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Effects of organic nutrient management on aromatic rice (*Oryza sativa*)-linseed (*Linum usitatissimum*) sequence

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ABSTRACT

The experiment was conducted during 2019 and 2020 at the Instructional-cum Research (ICR) Farm, Assam Agricultural University, Jorhat, Assam to study the impact of different combinations of organic nutrient sources on aromatic rice (*Oryza sativa* L.) (rainy-*kharif*) and their residual effect on linseed (*Linum usitatissimum* L.) (winter-*rabi*) crop for developing a double cropping sequence for rice growers of Assam with organic management. The experiment comprised three aromatic rice cultivars, viz. Kola joha, Keteki joha and Chakhao poireiton and five combinations of organic nutrient sources. Out of the organic nutrient sources, application of N @30 kg/ha through vermicompost along with pre-season green manuring of *Sesbania bispinosa* and root dip treatment of rice seedlings with *Azospirillium* and phosphorus solubilising bacteria @3.5 kg/ha each (N_3) resulted the highest number of panicles/m^2 (216.72 in 2019 and 223.96 in 2020), highest yield of rice (30.26 q/ha in 2019, 32.58 q/ha in 2020 grain yield and 65.99 q/ha in 2019, 68.98 q/ha in 2020 straw yield). The highest seed yield (394.52 kg/ha in 2019, 416.97 kg/ha in 2020) and stover yield (890.09 kg/ha in 2019, 896.63 kg/ha in 2020) of succeeding relay sown linseed were recorded with the N_3 treatment. The highest available N (250.10 kg/ha), P_2O_5 (20.40 kg/ha) and K_2O (140.06 kg/ha), organic C (0.65%), soil organic carbon (SOC) stock (13.29 t/ha), soil microbial biomass carbon (SMBC) (183.43 µg/g of soil) in soil were recorded with the N_3 treatment after harvest of linseed in 2020. The study affirmed the suitability of rice-linseed cropping sequence for efficient utilization and conservation of resources.

Keywords: Aromatic rice, Green manuring, Relay linseed, Root dip treatment, Vermicompost

Rice (*Oryza sativa* L.) is the staple food crop of south-east Asia in general and north-eastern states of India in particular with approximately 3.51 million ha acreage which exceeds 80% of total cultivated area of the north-east (NE) region and 7.8% of total national rice area (Harish *et al.* 2019). Mono-cropping of rice has become a big threat to sustainability of agriculture in NE states as evident from stagnant yield of crops, declining SOC, multiple nutrient deficiencies and reduced soil microbial activities (Verma *et al.* 2017). Rice occupies 2.54 million ha out of 4.16 million ha of gross crop area in Assam, India which contributes around 96% of the total food grain produced in the state (https://www.rkbassam.in). Assam is known for special quality aromatic rice known as Joha grown during the *kharif* season. However, the long duration aromatic rice cultivars occupy the rice field till last week of November due to which *rabi* crops can not be sown in time after the *kharif* rice. This has become a serious constraint of crop intensification in Assam. Linseed (*Linum usitatissimum* L.) having tolerance to moisture stress and ability to germinate and grow as a relay crop in the rice field is a promising crop for the state and could be a good option in areas occupied by long duration paddy cultivars. Aromatic rice (*kharif*)-relay linseed (*rabi*) sequence may be a promising cropping sequence for doubling the cropping intensity in rice areas occupied by long duration rice cultivars like the aromatic rice in Assam, India.

There is enormous scope for cultivation of aromatic rice organically in Assam with abundance of biomass for organic manure production, sufficiency of rainfall in *kharif* season and less use chemical inputs in the state. In organic production system, the first crop receives good amount of organic matter; hence the residual soil fertility may fulfill the nutritional requirement of the second crop. Suitable rice-based cropping sequence with efficient nutrient management practices through organic sources needed particularly for the organic rice growers in order to promote double cropping. Considering the above facts, the experiment was conducted with the objectives to study the impact of combinations of organic nutrient sources on growth, yield attributes and productivity of aromatic rice cultivars, residual effects of organic nutrient sources on growth and yield of succeeding relay linseed and their effects on the properties of soil grown in rainfed medium land situation.

