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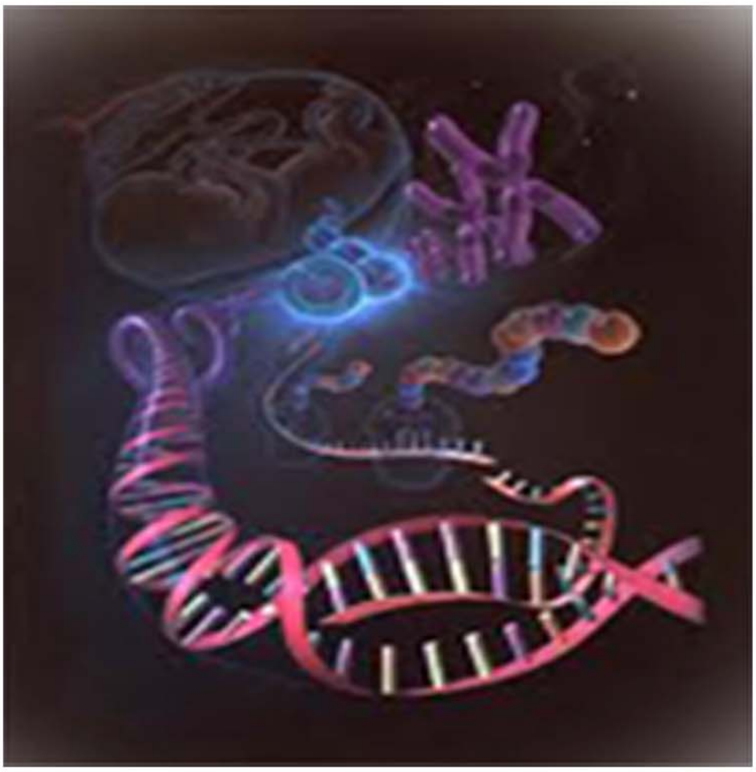

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Research Paper

IMPROVING INCOME AND NUTRITION BY INCORPORATING MUNGBEAN IN THE PRESENCE OF SURFACE RETAINED RESIDUES IN RICE-WHEAT CROPPING SYSTEM

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Continuous cultivation of rice and wheat has resulted in deterioration of soils,declination of water tables, salinization has set in, insect pests and plant diseases have increased, and environmental problems have been growing in the region. The answer to the said problems is'crop diversification' through the introduction of soil-enriching legumes that can revive the soils, decrease moisture consumption, disrupt the insect and disease cycles by converting the cereal-cereal mono-cropping to cereal pulse-cereal cropping system. A field experiment was conducted over 3 years to compare conventional and conservation agriculture technologies in rice-wheat-mungbean cropping systems, with and without retention of crop residues. The results indicated that yield were similar when rice was conventionally puddled transplanted and unpuddled transplanted on wide raised beds and unpuddled transplanted flat beds in normal spacing. In wheat crop zero till paired row planting with or without residue retained seed yields were 6 to 8% greater for equal spacing conventional practices. Total system productivity increased by10-13% in residue retention with permanent wide raised beds over conventional. Various crop establishment techniques had a significant effect on rice agronomic efficiency of N ranged from 2.8 to 11.1, recovery efficiency with residue and without residue ranged from 33 to 61% and physiological efficiency ranged from 5.2 to 27.5, respectively.

Keywords: Crop residue, Soil health, Water productivity, System productivity

INTRODUCTION

Rice is transplanted in flat fields that are typically ponded for long periods or continuously from transplanting until shortly before harvest. A change from growing crops on the flat to raised beds offer more effective control of irrigation water and drainage (Naresh *et al*., 2010), suggested that permanent raised beds might offer significant advantages to the farmers such as increased opportunities for crop diversification, mechanical

