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Performance of Basmati rice as influenced by green manuring and sulphur fertilization

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ABSTRACT

Basmati rice (*Oryza sativa* L.) cultivation is mainly confined to the Himalayan foothill belt of Indo-Gangetic plains owing to its specific climatic requirement for its quality. Green manuring and sulphur fertilization play an essential role for sustaining productivity and maintaining grain quality. A two-year field experiment was conducted at the research farm of the ICAR–Indian Agricultural Research Institute, New Delhi, India, during *kharif* (June–November) 2018–19. The experiment was conducted in a split-plot design with two green manure crops such as dhaincha (*Sesbania aculeata*), sunhemp (*Crotalaria juncea*) and control in the main-plot and sulphur fertilization such as 20 kg S/ha to rice, 40 kg S/ha to rice, 20 kg S/ha to wheat, 40 kg S/ha to wheat, 20 kg S/ha both to rice and wheat, 40 kg S/ha both to rice and wheat, and control (no sulphur) in the sub-plots with three replications. Dhaincha green manuring recorded the highest yield attributes with 47 more effective tillers/m^2, panicle length by 1.50 cm, panicle weight by 0.21 g, and numbers of filled grains by 7 compared to control. It was also recorded 22% more grain yield and higher monetary returns with a higher B:C ratio of 1.27. Application of 40 kg S/ha both to rice and wheat showed maximum Basmati rice yield attributes, higher productivity, which was statistically at par with 40 kg S/ha to rice. However, from an economic point of view 40 kg S/ha was recorded more monetary returns and average two-year extra-net returns of ₹11.784 × 10^3/ha than control and higher B:C ratio 1.21. Applying sulphur at 40 kg/ha to Basmati rice is recommended to harvest more yield and fetch additional monetary returns.

Key words: Economics, Productivity, *Sesbania* green manuring, Sulphur, Yield attributes

Basmati rice cultivation is mainly confined to Indo-Gangetic plains of the foothill of Himalayan for its specific climatic requirement for grain quality. In India, it is grown exclusively in the northern part of India (FAO 2015), and contributes the largest producer and exporter of Basmati rice. India has exported around 4.5 million metric tonnes of Basmati rice to the world worth ₹32.8 thousand crores during 2018–19 (APEDA 2019). Green manuring improved soil physical properties such as soil water retention and aggregate stability (Bhaduri *et al.* 2018), enhanced microbial community activities (Chen *et al.* 2017) and soil health (Sahu *et al.* 2017), which may sustain crop productivity. Besides, incorporating green manures to *kharif* rice increases the availability of N, P, K and S in the soil (Ehsan *et al.* 2014). Therefore, identifying suitable green manure crops for Basmati rice is an important task that sustains crop productivity and maintains soil health.

Sulphur is the fourth major plant nutrient after N, P and K. In India, 46% of soil is under sulphur deficiency, and 30% of soil is potentially deficient as reported based on the TSI-FAI-IFA project (1997–2006) in the ICAR system (TSI 2020). Generally, sulphur is applied to crop fields either as a secondary nutrient present in major fertilizers or as a component of micronutrients or as sulphur fertilizers (Prasad 2007). Shivay *et al.* (2014) reported that response to S application was obtained up to 45 kg S/ha in bentonite-S for higher productivity and better quality of rice. However, Khurana *et al*. (2008) found a response of sulphur in rice up to 42 kg/ha in India. In this context, there is a lack of information on the conjunctive use of green manuring and sulphur in Basmati rice production. Therefore, a study was undertaken to find out suitable green manure crop and an optimum sulphur dose, which are economically feasible and profitable for the good quality of Basmati rice production.

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MATERIALS AND METHODS

A field experiment was conducted at the research farm of ICAR–Indian Agricultural Research Institute, New Delhi, India, during *kharif* (June–November) 2018–19. The Institute farm is located at the latitude of 28°38′ N and longitude of 77°10′ E at an altitude of 228.6 meters above the mean sea level. The mean annual rainfall of the area is 650 mm and received more than 80% during the south-west monsoon (July–September), with mean annual evaporation is 850 mm. The mean annual minimum and maximum temperatures are 18°C and 35°C, respectively.

