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Productivity and Profitability of Rainfed Relay Linseed as Influenced by Residual Effects of Organic Nutrient Management in Aromatic Rice Varieties

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ABSTRACT: A field experiment was carried out at organic block of Instructional-cum-Research Farm of Assam Agricultural University, Jorhat, Assam, India during rabi (November -March) season of 2019 and 2020 to study the residual effects of organic nutrient management in aromatic rice varieties on relay sown linseed in rainfed condition. Most of the rice fallow areas in Assam, India are kept fallow due to lack of suitable crops adapted to moisture deficit condition after the harvest of the long duration kharif rice crop. The study was carried out to study the performance of linseed as a relay crop after the long duration kharif rice under residual fertility and moisture condition. The experiment was laid out in factorial randomized block design (RBD) and replicated thrice. The experiment consisted of three aromatic rice varieties and five organic nutrient management practices applied in the rice crop. The linseed crop received no external input and grown with residual fertility and moisture. Among the organic nutrient management practices, application of vermicompost @ 30 kg N ha^{-1} with *in situ* green manuring with *Sesbania aculeata* and seedling root dip treatment with *Azospirillium* and phosphorus solubilizing bacteria (PSB) @ 3.5 kg ha^{-1} each in preceding aromatic rice varieties produced significantly higher values of plant population, plant height at harvest, number of branches plant^{-1}, root and shoot dry weight, capsule plant^{-1}, seeds plant^{-1}, seed yield (394.52 kg ha^{-1} and 416.97 kg ha^{-1}), stover yield (890.09 kg ha^{-1} and 896.63 kg ha^{-1}) and oil yield (135.16 kg ha^{-1} and 144.56 kg ha^{-1}) uptake of N, P and K and profitability of linseed during both the years. The residual effects of aromatic rice varieties on linseed were not found significant. The study revealed that linseed could be a good choice as a relay crop in rice based cropping system in rainfed organic ecosystem.

Keywords: Aromatic rice, Productivity, profitability, organic nutrient management, relay linseed, residual effect.

INTRODUCTION

Linseed (*Linum usitatissimum* L.) is one of the oldest crops, grown in almost all countries of the world for extracting industrial oil and fibre. It is traditionally being used in a number of Ayurvedic preparations from ancient times (Bunga and Patlolla 2020). Among the winter oilseeds cultivated in India, linseed is the second most important oilseed crop after rapeseed-mustard in area as well as production. In technical oil production, it ranks first in the country. Every part of the linseed plant is used commercially, either directly or after processing (Singh *et al.*, 2018). It is considered as a medicinal plant, besides providing oil (41%), protein (20%), and dietary fibre (28%). The oil is nutritionally superior due to the greater amount of Alpha Linolenic Acid, an omega-3 fatty acid; and Linoleic Acid, an omega-6 fatty acid as well as vitamins A, B, D and E (Morris, 2007). Recent research has proved that linseed as the best herbal source of Omega-3 and Omega-6 fatty acids with immense nutritional as well as medicinal effects on human body system. Essential Omega-3 fatty acid in the form of alpha-linolenic acid (ALA) plays an important role in lowering cholesterol, reducing inflammatory disorder like rheumatoid arthritis and providing immunity and cardiovascular benefits. Linseed is one of the richest sources of lignin with 75 to 800 times more than any other plant source which provides protection against certain form of cancer due to estrogenic and anti-estrogenic activity in the body (Singh and Chopra 2018). Its unique fibre is lustrous and blends well with cotton and wool. The pulp is used in currency notes, reinforced plastics and for other artisan purposes. Linseed is an important Rabi crop chiefly grown under rainfed (63%), utera (25%) and irrigated (12%) conditions (Dash *et al.*, 2017). In India, it is predominantly cultivated as an oil seed crop under the sole cropping or utera cropping system. Tolerance to biotic and abiotic stresses is the most important characteristics of linseed and hence can be included in diverse agro-ecosystem and cropping sequence. Relay or utera cropping is one of the best practices for utilizing the residual moisture in rice fields where long duration rice varieties are grown and tillage is difficult. Timely sowing of a rabi crop after a kharif rice is practically impossible in Assam, when the fields are occupied by long duration winter varieties like the traditional aromatic rice varieties. Under such circumstances, crops which can be grown as relay and have good tolerance against the moisture stress bears immense promise as a successful rabi crop in rice (Kharif) - oilseed (rabi) sequence in Assam, India. Linseed having tolerance to moisture stress and ability to germinate and grow as a relay crop in the rice ecosystem is a promising crop for the state of Assam particularly in organic production system. In organic production system, the preceding rice crop receives sufficient quantities of organic nutrition; hence the residual soil fertility can meet up the nutritional requirement of the succeeding relay linseed. Organic manures, after supplying some amount of the essential nutrients to the first crop, often leave substantial quantity of nutrients for the succeeding crops in the cropping sequence. The positive influence of organic manure application in the preceding crop on the growth and yield of succeeding crop was earlier reported by Thakuria and Thakuria (2016); Singh and Shivay (2013); Shah *et al.* (2017); Chitale *et al.* (2015). In view of its many good attributes, linseed is considered as a potential crop in the long duration aromatic rice (kahrif)–oilseed (relay) sequence in organic production system under rainfed medium land situation in Assam. Hence, an experiment was conducted to investigate the residual effects of organic nutrient management in aromatic rice varieties on relay linseed in rainfed situation of Assam.

