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On-farm trials of the effect of introducing a summer green manure of mungbean on the productivity of a rice–wheat cropping system

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SUMMARY

Fourteen field trials were conducted on farmers' fields in five villages of the Union Territory of Delhi, India during 1995–96 and 1996–97 to study the effect of introducing a crop of summer mungbean on the productivity of a rice–wheat cropping system. Timely sown summer mungbean yielded 0·4–1·3 t/ha protein-rich grain and, on average, increased rice yields by 0·5–0·9 t/ha and the yields of the succeeding wheat by 0·4–0·7 t/ha. The yield response of rice to the summer mungbean crop was greater when less urea-N fertilizer was applied, and N applied to the rice did not decrease the residual effect of the summer mungbean on the succeeding wheat. The increase in total productivity of rice–wheat cropping system due to summer mungbean ranged from 0·3 to 2·6 t/ha with an average of 1·6 t/ha.

INTRODUCTION

Rice–wheat cropping systems are used on 22 million hectares in India, Pakistan, Nepal, Bangladesh and China. In India, they are used on 10 million hectares and form the mainstay of India's self-sufficiency in food. However, the sustainability of this highly productive cropping system (10–15 t/ha/year) has been questioned (Singh & Paroda 1994). Grain yields of rice have declined in some long-term rice–wheat cropping experiments in India (Nambiar 1995). Fujisaka *et al*. (1994) reported that increased rates of fertilizer are needed to maintain the current yield levels of rice–wheat cropping system. Our earlier studies (Singh *et al*. 1990) indicated that green manuring in summer can partly meet the nitrogen requirement of a rice–wheat cropping system and may sustain it. This practice has not found favour with the farmers because there is no direct monetary return from the green manure crops. Research at the Indian Agricultural Research Institute has shown the benefits of growing a dual-purpose, short duration (60 days) crop of summer mungbean from which the grain can be harvested for protein and the residue incorporated as green manure in the summer (May–June) prior to transplanting the rice crop. The work showed that mungbeans were capable of producing 0·5–1·1 t/ha protein-rich grain and its residues benefited the following rice and a succeeding wheat crop (Sharma *et al*. 1995; Sharma & Prasad 1999). The use of mungbean residues in the rice–wheat cropping system was equivalent to the use of 30–120 kg urea-N/ha. The present paper reports results of on-farm trials to extend this research.

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MATERIALS AND METHODS

Fourteen on-farm trials were conducted during the 1995–96 and 1996–97 growing seasons in five villages of Alipur region of the Union Territory of Delhi, India. The soil of all the fields where trials were conducted was a sandy clay loam. Soil characteristics of the fields (Table 1) indicate that soils were sodic (pH 8·1 to 8·4). Electrical conductivity of the soils (0–30 cm layer) was only 0·35 to 1·0 dS/m. The soils were low in organic C (0·36–0·94%), and low to high in 0·5 M $NaHCO_3$ extractable P (7·2 to 85·5 kg/ha) and 1 N CH_3COONH_4 extractable K (78–448 kg/ha).

Each trial occupied 0·4 ha divided into two equal 0·2 ha plots. In summer, one plot was sown with mungbean and the other left fallow. The mungbean was sown between 24 April and 11 May in 1995, and between 20 April and 5 May in 1996 (Table 1). In 1995, mungbean cultivar PS 16 was sown in trials 2, 3, 4 and 5, and KS 851 in the rest. In 1996, all the trials were sown with PS 16 or with its improved lines. Mungbean received 18 kg P/ha as diammonium phosphate. Crops sown after 5 May failed to mature

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Table 1. *Chemical properties of soil at the start of study and dates of sowing/transplanting of different crops*

