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Residual Effect of Nutrient Management Practices in Lowland Rice Varieties on Growth, Productivity, Economics and Nutrient Uptake of Succeeding Black Gram in Rice–Black Gram Cropping Sequence

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ABSTRACT

A field experiment was conducted during *rabi* seasons (December–March) of 2019–20 and 2020–21 to study the residual effect of nutrient management practices in lowland *kharif* rice varieties on succeeding black gram variety PU 31. The experiment was set in split plot design with four rice varieties in main plots (viz. CR 1009 sub-1, CR 1018, Pooja and Upahar) and six nutrient management practices in sub-plots [(viz. Control, 100% Recommended dose of fertilizers (RDF: 80-40-40 kg N, P_2O_5, K_2O ha^{-1}), 50% RDF+FYM (@ 8 t ha^{-1}), 50% RDF+*Sesbania* green manuring (@ 1.5 t ha^{-1}), Rice crop manager (115.5 -32.7-52.8- 25.0 kg N, P_2O_5, K_2O, $ZnSO_4$ ha^{-1}+FYM @ 3 t ha^{-1}) and Real time nitrogen management (RDF+customised leaf colour chart (CLCC)] and each treatment was replicated thrice. Among different nutrient management practices in rice, rice crop manager exhibited highest number of pods plant^{-1} (31.3), seeds pod^{-1} (7.8), 1000 seed weight (39.6 g), seed yield (877 kg ha^{-1}), haulm yield (2512 kg ha^{-1}), gross return (₹ 51352 ha^{-1}), net return (₹ 38947 ha^{-1}) and return ₹$^{-1}$ invested (₹ 4.14) and highest uptake of N (78.83 kg ha^{-1}), P (7.60 kg ha^{-1}) and K (53.09 kg ha^{-1}) in residual black gram. This was at par with 50% RDF+FYM @ 8 t ha^{-1} and significantly higher than all other nutrient managements in preceding rice. So, nutrient management as per rice crop manger and 50% RDF+8 t FYM ha^{-1} to the preceding rice crop had significant residual influence in achieving highest yield and economic returns from succeeding black gram in rice-black gram cropping sequence.

KEYWORDS: Economics, nutrient uptake, residual black gram, yield

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1. INTRODUCTION

Black gram is one of the most important legume crops which is grown in an area of 4.2 mha with an annual productivity of 557 kg ha^{-1} in India. (Anonymous, 2021). In Odisha, black gram production stands at 198 ('000MT) from total pulse production of 1035 ('000MT). (Anonymous, 2022). It is rich in carbohydrates (50–60%), protein (22–25%), fat (1–3%), phosphorus, calcium, iron, riboflavin and thiamine (Verma et al., 2011; Pandey and Singh, 2022). Rice based cropping systems are of prime importance in global food production (Samant et al., 2021). In India, rice is the principal crop during *kharif* and the area under rice fallow is never utilised fully. There is a larger scope to utilise the area under rice- fallow that will provide a huge scope and opportunity in reducing the food and nutritional insecurity. Black gram being a short duration hard crop, fits in the cropping sequence utilising the residual nutrients, moisture and other residual inputs from the preceding crop. Rice monocropping with excessive use of chemical fertilisers with improper crop and nutrient management deteriorates the soil physico-chemical and biological properties that has threatened the productivity and sustainability of the system (Patra et al., 2019), which can be partly solved by changing into rice-legume cropping system (Deep et al., 2018). Organic manures are rich source of organic carbon, both macro and micro nutrients that enhances soil proprieties and have carry over effect on succeeding crop in rice-based cropping system (Khan et al., 2009; Mondal et al., 2019; Shweta et al., 2021). Dhanicha (*Sesbania aculeata* L.), one of the most important green manuring crops add around 60–80 kg nitrogen ha^{-1} on soil incorporation. It increases soil humus, available soil nitrogen and improves soil physico-chemical and biological properties and also acts as chelating compound that helps in increasing the availability of nutrients i.e., Zn, Cu, Mn etc. to the succeeding crop (Sanjeev and Sukul, 2020). On the other hand, chemical fertilizers are artificially produced that provides mineral nutrients in higher concentration that are soluble and readily plant available. Moreover continuous application of nutrients from chemical sources result in deterioration of soil fertility (Masu et al., 2019). Thus, integration of organic and inorganic fertilizers will play a significant role in increasing the soil nutrient availability, restoring soil fertility and enhanced the sustainability (Annadurai et al., 2009; Sahu et al., 2017, Mahmood et al., 2017; Kamble et al., 2018; Saikia et al., 2018; Midya et al., 2021). Integration of organic source of nutrients viz. FYM, dhanicha and inorganic chemical fertilisers supply all the macro and micro nutrients which are required by crop for balanced nutrition (Patil et al., 2010) that enhances the crop growth and yield (Chhaya and Jain, 2014) with higher economic return (Nagar et al., 2016; Samant et al., 2021). It is flexible and minimizes the use of chemicals and improve the soil health (Jana et al., 2020) and have more carry over impact on the succeeding crop. Further, rice–fallow pulse cropping sequence will not only sustain the growers, by fetching more price and income but also, will improve the sustainability of rice production system by improving soil health and it will also improve the food and nutritional security to the poverty driven small farm families (Bastia et al., 2008, Prasad et al., 2013). Keeping this in view, a field experiment was conducted to study the residual effect of different nutrient management practices in lowland rice varieties in *kharif* on growth, yield components, yield and economics and nutrient uptake of succeeding *rabi* black gram.