MATERIALS AND METHODS

The experiment was carried out at organic block of the Instructional-Cum Research Farm of the Assam Agricultural University, Jorhat, Assam, India during rabi (November to March) season of 2019 and 2020. The farm is located at 26° 47′N latitude and 94° 12′E longitudes at an elevation of about 86.6 m above mean sea level. The soil of the experimental plot was sandy loam in texture, low in available nitrogen (239.50 kg ha^{-1}), medium in available phosphorus (18.60 kg ha^{-1}) and available potassium (140.60 kg ha^{-1}) and medium in organic carbon (0.58 %) with pH 5.3. The relay crop received 97.3 mm rainfall in 2019 and 50.9 mm in 2020.The experiment consisted of three aromatic rice varieties *viz*., Kola joha (V_1), Keteki joha (V_2) and Chakhao poireiton (V_3) and five organic nutrient management practices *viz*., control (N_0), vermicompost @ 40 kg N ha^{-1} (N_1), vermicompost @ 30 kg N ha^{-1}along with in situ green manuring with *Sesbania aculeata* (N_2),vermicompost @ 30 kg N ha^{-1} with *in situ* green manuring with *Sesbania aculeata* and seedling root dip treatment with *Azospirillium* and phosphorus solubilizing bacteria (PSB) @ 3.5 kg ha^{-1} each (N_3) and vermicompost @ 20 kg N ha^{-1} along with in situ green manuring with *Sesbania aculeata* and seedling root dip treatment with *Azospirillium* and PSB @ 3.5 kg ha^{-1} each (N_4). The experiment was laid out in factorial randomised block design (RBD) and replicated thrice. The plot size was 5m×3m. Linseed variety 'T-397' seeds were soaked in plain water the day before sowing. Seeds were sown uniformly by broadcasting method @ 30.0 kg seed ha^{-1} 15 days after 50% flowering of rice. Relay linseed was grown as a residual crop and no external nutrition was supplied. The crop was grown rainfed and no pest and diseases were observed during both the years of experimentation. One light hand weeding was given at 30 days after sowing. In order to record the data on growth and yield attributes five plants per plot were selected randomly in the net plot area and tagged for observations. Root and shoot dry weight was computed at harvest from five randomly uprooted plants. Root and shoot portions were detached and sun dried followed by drying in hot air oven at 60 ^{0}C for 48 h to record constant dry weight. Seed yield of the net plot was recorded after threshing, winnowing and drying then converted to kg ha^{-1}. Oil content of seeds was determined in "Socs Plus" apparatus as per method described in AOAC (Anonymous, 1960). The amount of oil in kg ha^{-1} was obtained by multiplying the seed yield ha^{-1} by the corresponding seed oil percentage obtained from the oil content analysis. Nitrogen content (%) was determined by modified Kjeldahl's method, phosphorous by vanadomolydophosphoric acid yellow colour method and potassium by using Flame-photometer from the extract obtained by digestion with triacid mixture (Jackson, 1973). Cost of cultivation was calculated for each treatment based on the prevailing market prices of the different inputs. Benefit –cost ratio was computed dividing the net return by total cost of cultivation. Statistical analyses were done using the F- test, following the procedure given by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect on growth parameters: All the organic nutrient management practices resulted significantly higher plant population, plant height at harvest, number of branches per plant and root and shoot dry weight of linseed compared to the control in both the years (Table1). Application of vermicompost @ 30 kg N ha^{-1}+ *in situ* green manuring with *Sesbania aculeata* +seedling root dip treatment with *Azospirillium* and PSB @ 3.5 kg ha^{-1}each (N_3) in preceding rice varieties resulted the highest plant population of linseed which was found to be statistically at par with N_2 and N_4 treatments during both the years. Similarly, the N_3 treatment resulted the tallest plants which were found to be statistically at par with N_1, N_2 and N_4 treatments during both the years. The N_3 treatments also resulted the highest number of branches $plant^{-1}$, root dry weight and shoot dry weight during both the years of experimentation. Number of branches recorded and root dry weight recorded under the treatment N_1 and N_4 were found to be statistically at par. The effects of preceding aromatic rice varieties on linseed were found not significant during both the years.