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weeding and placement of fertilizers, relay cropping and intercropping, and reduced tillage and water saving. Inclusion of grain legumes in the dry-wet transition of rice-wheat system as a third crop may be another option to increase cropping intensity, soil fertility and productivity of the system. Due to lack of suitable crop establishment practices and temporary water logging at reproductive stage, inclusion of a grain legume like mungbean in the rice-wheat cropping system very often faces problems. Bed planting may be a solution for these problems because raised beds not only facilitates irrigation but also drainage and theirin lies their potential to increase the productivity of crops in the system. Crop residues are an important source of soil organic matter vital for the sustainability of agricultural ecosystems. About 40% of the nitrogen (N), 30 to 35% of the phosphorus (P), 80 to 85% of the potassium (K), and 40 to 50% of the sulfur (S) taken up by rice remains in vegetative plant parts at crop maturity is retained in crop residues, making them valuable nutrient sources (Dobermann and Fairhurst, 2002) . Wheat and rice straw are usually removed from fields for cattle feed and for purposes such as livestock bedding, thatching material for houses or for fuel, leaving little for incorporation into the soil.

Due to continuous cultivation of cereals in intensively cropped areas, nutrient (NPK) uptake increased by 663 kg against the applied 400 kg ha^{-1} to yield 8.8 t ha^{-1} in rice-wheat rotation, and 438 kg against the applied 358 kg ha^{-1} to yield 6.3 t ha^{-1} in rice-rice rotation (Ali and Kumar, 2004). Furthermore, the optimum NPK ratio of 4:2:1 widened to 8.5:3.1:1 at the national level; the western Indo-Gangetic Plains shows maximum distortion (37.1:8.9:1) where rice and wheat are grown in sequence on 82% of the total cropped area (Ali and Kumar, 2004). This is leading to a rapid decline in the organic matter content of soils, particularly in Punjab (0.2% carbon content) (Ali and Kumar, 2004). Planting rice two months before the onset of the monsoon has dangerously lowered the water table at the rate of 300 mm per year. Excessive and indiscriminate use of irrigation water causes salinity to increase and water to stagnate. After the harvest of wheat and before the transplanting of rice, the land remains fallow for 65-70 days (late March/April to early July). This period could be used to raise a catch crop of summer mungbean. A low input, short duration, high value crop, mungbean fits very well into rice-wheat cropping systems and other crop rotations. Mungbean fixes nitrogen in the soil, requires less irrigation than many field crops to produce a good yield, and helps maintain soil fertility and texture. Adding mungbean to the cereal cropping system has the potential to increase farm income, improve human health and soil productivity, save irrigation water, and promote long-term sustainability of agriculture. The productivity of rice-wheat system can be sustained partly by inclusion of legumes in the existing cropping systems. Adding of legumes in cereal based cropping system can improve soil structure, improve nutrient exchange, and can maintain healthy sustainable soil system (Hossain, 2009). Straw mulch also lowers soil evaporation, leading to higher soil water content and/or crop water use (Rahman *et al.,* 2005; Sidhu *et al.*, 2007). The magnitude of the reduction in evaporation depends on the straw load, soil water content and evaporative demand. The effects that mulching has on soil moisture and temperature will influence many soil and plant processes that ultimately determine the growth and yield of crops. Straw mulch may also reduce weed growth by mechanisms such as reduced light, effects on soil temperature, physical suppression and allelopathy (Dhima *et al.*, 2006).

MATERIALS AND METHODS

An experiment on different crop establishment and tillage management techniques involving residue retention or residue removal were conducted under researcher-designed and farmer-managed, with a single replicate, repeated over many farmers. Therefore, the experimental design was Randomized Block Design in which farmer as a replicate commencing with kharif in 2008 at Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut sites in the North West India (28° 402 073 N to 29° 282 113 N, 77° 282 143 E to 77° 442 183 E). The climate of the area is semiarid, with an average annual rainfall of 805 mm (75-80% of which is received during July to September), minimum temperature of 4 °C in January, maximum temperature of 41-45 °C in June, and relative humidity of 67-83% during the year. The soils are generally sandy loam to loam in texture and low to medium in organic matter content. Groundwater pumping is the predominant method of irrigation. Wheat is grown by broadcasting after four to five dry-tillage operations and rice planted after three to four dry tillage operations. The plots consisted of eight layout or crop establishment straw treatments. The sites, treatments and management are briefly summarised here for convenience, together with details of the water and soil water monitoring (Table 1). The width of the wide beds (mid furrow to mid furrow) was 137 cm, with 107 cm wide flat tops and 12 cm furrow depth. Plot size was 15 × 10 m, with earth bunds around each plot.

