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Sesbania aculeata a Cost Effective Alternative to Enhance the Soil Health and Productivity of Rice-Wheat System

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ABSTRACT

Background: Cereal based cropping systems are predominantly followed in south Asia because of higher productivity and profitability and ensuring food security. Rice is grown once a year in rotation mainly with wheat. Continuous cultivation of rice results in the formation of a hard pan below the ploughing layer, which may act as a barrier to normal root growth of the subsequent wheat crop. Consequently, soil bulk density is increased and hydraulic conductivity is reduced thus leading to non-conducive soil physical characteristics for the subsequent wheat crop. To reduce these ill effects, FYM is used as organic source. But live stock population is not increasing in the ratio as it is required to meet the FYM demand. Organic source requirement cannot meet through use of FYM in rice-wheat system, which is vital for food security point of view. There is need of alternate cost effective source of FYM which could enhance the soil health as well as productivity of rice-wheat system. The present study aimed to see the efficacy of growing green manure crop (*Sesbania aculeata*) as an alternative of FYM in the rice-wheat rotation.

Methods: In this experiment conducted during *kharif* and *rabi* seasons of 2014-15 and 2015-16 in on-going long term permanent manorial trial since 1984 at research farm (Bihar Agricultural University, Sabour, Bihar, India), twelve treatments were taken under RBD in four replications. Observations and analysis were carried out by following the standard procedures.

Result: The present investigation showed that combination of inorganic fertilizer and *Sesbania aculeata* helped in increasing yield as well as improving soil health. *Sesbania aculeata* can be used as a viable and cost effective alternative through partial substitution of inorganic fertilizers to enhance the soil health and productivity of rice-wheat system.

Key words: Economics, Rice-wheat system, *Sesbania aculeata,* Soil properties, Yield.

INTRODUCTION

Cereal based cropping systems are predominantly followed in south Asia because of higher productivity and profitability and ensuring food security. Rice is grown once a year in rotation mainly with wheat. Continuous cultivation of rice results in the formation of a hard pan below the ploughing layer, which may act as a barrier to normal root growth of the subsequent wheat crop. Consequently, soil bulk density is increased and hydraulic conductivity is reduced thus leading to non-conducive soil physical characteristics for the subsequent wheat crop (Gangola *et al.,* 2012). To reduce these ill effects, FYM is used as organic source. But live stock population is not increasing in the ratio as it is required to meet the FYM demand. During 19th Live Stock Census (2012), total live stock population (512.06 million) was 3.5% lesser in comparison to 2007 (529.70 million). Thus, organic source requirement cannot meet through use of FYM in rice-wheat system, which is vital for food security point of view. There is need of alternate cost effective source of FYM which could enhance the soil health as well as productivity of rice-wheat system. The present study was, therefore, undertaken to see the efficacy of growing green manure crop (*Sesbania aculeata*) as an alternative of FYM in the rice-wheat rotation.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* and *rabi* seasons of two consecutive years, 2014-15 and 2015-16 in on-going long term permanent manorial trial since 1984 at research farm (Bihar Agricultural University, Sabour, Bihar, India). The experiment was laid under RBD in four replications. Net plot size was 7.5 m x 4.35 m for rice and 7.5 m x 4.15 m for wheat. FYM and wheat straw were used in the experiment. For green manuring 50 days old succulent crop of *Sesbania aculeata* (Dhaincha) was used from which required quantity of twigs were chopped and incorporated during puddling as green manure. Pre and post-harvest soil samples was collected up to 0-15 cm treatment wise from all replications of ongoing permanent manurial trial after harvest of wheat crop during 2014-15 and 2015-16. The soil was sandy loam having pH 7.4, organic carbon 0.46%, available N 194 (kg/ha), P 23 (kg/ha) and K 155 (kg/ha) initially. Bulk density, organic carbon, available nitrogen, phosphorous and K were determined by standard methods. Bacteria, fungi and actinomycetes population in soil were determined by following the technique of Standard Pour Plate using soil extract agar, Rose Bengal agar and Ken Knight's agar medium, respectively as described by Rangaswamy and Bagyaraj (1993).

