Effects of Organic Residue Management on Productivity of the Rice-Wheat Cropping System

T S Verma and P K Sharma[1]

Abstract

Two long-term field experiments were conducted to study the potential of rice straw (Exp. I) and *Lantana* biomass (Exp. II) as soil amendments to improve soil productivity under rice-wheat cropping. Rice straw with farmyard manure (SI + FYM) and without FYM (SI) was incorporated in soil before sowing of wheat, while *Lantana* biomass @ 10–30 t ha^{-1} (fresh biomass) was incorporated before puddling for rice. In Exp. I, wheat yields started increasing over the control with SI + FYM (28%) in the second cropping season, SI (38%) in third season, and straw mulch (SM) in wheat (36%) in the fourth season. Rice yields during fifth cropping sequence with SI, SM, FYM, and SI + FYM were higher than control by 42, 40, 43, and 65% respectively. In Exp. II, rice and wheat crops started responding to *Lantana* additions to rice during third cropping cycle. With 20–30 t ha^{-1} *Lantana*, rice grain yield at 50% nitrogen (N) level was the same as that with 100% N without *Lantana* in 1992, i.e., the fifth rice crop. Wheat yield with 50% N level was the same as that with 100% N without *Lantana* in 1993/94 (sixth crop) when supplemented with 20 t ha^{-1} *Lantana*, and in 1992/93 (fifth crop) when supplemented with 30 t ha^{-1} *Lantana*. Chemical analysis at the end of 5 years in Exp. I and 6 years in Exp. II improved soil fertility in terms of organic carbon, available NPK, and DTPA-extractable micronutrients.

Introduction

Wheat (*Triticum aestivum* L.) yields are relatively low in post-rice (*Oryza sativa* L.) soils because of unfavorable physical and chemical environment created by puddling and submergence in the preceding rice crop (Sharma and De Datta 1986). Plowing of puddled soils after the rice harvest results in cloddy soil surface. Large amounts of energy and time are consumed in pulverizing soil clods; otherwise, in coarse tilth, wheat emergence is adversely affected due to poor seed-soil contact. Coupled with this are problems of nutritional imbalances, restricted rooting, and impaired drainage.

Use of organic amendments such as farmyard manure (FYM), compost, and plant residues are known to improve soil productivity in rice-wheat cropping (Chaudhary and Ghildyal 1969; Sahoo et al. 1970; Fagi and De Datta 1983; Verma and Bhagat 1992; Sharma et al. 1995). However, the problems frequently encountered in organic manuring are the availability and handling of bulky organic materials. The challenge is to identify organic sources, which are waste materials with little value as fodder and fuel, and are locally available at a relatively low cost.

Rice straw has little value as cattle feed (Ponnamperuma 1982), and is readily available in quantities varying from 2 t ha^{-1} to 5 t ha^{-1}. Similarly, *Lantana* spp is a fast-growing obnoxious weed, encroaching on cultivated lands at an

1. Himachal Pradesh Krishi Vishwavidyalaya, Palampur 176 062, Himachal Pradesh, India.

Verma, T.S. and **Sharma, P.K.** 2000. Effects of Organic Residue Management on Productivity of the Rice-Wheat Cropping System. Page 163–171 *in* Long-term Soil Fertility Experiments in Rice-Wheat Cropping Systems (Abrol, I.P., Bronson, K. F., Duxbury, J. M. and Gupta, R. K. eds.). Rice-Wheat Consortium Paper Series 6. New Delhi, India: Rice-Wheat Consortium for the Indo-Gangetic Plains.

alarming rate in northwestern Himalayan region. The State Government of Himachal Pradesh, India is seriously considering programs for the complete eradication of *Lantana*. Hence, these two materials appear potential organic amendments in soils under rice-wheat cropping.

Materials and Methods

Two long-term field experiments using organic amendments were started at the experimental farm, Palampur, Himachal Pradesh (30°6' N, 73°3' E, 1,300 m above mean sea level) in November 1984 with rice straw (Exp. I) and in June 1988 with *Lantana* (Exp. II). The area falls under wet temperate zone, with annual rainfall of 2,500–3,000 mm, 80% of which is received during June–September. The average temperature is around 26°C during rice cropping season (rainy season) and 14°C during wheat cropping season (winter).

