Indian J. Agron. **40** (1) : 4–13 (March 1995)

Effect of fertilizer application and green-manuring on physico-chemical properties of soil and grain yield in rice (*Oryza sativa*)–wheat (*Triticum aestivum*) crop sequence

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Received: September 1993

ABSTRACT

A field experiment was carried out during 1989–90, 1990–91 and 1991–92 to evaluate the effectiveness of prickly sesban or *dhaincha* [*Sesbania cannabina* (Retz.) Pers.] and Frenchbean (*Phaseolus vulgaris* L.) green-manures grown in rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L. emend. Fiori & Paol.) crop sequence under irrigated conditions. Direct and carry-over effects on crop yield, rice-blast incidence, physical and chemical properties of soil were also studied under double-cropping system. Seed and straw yields of rice increased significantly due to green-manuring, and prickly sesban proved better green-manure crop. Fertilizer dose to rice could be saved up to 50% of the recommended dose. Neck-blast incidence increased with increasing fertilizer dose to rice in the presence of higher green-matter addition. No residual effect on wheat yield could be obtained. Bulk density after rainy season (*kharif*), i.e. rice harvest, was more whereas cumulative infiltration, available N, P and K were low compared with that after winter season (*rabi*) (wheat harvest), but the relative values due to green-manuring with *dhaincha* were higher than those under green-manuring with Frenchbean. However, the treatment differences were not significant after the wheat harvest.

Increase in cost of fertilizers, world-wide energy crisis, rapid exhaustion of fuel and their limited availability have inspired the scientists to rely more on renewable resources through integrated nutrient-supply system. In (*Oryza sativa* L.)–wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping sequence, green-manuring can be practised as a catch crop after the harvest of wheat for manuring forthcoming rice crop (Tiwari *et al.*, 1980). An experiment was conducted to study the effect of 2 green-manure crops, viz. prickly sesban or *dhaincha* [*Sesbania cannabina* (Retz.) Pers.] and Frenchbean (*Phaseolus vulgaris* L.) in rice–wheat crop sequence on the crop yield, rice-blast incidence and change in physico-chemical properties of soil.

MATERIALS AND METHODS

The field experiment was conducted at Palampur during 1989–90, 1990–91 and 1992–92. The soil of the experimental field was acidic in reaction and silty clay loam in texture, with organic carbon 0.61%, available N 677.32 kg/ha, available P 27.31 kg/ha and available K 238.10 kg/ha. The experiment was laid out in randomized block design with 8 treatments, each replicated 4 times. There were 2 sets of 4 treatments each in green-manure crops of *dhaincha* and Frenchbean. First 3 treatments in both green-manure crops received recommended (20 kg N + 50 kg P_2O_5 + 50 kg K_2O/ha) dose of NPK (100%) with the 1 control as fourth treatment. Rice followed by each green-manure crop received 100% (90 kg N + 40 kg P_2O_5 + 40 kg K_2O/ha), 75%, 50% and 100% NPK respectively in both the sets of treatments. Wheat crop was raised with recommended (120 kg N + 90 kg P_2O_5 + 30 kg K_2O/ha) dose of NPK (100%) in all the treatments. In both rice and wheat crops, half of N and entire quantities of P_2O_5 and K_2O were applied as basal dose. Remaining N was applied at tillering stage. 'HPU 741' and 'S 308' were the test varieties of rice and wheat respectively.

