Nitrogen management in wheat sown in rice straw as mulch in North West India

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Abstract
Burning of rice straw after rice harvest in the Rice Wheat System of North west India can be overcome by sowing wheat into rice straw with the help of a machine called the 'Happy Seeder'. The adoption of zero tillage and retaining rice straw on the soil surface alters the nitrogen demand of the wheat crop due to changes in soil temperature and soil moisture under rice straw mulch, which in turn affects microbial growth. The microbes can either immobilise nitrogen or mineralise it and thus affects the plant growth. A field experiment was conducted to optimise the management of N fertilizer for wheat production under rice straw mulch so as to ensure high grain yield, high N use efficiency. Whilst band placement of nitrogen fertiliser at 180 kg/ha resulted in higher grain yield when rice straw was burnt, banding was not effective in increasing yield when straw was retained. The retention of rice straw as a mulch also resulted in higher mineral N concentrations remaining in the soil after harvest which may be used by subsequent crops in leaching can be minimised. This work provides evidence that retention of rice straw is not detrimental to yield if N management is optimised.

Key Words
Mineral nitrogen, band placement, broadcast application, N fertiliser, rice wheat system.

Introduction
The main production system of NW India is an annual rice/wheat rotation. The wheat straw can be used as animal fodder; the management of rice straw is more problematic. The time between harvesting of rice and sowing of wheat crop is limited and allowing time for the rice residue to breakdown delays the sowing of wheat beyond the optimum sowing date (15-20 November). This delay results in yield losses of 1% per day delay in sowing. To avoid sowing delays and blockage of cultivation implements by rice residue, farmers burn rice straw in the field. However, this results in nutrient loss and decreases in soil microbial populations. Burning also produces harmful greenhouse gases and particulate emissions, associated with human health problems. To eradicate the problems of burning residues and late sowing of wheat, a machine called the 'Happy Seeder' has been developed which simultaneously cuts and spreads rice straw on the soil surface (as mulch) while sowing wheat with zero or strip tillage (Sidhu *et al.* 2007). The adoption of the Happy Seeder with zero tillage and residue retention increases the carbon return to the soil and has therefore induced major changes in nitrogen management. Addition of rice straw as mulch increases the C:N ratio, which influences the balance between mineralization and immobilization of nitrogen. Therefore, with rice straw as mulch on the soil surface, it is possible that surface applied N will be immobilised (Janssen 1996). The mulch also retains the broadcasted fertiliser granules and ammonia volatilization losses can be enhanced (Bacon *et al.* 1986). Thus, placing the fertiliser deeper in the profile may be an effective management technique to increase N use efficiency where large quantities of rice straw are present. There had been reports in the literature that suggest that higher N rates are required (Gangawar *et al.* 2006), or low N rates are required (Rahman *et al.* 2005) to crops sown in straw mulch. Therefore, the aim of the field study was to determine the best method of fertiliser application with the optimum N rate in wheat sown in rice straw mulch.

Experiment details
Field preparation for wheat
The experiment was conducted in split plot design with three replications. Each plot size was 9 m long and 7.5 m wide. The soil was a sandy loam (typic Ustrochrept) with a pH of 7.5 and EC of 0.11 dS/m (1:2; soil: water). The available N, available P (Olsen P) and available K (1 M ammonium acetate extractable K) of the soil were 113, 17.5 and 102 kg/ha, respectively. There were two main treatments: with rice straw mulch (11.3 t/ha dry weight) and rice straw removed by burning. Two fertiliser application treatments were tested; band placement and surface broadcast. Band placement of urea occurred one day before sowing of wheat at the depth of 5 cm with hand plough and broadcast application of urea was done in two equal splits, at the time of wheat sowing and 25 days after sowing. Four Nitrogen rates (0, 60, 120 and 180 kg N/ha) were

applied by each application method. The wheat (PBW343) was sown at rate of 100 kg/ha with 20-cm row spacing with the 'Happy Seeder' at the soil depth of 8 cm. Single super phosphate at the rate of 26 kg P/ha was drilled at sowing in all treatments. After sowing, bunds and irrigation channels were made. In addition to pre- sown irrigation, four irrigations of amount approximately 75mm were given at 24, 58, 104 and 124 days after sowing. *Algrip* (metsulfuron methyl 20% WP) was sprayed at 37 DAS to kill the weeds, *Chloropyriphos-20% EC* was sprayed to kill the rice pests and *Tilt* fungicidal spray was applied to avoid Yellow rust after 98 DAS.