Sowing of Mungbean: Summer mungbean, cultivar SML 668 was planted by two methods: (1) Sown as a broadcast just before the last irrigation of standing wheat crop. After wheat harvest the mungbean crop was left undisturbed in the rice-wheat system with and without residue retain. (2) After harvest of wheat crop mungbean was planted by multi crop zero till zero cum ferti seed drill with enclined plate metring device machine with and without residue retain. The characteristic of SML 668 variety is that it attains 80% uniform maturity. After maturing of mungbean

Table 1: Treatments in the Replicated Experiment in Rice-wheat Rotation

Layout	Abbrevations	Layout	Abbrevations
T_1– Rice direct seeded by zero till drill	ZT–DSR	T_1– Wheat planted by ZT turbo happy seeder	ZT–HS
T_2–TPR on wide beds + mulch	WBed–TPR+M	T_2–Wheat on wide beds + mulch	WBedZT–DSW+M
T_3 –TPR on wide beds – mulch	WBed–TPR–M	T_3 –Wheat on wide beds – mulch	WBedZT–DSW–M
T_4 –UP TPR in paired row + mulch	UPTPRPR + M	T_4 –Wheat planted by ZT paired row + mulch	ZT–DSW PR +M
T_5 –UPTPR in paired row – mulch	UPTPR PR–M	T_5 –Wheat planted by ZT paired row – mulch	ZT–DSW PR –M
T_6–UPTPR in normal spacing + mulch	UPTPR+M	T_6–Wheat planted by ZT normal spacing+ mulch	ZT–DSW+M
T_7– UPTPR in normal spacing – mulch	UPTPR–M	T_7– Wheat planted by ZT normal spacing– mulch	ZT–DSW –M
T_8 –Conventional practices	CT–TPR	T_8 –Conventional practices	CT–BCW

Note: TPR=Transplanted rice, UPTPR=Unpuddled transplanted rice, CT-TPR=Conventional puddled transplanted rice ZT=Zero till drill, ZTDSW =Zero till drill direct seeded wheat, CT-BCW=Conventional till broad casting wheat.

a spray of glyphosate herbicide @ 1.5l/ha was done to shed the green leaves and then the picking was done. The residue of mungbean was retained on the surface for the next rice crop.

RESULTS AND DISCUSSION

Crop Yields: The various tillage and crop establishment techniques had a significant effect on rice yield (Table 2). Yield were similar when rice was conventionally puddled transplanted (CT-TPR), transplanted on wide raised beds (WBedTPR) unpuddled transplanted in paired rows only slits open by zero till drill (UPTPRPR) and unpuddled transplanted in normal spacing (UPTPR) in all techniques with or without residue retained. This indicated that puddling of soil, for which normally a large amount of water and labor are required can be avoided without any penalty in rice. Treatments T_4 and T_6 were at par with each other, however, they recorded higher grain yield over T_1 treatment which recorded lowest grain yield (4.40 t ha^{-1}). On T_4 yielded 6.2 to 14.9 % higher than unpuddled transplanting equal spacing with or without residue retained and direct seeded rice.

