Productivity of multi-crops sown on permanent raised beds in the tropics

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Abstract

Present rice–wheat systems in Bangladesh to meet up the food security of an expanding population are threatened by productivity decline, scarcity of resources, and environmental factors. Raised bed agriculture is widely used in developed countries to improve system productivity. Straw retention can be a potential source for improving soil health and crop productivity. The consequences of straw removal on productivity and profitability of rice-wheat systems have not previously been documented in Bangladesh. A 3-yr study was conducted at the Wheat Research Centre, Dinajpur, Bangladesh to compare the effects of 4 N levels (0, 50, 100 and 150% of recommended) and 3 straw management (straw removal of all crops, 50% and 100% straw retention of all crops) in wheat-maize-monsoon rice cropping systems on permanent raised beds. Compared with straw removal, the 50% straw retention with 100% N significantly increased grain yield (by 32%) in maize, with no statistical difference with 150% N plus 100% straw retention. The subsequent rice yields were also increased significantly by 33% with 100% N compared to straw removal and was not significantly different from 50% or 100% straw retention with 50% or 150% recommended N. In wheat, the highest grain yield was recorded from 50% straw retention plus 150% N, which was 26% higher than straw removed plots. In 100% straw retention with 150%N treatment, the yield was negatively affected and in 50% N plus 50% straw retention treatment the profit was maximized. Weed pressure was also reduced with straw retention. Results reveal considerable benefits of straw retention of crops with the use of 50-100% recommended N in terms of yield and economic benefit.

Media summary

Use of permanent beds and straw retention improves crop productivity, more economic gains, reduces weed pressure, conserves water resources, and maintains system productivity.

Keywords head

Rice, wheat, maize, permanent bed, straw retention, nitrogen

Introduction

Land degradation and the deterioration of soil fertility are among the main causes of the stagnation or decline of agricultural production in many tropical countries. Approximately 85% of rice-wheat system is practiced in the Indo-Gangetic Plains of South Asia in India, Pakistan, Nepal and Bangladesh (Timsina and Connor 2001). Rice is planted in damp and flat soils after thorough plowing, which negatively affects soil properties (Hobbs and Giri 1998). Wheat is then planted in these degraded soils. Change from growing crops on the flat to planting crops on raised beds offers more effective control of irrigation and drainage in addition to increased nutrient uptake and efficiency as well as rain water management during the monsoon season. Connor *et al* (2003) reported that permanent raised beds may offer farmers significant advantages, such as reduced tillage, increased opportunity for crop diversification, mechanical weeding and placement of fertilizers, opportunities for relay cropping and intercropping, and water savings. There are also indications that crop yields from beds can be further increased with higher N doses and later irrigation because of the reduced risk of lodging (Sayre and Ramos 1997). Raised beds are widely used in developed countries but have been introduced only recently in Bangladesh to improve system productivity (Talukder *et al* 2002). Crop residues are an important natural resource in the stability of agricultural ecosystems. About 25% of N and P, 50% of S and 75% of K uptake by cereal crops can be retained in crop residues, making them valuable nutrient sources (Singh 2003). Traditionally, in rice-wheat or other systems of South Asia, straw is fed to cattle, burned for fuel, or used as building material leaving little for soil incorporation. As a result soil organic matter levels are declining in these cropping systems which can have serious implications for soil health. These factors, along with N fertilization, must be considered to develop new farming practices that can increase system yields. Investigations were undertaken on permanent bed systems to: (i) evaluate yields of multi crops and (iii) study the profitability of the pattern, as affected by N levels and straw management.

Methods

A wheat (*Triticum aestivum* L.)-summer maize (*Zea maize* L.)-monsoon rice (*Oriza sativa* L.) cropping pattern during 2001-02, 2002-03 and 2003-04 seasons was studied at the Wheat Research Centre, Dinajpur, Bangladesh (25^{0}38' N, 88^{0}41' E, and 38.2 m asl). The experimental soil had low organic matter (0.8 %) and low nitrogen [Total N (35?g/g soil)]. The soil was sandy loam and acidic in nature (pH 5.5). The study was designed in a split plot with three straw management practices (straw removed, and 50% and 100% straw retention) as the main plots and four N levels (0, 50, 100 and 150% of recommended) in sub-plots, all on permanent raised beds. In straw removed treatment, straw of all crops was removed. The beds reshaped with little tillage prior to planting of each crop.

The width of the bed was 75 cm. Two rows of wheat (var. Kanchan), or rice (var. BRRI Dhan 32), and 1 row of maize (var. Pacific 11) were planted on the top of each bed during the respective crop seasons. The mungbean (var. BARI Mungbean-5) was sown on the furrows between the maize beds as a bonus and indicator plant to see the microbial activities in the soil environment. Mungbean was harvested in about 65 days after seeding. The space between wheat and rice row on the bed was 30 cm. Rice and maize were planted with a spacing of 30cm x 20cm and 75cm x 25cm, respectively. Chemical weed control in all crops was administered 1 or 2 days before planting through the application of 1.4 kg a.i./ha glyphosate [N-(phosphonomethyl)glycine]. Manual weed control was done after the first irrigation for wheat, 45 days after planting for maize and rice, and 25 days after planting for mungbean. All crops were harvested by cutting a 7.5 m^2 portion at the center of each micro-plot. Finally, grain yields were adjusted to 155 g/kg moisture for maize and 120 g/kg for others. Soil and plant samples were also taken for N-uptake calculation. Data were analyzed for variance (ANOVA) by using MSTAT-C. Treatment means were compared using Duncan's Multiple Range Test (DMRT) at $P \leq 0.05$. The partial budget and marginal analysis of undominated treatment responses of pooled yield were done by the method of Elias and Karim (1984).