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Treatments

Treatments	Rice	Wheat
T_1	No application of any manure/fertilizer	No application of any manure/fertilizer
T_2	50% RDF	50% RDF
T_3	50 % RDF	100% RDF
T_4	75% RDF	75% RDF
T_5	100% RDF	100% RDF
T_6	50% N through FYM + 50% RDF	100% RDF
T_7	25% N through FYM + 75% RDF	75% RDF
T_8	50% N through wheat straw + 50% RDF	100% RDF
T_9	25% N through wheat straw + 75% RDF	75% RDF
T_{10}	50%N through green manure (*Sesbania aculeata*) + 50% RDF	100% RDF
T_{11}	25% N through green manure (*Sesbania aculeata*) + 75% RDF	75% RDF
T_{12}	Farmers' practice ($N_{70}P_{30}K_{10}$)	Farmers' practice ($N_{80}P_{30}K_{15}$)

RDF: Recommended dose of fertilizer

The experiment was conducted in randomized block design with four replications. The recommended dose of fertilizer for rice was 80 kg N + 40 kg P_2O_5 + 20 kg K_2O ha^{-1} while it was 120 kg N + 40 kg P_2O_5 + 40 kg K_2O ha^{-1} for wheat.

RESULTS AND DISCUSSION

Data revealed that level of application of inorganic fertilizers and organic sources applied in *kharif* crop, significantly influenced grain yield of the system. The highest rice equivalent yield (12185 kg ha^{-1}) was recorded in T_6 getting 100% RDF (in plot of 50% N through FYM and 50% RDF through inorganic fertilizers during *kharif*) and was statistically at par with T_8 (11546 kg ha^{-1}) and T_{10} (11994 kg ha^{-1}) and significantly superior to T_1, T_2, T_3, T_4, T_5, T_7, T_9 T_{11} and T_{12} (Table 1).

The data showed that the maximum net return and B:C ratio was recorded in the treatment having *Sesbania aculeata* (Rs. 84379/- ha^{-1} and 1.27), which was significantly to all other treatments (Table 2).

Critical examination of the data revealed significant effect of treatments on soil organic carbon content of soil. Initial soil organic carbon content (SOC), pH and EC at the start of the experiment during 1984-85 was 0.46%, 7.40 and 0.29 (dSm^{-1}), respectively. Integrated use of organics along with chemical fertilizers resulted in increase in SOC of soil (up to 0.79) and decreased in pH and EC (Table 3).

Initial available N, P and K of soil at the start of the experiment in 1984-85 was 194.00, 23.0 and 155.0 kg ha^{-1}, respectively. Continuous cropping of rice-wheat revealed that in control (T_1) as well as T_2, T_3, T_4, T_5 and T_{10}, there was decline in available N content of soil from its initial value (194.00 kg ha^{-1}). However, treatments receiving either 25% or 50% N substitution through organic source resulted a higher built up of available N, P and K content in soil. The maximum available N, P and K (228.45, 49.54 and 168.40 kg ha^{-1}), respectively were noticed in treatment 50% N through FYM in rice followed by *Sesbania aculeata* (226.10, 48.55 and 170.20 kg ha^{-1}), respectively which was statistically at par with each other (Table 3).

Table 1: Effect of *Sesbania aculeata* practice on yield.

	Treatments		Grain yield (kg ha^{-1})						REY (kg ha^{-1})		
			Rice			Wheat					
	Rice	Wheat	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	$N_0P_0K_0$	$N_0P_0K_0$	935	906	920	771	751	761	2112.00	2033.00	2072
T_2	50% RDF	50% RDF	2759	2702	2730	1976	1952	1964	5774.00	5629.00	5701
T_3	50% RDF	100% RDF	2782	2743	2762	3719	3558	3638	8458.00	8081.00	8269
T_4	75% RDF	75% RDF	3601	3542	3571	3028	2932	2980	8233.00	7939.00	8086
T_5	100% RDF	100% RDF	4912	4875	4893	3904	3855	3879	10870.00	10658.00	10764
T_6	50% N through FYM + 50% RDF	100% RDF	5510	5615	5562	4345	4410	4377	12142.00	12229.00	12185
T_7	25% N through FYM + 75% RDF	75% RDF	5046	5210	5128	3976	4000	3988	11114.00	11210.00	11162
T_8	50% N through WS + 50% RDF	100% RDF	5280	5442	5361	4080	4096	4088	11507.00	11586.00	11546
T_9	25% N through WS + 75% RDF	75% RDF	4965	4927	4946	3896	3928	3912	10911.00	10818.00	10864
T_{10}	50% N through GM + 50% RDF	100% RDF	5479	5506	5492	4289	4305	4297	12025.00	11964.00	11994
T_{11}	25% N through GM + 75% RDF	75% RDF	5027	5185	5106	3968	3976	3972	11083.00	11149.00	11116
T_{12}	FP ($N_{70}P_{30}K_{10}$)	FP ($N_{80}P_{30}K_{15}$)	3272	3248	3260	2651	2522	2586	7318.00	7031.00	7174
	SEm(±)		201.82	209.61	131.75	192.62	178.71	118.53	501.96	479.17	321.53
	CD at 5%		591.87	614.71	373.32	564.87	524.09	335.87	1472.06	1405.24	885.59

RDF: Recommended dose of fertilizer, WS: Wheat straw GM: Green manure, FP: Farmers' practice, REY: Rice equivalent yield.