Plant and soil analysis

Crop germination was recorded after 15 DAS by counting the number of emerged seedlings in 100cm row lengths at 3 locations in with rice straw mulch and with burnt rice straw plots to determine plant density. Plant sampling was done at critical growth stages of wheat crop: at 34, 72, and 107 DAS and at maturity from 2 rows of 100 cm lengths. At these times tiller count, spike length and plant height were measured. At each plant sampling, plant biomass was determined after drying the plant samples at 65^{o}C. After recording the dry weight, the plant samples were analysed for total N by Kjeldahl distillation method (Nelson and Sommers 1973). Grain yield and straw yield was determined after harvesting manually from an area of 15 m^2. Agronomic efficiency of added N (kg grain/kg of N applied) was calculated. This estimates the overall efficiency of the system. Soil sampling for moisture content and mineral N content was done before sowing of crop, 23, 34, 70 DAS and at harvest. Soil sampling at sowing and harvesting was done up to 120 cm of soil depth, whereas at others soil sampling time, soil sampling was done at varied soil depths so that the nitrate concentrations in soil profile can be tracked. In broadcast treatments, soil sampling was done randomly from three locations in each plot whereas in band placement treatments, soil sampling was conducted by coring side by side such that composite soil samples of three cores contained only one band of fertilizer. Soil mineral N was analysed by extracting in 2M KCl solution (soil: solution, 1:5) and shaking for 1 hour. The supernatant was filtered through filter paper Whatman 42. The filtrate was kept in refrigerator at 4^{o}C until analysis was conducted by Kjedahl method (Mulvaney 1996). The remaining soil from each sample was used for determining gravimetric moisture content of soil. The wet soil samples were dried at 105^{o}C for 48 hours. Data was analysed using Analysis of Variance of Genstat 5 (Release 3.5). Least Significant difference (LSD) at 0.05 and 0.001 probability levels of significance was used to compare the results.

Results and discussion

The grain yield ranged from 1.57 t/ha in unfertilised treatment to 5.04 t/ha in fertilised treatments (Table 1) and was highly significant with rice straw treatment, method of fertilizer placement and N rate. Under all methods of application and rice straw treatments, the highest yields were obtained from the highest N application rate (180 kg N/ha) (Table 1). However, agronomic efficiency was not optimised at that application rate (Table 1).

Table 1. The effect of rice straw as mulch, fertiliser N rate and method of fertiliser application on grain yield (t/ha) and agronomic efficiency (kg grain/ kg of N applied).

Straw treatments	N rate (kg/ha)	Band placement	Broadcast application	Band placement	Broadcast application
		Grain Yield (t/ha)		Agronomic Efficiency	
Rice straw burnt	0	1.62	1.86	-	-
	60	2.63	2.77	16.8	15.2
	120	3.86	3.70	18.7	15.4
	180	5.04	4.80	19.0	16.3
Rice straw mulch	0	1.57	1.77	-	-
	60	2.38	2.44	13.6	11.1
	120	3.62	4.26	17.1	20.7
	180	4.58	4.63	16.8	15.9
LSD (0.001)		0.11		1.6	

