels (Table 4.43). The interaction between line sowing x RLC-92 (S_1V_1) and 50% more RDF (F_2) registered significantly higher seed yield as compared to other interactions, but it was at par to interactions between RLC-92 sown in criss-cross x 50 % more RDF (S_2V_1 x F_2), Deepika sown in lines x 50 % more RDF (S_1V_2 x F_2), RLC-92 sown in lines x RDF + S (S_1V_1 x F_1), RLC-92 sown in criss-cross x RDF + S (S_2V_1 x F_1) and Deepika sown in lines x RDF + S (S_1V_2 x F_1) during both the years and on mean basis.

The data on seed yield of linseed reveal that significantly highest seed yield of 11.71 q ha^{-1} on mean basis was noted under line sowing x RLC -92 (S_1V_1) followed by criss-cross x RLC -92 (S_2V_1) and line sowing x Deepika (S_1V_2). Increase in seed yield was also contributed due to corresponding increase in growth parameters viz., plant height, number of branches plant^{-1}, leaf area index and dry matter accumulation and yield components viz. number of seeds capsule^{-1}, number of capsules plant^{-1} and 1000-seed weight. It is well known fact that nitrogen, phosphorus and potassium play a major role in photosynthesis, development of capsules plant^{-1}, 1000-seed weight consequently helping in increased yield. This observation is in close conformity with the findings of Sharma and Thakur (1989) [9], Sood and Kumar (1993) [11], Dhiman *et al.* (1997) [2], Singh *et al.* (1997) [10] and Khare *et al.* (1999) [4].

The treatment line sowing produced higher yield followed by broadcast. Higher seed yield may be because of proper placement of seed and fertilizer through seed-cum-fertilizer drill and availability of nutrient for longer period. Whereas, in broadcast some of the applied nitrogen might have been lost due to volatilization from surface application as the soil reaction was conducive for such a loss. Similar results were reported by Bhati *et al.* (1989) [1].

The higher yield of linseed under 50% more RDF treatment can be ascribed due to higher value for growth parameters like plant height, dry biomass of plant, number of branches plant^{-1}, LAI and CGR during both the years. The above findings clearly suggest that higher nutrient doses enhanced the growth parameters, which ultimately increase seed yield. The higher yield obtained was also due to higher yield attributes *viz*., number of seeds capsule^{-1}, number of capsules plant^{-1} and 1000-seed weight. The similar findings were also obtained by Mahmud *et al*. (1997) [6] and Ramamoorthy *et al.* (1997) [7].

Stalk yield (q ha^{-1})

The data presented in Table 2 reveals that among sowing methods x varieties, the stalk yield of linseed was significantly higher under line sowing x RLC-92 (S_2V_1) as compared to other treatments, however, it was at par to criss-cross x RLC-92 (S_2V_1), broadcast x RLC-92 (S_0V_1) and broadcast x Deepika (S_0V_2) during 2009-10 and on mean basis. During 2010-11, treatment criss-cross x RLC-92 (S_2V_1) registered significantly higher stalk yield of linseed as compared to other treatments, but it was comparable to line sowing x RLC-92 (S_1V_1) and broadcast x Deepika (S_0V_2).

Linseed seeded under fertilizer levels showed significant variation in stalk yield. The 50% more RDF (F_2) produced significantly higher stalk yield (25.11, 23.19 and 24.15 q ha^{-1} during 2009-10, 2010-11 and on mean basis, respectively) than RDF (F_0), however, it was comparable to RDF + S (F_1) treatment during both the years and on mean basis. Similar findings have been also reported by Subbain and Ramaih (1981) [12].

The different sowing methods x varieties influenced the stalk yield and maximum stalk yield was obtained under line sowing x RLC-92 (S_1V_1) in 2009-10 and on mean basis and under criss-cross sowing x RLC-92 (S_2V_1) during 2010-11 as compared to other sowing methods x varieties. This treatment may be attributed to better performance of plant growth parameters (plant height, primary and secondary branches) through optimum utilization of resources which had direct bearing on the production of higher dry matter. This might also because of favourable physical environment that might have increased the mineralization mobility of fertilizer resulting higher nutrient uptake and crop growth thus, leading to higher dry matter production. The results are in conformity with the findings of Kondazatowicz (1970) [5] and Jaiswal and Singh (2001) [3].

Biological yield (q ha^{-1})

The data presented in Table 2 reveal that among sowing methods x varieties, the biological yield was significantly higher under line sowing x RLC-92 (S_1V_1) as compared to other treatments, however, it was at par to criss-cross x RLC-92 (S_2V_1) during both the years and on mean basis. Treatment line sowing x Deepika (S_1V_2) was also found comparable during 2010-11.

The biological yield was significantly affected due to fertilizer levels. Significantly higher biological yield of linseed was observed under 50% more RDF (F_2) than RDF (F_0), however, it was statistically at par to RDF + S (F_1) during both the years and on mean basis.