Green-manure crops of *dhaincha* and Frenchbean were sown in May after the harvest of wheat every year. The crops were raised from May to July for a period of 60–65 days under irrigated conditions. Immediately after the incorporation of green-manures, 25–30-day-old seedlings of rice were transplanted. The average green-matter production during the 3 years by *dhaincha* was 17.3–19.9 tonnes/ha when it was fertilized. However, without fertilizers the average green-matter production was 11.5 tonnes/ha. For fertilized Frenchbean the green-matter production was 1.2–1.4 tonnes/ha and 1.0 tonnes/ha without fertilizers. The addition of N due to *dhaincha* averaged 61.8 and 77.9 kg/ha when crop was with fertilizer and without fertilizers; the addition was 43.3 kg N/ha. The addition of N due to Frenchbean was only 9.1–10.5 kg/ha when fertilized and only 7.6 kg/ha in the absence of any fertilizer to green-manure crop (Table 1). Soil samples from 0–15 and 15–30 cm soil depths were collected before and after each crop season and analysed for available N (Subbiah and Asija, 1956), P (Olsen *et al.*, 1954) and K (Jackson, 1967). Bulk density from each plot was determined *in situ* by core sampler. Cumulative infiltration/hr was determined by ring infiltrometers.

Table 1. Effect of green-manure of legumes on green-matter production and nitrogen addition (mean data of 3 years)

Treatment	Green-matter (tonnes/ha)	N addition (kg/ha)
Dhaincha + 100% NPK*	19.9	77.9
Dhaincha + 100% NPK	17.3	61.8
Dhaincha + 100% NPK	17.7	66.3
Dhaincha	11.5	43.3
Frenchbean + 100% NPK	1.2	9.1
Frenchbean + 100% NPK	1.2	9.5
Frenchbean + 100% NPK	1.4	10.5
Frenchbean	1.0	7.6

*100% recommended dose of NPK

RESULTS AND DISCUSSION

Physical properties of soil

Soil-bulk density increased after rainy season (rice harvest) compared with initial values, but again decreased following an upland crop of wheat during the winter season (Fig. 1). Soil puddling increases the bulk density after rice harvest (Saroch and Thakur, 1991). Bulk density after wheat harvest (winter season) during both the years did not vary significantly due to different green-manure treatments applied to rice crop. However, after rice during both the years, significantly lower values were recorded due to the green-manuring with *dhaincha* than with Frenchbean. During the process of decomposition, polysaccharides, polyuronoides, cellulose and humus are produced which are responsible for firm binding between soil particles, resulting in more stable aggregates causing a reduction in bulk density. Significant reduction in bulk

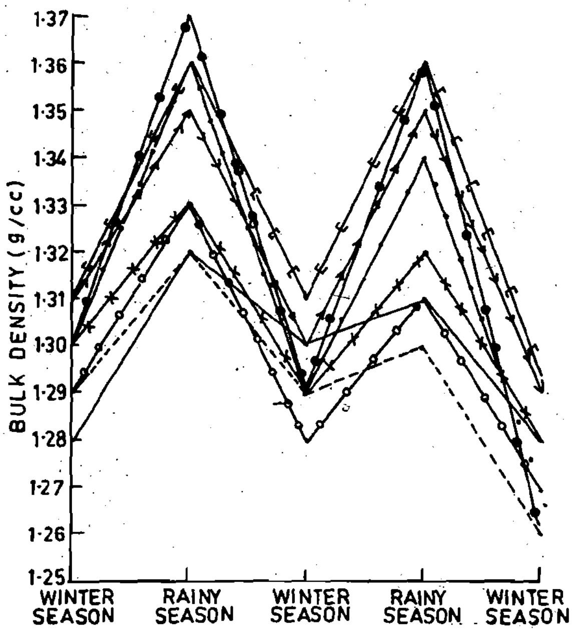

Fig. 1. Seasonal and treatment effect on bulk density of soil. [T_1 (- - - -), Dhaincha 100%–Rice 100%–Wheat 100%; T_2 (-o-o-o-), Dhaincha 100%–Rice 75%–Wheat 100%; T_3(——), Dhaincha 100%–Rice 50%–Wheat 100%; T_4 (x x x), Dhaincha 0%–Rice 100%–Wheat 100%; T_5(-•-•-•-), Frenchbean 100%–Rice 100%–Wheat100%; T_6(->->->-), Frenchbean 100%–Rice 75%–Wheat 100%; T_7(—•—•—•—), Frenchbean 100%–Rice 50%–Wheat 100%; T_8 (-+-+-+-), Frenchbean 0%–Rice 100%–Wheat100%]

density due to green-manuring is closely related with increased cumulative infiltration (Fig. 2). Each year after the harvest of rice, the volume of water unfiltered through soil was significantly higher due to green-manuring with *dhaincha* than with Frenchbean. After wheat (winter season), though the infiltration increased, the treatment effects were not significant during both the years. The stable aggregates formation and improvement in soil structure probably resulted in increased cumulative infiltration due to green-manure application.