For any given rate of N and method of placement, yield was highest when rice straw was burnt compared to where it was mulched with the exception of when N was broadcast at a rate of 120kg N/ha. At that rate of N addition yield was optimised (4.26 t/ha) when fertiliser was broadcast onto the rice straw. This rate and application method resulted in the highest agronomic efficiency (20.7 kg grain/kg N applied) of the combinations tested on mulched plots. This may be due to decreased volatilisation of applied urea on mulched treatments as the surface wind speed and soil temperature would have been lower than on burnt

plots, these factors are known to decrease losses by volatilisation (Rachhpal-Singh and Nye 1986).
At higher N application rates (120 and 180 kg N/ha) banding created higher yields compared to broadcasting in the burnt plots (Table 1). When rice straw was retained, banding either had no effect at 180 kg N/ha or created lower yield at 120 kg N/ha compared to broadcasting.
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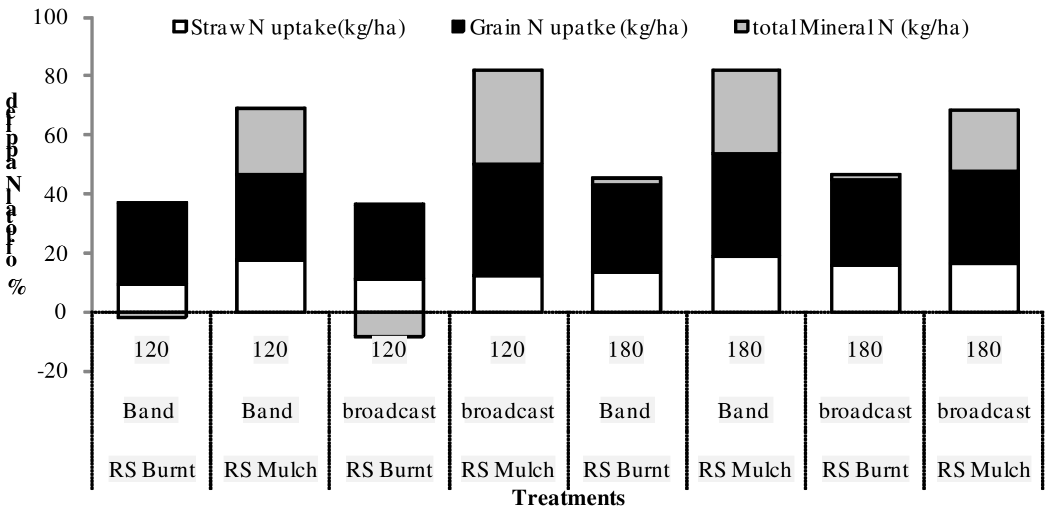

Figure 1. The percentage of total N applied through fertiliser measured in grain, wheat straw and in soil as mineral N at 120 and 180 kg N/ha. Data are those of the treatment minus control for each fertiliser placement and rice straw treatment. RS = rice straw.

The rice straw mulch treatment resulted in higher mineral N concentrations regardless of the method of fertiliser application (Figure 1). This may be due to the re-mineralisation of immobilised N as the microbial population dies (Kumar and Goh 2000) or due to faster re-mineralization of immobilised N in straw amended soil than mineralization in unamended soil (Yadvinder *et al.* 2005). Application of high fertilizer N rate in high C:N residue amended soils lowers the C/N ratio of the residue which avoids net immobilization but enhances the mineralization process (Pathak *et al.* 2006). This N remained in the soil after harvest and helped to maintain inorganic N concentrations in soil. This represents significant savings in the fertilisation of the following crop assuming it is not lost by leaching. Further research is required to determine the best rapidly growing short term crop species to grow after wheat and prior to the following rice crop in the rotation.

Conclusion

The retention of rice straw during the growth of wheat in the rice-wheat rotation will not reduce wheat yields compared to where straw is burnt if N fertiliser is broadcast. Banding of N fertilisers did not result in greater yields when rice straw was retained as mulch. Therefore this work is evidence that farmers in North West India using the "Happy Seeder" can retain rice straw and grow wheat without comprising yield. Thus the need to burn rice straw and the environmental pollution associated with that practice is removed

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