The soils at both locations in Exp. I (Soil I) and Exp. II (Soil II) were silty clay loams (Typic Hapludalf), having pH 5.9 and 5.6, and organic carbon content of 1.10% and 0.88% respectively. Alkaline $KMnO_4$-nitrogen (N), Olsen's phosphorus (P), and neutral normal NH_4OAc-potassium (K) in Soil I were 300, 14, and 148 kg ha^{-1}; and in Soil II were 269, 18, 170 kg ha^{-1} respectively. In Exp. I, organic amendments to wheat crop were: control or no rice straw (C); incorporation of chopped rice straw (SI); rice straw mulch (SM); incorporation of FYM; and incorporation of rice straw and FYM (SI + FYM). Rice straw and FYM were applied @ 5 t ha^{-1} on dry-weight basis. The straw management treatments were tested at 3 N levels (0, 60, and 120 kg ha^{-1}) in both rice and wheat crops. Rice straw used as mulch (SM) in the wheat crop was incorporated into the soil during puddling for rice.

The Exp. II was started with 12 treatment combinations of *Lantana* incorporation at 4 levels (0, 10, 20, and 30 t ha^{-1} on fresh-weight basis) and 3 tillage treatments (no puddling, puddling, and soil compaction) in rice. Wheat was grown as a general crop with recommended fertilizer application rates. During 1993, tillage treatments in rice were replaced with 3 N levels (50, 75, and 100% of recommended rate, which is 90 kg N ha^{-1}). Wheat crop growing in rice plots received 50, 75, and 100% of recommended N (120 kg ha^{-1}). The chemical composition of rice straw, FYM, and *Lantana* are given in Table 1. Organic residues (rice straw to wheat in Exp. I and *Lantana* to rice in Exp. II) were incorporated in the plow layer 10 to 15 days before seeding of wheat or puddling and transplanting of rice. In both the experiments, N was applied as urea. Uniform doses of P and K @ 17 kg P ha^{-1} and 33 kg K ha^{-1} to rice and 26 kg P ha^{-1} and 25 kg K ha^{-1} of wheat were applied in all the plots, including the control. In wheat, 50% N was applied at seeding and remaining in two equal splits, one each at active tillering and flowering

Table 1. Chemical composition of different organic residues.[1]

Ogranic residue	C (%)	N (%)	P (%)	K (%)	C:N ratio	C:P ratio
Rice straw	32.3	0.85	0.20	2.50	38 : 1	162 : 1
FYM	26.9	1.68	0.21	1.96	16 : 1	128 : 1
Lantana	52.5	2.50	0.25	1.40	21 : 1	210 : 1

1. C=Carbon; N=nitrogen; P=phosphorus; K=potassium; FYM=farmyard manure.

stage. In rice, 50% was applied at 10 days after transplanting and remaining half equally at 30 and 50 days after transplanting. The seeding rate of wheat was 100 kg ha^{-1} (cv S308 in Exp. I and cv Aradhana in Exp. II). Rice seedlings (cv HPU 741 in Exp. I and cv HPU 2216 in Exp. II) were transplanted @ 2–3 seedlings hill^{-1} at 15 cm × 20 cm spacing. Standard cultural practices were followed to raise the crops. Wheat crop received 3 irrigations, one each at crown-root initiation, late jointing, and late flowering stage, irrespective of residue treatment. Rice fields remained continuously submerged until 10–15 days before harvesting. In both the experiments, the treatments were replicated thrice in randomized complete block design.

The crops were harvested at maturity, and grain and straw yields were recorded. The plant samples were analyzed for N. The Exp. I was terminated after 5 cropping cycles when composite soil samples from each plot in 0–20 cm depth were collected with screw auger and analyzed for pH, organic carbon, available NPK, and DTPA-extractable iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn) (Table 2). Exp. II is in progress. Soil analysis in this experiment was done at the end of 6 cropping cycles on composite soil samples collected in 0–20 cm soil layers (Table 2).