Wheat grain yield t ha^{-1} treatment T_2 was found significantly superior to all the treatments, and recorded maximum grain yield. Grain yield increased significantly within various resource conserving technologies with residue. Treatment T_4 was significantly superior to the remaining treatments. T_5, T_6 and T_7 were at par with each other, how ever, they recorded significantly higher grain yield over T_8 treatment which recorded lowest grain yield. Treatments T_4 and T_5 seed yields were approximately 6 to 8% greater for equal spacing conventional practices. The crop residues retained as surface mulch (partially anchored and partially loose) @ 6.0 mg ha^{-1} that helped in regulating the soil temperature and moisture and more response was mainly due the aberration in weather conditions during the crop growth period.

Total System Productivity: Straw retention increased productivity rapidly, starting from the second crop cycle. We believe this is an important findings because, if repeated on farmers fields, farmers will quickly realize the benefits and be more interested in adopting the technology. Total system productivity increased by 10-13% in

Table 2: Total System Productivity ,Water Application and Productivity Under Tillage Options and Straw Levels in Rice-wheat-mungbean Systems

Crop Establishment	Grain Yield(t/ha)				Irrigation Water Applied (mm ha^{-1})				Water Productivity (kg grain m^{-3})			
	Rice	Wheat	Mungbean	System	Rice	Wheat	Mungbean	System	Rice	Wheat	Mungbean	System
T_1	4.40	5.18	1.34	10.92	2410	328	250	2988	0.179	1.579	0.536	0.365
T_2	5.38	5.51	1.47	12.36	2128	301	223	2652	0.253	1.836	0.659	0.466
T_3	5.19	5.20	1.38	11.77	2293	316	235	2843	0.226	1.646	0.587	0.414
T_4	5.17	4.98	1.36	11.51	2635	340	260	3253	0.193	1.465	0.523	0.354
T_5	5.01	4.80	1.32	11.13	2825	355	270	3450	0.174	1.352	0.489	0.323
T_6	4.97	4.75	1.33	11.05	2740	323	253	3316	0.178	1.471	0.526	0.333
T_7	4.85	4.67	1.29	10.79	2935	342	265	3542	0.162	1.365	0.487	0.305
T_8	5.45	4.08	1.21	10.74	3170	410	275	3855	0.169	0.995	0.440	0.279
CD at 5 %	0.95	0.40	0.32	1.42	–	–	–	–	–	–	–	–

residue retention with permanent wide raised beds system over conventional (Table 2). Total system productivity of rice, wheat and mungbean (R-W-M) was 12.36 t $ha^{-1}yr^{-1}$. For all crops the highest system yields occurred in residue retained, but the differences between residue removal and residue retained were always significant for the three crops.

Surface Retained Wheat Residue Effect on Mungbean: The results of summer mungbean, cultivar SML 668, grown as a broadcast just before the last irrigation of standing wheat crop. Mungbean helped in controlling the adverse effect of terminal heat on wheat crop. After wheat harvest the mungbean crop was left undisturbed in the rice-wheat system under different residue loads of zero to 6 t/ha, indicated the possibility of diversifying the system coupled with enhanced productivity and profitability to farmers. The mungbean grain yield recorded without residue retained was 1.29 t/ha that increased to 1.47 t/ha with 6 t/ha residue retention (Figure 1). This difference in wheat residue retained can be attributed to temperature moderation and water conservation compared to the treatment where residue was removed from the plots.

Water Application and Water Productivity

The input water application includes the irrigation water applied and the rain water during the rice season (634 mm) and wheat season (71 mm). The total water application in rice varied markedly due to tillage and crop establishment techniques (Table 2). The conventional puddled transplanted rice consumed more water (3170 mm ha^{-1}, T_8) compared to transplanted rice on wide raised beds with residue retained (T_2) ,rice seeded by zero till drill T_1 and unpuddled transplanted rice in paired rows with residue retained (T_4 , 2128 mm, 2410 mm and 2635 mm). The savings in water use with beds with or without residue retained was 23.9 to 32.9% compared to conventional puddled transplanted rice. Similarly, the water application in wheat was remarkably lower with permanent beds compared to other practices. The higher irrigation water application in wheat under residue removal treatments as compared to residue retain plots. Similarly, the water application in mungbean was remarkably lower with permanent beds compared to other practices. The higher irrigation water application in mungbean under residue removal treatments as compared to residue retain plots. The total system water use was remarkably lower with permanent beds compared to other practices but the maximum water use was recorded with T_8 and without residue retain mungbean. The system irrigation water productivity under permanent beds was higher compared to other tillage and crop