Chemical properties of soil

There was a considerable build-up in soil fertility due to green-manuring. In 0–15 cm soil layer all the treatments receiving *dhaincha* green-manure resulted in significantly higher content of organic carbon (%) after the rainy season (rice harvest) in first year as compared to the Frenchbean (Fig. 3). Though after the winter season (wheat harvest) the contents decreased, the residual treatment effects were not significant. In the second year after rainy-season rice the contents again increased and *dhaincha* treatments were significantly superior to Frenchbean treatment. Unlike first year the contents increased significantly after the second crop of wheat. It indicates the build up of organic carbon in soil. In the lower

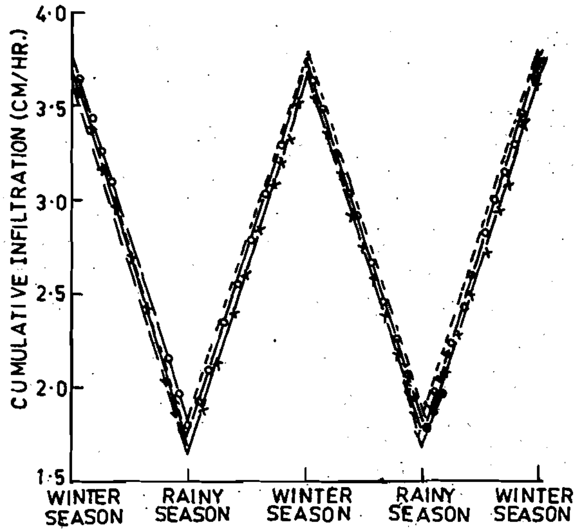

Fig. 2. Seasonal and treatment effect on cumulative infiltraction. [T_1 (- - - -), Dhaincha 100%–Rice 100%–Wheat 100%; T_2 (-o-o-o-), Dhaincha 100%–Rice 75%–Wheat 100%; T_3(——), Dhaincha 100%–Rice 50%–Wheat 100% ; T_4 (x-x-x), Dhaincha 0%–Rice 100%–Wheat 100%; T_5(-•-•-), Frenchbean 100%–Rice 100%–Wheat100%; T_6(->->->-), Frenchbean 100%–Rice 75%–Wheat 100%, T_7(—•—•—•—), Frenchbean 100%–Rice 50%–Wheat 100%; T_8 (-+-+-+-), Frenchbean 0%–Rice 100%–Wheat100%]

layer of soil (15—30 cm) the organic carbon status was much lower than that of surface layer (0—15 cm), but the trend of treatment effects was similar as observed in surface soil layer.

Green-manuring significantly influenced the contents of available nutrients in the soil. Treatment effects on available nitrogen were visible only after the harvest of rainy-season rice during both the years at both soil depths (Table 2). Green-manure treatments with *dhaincha* significantly increased N content than Frenchbean. However, after winter-season wheat during both the years at both the soil depths, the contents were not affected significantly due to any of the treatments given to rice crop. There was increase in build up of available soil N after each crop season.