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MATERIALS AND METHODS

A field experiment was conducted during 2019 and 2020 at the Instructional-cum Research (ICR) Farm of the Assam Agricultural University (26°47′N and 94°12'E), Jorhat under rainfed medium land situation. The soil texture of the field was sandy loam with *p*H 5.3, available nitrogen (239.50 kg/ha), available phosphorus (18.60 kg/ha), available potassium (140.60 kg/ha) and organic carbon 0.58%. The experiment consisted of 3 aromatic ricecultivars, viz. Kola joha (V_1); Keteki joha (V_2); and Chakhao poireiton (V_3) and 5 combinations of organic nutrient sources, viz. control (N_0); N @40 kg/ha through vermicompost (N_1); N @30 kg/ha through vermicompost along with preseason green manuring with *Sesbania bispinosa* (N_2); N @30 kg/ha through vermicompost along with pre-season green manuring with *Sesbania bispinosa* and root dip treatment of rice seedlings with *Azospirillium* and phosphorus solubilising bacteria (PSB) @3.5 kg/ha each (N_3); and N @20 kg/ha through vermicompost along with pre-season green manuring with *Sesbania bispinosa* and root dip treatment of rice seedlings with *Azospirillium* and phosphorus solubilising bacteria (PSB) @3.5 kg/ha each (N_4). Kola joha is a tall (140 cm), long duration (160–170 days) and a popular traditional aromatic rice cultivar of Assam. *Keteki joha* is a high yielding aromatic rice variety of Assam, medium in height (130–135 cm) and long duration (160–165 days). Chakhao poireiton is a tall (152 cm), long duration (165–170 days) aromatic black rice cultivar of Manipur, India. The experimental design was randomized block design (RBD) and each treatment was replicated thrice. Seeds of *Sesbania bispinosa* var. local were broadcast @40 kg/ha in the specified plots as per treatments. The fresh biomass of green manure (61.00 q/ha in first year and 56.70 q/ha in second year) was incorporated *in-situ* after 42 days of sowing. Vermicompost (N, 1.64%; P, 1.18%; K, 1.54%) was applied seven days before transplanting according to treatments. The phosphorus and potassium requirement of the rice crop were not supplied separately. The roots of the uprooted rice seedlings were kept in biofertilizer mud slurry for 6 h according to the treatments. Linseed variety T-397 seeds were uniformly sown using the broadcasting method at a rate of 30.0 kg/ha, 15 days after reaching 50% flowering in rice. No external nutrition was supplied to the relay linseed. In order to record the biometric data of crops, five plants in each plot were selected randomly in the net plot area and tagged for recording observations. 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). Organic carbon was determined as per the method given by Walkley and Black (1934). Chloroform fumigation-extraction technique was followed for determination of Soil Microbial Biomass Carbon (Vance *et al.* 1987). The soil organic carbon (SOC) stock was calculated by the formula given by Pearson *et al.* (2007).

SOC (t/ha) = Soil organic carbon content (%) × Bulk density of soil (g/cc) × Thickness of soil at which sample was collected (cm). The soil sample was collected up to 15 cm depth.

RESULTS AND DISCUSSION

Yield attributes (rice): The highest number of panicles/m^2 (216.72 in 2019 and 223.96 in 2020) was found under the N_3 treatment which was found to be on par with N_2 and N_4 treatments. Similarly, the longest panicles were found in N_3 treatment, which were found to be on par with N_1, N_2 and N_4 treatments. The highest number of panicles/m^2 was recorded in Keteki joha and the lowest was recorded in Chakhao poireiton (Table 1). All the organic nutrient sources created more conducive growth conditions by providing the essential nutrients right from early vegetative stage for synthesis of growth promoting constituents in the plant system compared to the control. Benarjee *et al.* (2013) and Sharma *et al.* (2017) also recorded favourable impact of organic nutrient sources on growth and yield attributes of aromatic rice. The highest thousand grain weight was found in N_3 treatment which was found to be statistically on par with N_1, N_2 and N_4 treatments. The significant reduction in 1000-grain weight under the control treatment may be ascribed to the deficiency of essential nutrients at grain filling stage. The decrease in test weight of rice grain at lower level of nutrients availability was earlier reported by Bora *et al.* (2014) in Keteki joha variety of aromatic rice; Gangmei and George (2017) in aromatic black rice.