Results and Discussion

Rice straw management

The effects of different straw management practices on wheat yield and N uptake differed and changed with time (Figs. 1 and 2). In general, beneficial effects of straw management

Table 2. Changes in nutrient status of experimental soils due to organic amendments in rice-wheat system at Palampur, India.[1]

Treatment[2]	pH	OC (%)	N (mg kg^{-1})	P (mg kg^{-1})	K (mg kg^{-1})	Micronutrients (mg kg^{-1})			
						Zn	Cu	Fe	Mn
Straw management (after 5 years)									
C	5.9	1.09	120.4	12.6	49.7	1.50	1.00	22.9	31.0
SI	6.0	1.24	150.0	15.4	73.0	1.60	1.20	23.4	33.4
SM	6.1	1.26	149.3	15.0	74.0	1.60	1.20	23.0	33.2
FYM	6.1	1.30	158.5	21.2	85.1	2.00	1.30	25.6	38.5
SI + FYM	6.0	1.37	191.0	24.0	95.4	2.00	1.30	28.9	41.5
LSD (P=0.05)	NS	0.30	6.5	1.7	4.3	0.07	0.05	2.1	2.7
Initial (1984)	5.9	1.14	134.0	6.3	66.1	–	–	–	–
***Lantana* (t ha^{-1}) (after 6 years)**									
0	5.7	1.10	134.5	11.1	86.3	0.51	1.25	–	–
10	5.9	1.24	143.0	13.7	130.6	0.63	1.41	–	–
20	6.0	1.31	152.0	16.9	149.5	0.65	1.62	–	–
30	6.2	1.39	160.4	18.8	158.3	0.72	1.91	–	–
LSD (P=0.05)	0.06	0.04	3.5	1.0	6.4	0.02	0.04	–	–
Initial (1988)	5.6	0.88	120.1	8.0	76.0	–	–	–	–

1. OC=Organic carbon; N=nitrogen; P=phosphorus; K=potassium; Zn=zinc; Cu=copper; Fe=iron; and Mn=manganese.
2. C=Control; SM=rice straw mulch; SI=rice straw incorporation; FYM=farmyard manure.

Figure 2. Effect of different straw management practices and nitrogen (N) application (kg ha^{-1}) on N-uptake (grain + straw) by wheat during 5 years [from 1984/85 (year 1) to 1988/89 (year 5)] of wheat-rice rotation at Palampur, India (see Figure 1 for treatments).

in terms of wheat production and N uptake were observed in the third cropping season. During the first two seasons, particularly in the absence of N application, incorporation of rice straw, with or without FYM, lowered wheat yields and N uptake below that in the control treatment, probably because of N immobilization in the soil (Modgal et al. 1982). This effect was reduced with N application (@ 60–120 kg ha^{-1}), because it compensated to some extent for temporary loss of native N due to immobilization. With time, probably the size of labile pool of soil organic N increased, resulting in increased N supply capacity of soil; and thus SI started showing positive results. In general, SM increased the wheat yield and N uptake to levels almost comparable to FYM and SI + FYM, particularly along with added N, and remained higher than SI treatment. It could probably be due to increase in the soil temperature and biological activity due to mulching.

The FYM alone or in combination with SI gave higher wheat yields and N uptake than the control or SI alone, especially in the first 2 to 3 years, because it supplied higher amounts of NPK in easily available form to soil. The FYM also contains secondary and micronutrients in easily available forms (Kawata and Seegima 1976).

Straw treatments saved N fertilizer. Averaged over the last 3 cropping cycles, wheat yield with 120 kg N ha^{-1} alone was 2.26 t ha^{-1}. With 60 kg N ha^{-1} the yield was 2.62 t ha^{-1} with SI + FYM and 2.19 t ha^{-1} with SM. Without addition of organics, the wheat yield declined linearly with time at all the N application rates (Fig. 1). This may be due to decrease in N supplying capacity of soil at N application rate recommended for wheat. Thus to sustain crop productivity, addition of organics is essential.

Different rice straw treatments showed residual effects on rice yield and N uptake by rice (Figs. 3 and 4). The increase in rice yield over the control, in the absence of N application, was observed with FYM and SI + FYM (28%) in the second season, with SI (38%) in the third season, and with SM (36%) in the