Trial No.	Chemical properties of soil (0–30 cm depth) pH	EC (dS/m)	OC (%)	Available P* (kg/ha)	Available K** (kg/ha)	Dates of sowing: Mungbean 1995	Mungbean 1996	Rice 1995	Rice 1996	Wheat 1995–96	Wheat 1996–97
1	8·3	0·50	0·61	18·9	95	May 9	April 20	July 27	July 15	Nov 28	Nov 20
2	8·1	1·00	0·94	42·3	112	April 24	May 1	July 9	July 7	Nov 16	Nov 16
3	8·3	0·55	0·59	19·8	101	April 25	April 24	July 22	July 9	Nov 20	Nov 25
4	8·2	0·50	0·57	27·0	179	May 5	April 20	July 27	July 15	Dec 5	Dec 7
5	8·1	0·35	0·54	85·5	106	May 5	April 20	July 27	July 22	Dec 5	Dec 8
6	8·2	0·60	0·38	10·8	101	May 11	May 4	July 17	July 10	Nov 25	Nov 28
7	8·3	0·70	0·67	22·5	134	May 11	May 7	July 17	July 10	Nov 25	Nov 28
8	8·2	0·60	0·52	85·5	146	May 7	April 28	July 17	July 12	Dec 7	Dec 10
9	8·3	0·90	0·52	7·2	448	May 9	May 5	July 14	July 12	Dec 10	Dec 8
10	8·1	0·70	0·59	18·0	118	May 7	NC	July 1	NC	Nov 17	NC
11	8·4	0·60	0·54	22·5	134	May 10	NC	July 3	NC	Nov 18	NC
12	8·3	0·45	0·36	22·5	78	May 10	May 5	July 20	July 17	Dec 11	Dec 10
13	NA	NA	NA	NA	NA	NC	April 24	NC	July 10	NC	Nov 25
14	NA	NA	NA	NA	NA	NC	April 24	NC	July 11	NC	Nov 26

* 0·5 M $NaHCO_3$ extractable, ** 1 N CH_3COONH_4 exchangeable; EC: electrical conductivity, OC: organic carbon, NC: not conducted, NA: not analysed.

and were not harvested for grain but were ploughed-in as a green manure. In trials in which the mungbeans matured, the pods were collected by hand and the crop residues were incorporated into soil as green manure.

During the following rainy season, the fallow and mungbean plots were both divided into two equal 0·1 ha subplots into which rice was transplanted. One subplot was fertilized with 60 kg N/ha and the other with 120 kg N/ha in 1995–96. In 1996–97, only one rate of nitrogen (90 kg N/ha) was applied to the rice plots. The rice variety Pusa Basmati 1 was grown in most of the trials. The cultivar Madhu was sown in trial 2 and Haryana Basmati 1 in trials 3, 6, and 7 in 1995 and in trial 11 in 1996. To grow the rice, each plot was flooded with water, tilled with a tractor-drawn cultivator and levelled with a wooden plank. At the final puddling, 20 kg P/ha was applied to each plot as diammonium phosphate, together with 30 kg K/ha as muriate of potash and 4 kg Zn/ha as zinc sulphate heptahydrate. Two to three seedlings per hill (25–40 days old) were transplanted between 1 and 27 July in 1995 and 7 and 12 July in 1996 (Table 1). The nitrogen treatments were applied as prilled urea in two equal dressings, the first 10 days and second 30 days after transplanting. Adjustments were made for the N supplied in the initial phosphate fertilizer. The rice crops were harvested during the first fortnight of November.

Plots were irrigated after harvesting rice and, when workable, the soil was disced twice and then levelled with a wooden plank. Basal fertilizers containing 40 kg N/ha, 20 kg P/ha and 30 kg K/ha were applied at final discing. Wheat varieties HD 2329 and CPAN 3004 were sown in the second fortnight of November in trials 1, 2, 3, 6, 7, 10, 12, 13 and 14, whereas a late sown variety, HD 2285, was sown during the first fortnight of December in trials 4, 5, 8, 9 and 11. Wheat was harvested during the second and third weeks of April. Grain yield data of rice and wheat were analysed by the procedure suggested by Gomez & Gomez (1984) using individual trials as replicates.

RESULTS AND DISCUSSION

Mungbean

The sowing of summer mungbean was delayed in 1995 and the crop sown after May 5 failed to mature and was incorporated as a green manure (Table 2). When sown at the appropriate time, the yield of summer mungbean ranged from 0·6 to 1·1 t/ha (Table 2). In 1996, the summer mungbean matured in all fields before the rice needed to be transplanted and yields ranged from 0·4–1·3 t/ha with an average of 0·7 t/ha (Table 2). Sharma *et al.* (1995) also reported a yield range for summer mungbean of 0·5 to 1·1 t/ha. Early sown crops produced higher yields than late sown crops (Tables 1 and 2).