The experimental field soil was clay in texture, having sand (11.84%), silt (36.0%) and clay (52.16%). The soil had 175.9 kg/ha alkaline permanganate oxidizable nitrogen, 16.84 kg/ha available phosphorus, 320.0 kg/ha 1 N ammonium acetate potassium, 8.76 mg/kg available sulphur and 0.67% organic carbon. The *p*H of the soil was 7.77 and electrical conductivity was 0.45 dS/m in 1: 2.5 soil and water ratio. The experiment was conducted in a split-plot design with two green manure crops such as dhaincha (*Sesbania aculeata* Pers.), sunhemp (*Crotalaria juncea* L.) and a control in the main plots, and sulphur fertilization such as 20 kg S/ha to rice, 40 kg S/ha to rice, 20 kg S/ha to wheat, 40 kg S/ha to wheat, 20 kg S/ha both to rice and wheat, 40 kg S/ha both to rice and wheat, and control (no sulphur) in subplots with three replications. Bentonite-S (90% S) was used as a sulphur source. The green manure crops were sown during the third week of May in the respective years and incorporated at 45 days after sowing. The recommended dose of $N:P_2O_5:K_2O$ was applied at 110:60:40 kg/ha in the form of urea, diammonium phosphate, and murate of potash. Nitrogen was applied in 3 split as $1/3^{rd}$ as basal, $1/3^{rd}$ at 50% tillering and rest $1/3^{rd}$ at the panicle initiation stage. Phosphorus, potash, and sulphur were applied as basal by broadcasting. Two to three 25 days old seedling of rice variety Pusa Basmati 1637 was transplanted at a spacing of 20 cm × 15 cm in the first fortnight of July in *Kharif* 2018–19. Other cultural operations were carried out followed by recommended package of practices. Harvesting of Basmati rice was carried out when it attained physiological maturity. Rice grain yield and straw yield were taken from the net plot demarcated and converted into t/ha, and yield attributes were recorded from the rest portion of the plot. The grain yield of rice was recorded with moisture content adjusted to 14%. Harvest index was calculated using grain yield divided by biological yield and multiplied by 100. The costs of cultivation of various treatments were calculated based on the prevailing market prices of inputs in the local market. Gross returns were calculated by multiplying Basmati rice grain and straw yield with prevalent market prices in the local area in respective years. The net returns were calculated by subtracting the total cost of cultivation from the gross returns of the respective treatments. The benefit: cost ratio (B: C) was calculated by the net returns divided by the cost of cultivation. Statistical analysis was performed by a window-based SAS 9.3 program. Least significant difference (LSD) values at a 5% level of significance were used to determine the significance of differences between treatment means.

RESULTS AND DISCUSSION

Yield attributes: Yield attributes of Basmati rice were significantly different by green manuring crops and sulphur fertilization (Table 1). Dhaincha as green manuring recorded the highest effective tillers, panicle length, panicle weight, filled grains weight per panicle, number of filled grains/panicle and 1000–grains weight, and lowest non-effective tillers and non-filled grains per panicle (Table 1). The average two years' data in dhaincha green manuring recorded approximately 47 more effective tillers/m^2 than control, and panicle length by 1.5 cm, panicle weight by 0.21 g and numbers of filled grains/panicle by 7. Leguminous green manure with a low C/N ratio often is resulting in high and rapid mineralization that enhances crop growth and yield attributes of rice (Islam *et al*. 2019, Zhou *et al*. 2020). Also, dhaincha fixed more atmospheric N_2 and accumulated the highest dry matter than sunhemp that in turn added more nutrients to the soil and supplied to succeeding Basmati rice crop for better growth and resulted in the highest yield.

Application of 40 kg S/ha to both rice and wheat recorded the highest effective tillers, panicle length (cm), panicle weight (g), filled grains weight (g)/panicle and number of filled grains/panicle and remained statistically at par with 40 kg S/ha to rice (Table 1). It is clear that, the cumulative and direct effect of 40 kg S/ha was showed similar results. Application of 40 kg S/ha to both rice and wheat recorded significantly higher panicle length (32.5 cm), panicle weight (3.95 g), filled grains weight/panicle (2.59 g) and numbers of filled grains/panicle (135.4) and remained statistically at par with 40 kg S/ha to rice. Sulphur is known to have synergistic interaction with almost all essential macronutrients, secondary nutrients, and micronutrients (Abdin *et al*. 2003). These positive interactions might have enhanced nutrient uptake, which improved crop growth and in turn recorded the highest yield attributes and yields with the application of 40 kg S/ha.

Productivity: Basmati rice productivity was significantly influenced by green manuring crops and sulphur fertilization (Table 2). Two years' average grain yield with the incorporation of dhaincha green manuring recorded by 4.55 t/ha and sunhemp green manuring by 4.48 t/ha which was 22% and 20% higher compared to control. The highest straw yield was also recorded with the incorporation of dhaincha green manuring with addition to 0.54 t/ha straw more compared to control. Harvest index of Basmati rice was significantly higher (30%) in dhaincha green manuring than in control (27%). Higher productivity in dhaincha green manuring plots might be due to maximum yield attributes recorded than other treatments. Singh and Shivay (2015) reported that green manuring with *Sesbania aculeata* (Dhaincha) in Basmati rice grain yield was increased by 13.97% over control.