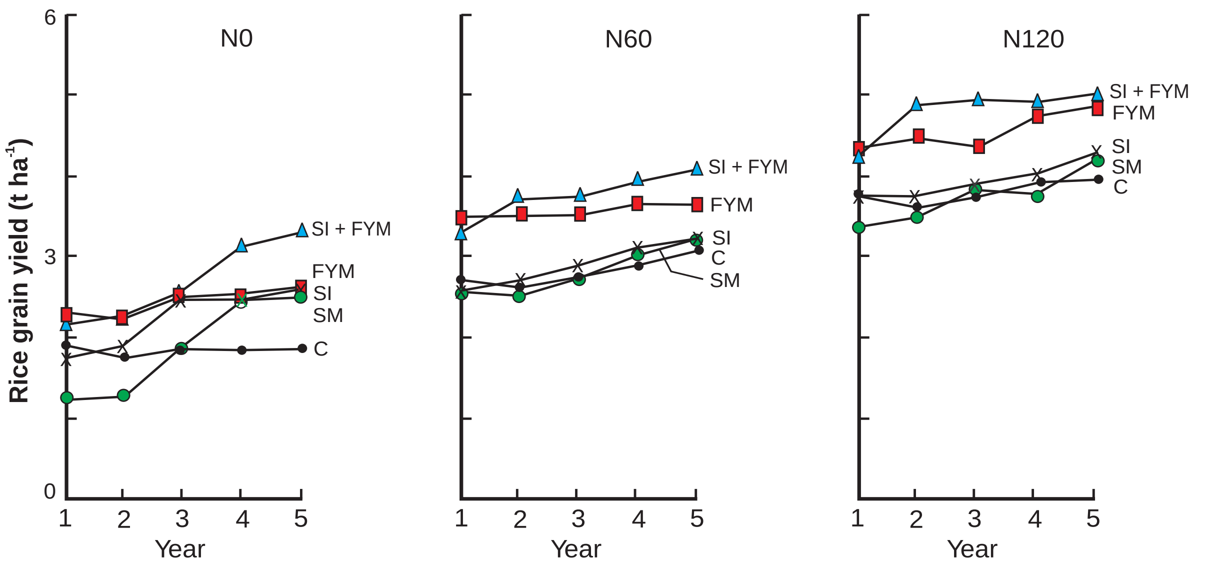


Figure 3. Effect of different straw management practices and nitrogen (N) application (kg ha^{-1}) on rice yield during 5 years [from 1985 (year 1) to 1989 (year 5)] of wheat-rice rotation at Palampur, India (see Figure 1 for treatments).

fourth season. During the fifth cropping cycle, the increases in rice yield with SI, SM, FYM, and SI + FYM treatments over the control were 42, 40, 43, and 65% respectively. Application of N (60 and 120 kg ha^{-1}) slightly enhanced the response time by providing readily available N to rice plants. Rice production with 120 kg N ha^{-1} was the same as with 60 kg N ha^{-1} along with FYM or SI + FYM during the third cropping season, but low during subsequent cropping cycles.

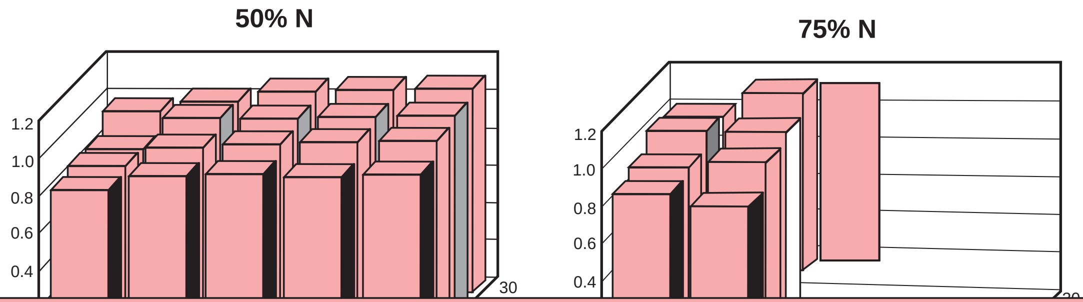
Lantana management

Response to *Lantana* incorporation in soil (before puddling) was observed on rice yield and N uptake during the third and subsequent cropping cycles. Rice yield and N uptake increased with addition of *Lantana* (Figs. 5 and 6). The interactions of *Lantana* and N levels were significant. In 1995, grain yield with 50% N and 10 t ha^{-1} *Lantana* equaled that with 100% N (without *Lantana*), while in 1992 it equaled grain yields with 20 and 30 t ha^{-1} *Lantana*. It shows that with the incorporation of 20 to 30 t ha^{-1} *Lantana*, inorganic N could be saved by 50% during the fifth rice crop. This period was reduced at higher N application rates (Fig. 5).

