

Effect of Green Manuring on Micronutrient Availability in Rice-wheat Cropping System of Northwest India

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Abstract

Rice cultivation in highly permeable coarse-textured soils in recent years has given rise to a number of micronutrient deficiency problems. While paddy yields in such soils are poor due to iron (Fe) deficiency, wheat yields are low because of manganese (Mn) deficiency. In view of the observations that *Sesbania* green manuring can help improve rice yield, the present investigation was undertaken to study the effects of regular incorporation of *Sesbania* green manure for sustaining yields of rice-wheat system. Regular incorporation of *Sesbania* green manure before rice transplanting resulted in significant improvement in paddy yield over that in the non-green manured plots. The increase in micronutrients, particularly Fe and Mn, and of organic carbon seemed to be responsible for increased rice yields in these soils. No residual effect of green manuring was observed in wheat.

Introduction

Assured irrigation and favorable climate for rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system have prompted farmers of Punjab in India to extend rice cultivation to coarse-textured soils as well, which are otherwise not ideal for growing rice. Yields of rice in these soils are much lower than those obtained in

ideal paddy soils. The poor rice yields are attributed mainly to deficiency of iron (Fe) emanating from soil-environment not favorable for reducing Fe^{3+} to Fe^{2+} , the Fe^{2+} being more available to rice. Foliar application of Fe is considered the most efficient method of combating Fe deficiency (Nayyar et al. 1990). Even with repeated foliar application of Fe, the crop often failed to produce desirable yields, particularly during the initial years of rice cultivation on these soils. Preliminary studies carried out by the authors have revealed that incorporation of *Sesbania* (*Sesbania aculeata* Poir.) green manure (GM) before transplanting rice can ameliorate Fe deficiency by promoting reduced conditions besides improving other physico-chemical characteristics of the soil (Nayyar and Takkar 1989). Regular cultivation of rice on such soils causes manganese (Mn) deficiency in the following crops of wheat/berseem (*Trifolium alexandrinum* L.) because of excessive leaching of soluble Mn resulting from submergence during rice cultivation and oxidation of limited amount of available Mn in surface soil to its higher oxides during wheat/berseem cultivation (Takkar and Nayyar 1981). To overcome that loss, foliar application of Mn was suggested (Nayyar et al. 1990). It is, however, expected that regular incorporation of *Sesbania* GM before transplanting rice may improve availability of not only Fe but also other micronutrient cations. The present investigation was, therefore, undertaken to assess long-term effects of green manuring on micronutrient status of a highly permeable coarse-textured soil under rice-wheat cropping system.

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Materials and Methods

A long-term field experiment was initiated at the Punjab Agricultural University farm, Ludhiana, India during 1991. It was laid out in a randomized block design with two treatments, i.e., with GM and without GM (NGM); the plot size being 19 m × 7 m. The experimental soil (Typic Ustipsamment) was Fatehpur loamy sand (sand 84.4%, silt 11.9%, and clay 3.7%) with pH 8.23, electrical conductivity 0.20 dS m⁻¹, and organic carbon content of 0.19%. *Sesbania* was sown during the last week of April 1991. After two months, the GM crop was incorporated into the field, followed by proper puddling with disc plow. Then 45-day-old healthy seedlings of rice (PR 108) were transplanted. To this crop a basal dose of nitrogen (N) (60 kg ha⁻¹ through urea), phosphorus (P) (26 kg ha⁻¹ through diammonium phosphate), and potassium (25 kg ha⁻¹ through muriate of potash) was applied at transplanting. The remaining dose of N (60 kg ha⁻¹) was top-dressed in two equal splits, i.e., one at 3 weeks and second at 6 weeks after transplanting. Recommended weedicides and insecticides were used. After harvesting rice, wheat (HD 2329) was seeded with simultaneous application of 60 kg N ha⁻¹, 26 kg P ha⁻¹, and 25 kg K ha⁻¹. The remaining dose of N (60 kg ha⁻¹) was applied with first irrigation. This crop rotation was followed up to 1995–96 and both crops in rotation were fertilized in the same way as in the initial year. Irrigation to each crop was given with a good quality underground water.