Rice

Grain yields of rice were significantly greater when grown after summer mungbeans than after a fallow in both the years (Table 2). In 1995, the increase in rice yield produced with summer mungbean incorporation

Table 2. *Productivity* (*t*/*ha*) *of rice–wheat cropping system as influenced by summer mungbean*

			1995–96						1996–97			
			Rice		Wheat		Total					
			N level to rice (kg/ha)		N level to rice (kg/ha)		N level to rice (kg/ha)					
Trial No.	Summer crop	Mung	60	120	60	120	60	120	Mung	Rice	Wheat	Total
1	Fallow	—	3·8	2·6	4·1	4·1	7·9	6·7	—	4·0	4·1	8·0
	Mung	NM	5·2	2·7	4·5	4·5	9·7	7·2	0·7	4·6	4·6	9·9
2	Fallow	—	3·3	3·6	4·2	4·3	7·5	7·9	—	4·2	4·2	8·4
	Mung	1·1	3·4	3·6	4·8	4·7	9·3	9·4	0·4	4·8	4·6	9·8
3	Fallow	—	4·3	4·8	4·6	4·6	8·9	9·4	—	5·1	3·8	8·9
	Mung	0·7	4·9	5·8	5·3	5·3	10·9	11·8	0·9	5·3	4·5	10·7
4	Fallow	—	1·3	1·1	4·2	4·6	5·5	5·7	—	4·4	5·0	9·4
	Mung	0·6	1·6	2·0	5·1	5·6	7·3	8·2	1·3	5·4	5·3	12·0
5	Fallow	—	0·7	0·9	3·3	3·7	4·0	4·6	—	3·4	3·5	6·9
	Mung	0·6	1·4	1·2	3·5	4·0	5·5	5·8	1·3	3·8	3·9	9·0
6	Fallow	—	3·6	4·4	4·4	4·4	8·0	8·8	—	4·7	4·0	8·7
	Mung	NM	4·9	4·9	5·6	5·6	10·5	10·5	0·4	5·6	4·3	10·3
7	Fallow	—	3·8	4·2	4·2	4·2	8·0	8·4	—	5·6	4·2	9·8
	Mung	NM	4·9	4·9	5·3	5·3	10·2	10·2	0·4	5·6	4·6	10·6
8	Fallow	—	1·7	2·5	3·5	4·1	5·2	6·6	—	4·8	4·4	9·2
	Mung	NM	2·8	3·2	3·8	4·8	6·6	8·0	0·6	4·9	4·7	10·2
9	Fallow	—	3·2	3·4	3·7	4·3	6·9	7·7	—	4·1	4·1	8·2
	Mung	NM	3·9	3·6	4·0	4·4	7·9	8·0	0·4	4·0	4·3	8·7
10	Fallow	—	2·9	3·0	4·1	4·1	7·0	7·1	NC	NC	NC	NC
	Mung	NM	4·0	3·7	5·0	5·0	9·0	8·7	NC	NC	NC	NC
11	Fallow	—	3·1	3·1	4·1	4·1	7·2	7·2	NC	NC	NC	NC
	Mung	NM	4·0	3·1	5·0	5·0	9·0	8·1	NC	NC	NC	NC
12	Fallow	—	3·1	3·6	3·3	3·6	6·4	7·2	—	2·9	4·1	7·0
	Mung	NM	4·5	4·7	3·8	4·2	8·3	8·9	0·4	3·9	4·3	8·6
13	Fallow	NC	NC	NC	NC	NC	NC	NC	—	4·5	4·1	8·6
	Mung	NC	NC	NC	NC	NC	NC	NC	1·2	4·9	4·8	10·9
14	Fallow	NC	NC	NC	NC	NC	NC	NC	—	4·0	3·8	7·8
	Mung	NC	NC	NC	NC	NC	NC	NC	0·7	4·8	4·5	10·0
Mean	Fallow	—	2·9	3·1	4·0	4·2	6·9	7·3	—	4·3	4·1	8·4
	Mung	0·8	3·8	3·6	4·6	4·9	8·7	8·7	0·7	4·8	4·5	10·0
	S.E.	—	0·50		0·21		0·59		—	0·27	0·13	0·45
	D.F.	—	22		22		22		—	11	11	11