Harvest index (%)

The data presented in Table 2 reveal that among sowing methods x varieties, the harvest index was significantly higher under line sowing x RLC-92 (S_1V_1) as compared to other treatments, however, it was at par to criss-cross x RLC-92 (S_2V_1) and line sowing x Deepika (S_1V_2) during both the years and on mean basis. Treatment criss-cross x Deepika (S_2V_2) was also comparable on mean basis.

Harvest index was significantly affected due to fertilizer levels. Significantly higher harvest index was noted under 50% more RDF (F_2) as compared to RDF (F_0), however, it was statistically at par with RDF + S (F_1) during both the years and on mean basis. The similar findings were also reported by George *et al.* (1981) and Saxena *et al.* (1996) [8].

Table 1: Yield attributes of linseed as influenced by sowing methods x varieties and fertilizer levels

Treatment	Number of seeds capsule $^{-1}$			Number of capsules plant $^{-1}$			1000 - seeds wt. (g)		
	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean
Sowing methods x Varieties									
S_0V_1: Broadcast x RLC-92	6.98	6.96	6.97	48.06	47.51	47.78	6.26	6.16	6.21
S_1V_1: Line sowing x RLC-92	9.11	9.07	9.09	66.29	66.07	66.18	8.49	8.37	8.43
S_2V_1: Criss-cross x RLC-92	7.91	7.89	7.90	49.00	50.22	49.61	7.43	7.24	7.34
S_0V_2: Broadcast x Deepika	7.67	7.64	7.66	47.21	47.07	47.14	6.13	5.98	6.06
S_1V_2: Line sowing x Deepika	8.87	8.84	8.86	65.04	65.04	65.04	8.34	8.23	8.29
S_2V_2: Criss-cross x Deepika	7.78	7.73	7.76	48.73	49.92	49.33	6.43	6.39	6.41
SEm±	0.29	0.24	0.23	0.78	0.66	0.65	0.16	0.14	0.14
CD (P=0.05)	0.92	0.77	0.92	2.45	2.08	2.05	0.51	0.47	0.45
Fertilizer levels									
F_0 : RDF	6.86	7.00	6.93	46.48	46.53	46.51	6.29	6.36	6.33
F_1 : RDF + S	8.50	8.28	8.39	57.57	57.24	57.41	7.48	7.29	7.39
F_2 : 50 % more RDF	8.80	8.79	8.79	58.71	58.54	58.63	7.78	7.53	7.65
SEm±	0.16	0.18	0.16	0.82	0.75	0.76	0.21	0.23	0.15
CD (P=0.05)	0.47	0.54	0.47	2.45	2.21	2.21	0.62	0.69	0.45

Table 2: Seed yield, stalk yield, biological yield and harvest index of linseed as influenced by sowing methods x varieties and fertilizer levels

Treatment	Seed yield (q ha^{-1})			Stalk yield (q ha^{-1})			Biological yield (q ha^{-1})			Harvest index (%)		
	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean
Sowing methods x Varieties												
S_0V_1: Broadcast x RLC-92	9.33	8.92	9.13	23.72	21.61	22.67	32.01	31.40	31.71	29.14	28.43	28.78
S_1V_1: Line sowing x RLC-92	11.76	11.67	11.71	23.94	21.94	22.94	35.47	33.28	34.38	34.11	34.04	34.07
S_2V_1: Criss-cross x RLC-92	10.73	10.63	10.68	22.92	22.92	22.92	34.55	32.65	33.60	31.51	31.66	31.59
S_0V_2: Broadcast x Deepika	9.02	8.68	8.85	22.68	22.48	22.58	32.96	30.62	31.79	27.90	27.13	27.51
S_1V_2: Line sowing x Deepika	10.60	10.56	10.58	21.47	21.47	21.47	32.07	32.03	32.05	32.93	32.88	32.91
S_2V_2: Criss-cross x Deepika	9.36	8.97	9.16	21.80	21.86	21.83	32.16	31.83	31.99	32.15	31.24	31.69
SEm±	0.47	0.42	0.44	0.46	0.33	0.36	0.61	0.52	0.41	1.23	0.95	0.81
CD (P=0.05)	1.48	1.33	1.39	1.46	1.04	1.13	1.92	1.64	1.30	3.89	2.78	2.56
Fertilizer levels												
F_0 : RDF	8.06	8.00	8.03	20.90	18.82	19.97	28.12	27.93	28.02	29.18	29.14	29.16
F_1 : RDF + S	10.76	10.42	10.59	24.26	22.14	23.09	34.68	34.12	34.40	31.93	31.30	31.62
F_2 : 50 % more RDF	11.53	11.34	11.44	25.11	23.19	24.15	35.31	35.36	35.34	32.65	32.17	32.41
SEm±	0.27	0.33	0.31	0.32	0.36	0.40	0.47	0.55	0.38	0.70	0.77	0.57
CD (P=0.05)	0.80	0.98	0.91	0.93	1.06	1.17	1.38	1.63	1.13	2.04	2.25	1.68

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