Sulphur fertilization enhances crop physiological activity and growth which in turn increase the performance of crop for better yield (Haque *et al*. 2015). Application of 40 kg S/ha recorded higher grain yield, straw yield and harvest index (Table 2). In 2018, 40 kg S/ha recorded 0.40 t/ha and 0.84 t/ha additional grain and straw yields, respectively, compared to control. The percentage of increase in grain yield was by 9.9% with application of 40 kg S/ha to rice over control. In 2019, the direct, residual and cumulative effect of S fertilization was prominent. The cumulative effect of 40 kg S/ha to both rice and wheat recorded higher grain yield (4.50 t/ha) and straw yield (10.57 t/ha), and remained statistically at par with the direct effect of 40 kg S/ha to

Table 1 Effect of summer green manuring crops and sulphur fertilization on yield attributes of Basmati rice

Treatment	Effective tillers/m^2		Non-effective tillers/m^2		Panicle length (cm)		Panicle weight (g)		Filled grains weight (g)/panicle		Filled grains/panicle (Nos.)		Non-filled grains/panicle (Nos.)		1000-grains weight (g)	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Green manuring crops																
Control	389.9	415.9	104.6	58.7	30.6	30.8	3.60	3.63	2.23	2.27	121.0	121.2	54.3	57.7	19.66	19.85
Dhaincha	441.3	458.9	87.0	34.9	32.1	32.3	3.78	3.87	2.46	2.51	127.1	129.3	51.7	47.5	19.79	19.86
Sunhemp	431.6	442.6	93.3	49.0	31.7	32.2	3.74	3.84	2.37	2.47	123.3	126.1	52.8	52.8	19.80	19.73
SEm±	2.44	2.70	2.08	1.82	0.20	0.18	0.04	0.06	0.03	0.07	1.60	0.68	0.40	0.62	0.12	0.14
LSD (P=0.05)	9.57	10.61	8.53	7.16	0.78	0.70	0.16	0.22	0.10	0.27	6.27	2.67	1.59	2.43	NS*	NS
Sulphur fertilization																
Control	373.0	399.4	103.8	55.6	31.1	31.2	3.48	3.49	2.20	2.21	114.3	116.9	58.2	61.1	19.41	19.77
20 kg S/ha to rice	425.6	444.6	91.1	52.2	31.7	31.8	3.80	3.83	2.45	2.45	122.9	123.1	49.3	50.6	19.45	19.56
40 kg S/ha to rice	456.7	465.8	86.5	40.7	32.2	32.3	3.98	3.93	2.46	2.52	133.5	134.2	48.6	49.5	19.87	20.34
20 kg S/ha to wheat	401.1	412.3	99.6	55.3	31.0	31.4	3.47	3.64	2.21	2.30	117.2	120.1	58.7	57.2	19.44	19.59
40 kg S/ha to wheat	399.8	421.0	104.8	55.6	30.4	31.5	3.45	3.72	2.26	2.39	119.4	122.5	57.9	52.2	19.99	19.77
20 kg S/ha to both rice + wheat	433.6	449.1	94.8	40.5	31.6	31.7	3.87	3.89	2.44	2.47	125.5	126.4	49.1	49.8	20.21	19.89
40 S kg/ha to both rice + wheat	457.0	481.7	84.4	33.0	32.4	32.5	3.90	3.95	2.46	2.59	134.1	135.4	48.7	48.3	19.88	19.77
SEm±	5.61	5.08	2.06	1.17	0.25	0.21	0.08	0.06	0.07	0.06	1.66	1.73	0.80	0.89	0.21	0.20
LSD (P=0.05)	16.08	14.58	5.92	3.36	0.71	0.61	0.22	0.17	0.20	0.17	4.75	4.97	2.30	2.56	NS	NS
Interaction effect	S**	S	NS	NS	NS	NS	S	S	NS	NS	NS	NS	NS	NS	NS	NS

NS*, Non-significant; S**, Significant

Table 2 Effect of summer green manuring crops and sulphur fertilization on productivity and harvest index of Basmati rice