2. MATERIALS AND METHODS

A field experiment was conducted at farmer's field of Niali, Cuttack, Odisha, India that lies at 20°11´N latitude and 86°11´E longitude, respectively with an altitude of 35.66 m above the mean sea level. The site falls under the Agro-Climatic Zone of East and South Eastern Plain Zone of Odisha. The experiment was conducted during *rabi* (December–March) 2019–20 and 2020–21 and was carried out in split plot design with four rice varieties in main plots (viz. V_1: CR 1009 sub-1 (155 days), V_2: CR 1018 (160 days), V_3: Pooja (150 days), V_4: Upahar (160 days)) and six nutrient management practices in sub-plots (viz. N_0: Control, N_1: 100% Recommended dose of fertilizers (RDF): 80-40-40 kg N, P_2O_5, K_2O ha^{-1}) from chemical fertilizers, N_2: 50% RDF from chemical fertilizers+FYM (@ 8 t ha^{-1}), N_3: 50% RDF from chemical fertilizers+*Sesbania* green manuring (@ 1.5 t ha^{-1}), N_4: Rice crop manager (115.5-32.7-52.8-25.0 kg N, P_2O_5, K_2O, $ZnSO_4$ ha^{-1}+FYM @ 3 t ha^{-1}), N_5: Real time nitrogen management (RDF+customised leaf colour chart (CLCC) and each twenty four treatment combinations were replicated thrice. Black gram variety PU 31 was grown as succeeding test crop in *rabi* to study the impact of treatments imposed in the preceding *kharif* rice on succeeding *rabi* black gram. The mean N, P and K content (on dry weight basis) of FYM and *Sesbania aculeata* were 0.52, 0.27 and 0.48 and 2.73, 0.77 and 1.34, respectively. Periodic data on plant height, number of primary branches $plant^{-1}$, leaf area index (LAI) and dry matter accumulation were calculated at 45 DAS and at harvest. Observations on yield components e.g., number of pods $plant^{-1}$, number of seeds pod^{-1} and 1000 seed weight (g) were taken at harvest. Seed yield and haulm yield were calculated as kg $plot^{-1}$ and later converted into kg ha^{-1}. Economical parameters (gross return, net return and return ₹$^{-1}$ investment) were calculated taking consideration the market value of inputs, products (Seed) and by product (haulm). Nutrient content of seeds and stick was calculated separately and the nutrient uptake was calculated by multiplying the seed and stick yield with the respective nutrient content and was expressed as kg ha^{-1}. For analysis of the experimental data, Fisher's method of variance analysis of the pooled data was adopted as outlined by Gomez and Gomez (1984) to draw a logical conclusion. The values of critical difference (CD) at 5% level of significance were used to test variation in the treatments.