Yield of rice: The grain yield of Keteki joha (25.54 q/ha in 2019 and 29.37 q/ha in 2020) and Chakhao poireiton (25.79 q/ha in 2019 and 27.87 q/ha in 2020) were recorded on par during the two years. The highest grain yield (30.26 q/ha in 2019 and 32.58 q/ha in 2020) and straw yield (65.99 q/ha in 2019 and 68.98 q/ha in 2020) was found in N_3 treatment which was found on par with N_2 treatment in first year and N_2 and N_4 treatments in second year (Table 2). Pre-season green manuring followed by vemicompost application and root dip treatment with *Azospirillum* and PSB resulted maximum availability of nutrients which created a favourable soil physical, chemical and biological environment. Vermicompost, besides being a rich source of macro and micro nutrients, also acts as a chelating agent and regulates the crop growth by providing the nutrients in available forms. Biofertilizers applied by the seedling root dip method increased the uptake of essential nutrients. Kumar *et al.* (2017) recorded that vermicompost application with biofertilizer boosted the yield of cereal legume system. Yadav *et al.* (2013) and Kaur *et al.* (2022) also recorded yield improvement in rice with organic nutrient management.

Yield attributes of linseed: The highest number of capsule/plant and number of seeds/capsule of linseed was recorded in the N_3 treatment. Though, no significant variations among the organic sources were observed with regard to the studied parameters, the carry over effect of treatments with green manuring was more than the treatments without green manuring. The combined effect

Table 1 Yield attributes of aromatic rice and linseed (relay) as influenced by organic nutrient sources in aromatic rice cultivars

Treatment	Rice						Linseed					
	Number of panicle/m^2		Length of panicle (cm)		1000-grains weight (g)		No. of branches/ plant		No. of capsule/ plant		1000-seeds weight (g)	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Variety (V)												
V_1	176.92	187.03	23.03	23.01	11.87	11.92	2.67	2.66	19.20	19.70	4.56	4.62
V_2	205.05	214.37	23.29	23.33	17.83	18.11	2.72	2.71	19.55	20.02	4.55	4.61
V_3	137.24	145.88	26.11	26.47	28.70	28.83	2.70	2.67	19.27	19.74	4.55	4.63
SEm±	5.20	5.40	0.38	0.44	0.34	0.33	0.02	0.03	0.27	0.29	0.02	0.02
CD (P≤0.05)	15.08	15.66	1.10	1.20	1.00	0.97	NS	NS	NS	NS	NS	NS
Organic nutrient sources (N)												
N_0	72.04	76.67	21.94	22.19	18.0	18.07	1.53	1.53	13.84	13.84	4.47	4.54
N_1	173.86	195.68	24.06	24.11	19.66	19.94	2.73	2.71	17.92	18.30	4.56	4.62
N_2	202.00	211.13	25.17	25.23	19.83	19.10	3.13	3.10	22.48	23.10	4.60	4.66
N_3	216.72	223.96	25.37	25.61	20.14	20.44	3.41	3.40	24.06	25.06	4.60	4.66
N_4	200.73	204.71	24.19	24.21	19.69	19.73	2.67	2.69	18.40	18.76	4.56	4.62
SEm±	6.72	6.98	0.49	0.57	0.44	0.43	0.04	0.04	0.36	0.37	0.03	0.01
CD (P≤0.05)	19.47	20.21	1.43	1.66	1.29	1.25	0.11	0.13	1.03	1.08	NS	NS

Treatment details are given under Materials and Methods.

of all the organic sources of nutrients on soil physico-chemical properties helped in yield improvement in N_3 treatment. Significant residual effect of organic sources of nutrients applied in preceding rice crop on crop growth as well as yield attributes of succeeding crops was reported by Mahunta *et al.* (2017) in greengram and Dhaliwal *et al.* (2023) in wheat.