Like available N, the available phosphorus in 0—15 cm soil layer estimated after harvest of winter-season wheat during all the years did not vary significantly due to different green-manure treatments applied to rice (Table 3). Unlike N the available P decreased after each rice crop (rainy season), but increased after each winter season during both the years. Drying of soil followed by submergence may lead to occurrence of iron and aluminium hydrous oxides as discrete particles in soils or as coating or films on other soil particles. In general, soils with significant contents of Fe^{+++} and Al^{+++} oxides show increased P-fixation capacity, resulting in low quantity of P in available form. These soils are fairly rich in Al^{+++} and Fe^{+++} (Sharma and Tripathi, 1992). In 15—30 cm soil layer the P status was much

Table 2. Available nitrogen as influenced by green-manure of legumes and NPK fertilizer in rice–wheat crop sequence

Treatment	Available N (kg/ha)									
	0–15 cm					15–30 cm				
	Initial	1990 (after rice)	1990–91 (after wheat)	1991 (after rice)	1991–92 (after wheat)	Initial	1990 (after rice)	1990–91 (after wheat)	1991 (after rice)	1991–92 (after wheat)
T_1, DGM–rice (100 + 100)	680	692	706	712	749	629	642	654	658	690
T_2, DGM–rice (100 + 75)	679	689	704	707	740	626	640	652	655	690
T_3, DGM–rice (100 + 50)	677	691	705	711	743	623	638	651	654	686
T_4, DGM–rice (0 + 100)	680	689	706	708	741	622	639	652	655	688
T_5, FBGM–rice (100 + 100)	~~677~~	681	704	704	740	623	636	651	653	686
T_6, FBGM–rice (100 + 75)	676	677	701	700	735	618	633	648	649	684
T_7, FBGM–rice (100 + 50)	674	682	704	708	742	620	634	650	650	685
T_8, FBGM–rice (0 + 100)	675	677	700	703	737	621	631	650	650	684
CD (P = 0.05)	NS	6	NS	6	NS	NS	6	NS	6	NS

DGM, *Dhaincha* green-manure; FBGM, Frenchbean green-manure; 100, 100% recommended dose of NPK; NS, not significant lower but the trend of seasonal variation and treatment effects were similar to that of 0—15 cm soil layer. Treatments receiving *dhaincha* green-manure resulted in significantly higher available P after rice harvests than after Frenchbean. Organic anions arising from decomposition of organic matter form stable complexes with Fe^{+++}, Al^{+++} and prevent their reaction with phosphate ions, and result in significantly higher available P