NM: not matured due to delay in sowing, NC: not conducted.

over the fallow ranged from 0·1 to 1·4 t/ha with an average of 0·9 t/ha with 60 kg N/ha, and from 0 to 1·1 t/ha with an average of 0·5 t/ha with 120 kg N/ha (Table 2). The application of 120 kg N/ha produced significantly higher yields of rice than with 60 kg N/ha after a fallow, but not after a summer crop of mungbean (Table 2). This suggests that the mungbean residues could have supplied the equivalent of 60 kg N/ha. Sharma *et al*. (1995) and Sharma & Prasad (1999) reported a nitrogen saving of 30–120 kg N/ha by incorporation of summer mungbean residues in experiments at the research farm of the Indian Agricultural Research Institute, New Delhi. In 1996, a beneficial effect of a summer crop of mungbean over fallow was obtained in 10 out of 12 trials and the increase in rice yield due to summer mungbean over fallow ranged from 0.1 to 1 t/ha with an average of 0·5 t/ha (Table 2).

Wheat

A residual effect of summer mungbean was also observed on succeeding wheat yield. The yield increase in wheat due to summer mungbean over fallow ranged from 0·2 to 1·2 t/ha with an average of 0·7 t/ha in 1995–96 (Table 2) and from 0·2 to 0·7 t/ha with an average of 0·4 t/ha in 1996–97 (Table 2). These results are in accord with those of Sharma & Prasad (1999) who reported that the indirect and direct residual effects of *Sesbania* green manuring and mungbean residue incorporation were similar in rice, and that incorporation of mungbean residues increased the yields of succeeding wheat. Fertilizer nitrogen applied to rice had no significant residual effects on the succeeding wheat crop nor on the residual effect of summer mungbean residues on those wheats (Table 2).

Total productivity

Green manuring with summer mungbean increased the total productivity of the rice–wheat cropping system over use of a fallow by 1·0–2·5 t/ha with an average of 1·8 t/ha when 60 kg N/ha was applied and by 0·3–2·5 t/ha with an average of 1·4 t/ha with 120 kg N/ha in 1995–96 (Table 2). In 1996–97, the increase in total productivity of rice–wheat cropping system due to summer mungbean ranged from 0·5 to 2·6 t/ha with an average of 1·6 t/ha (Table 2).

Using summer growing mungbean as a green manure therefore sustains the productivity of a rice–wheat cropping system besides producing on average 0·7–0·8 t/ha of a protein-rich pulse grain.

REFERENCES

GOMEZ, K. A. & GOMEZ, A. A. (1984). *Statistical Procedures for Agricultural Research*. New York:: John Wiley & Sons.

FUJISAKA, S., HARRINGTON, L. & HOBBS, P. (1994). Rice–wheat in South Asia: System and long term practices established through diagnosis research. *Agricultural Systems* **46**, 170–187.

NAMBIAR, K. K. (1995). Major cropping systems in India. In *Agricultural Sustainability: Economic, Environment and Statistical Considerations* (Eds V. Barnett, R. Range & R. Steiner), pp. 133–169. Chichester, UK:: John Wiley & Sons.

SHARMA, S. N., PRASAD, R. & SINGH, S. (1995). The role of mungbean residue and *Sesbania aculeata* green manure in the nitrogen economy of rice–wheat cropping system. *Plant & Soil* **172**, 123–129.

SHARMA, S. N. & PRASAD, R. (1999). Effects of *Sesbania* green manuring and mungbean residue incorporation on productivity and nitrogen uptake of a rice–wheat cropping system. *Bioresource Technology* **67**, 171–175.

SINGH, R. B. & PARODA, R. S. (1994). Sustainability and productivity of rice–wheat systems in the Asia–Pacific region: Research and technology development needs. In *Sustainability of Rice–Wheat Production Systems in Asia* (Eds R. S. Paroda, T. Woodhead & R. B. Singh), pp. 1–35. New Delhi: Oxford & IBH Publishing Co. Pvt. Ltd.

SINGH, S., PRASAD, R., SINGH, B. V., GOYAL, S. K. & SHARMA, S. N. (1990). Effect of green manuring, blue green algae and neem cake coated urea on wetland rice. *Biology & Fertility of Soils* **9**, 235–238.