Perusal of the data (Table 4) revealed significant effect of treatments on microbial population (bacteria, fungi and actinomycetes). Soil microbial density as envisaged through the population of bacteria, fungi and actinomycetes observed in the experimental plots. It was revealed from the observation that the microbial count was found in the plots received organic sources. Treatment having FYM and *Sesbania aculeata* was significantly superior to rest of the treatments and both were statistically at par with each other. Among the three groups of microorganisms, the population of bacteria and actinomycetes were higher as compared to the fungal population.

Organic sources *viz*. FYM, wheat straw and *Sesbania aculeata* (green manure crop) used to substitute 50% of recommended N dose in rice were effective in bringing about marked improvement in chemical and biological properties of soils over the years. The quantity of biomass added to the soil through different organic sources and the quantity of end product of decomposition of the organic matter capable of imparting binding effect on soil particles might have been responsible to improve soil health.

Addition of organic matter through green manuring with *Sesbania* was helpful in improving status of organic carbon, available N, P and K in soil over the years of experimentation. Even during the course of present investigation, an increasing trend was observed. Organic carbon content which was 0.46% during the initial year (1984) reached to 0.78% in *Sesbania aculeata* and 0.79% in FYM plot during the year 2015-16. The control and plots receiving 50% RDF through inorganic fertilizers in both the crops exhibited drop in organic carbon. Incorporation of organic amendments induced an increasing effect on organic carbon status might due to improvement of physical and biological properties of the soil (Satish *et al*., 2011, Wallia *et al*., 2010).

Table 2: Effect of *Sesbania aculeata* practice on economics of rice-wheat system (Pooled).

	Treatments		Cost of cultivation	Gross return	Net return	B : C
	Rice	Wheat	(Rs. ha^{-1})	(Rs. ha^{-1})	(Rs. ha^{-1})	ratio
T_1	$N_0P_0K_0$	$N_0P_0K_0$	55397	26492	-28905	-0.52
T_2	50% RDF	50% RDF	59264	72580	13316	0.22
T_3	50% RDF	100% RDF	61505	103715	42210	0.68
T_4	75% RDF	75% RDF	61198	101896	40698	0.66
T_5	100% RDF	100% RDF	63131	135180	72049	1.14
T_6	50% N through FYM + 50% RDF	100% RDF	79231	153117	73886	0.93
T_7	25% N through FYM + 75% RDF	75% RDF	70061	140288	70227	1.01
T_8	50% N through WS + 50% RDF	100% RDF	66595	145186	78591	1.18
T_9	25% N through WS + 75% RDF	75% RDF	63743	136543	72800	1.14
T_{10}	50% N through GM + 50% RDF	100% RDF	66154	150533	84379	1.27
T_{11}	25% N through GM + 75% RDF	75% RDF	62929	139857	76928	1.22
T_{12}	FP ($N_{70}P_{30}K_{10}$)	FP ($N_{80}P_{30}K_{15}$)	60150	90850	30700	0.51
	SEm(±)		-	4466	1906	0.02
	CD at 5%		-	12657	5401	0.07

RDF: Recommended dose of fertilizer, WS: Wheat straw GM: Green manure, FP: Farmers' practice.

Table 3: Effect of *Sesbania aculeata* practice on Chemical properties of soil.

	Treatments		pH	EC (dSm^{-1})	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
	Rice	Wheat	2015-16	2015-16	2015-16	2015-16	2015-16	2015-16
T_1	$N_0P_0K_0$	$N_0P_0K_0$	7.37	0.28	0.34	115.60	13.80	105.20
T_2	50% RDF	50% RDF	7.34	0.28	0.39	142.10	19.40	111.35
T_3	50% RDF	100% RDF	7.32	0.28	0.45	154.45	32.55	118.45
T_4	75% RDF	75% RDF	7.30	0.28	0.48	161.45	36.65	121.30
T_5	100% RDF	100% RDF	7.28	0.28	0.54	168.55	40.60	128.90
T_6	50% N through FYM+50% RDF	100% RDF	7.21	0.25	0.79	232.85	50.60	176.50
T_7	25% N through FYM+75% RDF	75% RDF	7.25	0.28	0.74	214.50	44.80	160.70
T_8	50% N through WS+50% RDF	100% RDF	7.22	0.27	0.77	226.20	48.60	197.00
T_9	25% N through WS+75% RDF	75% RDF	7.27	0.26	0.72	207.95	43.15	177.75
T_{10}	50% N through GM+50% RDF	100% RDF	7.24	0.28	0.78	230.60	49.10	172.15
T_{11}	25% N through GM+75% RDF	75% RDF	7.27	0.26	0.73	214.00	45.05	162.15
T_{12}	FP ($N_{70}P_{30}K_{10}$)	FP ($N_{80}P_{30}K_{15}$)	7.36	0.27	0.46	140.80	26.45	116.05
	SEm(±)		0.10	0.01	0.01	2.41	0.78	2.41
	CD at 5%		0.28	0.02	0.03	6.82	2.21	6.84
	Initial value (1984-85)		7.40	0.29	0.46	194.0	23.0	155.0