3. RESULTS AND DISCUSSION

3.1. Growth attributes

Rice varieties grown in lowland ecosystem had no significant response on growth parameters (viz. plant height, number of primary branches $plant^{-1}$, leaf area index and dry matter accumulation) of succeeding black gram (Table 1). However, significant response from residual effect of nutrient management practices in rice was found on growth attributes of succeeding *rabi* black gram. Black gram, grown on residual soil after *kharif* rice with application of 50% RDF+FYM @ 8 t ha^{-1} showed highest plant height and leaf area index, (36.6 cm and 1.59, respectively) that was at par with recommendation as per rice crop manager (36.1 cm and 1.54, respectively). Highest number of primary branches per plant and dry matter accumulation (5.70 and 9.28 g $plant^{-1}$, respectively) was recorded in treatment with residual effect of nutrient management as rice crop manager which was at par with use of 50% RDF+FYM @ 8 t ha^{-1} (5.51 and 9.04 g $plant^{-1}$, respectively) but significantly higher than 50% RDF+*Sesbania* green manuring @ 1.5 t ha^{-1}. Dash et al. (2017) also confirmed substantial residual effect resulted from combined use of organic and chemical sources of plant nutrients in *kharif* hybrid rice on growth attributes and yield of succeeding *rabi* green gram in rice-green gram sequence. Similar reports of higher crop growth parameters viz. plant height, LAI, number of branches $plant^{-1}$ and dry matter accumulation in succeeding green gram due to integrated nutrient management in preceding rice has also been reported by Kundu and Brahmachari (2012) and Sudhagar Rao et al. (2019).

Table 1: Residual effect of nutrient management practices in lowland rice varieties on growth attributes of succeeding *rabi* black gram

Treatments	Plant height (cm)		No. of primary branches $plant^{-1}$		Leaf area index (LAI)		Dry matter accumulation (g) $plant^{-1}$	
	45 DAS	Harvest	45 DAS	Harvest	45 DAS	Harvest	45 DAS	Harvest
Variety (V)								
V_1	31.4	33.3	4.37	4.63	3.00	1.37	4.63	7.88
V_2	32.4	34.3	4.54	4.83	3.00	1.39	4.76	8.00
V_3	32.9	34.7	4.77	5.05	3.12	1.45	4.70	8.10
V_4	31.3	33.3	3.96	4.35	2.95	1.33	4.35	7.66
SEm±	0.4	0.5	0.06	0.13	0.05	0.03	0.12	0.11
CD (*p*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management practices (N)								
N_0	25.0	27.2	2.74	2.98	2.32	1.02	1.98	3.91
N_1	31.4	33.5	4.21	4.41	2.90	1.37	4.49	8.08
N_2	34.8	36.6	5.16	5.51	3.39	1.59	5.5	9.04
N_3	33.7	35.6	4.69	5.05	3.19	1.44	5.3	8.84
N_4	34.1	36.1	5.28	5.70	3.33	1.54	5.71	9.28
N_5	33.0	34.6	4.38	4.65	2.98	1.37	4.68	8.31
SEm±	0.6	0.3	0.06	0.08	0.03	0.02	3.73	0.15
CD (*p*=0.05)	1.6	0.9	0.17	0.23	0.08	0.06	10.49	0.43
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

Note: V_1: CR 1009 sub-1; V_2: CR 1018, V_3: Pooja; V_4: Upahar; N_0: Control; N_1: 100% Recommended dose of fertilizers (RDF: 80-40-40 kg N, P_2O_5, K_2O ha^{-1}); N_2: 50% RDF from chemical fertilizers+FYM (@ 8 t ha^{-1}), N_3: 50% RDF from chemical fertilizers+ Sesbania green manuring (@ 1.5 t ha^{-1}); N_4: Rice crop manager (115.5-32.7-52.8-25.0 Kg N, P_2O_5, K_2O, $ZnSO_4$ ha^{-1}+FYM@ 3 t ha^{-1}); N_5: Real time nitrogen management (RDF+CLCC); SE: Standard Error; CD: Critical difference at 5% probability level