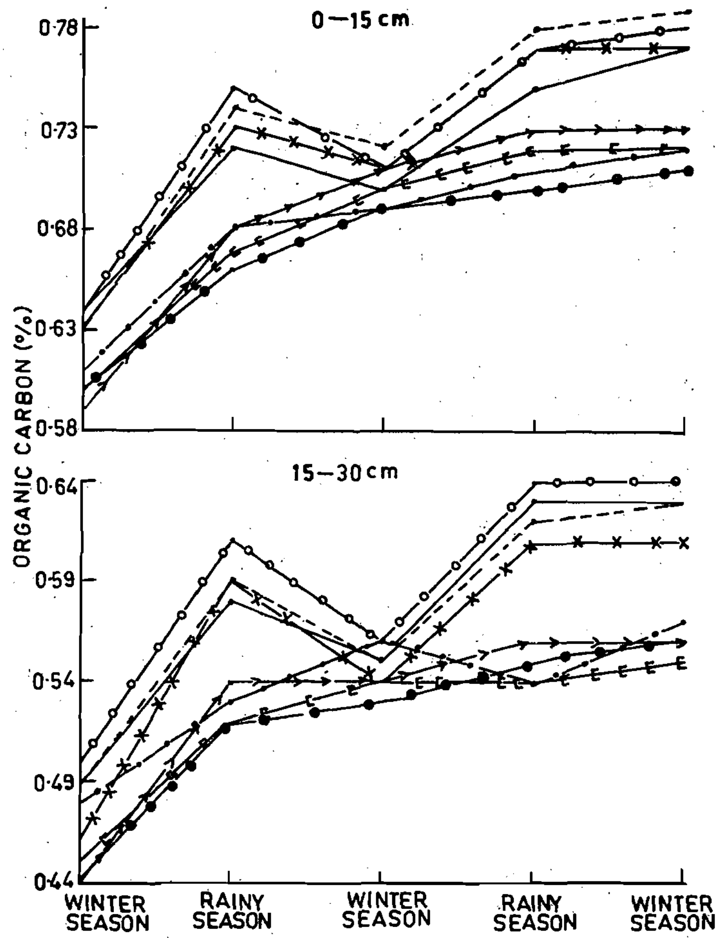

Fig. 3. Seasonal and treatment effect on organic carbon content of soil. [T_1 (- - - -), Dhaincha 100%—Rice 100%—Wheat 100%; T_2 (-o-o-o-), Dhaincha 100%—Rice 75%—Wheat 100%; T_3(——), Dhaincha 100%—Rice 50%—Wheat 100%; T_4 (x-x-x), Dhaincha 0%—Rice 100%—Wheat 100%; T_5(-•-•-•-), Frenchbean 100%—Rice 100%—Wheat100%; T_6(>>>), Frenchbean 100%—Rice 75%—Wheat 100%; T_7(—●—●—●—), Frenchbean 100%—Rice 50%—Wheat 100%; T_8 (ꜫꜫꜫ), Frenchbean 0%—Rice 100%—Wheat100%]

Table 3. Available phosphorus as influenced by green-manure of legumes and NPK fertilizer in rice–wheat crop sequence

Treatment	Available P (kg/ha)									
	0–15 cm soil depth					15–30 cm soil depth				
	Initial	1990 (after (rice)	1990–91 (after wheat)	1991 (after rice)	1991–92 (after wheat)	Initial	1990 (after rice)	1990–91 (after wheat)	1991 (after rice)	1991–92 (after wheat)
T_1	28.9	24.8	32.8	28.2	33.7	18.8	15.0	21.1	19.3	22.8
T_2	28.6	23.6	31.1	26.1	32.8	18.5	13.2	21.3	17.0	22.7
T_3	28.3	24.3	30.9	26.5	31.1	18.1	14.3	20.8	17.1	21.7
T_4	28.5	24.5	31.2	27.1	31.9	18.3	14.6	21.6	17.9	22.9
T_5	27.3	22.1	30.8	25.5	31.2	17.7	13.3	21.0	15.6	21.6
T_6	25.9	20.6	28.5	24.0	29.6	16.7	12.8	19.6	14.1	20.1
T_7	25.0	19.6	28.1	22.9	29.0	15.6	11.9	18.9	14.0	20.4
T_8	26.0	21.6	29.3	24.0	29.9	16.1	12.0	19.5	14.7	21.0
CD ($P = 0.05$)	NS	2.6	NS	2.6	NS	NS	2.1	NS	2.4	NS

Details of treatments are given in Table 2
NS, Not significant

Table 4. Available potassium as influenced by green-manure of legumes and NPK fertilizer in rice—wheat crop sequence

Treatment	Available P (kg/ha)									
	0–15 cm soil depth					15–30 cm soil depth				
	Initial	1990 (after (rice)	1990–91 (after wheat)	1991 (after rice)	1991–92 (after wheat)	Initial	1990 (after rice)	1990–91 (after wheat)	1991 (after rice)	1991–92 (after wheat)
T_1	241	229	254	241	264	220	223	231	238	245
T_2	241	227	252	237	260	221	221	228	235	243
T_3	240	224	253	238	263	219	220	229	237	244
T_4	241	227	253	242	265	220	222	230	238	245
T_5	237	224	251	240	263	218	220	228	236	243
T_6	234	218	251	236	258	218	216	227	233	243
T_7	235	217	250	233	258	216	213	227	230	242
T_8	236	221	252	238	260	217	218	229	234	242
CD ($P = 0.05$)	NS	6	NS	6	NS	NS	6	NS	3	NS

Details of treatments are given in text
NS, Not significant

Table 5. Grain and straw yields of rice as influenced by green-manure of legumes and NPK fertilizer