Composite surface soil (0–15 cm) samples were collected from each plot before initiating the experiment and after every rice and wheat crop over the years. At maturity, yield of each crop was recorded and straw and grain samples were collected for their chemical analysis. While soil samples were analyzed for available zinc (Zn), copper (Cu), Fe, and Mn by the DTPA

method of Lindsay and Norvell (1978), the plant samples were analyzed for total Zn, Cu, Fe, and Mn by digesting them in a diacid mixture of HNO₃ and HClO₄ in 3:1 ratio. The changes in different forms of Fe, Mn, and Zn, viz., complexed, organically bound, amorphous oxides, carbonate bound, and crystalline oxide bound were determined by using fractionation scheme of Raja and Iyengar (1986). The content of micronutrients in soil extracts and plant digests were estimated on an atomic absorption spectrophotometer.

Results and Discussion

Crop yields

Grain yield of rice increased significantly in GM over that in the NGM plots, and yield increases over the years ranged between 0.75 t ha⁻¹ and 0.89 t ha⁻¹ (Table 1). The increase in rice yields in GM plots is attributed to enhanced availability of micronutrients, particularly Fe. The Fe present in the soil remained mainly in Fe³⁺ form and the crop's requirement for this element could not be met fully. This was apparent from severe iron chlorosis observed in NGM plots during the initial year (1991) when even repeated foliar sprays of crop with 1% ferrous sulfate solution could not fully ameliorate deficiency and it was reflected in poor paddy yield in the initial year (Table 1). The increased availability of Fe with regular incorporation of *Sesbania* every year before transplanting rice was responsible for significantly higher yields in GM plots during subsequent years. The increased Fe availability in GM plots was further reflected by increased Fe uptake by the crop. The Fe uptake by rice increased from 701 g ha⁻¹ during 1991 and 983 g ha⁻¹ during 1995 in NGM to 904 g ha⁻¹ and 1,433 g ha⁻¹ respectively in GM plots. The increase in Fe availability may be much higher during the early period of rice

Table 1. Effect of *Sesbania* green manuring on grain yield (t ha⁻¹) of rice and wheat at Ludhiana, India.¹

Year	Rice		Wheat	
	NGM	GM	NGM	GM
1991/92	2.89	3.78	4.23	4.14
1992/93	3.27	4.02	3.60	3.65
1993/94	3.46	4.35	4.39	4.37
1994/95	3.68	4.53	3.56	3.67
1995/96	– ²	–	3.47	3.50
1996/97	3.70	4.68	3.55	3.66
LSD (P=0.05)	Year=0.16; GM=0.10		Year=0.14; GM=NS ³	

1. NGM=Without green manure; GM=Green manure.

2. Rice crop during 1995 was damaged by a severe attack of stem borer, so no data could be recorded.

3. NS=Not significant.

growth as compared to after rice harvest due to decrease in redox potential resulting from the release of electrons during the decomposition of easily bio-degradable GM. Non-appearance of deficiency symptoms of Fe in rice in GM plots lent support to these observations. Decrease in redox potential and increase in available Fe during first 4 weeks of submergence have also been reported by Sadana and Takkar (1985) and Khind et al. (1987).

Continuous incorporation of GM over years also increased organic carbon content of soil from 0.19% to 0.34% which may also be responsible for higher micronutrient availability. The DTPA-Fe content also increased in NGM plots over years which might have resulted from slow transformation of Fe fixed in crystal lattices and/or oxide minerals to amorphous form.

Grain yield of wheat following rice did not differ much in GM and NGM plots (Table 1) revealing thereby a little residual effect of *Sesbania* GM incorporated before rice transplanting. The variation in wheat yield over years seems to be the result of climatic fluctuations.