3.2. Yield components and yield

A significant response of various nutrient management practices in preceding *kharif* rice was observed on yield components, seed yield and haulm yield of succeeding black gram on pooled data basis while, the effect of *kharif* rice varieties were non-significant (Table 2). Highest values of yield components viz. number of pods plant^{-1} (31.3), number of seeds pod^{-1} (7.8) and 1000 seed weight (39.63 g) was recorded in black gram grown on residual soil with rice crop manager recommendation that was at par with residual effect of 50% RDF+FYM @ 8 t ha^{-1} (30.0, 7.6 and 38.79 g, respectively) but significantly higher than application of 50% RDF+*Sesbania* green manuring @ 1.5 t ha^{-1} (25.1, 7.3 and 37.88 g, respectively). Application of combined sources of nutrients from organic and inorganic sources in rice having substantial residual effect on crop growth, yield components and yield of succeeding *rabi* black gram in rice fallow was also evidenced from the findings of Kar et al. (2012) and Sudhagar Rao et al. (2019). Similar findings had been recorded in green gram by Mohanty et al. (2014). Similarly, highest seed and haulm yield (877 and 2512 kg ha^{-1}, respectively) was achieved from succeeding black gram grown on residual soil of rice with nutrient management as per rice crop manager which, was at par with use of 50% RDF+FYM @ 8 t ha^{-1} (875 and 2441 kg ha^{-1}, respectively) but significantly higher than 50% RDF+*Sesbania* green manuring @ 1.5 t ha^{-1} (855 and 2386 kg ha^{-1}, respectively). Highest harvest index was recorded with application of 50% RDF+FYM @ 8 t ha^{-1} (26.6%) and 50% RDF+*Sesbania* green manuring @ 1.5 t ha^{-1} (26.6%), but the values were at par with all other nutrient management practices. There was non-significant effect of *kharif* rice varieties on yield components, seed yield, haulm yield and harvest index of succeeding *rabi* black gram. Present findings with higher yield of succeeding black gram on residual fertility after rice were also in conformity with the findings of Rama Lakshmi et al. (2012) and Dash et al. (2017) where residual effect of organic and inorganic sources of nutrients in rice combinedly showed significantly higher growth, yield attributes and yield of succeeding *rabi* green gram than sole

Table 2: Residual effect of nutrient management practices in lowland rice varieties on yield components, yield and economics of succeeding *rabi* black gram

Treatments	Yield components			Yield			Economics		
	No. of pods plant^{-1}	No. of seeds pod^{-1}	1000 seed weight (g)	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index (%)	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	Return ₹$^{-1}$ invested (₹)
Variety (V)									
V_1	22.7	7.0	36.98	739	2152	25.52	43249	30839	3.49
V_2	23.9	7.0	37.76	747	2186	25.34	43703	31293	3.52
V_3	25.1	7.3	37.99	755	2216	25.25	44185	31775	3.56
V_4	21.8	6.9	36.65	727	2054	26.19	42574	30164	3.43
SEm±	0.8	0.1	0.4	7. 6	40.3	0.3	444	444	0.04
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management practices (N)									
N_0	10.1	5.6	33.46	332	1103	23.3	19427	7017	1.56
N_1	21.3	6.8	36.86	753	2213	25.6	44057	31647	3.55
N_2	30	7.6	38.79	875	2441	26.6	51187	38777	4.13
N_3	25.1	7.3	37.88	855	2386	26.6	50067	37657	4.04
N_4	31.3	7.8	39.63	877	2512	26.1	51352	38942	4.14
N_5	22.4	7.1	37.46	760	2258	25.4	44477	32067	3.58
SEm±	0.6	0.1	0.39	6.9	35.6	0.4	408	408	0.04
CD (p=0.05)	1.8	0.3	1.1	19.5	100.1	1.0	1147	1147	0.1
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS

1US$= ₹ 74.54 and ₹ 72.77 during both March'2020 and 2021 inorganic source and control. Higher yield in treatment comprising inorganic fertilizers in combination with organic manures might be due to the increased availability and uptake of macro and micro nutrients by the plant, resulting in higher rate of physiological (Barcchiya and Kushwah, 2017) and anabolic processes (Ramana et al., 2010).