Yield of linseed: The highest seed yield (394.52 kg/ha in 2019 and 416.97 kg/ha in 2020) and stover yield was found in N_3 treatment which was found to be on par with N_2 treatment. The N_3 treatment enhanced seed yield of linseed by 14.03% compared to the application of N @40 kg/ha only through vermicompost (N_1) and 74.61% over the control during the succeeding year. The yield performance of linseed was found higher with treatments that included green manuring than alone application of vermicompost at a higher dose. Release of nutrients from organic manure is gradual, and hence the nutrients remain in the soil for a longer time, which ensures a long term residual effect and enhance crop yield. The benefit of pre-season green manuring not only goes to the first crop but also the succeeding crop, which derives benefit from the 'slow N' component of green manuring. Higher seed and stover yield of linseed grown on residual fertility after rice was earlier reported by Thakuria and Thakuria (2016). Jangid *et al.* (2022) recorded highest yield of linseed with vermicompost application.

Soil parameters: Various organic nutrient sources applied to rice cultivars significantly influenced the availability of N, P_2O_5 and K_2O in postharvest soil of linseed and the highest values were found in N_3 which was found to be on par with N_1, N_2 and N_4 (Table 3). The N_3 recorded the highest buildup of organic carbon which was found to be on par with N_1, N_2 and N_4. The cumulative effect of accumulation of organic matter through multiple sources might have contributed to the improvement of organic carbon values. The effect of aromatic rice cultivars on SOC stock at the harvest of linseed was significant at the second year. The addition of plant biomass to the soil during the two years might have also helped in the improvement of the SOC stock. Among the rice cultivars, Chakhao poireiton added comparatively higher amount of crop residue to the soil through its long and voluminous roots and bigger stubbles that remained in the field after crop harvest and resulted in the highest SOC stock (13.23 t/ha in 2020). The N_3 treatment resulted in the highest SOC stock (13.29 t/ha in 2020) which was found on par with N_1, N_2 and N_4 treatments. Organic matter addition through multiple sources helped in buildup of SOC stock during the two years compared to the control. The soil microbial biomass carbon (SMBC) ranged from 140.13–183.43 µg/g of soil in the second year. The N_3 treatment resulted the highest SMBC (179.19 µg/g in 2019 and 183.43 µg/g of soil in 2020) which was found on par with N_2 treatment. Higher value of SMBC may be associated with enrichment of carbon through various organic nutrient sources which created favourable condition for microbial growth. Green manuring, vermicompost application and biofertilizer root dip treatment in rice showed favourable effect on soil fertility status compared to their initial values. Pre-season green manuring in rice-based cropping sequence reduced the loss of native nitrate, N accumulated during aerobic cycle and also conserved it, which otherwise would have

Table 2 Rice and linseed (relay) yield as influenced by organic nutrient sources in aromatic rice cultivars