Table 1: Residual effect of organic nutrient management in preceding aromatic rice varieties on growth and yield attributes of relay linseed.

Treatments	Plant population (Numberm^{-2})		Plant height at harvest (cm)		Root dry weight (g plant^{-1})		Shot dry weight (g plant^{-1})		Number of branches plant^{-1}		Number of capsule plant^{-1}		Number of seeds capsule^{-1}		1000 seeds weight (g)	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Varieties (V)																
V_1	62.55	64.52	55.03	56.83	0.13	0.13	1.29	1.33	2.67	2.66	19.20	19.70	7.71	7.79	4.56	4.62
V_2	63.74	66.01	54.33	56.25	0.13	0.14	1.29	1.33	2.72	2.71	19.55	20.02	7.95	8.10	4.55	4.61
V_3	63.65	66.84	54.97	56.69	0.13	0.14	1.29	1.33	2.70	2.67	19.27	19.74	7.79	7.93	4.55	4.63
SEm±	0.99	0.94	1.29	1.26	0.003	0.002	0.034	0.04	0.02	0.03	0.27	0.29	0.16	0.15	0.02	0.02
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Organic nutrient management (N)																
N_0	57.03	60.06	49.53	51.28	0.11	0.11	1.19	1.21	1.53	1.51	13.84	13.89	6.16	6.27	4.47	4.54
N_1	62.64	64.63	55.14	56.98	0.12	0.13	1.32	1.37	2.73	2.71	17.92	18.30	8.13	8.24	4.56	4.62
N_2	65.63	67.96	56.50	58.38	0.14	0.14	1.36	1.43	3.13	3.10	22.48	23.10	8.22	8.33	4.60	4.66
N_3	66.51	68.88	57.51	59.22	0.15	0.16	1.38	1.46	3.41	3.40	24.06	25.06	8.43	8.60	4.60	4.66
N_4	64.76	67.42	55.20	57.09	0.13	0.14	1.28	1.31	2.67	2.69	18.40	18.76	8.14	8.27	4.56	4.62
SEm±	1.28	1.22	1.67	1.63	0.004	0.003	0.04	0.05	0.04	0.04	0.36	0.37	0.20	0.19	0.03	0.01
CD(*P*=0.05)	3.72	3.54	4.84	4.72	0.01	0.01	0.13	0.16	0.11	0.13	1.03	1.08	0.59	0.57	NS	NS
Interaction (V×N)																
SEm±	2.22	2.12	2.89	2.82	0.007	0.006	0.077	0.10	0.06	0.08	0.61	0.65	0.34	0.34	0.06	0.06
CD(*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Effect on Yield attributes: The differences in number of capsule plant^{-1} and seeds capsule^{-1} due to residual effects of organic nutrient management practices were found significant during both the years (Table 1). The highest number of capsule plant^{-1} and number of seeds capsule^{-1} was recorded with the N_3 treatment. The number of capsule plant^{-1} recorded in N_1 and N_4 treatments were found at par in both the years and seeds per capsule recorded with the N_3 treatment were at par with N_1, N_2 and N_4 treatments during both the years. However**,** the differences in 1000 seeds weight due to carry over effect of organic nutrient management practices was found not significant during both the years. Though, no marked difference among the organic sources were observed in respect of the studied parameters, the residual effect of treatments involving green manuring with *Sesbania aculeata* was more prominent than those without green manuring for almost all the studied parameters. Residual effect on the second crop after incorporation of organic matter in the first crop might be due to the concept that organic amendments contain a component that slowly decomposes over prolonged period. Organic manure decomposition induced transformation and modified the dynamics of nutrient mobilization. The part of nutrient left unutilized by the first crop benefited the subsequent crop in addition to the advantages associated with improved physical properties of soil. Significant residual effect of organic nutrient sources applied to rice on succeeding crops has been reported by Singh *et al.* (2002); Mahunta *et al*. (2017). The effects of preceding aromatic rice varieties on the yield attributes were found not significant during both the years.