Treatment	Grain yield (t/ha)		Straw yield (t/ha)		Harvest index (%)		Cost of cultivation (×10^3 ₹/ha)		Net returns (× 10^3 ₹/ha)		B:C ratio	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Green manuring crops												
Control	3.73	3.74	9.94	9.97	27.23	27.30	67.90	67.90	62.68	62.98	0.93	0.93
Dhaincha	4.49	4.59	10.34	10.74	30.39	29.98	68.04	68.04	84.70	88.18	1.24	1.30
Sunhemp	4.43	4.52	10.07	10.44	30.63	30.24	68.29	68.29	81.78	85.13	1.20	1.25
SEm±	0.07	0.04	0.06	0.11	0.31	0.34	–	–	1.81	1.16	0.03	0.02
LSD (P=0.05)	0.26	0.17	0.24	0.42	1.21	1.33	–	–	7.10	4.57	0.10	0.07
Sulphur fertilization												
Control	4.12	4.03	9.54	9.57	29.45	29.62	66.21	66.21	70.63	71.30	1.06	1.07
20 kg S/ha to rice	4.20	4.28	9.98	10.34	29.79	29.21	67.28	67.28	77.29	79.39	1.15	1.18
40 kg S/ha to rice	4.25	4.46	10.10	10.51	30.58	29.72	68.34	68.34	82.04	83.51	1.20	1.22
20 kg S/ha to wheat	4.22	4.16	9.68	10.04	29.80	29.23	66.21	66.21	74.38	76.16	1.12	1.15
40 kg S/ha to wheat	4.03	4.18	9.85	10.37	29.03	28.68	66.21	66.21	72.28	77.88	1.09	1.17
20 kg S/ha to both rice + wheat	4.24	4.39	10.68	10.78	28.32	28.87	70.61	70.61	75.94	80.22	1.09	1.15
40 S kg/ha to both rice + wheat	4.47	4.50	11.00	11.06	28.93	28.89	71.68	71.68	82.15	82.89	1.15	1.17
SEm±	0.07	0.07	0.11	0.16	0.39	0.54	–	–	1.87	1.95	0.03	0.03
LSD (P=0.05)	0.19	0.21	0.31	0.45	1.11	1.56	–	–	5.35	5.58	0.08	0.08
Interaction effect	NS*	NS	NS	NS	NS	NS	–	–	NS*	NS	S**	S

NS*, Non-significant; S**, Significant

rice. The percentage of increase in grain yield with the cumulative effect of rice was 11.7% and the direct effect of 40 kg S/ha was 10.7% over control. Harvest index of rice was recorded higher i.e. 30.0% and 29.9% in 2018 and 2019, respectively with a direct effect of 40 kg S/ha to rice. Our findings are in conformity with Shivay *et al.* (2014). It was also reported that sulphur application increased rice yield from 5–51% (Biswas *et al*. 2004).

Economics: Costs of cultivation for green manuring and sulphur fertilization were different due to its inputs were different among treatments (Table 2). Costs of cultivation between green manuring crops were higher in sunhemp (₹ 68.30 × 10^3 /ha). However, the net returns, and B:C ratio was significantly higher in dhaincha green manuring compared to control during both years. Additional average two years' net returns were ₹ 23.69 × 10^3/ha and ₹ 23.55 × 10^3/ha, in dhaincha and sunhemp, respectively compared to control. Highest B:C ratio (1.24 in 2018 and 1.30 in 2019) was recorded in dhaincha green manuring. This might be due to the highest grain and straw yields were recorded in dhaincha green manuring crop incorporation that in turn resulted in higher monetary returns. A similar finding was also reported by Pooniya and Shivay (2012).

Among different sulphur fertilization treatments, net returns and B:C ratio was significantly different (Table 2). The highest net returns were recorded with application of 40 kg S/ha applied to both rice and wheat and remained statistically at par with 40 kg S/ha to rice in both years (Table 2). However, average two-years net returns were highest with 40 kg S/ha to rice (₹ 82.77 × 10^3/ha) followed by 40 kg S/ha both to rice and wheat (₹ 82.52 × 10^3/ha) which in turn fetched additional ₹ 11.78 × 10^3/ha with 40 kg S/ha to rice and ₹ 11.54 × 10^3/ha with 40 kg S/ha both to rice and wheat than control. B:C ratio was significantly higher with 40 kg S/ha to rice during both years than rest of the treatments (Table 2). The average two-years B:C ratio was 1.21 with 40 kg S/ha. Higher net returns and B:C ratio was recorded in 40 kg S/ha to rice as compared to 40 kg S/ha to both rice and wheat which might be due to the cost of cultivation was lower in previous treatment compared to later, which differed by ₹ 3,333/ha. Thus, the application of 40 kg S/ha to rice was more beneficial than the rest of the treatments. However, Singh *et al*. (2013) recorded the highest B:C ratio with the application of 20 kg S/ha to rice.

It can be concluded that practicing summer *Sesbania* green manuring was beneficial for harvesting additional Basmati rice yield and application of 40 kg S/ha to Basmati rice can be recommended for increased yield attributes, productivity and economics.

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