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Short Communication

Productivity, Profitability and Resource Use Efficiency of Linseed Varieties Under Different Establishment Methods and Foliar Nutrition in Rice Fallow

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Linseed (*Linum usitatissimum* L.), commonly known as flax or flaxseed, occupies a greater importance among oilseeds owing to its various uses and special qualities. It is an industrial crop cultivated for its seeds, fibres and oil purposes. Typically, linseed consists of approximately 40% fat, 28% dietary fiber, 21% protein, 4% ash and 6% carbohydrates (Vaisey-Genser and Morris, 2010). Linseed oil is rich in very healthy fatty acids *i.e.*, linoleic (LA, Omega-6) and more particularly alpha-linolenic (ALA, Omega-3, 53 to 57% of total fats) and polyunsaturated fatty acids (PUFA) that are beneficial for heart disease, inflammatory bowel disease, arthritis and a variety of other health conditions. It is an important *rabi* oilseed crop of India and is grown in an area of 1.75 lakh ha with a production of 1.11 lakh tonnes and productivity of 637 kg ha^{-1} (DES, 2020). The crop is grown under rainfed (63%), *utera*/*paira* (20%) and irrigated (17%) conditions (Rokade *et al.*, 2015). In Odisha, the crop is grown in limited districts over an area of 10.17 thousand ha mostly as a *paira* crop in rice fallow under residual soil moisture and nutrients with an annual production of 5.04 thousand tonnes and productivity of 496 kg ha^{-1} (DAFP, 2021).

As the crop is raised under residual soil moisture in rice fallow, relatively shorter-duration varieties are expected to perform well (Mishra *et al.*, 2016; Kumar *et al.*, 2019a). With the availability of zero till drill, the crop can be grown immediately after harvest of the previous rice crop in the medium land situation without any turnover period to take advantage of early sowing and better utilization of the residual soil moisture (Mishra *et al.*, 2016). The experiment was conducted considering the necessity of a comparative study for *paira* cropping, conservation and conventional method of stand establishment of linseed varieties in rice fallows of Odisha with and without foliar nutrition.

The experiment was conducted during *rabi* 2018-19 at the Central Research Station, Odisha University of Agriculture and Technology, Bhubaneswar (20° 26' N, 85° 81' E, 25.9 m above mean sea level and about 64 km away from the Bay of Bengal), Odisha. The research station comes under the East and South Eastern Coastal Plain Agro-climatic Zone of Odisha. The region is characterized by a sub-tropical climate with a hot and humid summer (March - June), hot and wet monsoon (late June - mid October) with a mean annual rainfall of 1456.8 mm and a mild and dry winter (November - February). The soil was loamy sand, slightly acidic in reaction (pH 5.67), low in organic carbon (0.45%) and available N (224.9 kg ha^{-1}), high in available P_2O_5 (31.4 kg ha^{-1}) and medium in available K_2O (54.1 kg ha^{-1}).

The field experiment was conducted in a two-factor split plot design by taking methods of crop establishment and linseed varieties in the main plot and nutrient management in the subplot (Gomez and Gomez, 1984). Therefore, six treatments comprising three methods of crop establishment (*Paira*, conventional and conservation tillage) and two linseed varieties 'Arpita' and 'Kartika' were allotted to the main plots and two nutrient management practices (Water spray (Control) and 19-19-19 NPK (2%) + B (0.02%) spray just before initiation of flowering) in the sub-plots. Linseed crop was grown following rice cv. 'Swarna'. Rice crop yield was taken for calculation of rice-linseed system yield in terms of rice equivalent yield (REY).

The linseed crop was sown in rows 30 cm apart behind the plough in the conservation and conventionally tilled plots with a seed rate of 25 kg ha^{-1}. The *paira* cropped plots were broadcasted 10 days before harvesting the rice crop with 1.5 times the recommended seed rate.The recommended dose of nitrogen (40 kg N ha^{-1}), phosphate (20 kg P_2O_5 ha^{-1}) and potash (20 kg K_2O ha^{-1})were applied at the time of sowing in conservation and conventional tillage and one day before sowing in *paira* crop. Foliar spray of 19-19-19 NPK (2%) + B (0.02%) in the form of Borax (0.2%) was sprayed just before the initiation of flowering. Quizalofop-p-ethyl (Targa super) was sprayed before flowering to control grassy weeds. Seed yield was determined per plot and was converted into yield ha^{-1}. The rice equivalent yield

(REY) of the rice-linseed system was calculated by taking the price of rice as ₹17.50 kg^{-1} and ₹40.00 kg^{-1} for linseed. The straw yield of rice and stalk yield of linseed were obtained plot-wise by subtracting grain or seed yield from the biological yield.