Available micronutrient status

Content of all the DTPA-extractable micronutrient cations in GM plots increased compared to NGM plots, as is reflected by the analysis of soil after rice as well as wheat harvest. However, magnitude of increase was much greater in soil after rice harvest than after wheat. The increase in Fe and Mn after rice seemed to be associated with reduction process. In GM plots content of DTPA-Fe and Mn considerably improved even after first rice crop and continued to increase over years. It may be due to the transformation of some of the Fe from crystal lattice and/or crystalline oxides of Fe and Mn to amorphous form which was more easily reduced in subsequent years under submerged conditions as supported by a decrease in content of Fe and Mn bound by crystalline oxide with a concomitant increase in their amount in amorphous oxide form (Table 2). Marked improvement in organically bound form of Fe both in GM and NGM plots might have also contributed towards its higher content after continuous cultivation of rice in rotation with wheat. The DTPA-Fe also improved over years even in NGM plots but effect was not as marked

Table 2. Changes in content (mg kg⁻¹ soil) of different fractions of iron, manganese, and zinc with *Sesbania* green manure in rice-wheat system at Ludhiana, India.¹

Fraction	Iron			Manganese			Zinc		
	1991	1996		1991	1996		1991	1996	
	(IV)	NGM	GM	(IV)	NGM	GM	(IV)	NGM	GM
Complexed	0.20	0.18	0.17	6.90	6.92	8.00	0.78	0.70	0.77
Organically bound	21.56	29.66	33.23	11.40	11.40	20.40	1.32	1.28	1.52
Amorphous oxides and bound by carbonates	62.60	70.80	75.20	62.90	73.70	90.40	4.60	4.50	4.73
Bound by crystalline oxides	149.00	140.00	121.00	9.80	8.80	8.40	0.66	0.65	0.80

1. IV=Initial value; NGM=Without green manure; GM=Green manure.

as in GM plots indicating that green manuring helps in mobilizing Fe from unavailable forms. The DTPA-Fe in the soil was less after wheat harvest than after rice, though its content remained higher in GM plots as compared to NGM plots. It indicates that during upland conditions, i.e., wheat cultivation, available Fe tends to get reconverted into its higher oxides.

The DTPA-Mn in the soil, after rice harvest, also increased in GM as well as NGM plots but increase was more prominent during first 3 years of rice cultivation and it declined thereafter. However, the differences between the GM and the NGM plots were not as marked as for Fe. The increase in Mn content might also have resulted from transformation of Mn associated with crystalline oxides into amorphous forms and increase in organically-bound form of Mn (Table 2). The decrease in DTPA-Mn after an increase in initial 2–3 years might be the consequence of its leaching during rice cultivation. Nevertheless, like Fe, the DTPA-Mn content also decreased after wheat harvest, and GM plots maintained a higher level of DTPA-Mn as compared to NGM plots. This again indicates that during alternate wetting and drying effects experienced in wheat growth period, both Fe and Mn slowly changed to higher oxides.

The DTPA-extractable Zn decreased over years in NGM plots both after rice and wheat harvest. In GM plots, DTPA-extractable Zn remained high as compared to NGM plots and also its content after rice was higher than that after wheat. In China, Chen (1983) observed an increase in available Zn of surface (0–10 cm) soil from 2.9 g g⁻¹ to 4.7 g g⁻¹ when vetch was grown for 3 years and he attributed it to mining of subsoil Zn by GM.

The DTPA-Cu also increased in GM plots after rice. Since availability of Cu in soil is independent of reduction process, increase in its content in GM plots may be ascribed to its affinity to combine with organic matter besides its recycling through GM. Application of *Sesbania* GM to a flooded soil has been reported to maintain at least 1.5 times higher content of DTPA-extractable Cu than that in unamended soil throughout the 12-week period of flooding (Singh et al. 1992). This indicates that continuous incorporation of *Sesbania* GM over years helps in improving DTPA-extractable micronutrient cations of the soil. It may be due to recycling of the micronutrients from subsurface layer to the surface layer of the soil during incorporation of GM and the build-up of organic carbon in the surface soil layer. It has

been observed in the present investigation that the *Sesbania* GM, on an average, adds annually about 145 g Zn ha⁻¹, 24 g Cu ha⁻¹, 1236 g Fe ha⁻¹, and 325 g Mn ha⁻¹.

Conclusion

The results of this investigation, thus reveal that in highly permeable coarse-textured soils with inherent low yield potential, incorporation of *Sesbania* GM before transplanting rice can certainly improve rice grain yield appreciably by enhancing the availability of micronutrients besides increasing organic carbon content of the soil.

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