Treatment	Rice				Linseed			
	Grain yield (q/ha)		Straw yield (q/ha)		Grain yield (kg/ha)		Stover yield (kg/ha)	
	2019	2020	2019	2020	2019	2020	2019	2020
Variety (V)								
V_1	20.29	21.45	39.95	41.79	338.89	356.66	820.14	822.66
V_2	25.54	29.37	55.59	57.07	339.99	358.99	821.12	825.46
V_3	25.79	27.87	77.90	79.75	335.69	356.78	820.73	826.27
SEm±	1.20	1.31	1.82	1.43	8.18	11.09	11.61	12.44
CD (P≤0.05)	3.50	3.81	5.28	4.13	NS	NS	NS	NS
Organic nutrient sources (N)								
N_0	12.84	14.30	45.67	46.84	219.12	238.80	669.28	677.24
N_1	24.60	27.09	56.43	57.36	344.26	363.74	832.49	831.96
N_2	27.49	29.37	61.29	63.17	374.87	393.39	868.09	872.79
N_3	30.26	32.58	65.99	68.98	394.52	416.97	890.09	896.63
N_4	24.17	27.82	59.69	61.24	358.18	374.48	843.38	845.36
SEm±	1.56	1.70	1.95	1.84	10.57	14.31	14.99	16.06
CD (P≤0.05)	4.52	4.92	5.65	5.34	30.63	41.43	43.45	46.54

Treatment details are given under Materials and Methods.

been washed out upon flooding. The biological nitrogen fixation by *Sesbania bispinosa* also added N to the soil. The incorporation of crop residues from rice and linseed also contributed valuable nutrients to the soil. Cropping sequence involving three crops (green manure crops-rice-linseed) had favourable effect on buildup of organic carbon in soil during the two years compared to the cropping sequence without green manuring. Improvement of organic carbon and SMBC with various organic sources and green manuring in rice-potato-okra cropping system (Patra *et al.* 2017) and in rice-linseed sequence (Singh *et al.* 2023).

On the basis of 2-year investigation, it may be concluded

Table 3 Soil properties at harvest of linseed as influenced by organic nutrient sources in aromatic rice cultivars in rice-linseed (relay) sequence

Treatment	Available N (kg/ha)		Available P_2O_5 (kg/ha)		Available K_2O (kg/ha)		Organic C (%)		SOC stock (t /ha)		SMBC (µg/g of soil)	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Variety (V)												
V_1	243.51	243.14	18.85	19.68	133.79	136.57	0.63	0.63	12.67	12.93	164.20	168.56
V_2	240.61	239.46	15.93	16.91	129.57	130.86	0.63	0.64	12.8	12.95	166.82	170.92
V_3	239.11	236.83	15.70	16.92	129.15	131.77	0.63	0.65	12.97	13.23	167.25	172.87
SEm±	0.75	1.83	0.33	0.76	1.28	1.57	0.003	0.003	0.08	0.09	0.98	1.96
CD (P≤0.05)	2.18	5.31	0.97	2.20	3.71	4.55	NS	0.009	NS	0.26	NS	NS
Organic nutrient sources (N)												
N_0	228.89	206.43	13.53	11.52	119.76	115.97	0.61	0.60	12.5	12.56	137.96	140.13
N_1	242.69	245.67	16.56	18.69	132.10	135.43	0.64	0.64	12.75	13.14	167.48	174.56
N_2	245.04	249.48	18.46	20.08	134.78	138.34	0.64	0.65	12.95	13.22	176.27	180.64
N_3	245.48	250.10	18.58	20.40	136.09	140.06	0.64	0.65	12.98	13.29	179.19	183.43
N_4	243.30	247.37	17.02	18.49	131.47	135.53	0.63	0.64	12.89	12.99	169.57	175.14
SEm±	0.97	2.36	0.43	0.98	1.65	2.02	0.004	0.004	0.1	0.11	1.26	2.53
CD (P≤0.05)	2.82	6.85	1.25	2.84	4.79	5.87	0.012	0.012	NS	0.34	3.66	7.35

SOC, Soil organic carbon; SMBC, Soil microbial biomass carbon. Treatment details are given under Materials and Methods.

that application of 30 kg N/ha through vermicompost with pre-season green manuring of *Sesbania bispinosa* and seedling root dip treatment with *Azospirillum* and PSB @3.5 kg/ha each (N_3) was found best regarding their effect on aromatic rice cultivars, residual influence on the succeeding linseed (relay), management of soil health and reducing environmental impact from agriculture. Aromatic rice-linseed (relay) cropping sequence may be followed for promotion of double cropping in rice field occupied by long duration varieties in Assam.

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