The water used by linseed crop was determined taking into account the soil moisture depletion, irrigation and rainfall amounts (Dastane, 1972) and for the rice variety 'Swarna' maturing in 145 days, it was taken as 145 cm assuming 1.0 cm day^{-1} during the duration of the crop under Odisha conditions. For the calculation of partial factor productivity, total nutrients used for both rice and linseed were considered. The recommended fertilizer dose for rice was $N:P_2O_5:K_2O$ @ 80:40:40 kg ha^{-1}. Energy input and output for both rice and linseed were calculated based on the machinery used, fuel consumed, labour engaged, inputs used and produce obtained by using the standard energy equivalents as per Devasenapathy *et al.* (2009). The following efficiency parameters were calculated on system mode for the rice-linseed cropping sequence.

$$\text{Land use efficiency (\%)} = \frac{\text{No. of days field occupied by crops}}{365} \times 100$$

$$\text{Partial factor productivity (kg REY kg}^{-1}\text{ nutrient)} = \frac{\text{System yield (kg REY ha}^{-1})}{\text{Total nutrient applied (kg NPKB ha}^{-1})}$$

$$\text{Water use efficiency (kg REY ha}^{-1}\text{ mm}^{-1}) = \frac{\text{System yield (kg REY ha}^{-1})}{\text{Water requirement of crop (mm)}}$$

$$\text{Energy productivity (kg REY MJ}^{-1}) = \frac{\text{System yield (kg REY ha}^{-1})}{\text{Total energy input (MJ ha}^{-1})}$$

The economics of production was worked out keeping in view the prevailing cost of the inputs used and the price of the produce. Net returns per hectare and B:C ratio (Gross returns/Cost of cultivation) were also worked out. All collected data were analyzed with the help of the analysis of variance (ANOVA) technique for split-plot design. The treatment variations were tested for significance by the 'F' test. The standard error of mean SEm± and critical difference (CD) at a 5% probability level was calculate das per Gomez and Gomez (1984).

Linseed variety 'Arpita' produced a seed yield of 0.64 t ha^{-1}, which was significantly higher than that (0.59 t ha^{-1}) recorded in the variety 'Kartika' (Table 1). Paira cropping registered a higher seed yield (0.65 t ha^{-1}) and was at par with the conventional method of establishment (0.61 t ha^{-1}), but was 11.5% more than conservation tillage. Foliar spray of NPK and B improved seed yield by 6.2% over water spray (0.60 t ha^{-1}). Our findings corroborated the results of Dalei *et al.* (2014) under a similar farming situation in rice fallow of Odisha. Though foliar nutrition did not serve as an effective supplement to or as a substitute for conventional soil fertilization practices, the crops grown in extremely deficient soil are expected to respond to fertilization Delesa and Choferie, (2016). The stalk yield of linseed followed a similar trend and that of variety 'Arpita' (1.98 t ha^{-1}) was 13.5% higher than in variety 'Kartika'. *Paira* cropping produced the maximum stalk yield of 1.97 t ha^{-1}, which was at par with conservation tillage but was significantly higher by 13.2% than in conventional tillage. Foliar spray of NPK + B increased the stalk yield by 7.1% as compared to water spray (1.80 t ha^{-1}).

The crop under conventional tillage registered a higher harvest index (HI) of (26.2%) than *paira* (24.9%) or conservation tillage (23.9%). Variety 'Arpita' recorded higher seed and stalk yield over 'Kartika', while both varieties were at par for HI. However, in this study, no significant interaction effect was observed amongst the varieties, establishment methods and nutrient management. The higher yield of the variety 'Arpita' may be due to its higher biomass accumulation and its proper partitioning. Such differences in cultivars have been reported earlier by Kumar *et al.* (2019b). It is also in conformity with the findings of Jana *et al.* (2018) and Elayan *et al.* (2018). Higher yield in *paira* cropping may be attributed to it permitting early sowing, better utilization of residual soil moisture, higher biomass accumulation and its proper partitioning. Also, the higher yield in *paira* cropping was due to its longer maturity duration which was reduced by about 17 and 12 days under conventional and conservation tillage respectively. The increased seed yield observed with foliar nutrition may be ascribed to the application of boron at the late vegetative stage, which promoted pollination and enhanced enzymatic activity that resulted in effective utilization of microelements which in turn improved photosynthesis and translocation of assimilates to the seeds. The results are in line with the findings of Sadeghi and Noorhosseini (2014) and Marzoka *et al.* (2018).