The residual effect of addition of *Lantana* wheat crop started appearing in the second crop onwards (Figs. 7 and 8). Wheat yield with 50% N and *Lantana* @ 10, 20, and 30 t ha^{-1} equaled wheat yield with control of 100% N without *Lantana* during 1995/96, 1993/94, and 1992/93, i.e., eighth, sixth, and fifth cropping cycle respectively. As in rice, this period decreased at higher N application rates (Fig. 7).

Physcio-chemical properties of soils

At the end of the fifth year in Exp. I, organic carbon and available NPK were higher than control with SI, SM, FYM, and SI + FYM; highest nutrient build-up was observed with SI + FYM. In Exp. II (at the end of sixth year) highest nutrient build-up was with 30 t ha^{-1} Lantana


50% N
75% N
1.2
1.0
0.8
0.6
0.4
30

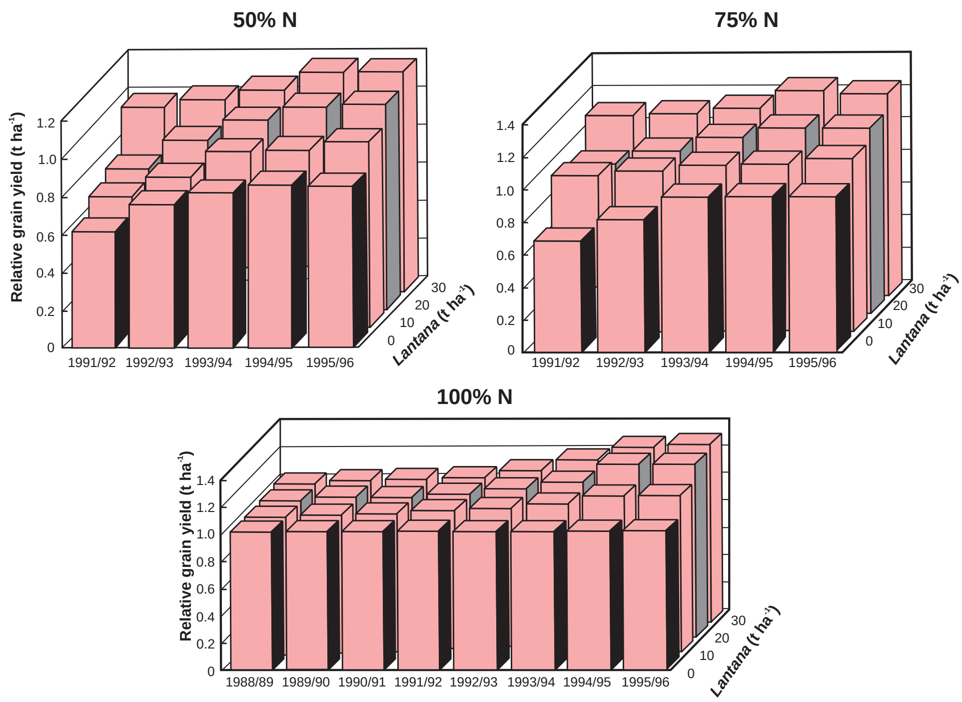


Figure 7. Temporal changes in wheat yield due to *Lantana* additions in rice relative to control of 100% nitrogen (N) without *Lantana* in rice-wheat system at Palampur, India.