Yield of the crop:

Seed yield. The variation in seed yield of linseed due to residual effect of organic nutrient management practices was found significant during both the years (Table 2). All the organic nutrient management practices resulted significantly higher seed yield of linseed compared to the control. The highest seed yield (394.52 kg ha^{-1} in 2019 and 416.97 kg ha^{-1} in 2020) was recorded in the N_3 treatment which was found to be statistically at par with N_2 treatment during both the years. The N_3 treatment increased seed yield of linseed by 14.03 % over the application of sole vermicompost @ 40 kg N ha^{-1} (N_1) and 74.61 % over the control in the second year. The yield performance of linseed proved the superiority of treatments involving green manuring than sole application of vermicompost at a higher dose. Green manure contains two N fractions. One which decomposes immediately after incorporation is named as 'Fast N' and the other which decomposes slowly over several years as 'Slow N'. In most of the green manures, 'Fast N' accounts for 50-80 % of total N. The benefit of pre-season green manuring not only goes to the first crop but also the succeeding crop derive benefit from the 'slow N' component of green manuring. The superiority of residual effect of organic nutrient management treatments might be attributed to the cumulative effect on improvement in soil physico-chemical properties. Similar result on seed yield as affected by the residual effect of organic nutrient management in preceding crop was reported by Mahunta *et al*. (2017)*;* Thakuria and Thakuria (2016); Patra *et al.* (2017); Husain *et al*. (2017). The effect of aromatic varieties on seed yield of linseed was found not significant during both the years.

Stover yield: All the organic nutrient management practices resulted significantly higher stover yield compared to the control during both the years. The highest stover yield was recorded with the N_3 treatment which was found to be statistically at par with N_2 treatment during both the years of experimentation. The effect of aromatic varieties on stover yield of linseed was found not significant during both the years of experimentation (Table 2).

Harvest Index (%): All the nutrient management practices produced significantly higher harvest index compared to the control during both the years and the treatments (N_1, N_2, N_3 and N_4) were found to be statistically at par. The effect of aromatic varieties on harvest index of linseed was found not significant during both the years.

Oil content (%): The differences in oil content due to aromatic rice varieties and residual effect of organic nutrient management in preceding rice crop were found not significant during both the years.

Oil yield: The differences in oil yield of linseed due to residual effect of organic nutrient management practices were found significant during both the years. The highest oil yield of 135.16 kg $ha^{-1}$and 144.56 kg ha^{-1} were recorded in N_3 treatment during first and second year respectively. Oil yield recorded under the treatments N_3 and N_2 and also under N_1 and N_4 was found to be statistically at par. The significant increase in oil yield under different nutrient management practices might be ascribed to higher seed yield recorded with these treatments as oil yield is a function of seed yield and seed oil content. The differences in oil yield due to aromatic varieties were found not significant during both the years.

Table 2: Residual effect of organic nutrient management in preceding aromatic rice varieties on yield of relay linseed.

Treatments	Seed yield (kg ha^{-1})		Stover yield (kg ha^{-1})		Harvest index (%)		Oil content (%)		Oil yield (kg ha^{-1})	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Variety (V)										
V_1	338.89	356.66	820.14	822.66	30.00	31.00	34.26	34.68	116.34	123.91
V_2	339.99	358.99	821.12	825.46	28.92	29.98	34.25	34.58	116.41	124.10
V_3	335.69	356.78	820.73	826.27	28.25	30.02	34.29	34.73	115.06	123.88
SEm±	8.18	11.09	11.61	12.44	0.91	1.02	0.21	0.13	3,02	3.94
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient Management (N)										
N_0	219.12	238.80	669.28	677.24	24.71	26.05	34.23	34.60	75.07	82.67
N_1	344.26	363.74	832.49	831.96	30.97	32.28	34.28	34.73	118.19	126.49
N_2	374.87	393.39	868.09	872.79	30.10	30.95	34.20	34.58	128.19	136.00
N_3	394.52	416.97	890.09	896.63	30.68	31.69	34.29	34.67	135.16	144.56
N_4	358.18	374.48	843.38	845.36	29.81	30.69	34.33	34.73	123.10	130.08
SEm±	10.57	14.31	14.99	16.06	1.18	1.32	0.28	0.17	3.90	5.08
CD(*P*=0.05)	30.63	41.43	43.45	46.54	3.43	3.82	NS	NS	11.30	14.74
Interaction (V×N)										
SEm±	18.31	24.80	25.97	27.82	2.05	2.28	0.49	0.30	6.75	8.81
CD(*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Nutrient uptake: The differences in N, P and K uptake by seed and stover due to residual effect of organic nutrient management practices were found significant during both the years (Table 3). The highest values were recorded with the N_3 treatment which was found to be at par with the N_2 treatment in both the years. The significant increase in uptake of nutrients by linseed under different nutrient management practices might be ascribed to higher seed and stover yield recorded with these treatments as uptake is a function of nutrient content and yield. This result was in the line of findings of Shah *et al.* (2017); Mondal and Ghosh (2005). The differences in N, P and K uptake by seed and stover due to aromatic varieties were found not significant during both the years.