Treatment	Grain yield (kg/ha)			Straw yield (kg/ha)			Straw : grain ratio (1989)	Neck-blast incidence (% panicles affected) (1991)
	1989 Actual	1990 Calculated	1991 Actual	1989 Actual	1990 Actual	1991 Actual		
T_1	5,182	5,002	2,319	5,943	5,733	5,999	1.146	67.8
T_2	4,912	4,966	2,349	5,930	5,995	6,555	1.207	65.9
T_3	5,386	4,905	3,604	5,531	5,033	6,389	1.026	44.8
T_4	5,372	5,517	3,741	5,628	5,777	5,645	1.047	40.2
T_5	4,461	5,382	3,965	3,881	4,683	4,904	0.870	38.4
T_6	4,568	4,612	4,298	3,990	4,026	4,612	0.873	36.1
T_7	4,092	4,353	4,432	3,908	4,158	4,777	0.955	26.6
T_8	4,599	4,476	4,465	4,634	4,508	4,853	1.007	26.2
CD (P = 0.05)	712	655	218	768	685	738		6.8

Details of treatments are given in Table 2

Table 6. Grain and straw yields of wheat as influenced by residual effect of green-manure of legumes and NPK applied to rice

Treatment	Grain yield (kg/ha)			Straw yield (kg/ha)		
	1989–90	1990–21	1991–92	1989–90	1990–91	1991–92
T_1	3,010	3,192	2,525	6,522	6,543	4,088
T_2	2,623	2,782	2,782	5,591	5,792	4,435
T_3	2,919	3,179	2,975	6,464	6,477	4,709
T_4	2,747	2,987	3,028	5,592	6,015	4,794
T_5	2,804	2,867	2,932	5,532	5,833	4,647
T_6	3,103	2,906	3,132	6,248	5,953	4,931
T_7	3,040	3,145	2,794	6,330	6,387	4,463
T_8	2,934	2,949	2,741	6,448	5,993	4,354
CD (P = 0.05)	NS	NS	NS	NS	NS	NS

Details of treatments are given in Table 2

due to green-manure treatments.

Available potassium also followed the similar trend as that of P in 0–15 cm soil layer (Table 4). During the process of puddling the silt and clay of soil increase in upper soil layer and result in fixation of K ions in the interlattice space and ultimately in the hexagonal cavity of clay minerals where K is present in non-exchangeable form (Sharma, 1980). Thus a lower content of available K in the surface soil layer after rice harvest during both the years was quite obvious. In 15–30 cm soil layer the increase in available K might be due to the leaching of some K ions from 0–15 cm soil layer as well as due to lower fraction of silt and clay. The treatment differences were visible only after harvest of rainy-season rice during each season at both the soil depths. *Dhaincha* might have released more K than Frenchbean. Most of the K in plants remains in organic form and also the decomposing organic matter may have solubilizing effect of native soil potassium (Tiwari *et al.*, 1980).

The grain yield during 1990 could not be recorded due to the damage caused by a heavy hail storm which occurred just before the harvesting. Therefore only straw yield could be recorded. Since the climatic conditions during the 2 years were identical, the straw : grain ratio calculated from grain and straw yields obtained during 1989 was used to estimate the possible grain yield during 1990 (Table 5). Yield data of 1989 revealed that the treatments receiving *dhaincha* as green-manure (T_1 to T_4) showed significantly higher grain yield than the treatments receiving Frenchbean manure (T_5 to T_8). More or less similar trend was observed in the estimated grain yield during 1990. The straw yield also followed the same trend during all the 3 years. Use of *dhaincha* reduced 50% of recommended fertilizer to rice without significant reduction in grain yield.

Contrary to the observations made during the first 2 years, during 1991 the green-matter addition accompanied with recommended levels of NPK to rice resulted in higher incidence of rice-neck blast. This caused a steep reduction in grain yield in T_1 and T_2 treatments. However, treatments receiving low green matter showed lesser incidence (40.2–26.2% infected panicles) compared with T_1 and T_2 (67.8 and 65.9% infected panicles).

Residual effect on wheat yield

There was no significant residual effect of green-manure and fertilizer levels given to rice on wheat grain and straw yields during all the 3 years (Table 6).

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