3.3. Economics

A significant residual effect from nutrient management in preceding *kharif* rice was found on gross and net return of succeeding *rabi* black gram while, the effect of varieties was non-significant (Table 2). Nutrient management as per rice crop manager recommendation in rice registered highest gross return and net return (₹ 51352 ha^{-1} and ₹ 38942 ha^{-1}, respectively) that was at par with application 50% RDF+FYM @ 8 t ha^{-1} (₹ 51187 ha^{-1} and ₹ 38777 ha^{-1}, respectively). However, this was significantly higher than 50% RDF+*Sesbania* green manuring @ 1.5 t ha^{-1} (₹ 50067 and ₹ 37657 ha^{-1}, respectively) as well as other nutrient management in rice. Return ₹$^{-1}$ invested with recommendation of rice crop manager (₹ 4.14), 50% RDF+FYM @ 8 t ha^{-1} (₹ 4.13) and 50% RDF+*Sesbania* green manuring (₹ 4.04) were at par with each other. Similar findings of significant response from combined use of organic and inorganic sources of plant nutrients in preceding crop were also reported by Shanwad et al. (2010) in maize- bengal gram sequence, Mohanty et al. (2014) in rice-green gram sequence and Samant et al. (2021) in rice groundnut cropping sequence.

3.4. Nutrient uptake

Different rice varieties had no significant residual influence on nutrient uptake of succeeding black gram, while, the effect of nutrient management in preceding rice was significant (Table 3). Black gram grown as succeeding crop after rice on residual plots with nutrient management as per recommendation of rice crop manager recorded highest total nitrogen (78.83 kg ha^{-1}), phosphorus (7.6 kg ha^{-1}) and potassium (53.09 kg ha^{-1}) that was at par with application of 50% RDF+FYM @ 8 t ha^{-1} (78.19, 7.48 and 51.6 kg ha^{-1}, respectively) and significantly higher than residual effects of all other nutrient management in previous rice crop. This substantial response might be due to higher availability of residual soil NPK owing to conjunctive application of organic and inorganic sources of nutrients in the preceding rice crop and there could be complementary effect of organic sources of nutrients in improving soil physio-chemical and biological properties which was also in conformity with the findings of earlier workers (Wadile et al., 2017 and Ghanshyam et al., 2010).

Table 3: Residual effect of nutrient management practices in lowland rice varieties on nutrient uptake of succeeding *rabi* black gram

Treatments	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})		
	Seed	Haulm	Total	Seed	Haulm	Total	Seed	Haulm	Total
Variety (V)									
V_1	25.22	41.41	66.63	2.26	3.93	6.19	8.15	36.06	44.21
V_2	25.51	42.18	67.69	2.34	4.14	6.48	8.29	37.46	45.75
V_3	25.83	42.84	68.67	2.45	4.23	6.68	8.43	38.09	46.51
V_4	24.71	39.36	64.07	2.17	3.60	5.77	7.81	33.49	41.3
SEm±	0.29	1.38	0.90	0.10	0.22	0.29	0.28	0.84	0.82
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management practices (N)									
N_0	11.09	20.48	31.58	0.90	1.85	2.76	3.42	17.28	20.69
N_1	25.43	41.91	67.34	2.21	4.04	6.26	8.15	36.90	45.06
N_2	30.17	48.02	78.19	2.89	4.59	7.48	9.78	41.81	51.60
N_3	29.39	46.82	76.21	2.76	4.39	7.15	9.48	40.60	50.08
N_4	30.08	48.75	78.83	2.77	4.84	7.60	9.86	43.24	53.09
N_5	25.76	42.70	68.45	2.29	4.13	6.42	8.32	37.81	46.13
SEm±	0.30	0.83	0.90	0.04	0.10	0.10	0.11	0.62	0.62
CD (p=0.05)	0.84	2.33	2.52	0.11	0.29	0.29	0.32	1.74	1.76
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS

4. CONCLUSION

Application of both organic and inorganic sources of nutrients as per rice crop manger recommendation (115.5-32.7-52.8-25.0 kg of N, P_2O_5, K_2O and $ZnSO_4$ ha^{-1}+FYM @ 3 t ha^{-1}) as well as use of 50% recommended dose of fertilizers along with 8 t FYM ha^{-1} to the preceding rice crop had significant residual influence for achieving highest yield and economic returns from succeeding black gram than other nutrient management practices in rice-black gram sequence.

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