The gross returns, net returns and benefit cost ratio (B:C) of the linseed varieties under different methods of establishment and foliar nutrition are presented in Table 1. Amongst the methods of crop establishment,

Table 1. *Effect of method of establishment and foliar nutrition on yield and economics of linseed varieties*

Particulars	Seed yield (t ha^{-1})	Stalk yield (t ha^{-1})	HI (%)	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
Variety						
Arpita	0.64	1.98	24.4	25,529	6,537	1.39
Kartika	0.59	1.74	25.5	23,719	4,727	1.28
SEm(±)	0.013	0.041	0.37	-	-	-
CD(p=0.05)	0.039	0.130	NS	-	-	-
Method of establisment						
Paira cropping	0.65	1.97	24.9	26,020	10,675	1.70
Conservation tillage	0.58	1.87	23.9	23,373	3,683	1.19
Conventional tillage	0.61	1.74	26.2	24,478	2,538	1.11
SEm(±)	0.015	0.051	0.46	-	-	-
CD(p=0.05)	0.048	0.159	1.4	-	-	-
Foliar nutrition						
Water spray	0.60	1.80	25.1	23,899	5,529	1.34
19:19:19 NPK (2%) + B (0.02%) spray	0.63	1.92	24.9	25,349	5,736	1.32
SEm(±)	0.011	0.035	0.38	-	-	-
CD(p=0.05)	0.035	0.107	NS	-	-	-

conventional tillage incurred the highest investment of ₹ 21, 940 ha^{-1} and the minimum was in *paira* cropping (₹ 15,345 ha^{-1}). Linseed variety 'Arpita'fetched higher gross (₹ 25,529 ha^{-1}) and net (₹ 6,537 ha^{-1}) returns and more B:C ratio (1.39) than cv. 'Kartika'due to its higher yield which is in agreement with the findings of Singh *et al.* (2013) and Kumar *et al.* (2019b). *Paira* cropping fetched the maximum gross (₹ 26,020 ha^{-1}) and net (₹ 10,675 ha^{-1}) returns as well as B:C ratio (1.70) followed by conventional and conservation tillage because of both higher yield and lower cost of cultivation. Behera *et al.* (2014) also reported higher B:C ratio in zero tillage as compared to conventional tillage practice. Foliar nutrition though fetched higher gross (₹ 25,349 ha^{-1}) and net (₹ 5,736 ha^{-1}) returns, possessed slightly lower B:C (1.32) than water spray because of additional cost of the nutrients (₹ 1,243 ha^{-1}).

The data on resource use efficiency has been presented in Table 2. The resource use efficiency parameters were found to be highest in the case of linseed variety 'Arpita', *paira* cropping and foliar nutrition except for higher values of LUE (64.6%) recorded in variety 'Kartika' and nutrient use efficiency under water spray (19.03 kg REY kg^{-1} of NPKB applied) than foliar nutrition. Higher system yield (4.67 t ha^{-1}), WUE (2.79 kg REY/ ha^{-1} mm^{-1}), PFP (19.24 kg REY kg^{-1} of NPKB nutrients) and energy productivity (0.145 kg REY MJ^{-1}) were exhibited by variety 'Arpita' than cv. 'Kartika', because of the higher yield of the former. However, a higher value of LUE observed with the variety 'Kartika' was due to its longer duration. Among the establishment methods (Table 2), maximum system yield (4.74 t REY ha^{-1}), LUE (64.8%), WUE (28.1 kg REY ha^{-1} mm^{-1}), PFP (19.53 kg REY kg^{-1} nutrient applied) and energy productivity (0.147 kg REY MJ^{-1}) were recorded withpaira based cropping system, because of higher system yield. Inclusion of oilseeds, pulse, and vegetables has been reported to increase resource use efficiency of rice-based cropping systems in Odisha (Patra *et al.*, 2018). In the study, higher system yield (4.66 t REY ha^{-1}), LUE (64.4%), WUE (2.78 kg REY ha^{-1}

Table 2. *Effect of linseed variety, method of establishment and foliar nutrition on resource use efficiency of rice-linseed cropping system*

Particulars	System yield (t REY ha^{-1})	LUE (%)	WUE (kg REY ha^{-1} mm^{-1})	PFP (kg REY kg^{-1} of NPKB)	Energy productivity (kg REY MJ^{-1})
Variety					
Arpita	4.67	63.7	2.79	19.24	0.145
Kartika	4.56	64.6	2.71	18.76	0.142
Method of establishment					
Paira cropping	4.74	64.8	2.81	19.52	0.147
Conservation tillage	4.49	63.8	2.67	18.50	0.140
Conventional tillage	4.61	63.8	2.77	18.98	0.144
Foliar nutrition					
Water spray	4.57	63.8	2.72	19.03	0.142
19:19:19 NPK (2%) +B (0.02%) spray	4.66	64.4	2.78	18.97	0.145

mm^{-1}) and energy productivity (0.145 kg REY MJ^{-1}) was recorded with foliar spray of 19-19-19 NPK (2%) + B (0.02%), because of higher linseed yield which possibly resulted from better availability of nutrients and assimilation of photosynthates.

The results of the present study revealed that the variety "Arpita" performed better under the rice fallow system. Besides, *paira* cropping and use of foliar nutrient application led to realization of better yields, resource use efficiencies and economic returns.

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CONFLICTS OF INTEREST

The authors report no conflicts of interest.

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