Table 3. Residual effect of organic nutrient management in preceding aromatic rice varieties on nutrient uptake by relay linseed.

Treatments	N uptake by seeds (kg ha^{-1})		N uptake by straw (kg ha^{-1})		P uptake by seeds (kg ha^{-1})		P uptake by straw (kg ha^{-1})		K uptake by seeds (kg ha^{-1})		K uptake by straw (kg ha^{-1})	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Varieties (V)												
V_1	5.56	5.87	2.95	2.97	1.29	1.35	1.75	1.80	3.02	3.18	9.73	9.76
V_2	5.59	5.93	2.98	3.02	1.31	1.38	1.78	1.79	3.02	3.02	9.73	9.79
V_3	5.51	5.88	3.01	3.04	1.31	1.37	1.77	1.79	3.00	3.19	9.7O	9.77
SEm±	0.13	0.18	0.04	0.05	0.03	0.03	0.03	0.03	0.06	0.1	0.14	0.15
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Organic nutrient management (N)												
N_0	3.56	3.91	2.38	2.42	0.82	0.89	1.40	1.44	1.93	2.11	7.93	8.02
N_1	5.64	5.97	3.02	3.02	1.32	1.39	1.8	1.82	3.07	3.24	9.84	9.83
N_2	6.17	6.53	3.16	3.21	1.44	1.50	1.86	1.90	3.34	3.52	10.31	10.36
N_3	6.52	6.91	3.30	3.32	1.52	1.60	1.95	1.97	3.52	3.74	10.55	10.66
N_4	5.88	6.14	3.00	3.07	1.37	1.44	1.82	1.83	3.20	3.35	9.97	9.99
SEm±	0.17	0.24	0.06	0.06	0.04	0.05	0.04	0.04	0.08	0.12	0.18	0.19
CD(P=0.05)	0.51	0.69	0.18	0.19	0.13	0.16	0.12	0.13	0.25	0.37	0.52	0.56
Interaction (V×N)												
SEm±	0.30	0.41	0.11	0.11	0.08	0.09	0.07	0.07	0.15	0.22	0.31	0.33
CD(*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4: Residual effect of organic nutrient management in aromatic rice varieties on economics of relay linseed (mean of two years).

	N_0	N_1	N_2	N_3	N_4	Mean
Net return (₹ ha^{-1})						
V_1	6491	16567	18315	18769	15989	15226
V_2	7032	14971	18152	19996	16066	15243
V_3	8542	13639	17716	18433	17310	15128
Mean	7355	15059	18061	19066	16455	
B: C						
V_1	0.79	1.99	2.22	2.28	1.90	1.83
V_2	0.85	1.82	2.21	2.29	1.95	1.82
V_3	1.03	1.65	2.15	2.24	2.11	1.83
Mean	0.89	1.82	2.19	2.27	1.99	

Economics: The N_3 treatment recorded the highest mean net return (₹19066.00 ha^{-1}) with mean B:C of 2.27 followed by the combination of N_2 treatment (₹18061.00 ha^{-1}) with mean B:C ratio of 2.19 (Table 4).

CONCLUSION AND FUTURE SCOPE

It may be concluded that application of 30 kg N ha^{-1} through vermicompost along with green manuring with *Sesbania aculeata* and seedling root dip treatment of rice with *Azospirillum* and PSB @ 3.5 kg ha^{-1} each (N_3) in preceding rice was found to be most effective with regard to residual effect on growth, yield, nutrient uptake and profitability of succeeding relayed linseed in aromatic rice-linseed sequence in rainfed condition. Linseed could be a promising relay crop in rice based cropping systems under organic management in medium land rainfed situation in Assam, India. The study may be further be conducted in low land rice fallow areas to investigate the potential of linseed in lowland situation.

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