Results

Table 1 shows that weed infestation was reduced due to retention of straw. Straw covered the soil surface and hence may have prevented weed seed germination. An initial light pre-seeding irrigation stimulated emergence of weeds, followed by their control with non-selective herbicides.

Table 1: Total weed (#/m^2) infestations in various crops as influenced by straw retention in rice-wheat-maize cropping system in permanent beds (2002-03 to 2003-04)

Treatment	Rice	Wheat	Maize

	NL[?]	BL	Sedge	NL	BL	Sedge	NL	BL	Sedge
Straw removed	41	0	10	43	64	14	89	0	13
50% straw retention	14	0	7	14	18	9	27	0	5
100% straw retention	9	0	5	10	16	7	13	0	4

[?]NL= narrow leaf, BL= broad leaf

Table 2: Grain yields (t/ha) of various crops (two years pooled) as influenced by straw management and N levels in a rice-wheat-maize cropping system on permanent beds.

N Levels (% of recom.)	Maize			Rice			Wheat		
	Straw removed	50% straw retention	100% straw retention	Straw removed	50% straw retention	100% straw retention	Straw removed	50% straw retention	100% straw retention
0	5.14 f[?]	6.15 ef [‡](+20)	6.62ef [†](+8)	2.32 d	2.97 cd (+28)	3.16 cd (+6)	2.07 g	2.39 fg (+15)	2.59 efg (+8)
50	7.27 de	8.53 cd (+17)	9.41 bc (+10)	3.64 bc	4.26 ab (+17)	4.79 a (+12)	3.04 def	3.20 de (+5)	3.74 cd (+17)
100	8.36 bc	11.00 ab (+32)	11.28 ab (+3)	3.79 bc	5.03 a (+33)	4.55 ab (-10)	3.75 cd	4.04 bc (+8)	4.23 bc (+5)
150	9.78 bc	11.03 ab (+13)	11.78 a (+7)	4.19 ab	5.12 a (+22)	4.53 ab (-12)	4.00 bc	5.03 a (+26)	4.63 ab (-8)
CV (%)		6.85			9.53			6.78	

[?]Within the treatment interactions the figures having the same letters are not significantly different at 5% level by DMRT.
[‡] Numbers in parentheses represent percentage increase over straw removal.
[†] Numbers in parentheses represent percentage increase or decrease in grain yield over 50% straw retention.

Retention of straw was important in achieving higher yields and increasing system productivity. Table 2 shows that the 50% straw retention plus 100% N treatment had a 32% increase in maize grain yield over straw removal at the same N rate. Maize yields from 50% and 100% straw retention at both 100% and 150% N rates were higher than the other N and straw treatments but not statistically different from each other. Subsequent rice yield also increased significantly by 33% with 50% straw retention plus 100% N rates over straw removal. There were no significant differences between 50% or 100% straw retention with 50 or 150% recommended N rates. The maximum grain yield of wheat (5.03 t/ha) was obtained from 50% straw retention plus 150% N rates, which was 26% higher compared to straw removed plots. Yield decreased by 8% with 100% straw retention compared to 50% retention under 150 kg N/ha N in wheat. These yield increases with straw retention may be due to the conservation of soil moisture, less weeds, and more efficient use of fertilizers. Limon-Ortega *et al* (2000) reported that permanent beds combined with retaining all crop residues in the soil as stubble have the potential to increase both wheat and maize yields with higher nitrogen management.

Economic analysis was done to find out the best straw and nitrogen dose combination that gives more economic benefit as well as higher yield. Marginal analysis, under partial budgeting systems, was done to find out economically the most profitable treatment. The costs that vary from treatment to treatment like quantity of straw and nitrogen level and labor for applying fertilizer, straw mulching and weeding were considered as variable costs. Other costs such as fertilizers, seeds and seeding, irrigations, etc. were assumed same and the existing market price was considered for the analysis. The marginal analysis of non-dominated cost treatments showed that the marginal rate of return (MRR) on investment was highest (1945%) for 50% straw retention plus 50% recommended N treatment, followed by 50% retention plus 100% N (1236%) (Table 3). The use of 50 or 100% recommended N with 50% straw retention optimized the yield and maximized the profit.

Table 3: Economic analysis of various treatments on permanent beds.

Treatment	Variable costs (Tk./ha)	Gross Margin ([?]Tk./ha)	Marginal gross margin (Tk./ha)	Marginal variable cost (Tk./ha)	Marginal rate of return (%)
50% SR + 150%N	13192	127436	5884	2761	213
50% SR + 100% N	10432	121552	15140	1225	1236
100% SR + 50% N	9207	106412	8561	1530	560
50% SR+ 50% N	7677	97851	24058	1237	1945
100% SR + 0% N	6440	73793	1468	1530	96
50% SR + 0% N	4910	72325			

[?]1US$=60 Taka; SR, Straw retention; N, % of recommended

Conclusion

Use of crop residues is an important component of soil restorative management, and may have a long-term positive impact on soil quality. Retention of crop residues may influence on soil organic matter content and moisture depletion. Fertilizer use efficiency may be increased with a change to permanent bed management and less problem of weeds and crop lodging. Raised beds also provides a means to help ameliorate the adverse effects of tillage and excess water leading to waterlogged conditions that hamper growth and development of most crops. The use of permanent beds reduced cost of production and long turn-around time with more economic gains. Permanent bed with 50% straw retention of previous crops in combination with use of 50-100% N fertilizer results in high yield and profit.

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