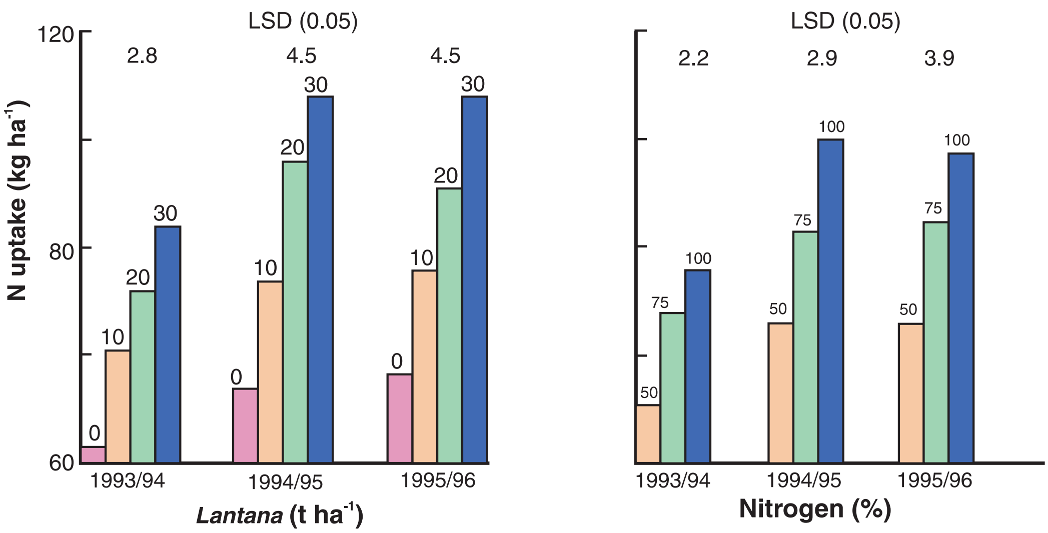


Figure 8. Effect of *Lantana* and nitrogen (N) application (% of recommended dose) on N uptake by wheat in rice-wheat system at Palampur, India.

7–34% with SI, SM, FYM, and SI + FYM respectively over control; the maximum increase again was with SI + FYM. Similarly, DTPA-extractable Zn and Cu increased with *Lantana* incorporation (10–30 t ha^{-1}) by 23–41% and 13–53% over the control; highest increase was with highest rate of *Lantana* addition. Soil pH increased by 0.1–0.2 units over the control of

5.9 with rice straw management, and by 0.0 to 0.3 units over the control of 5.7 with *Lantana* addition. Bhagat and Verma (1994) and Sharma et al. (1995) reported improvement in physical properties of soils owing to rice straw and *Lantana* addition.

Conclusion

Lantana biomass and rice straw are useful organic sources for improving soil productivity under rice-wheat cropping. *Lantana* (fresh biomass) incorporation to rice @ 20–30 t ha^{-1} or rice straw (+ FYM) incorporation to wheat @ 5 t ha^{-1} each on dry-weight basis, improved productivity of both the crops in sequence. Each treatment also saved chemical nitrogenous fertilizer by 50% during the fourth cropping cycle probably by increasing the size of labile pool of soil organic N.

References

Bhagat, R.M., and **Verma, T.S.** 1994. Tillage and residue management effects on soil physical properties and rice yield in northwestern Himalayan soils. Soil and Tillage Research 29:323–334.

Chaudary, T.N., and **Ghildyal, B.P.** 1969. Aggregate stability of puddled soil during rice growth. Journal of the Indian Society of Soil Science 17:261–265.

Fagi, A.M., and **De Datta, S.K.** 1983. Physical properties of rainfed wetland rice soil affected by cropping system and crop residue management. Field Crops Research 6:189–204.

Kawata, S.V., and **Seegima** 1976. The effect of compost application to the paddy yield and on some physical properties of sandy loam soils of Hisar. Journal of the Indian Society of Soil Science 23:380–383

Modgal, S.C., Sharma, H.L., and **Singh, M.P.** 1982. Studies on the crop residues and organic wastes in rice-wheat cropping systems in northwestern Himalayas. *In* Transactions of 12th International Congress of Soil Science, New Delhi, India.

Ponnamperuma, F.N. 1982. Straw as a source of nutrients for the wetland rice. *In* International Congress on Organic Matter and Rice. Los Bãnos, Philippines: International Rice Reasearch Institute.

Sahoo, R., Bandhopadhya, A.K., and **Nanda, B.B.** 1970. Effects of organic manures with and without drainage on rice yield, nutrient uptake and soil aggregation. Journal of the Indian Society of Soil Science 18:51–55.

Sharma, P.K., and **De Datta, S.K.** 1986. Physical properties and processes of puddled rice soils. Advances in Soil Science 5:139-178.

Sharma, P.K., Verma, T.S., and **Bhagat, R.M.** 1995. Soil structural improvements with the addition of *Lantana camara* biomass in rice-wheat cropping. Soil Use and Management 11:199–203.

Verma, T.S., and **Bhagat, R.M.** 1992. Impact of rice straw management practices on yield, nitrogen uptake and soil properties in a wheat-rice rotation in northern India. Fertilizer Research 33:97–106.