RDF: Recommended dose of fertilizer, WS: Wheat straw GM: Green manure, FP: Farmers' practice.

Table 4: Effect of *Sesbania aculeata* practice on microbial population (pooled).

	Treatments Rice	Wheat	Bacteria ($x10^4$ g^{-1} of soil) 2015-16	Fungi ($x10^4$ g^{-1} of soil) 2015-16	Actinomycetes ($x10^4$ g^{-1} of soil) 2015-16
T_1	$N_0P_0K_0$	$N_0P_0K_0$	327.95	49.35	162.65
T_2	50% RDF	50% RDF	443.95	83.25	221.25
T_3	50% RDF	100% RDF	436.70	82.90	236.25
T_4	75% RDF	75% RDF	480.15	74.45	252.05
T_5	100% RDF	100% RDF	498.05	92.05	269.85
T_6	50% N through FYM + 50% RDF	100% RDF	649.80	105.95	350.90
T_7	25% N through FYM + 75% RDF	75% RDF	576.40	83.65	280.25
T_8	50% N through WS + 50% RDF	100% RDF	558.20	77.50	290.65
T_9	25% N through WS + 75% RDF	75% RDF	480.80	66.60	259.45
T_{10}	50% N through GM + 50% RDF	100% RDF	614.95	98.55	311.05
T_{11}	25% N through GM + 75% RDF	75% RDF	569.30	78.55	274.65
T_{12}	FP($N_{70}P_{30}K_{10}$)	FP($N_{80}P_{30}K_{15}$)	427.80	53.30	198.05
	SEm(±)		9.03	1.20	6.00
	CD at 5%		25.60	3.40	16.98

RDF: Recommended dose of fertilizer, WS: Wheat straw GM: Green manure, FP: Farmers' practice.

Increase in available P_2O_5 in organo – inorganic combinations might be due to the mineralization of organic matter accompanied by the release of appreciable quantities of CO_2 which when dissolved in water, forms carbonic acid which is capable of decomposing certain primary minerals which might increase availability of P_2O_5. Higher potassium content in wheat straw than other sources might have been the possible reason for higher residual K in the soil. At the current level of productivity, the K uptake must have been much higher than its application, but still the charges in available K_2O after continuous rice-wheat cropping was of smaller magnitude probably because the crop requirement of K was largely met with non- exchangeable pool of soil (Sepehya *et al.*, 2012). Similar results was reported in different types of soils of India by Maurya *et al*. (2014).

Sesbania aculeata was helpful in getting the highest net returns as well as B: C ratio. The requirement of *Sesbania aculeata* can be met with seed production of *Sesbania aculeata* Soil biologia as envisaged through the population of bacteria, actinomycetes and fungi in experimental plot showed that substitution of inorganic fertilizers through organic manure in the proportion of 50% were instrumental in raising the microbial density significantly over the years. Pronounced effects of *Sesbania aculeata* on all the microbes may be explained in the light of the fact that both the amendments were of low C:N ratio, which induced a positive effect on microbial community. The availability of higher organic carbon and available N under the influence of these amendments might have enhanced the count of bacteria, actinomycetes and fungi whereas the effect of wheat straw was not so notable due to its higher C:N ratio. Application of balanced NPK or integrated nutrient management practices in rice had a stimulating influence on the microbial population as well as soil respiration due to proliferation of root exudates and addition of root biomass which increased carbon substrate for microbial growth. These results were in conformity with the findings of Singh *et al*. (2015).

CONCLUSION

It may be summarized as *Sesbania aculeata* can be used as a viable and cost effective alternative through partial substitution of inorganic fertilizers to enhance the soil health and productivity of rice-wheat system.

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