Figure 1: Effect of Different Levels of Surface Retained Residue on Productivity of Mungbean Tonnes Ha^{-1}

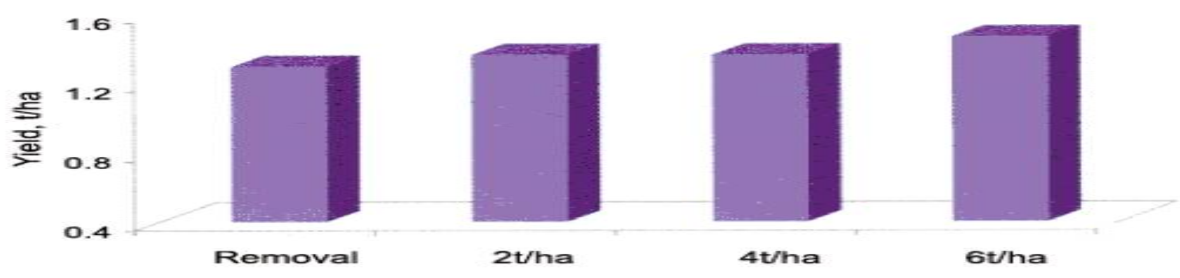

Table 3: Soil Physical Characteristics in Tilled And Permanent Beds at Different Residue Management in 0-20 cm Soil Layer After 3 Years

Treatment	Bulk Density ($Mg\ m^{-3}$)	Infiltration rate (mm/h)	Cone Index	MWD (mm)	Field Capacity (% Moisture)		Permanent Wilting Point (% Moisture)	
					0-5 cm	5-20 cm	0-5 cm	5-20 cm
T1	1.58	52.3	2.56	0.40	30	31	12	11
T2	1.55	78.7	2.45	0.45	32	33	11	11
T3	1.57	81.5	2.48	0.44	30	31	10	10
T4	1.56	69.5	2.60	0.43	31	32	12	10
T5	1.59	73.5	2.65	0.39	28	29	10	09
T6	1.60	55.8	2.80	0.30	30	31	12	10
T7	1.61	50.4	2.81	0.25	29	29	10	09
T8	1.66	36.5	2.85	0.26	29	29	10	09
Initial	1.50	–	2.27	0.32	–	–	–	–
C D at 5%	0.09	10.62	0.17	0.06	–	–	–	–

establishment techniques and lowest system water productivity was recorded with T_7 (UPTPR-M), T_8 (CT-BCW)+mungbean.

Planting System and Soil Quality

Soil from permanent wide raised beds with full residue retention had significantly higher Mean Weight Diameter (MWD) compared to conventional tilled flat beds (Table 3). The effect of residue removal on soil structure in permanent wide raised beds was very clear as the MWD decreased with decreasing amounts of residues retained. Similar results were found for infiltration rates on top of the raised bed and in the furrow. The standing stubble remaining on top of the permanent wide raised beds induces a 'vertical' mulching effect, resulting in bigger water infiltration than in fields without residue. The furrows in permanent wide raised beds are more compacted as all traffic is always concentrated in the furrows. At initial time bulk density of surface layers remains lower under residue retained bed planting than under conventional tillage. This is because top of beds remains loose. The lower bulk density means more porosity especially in upper surface. The cone index was increased significantly under all the tillage and crop establishment techniques but the extent of increase was more under conventional tillage system.

CONCLUSION

Retention of crop residue offer an important soil restorative strategy likely to have a long-term positive impact on soil quality and crop productivity in intensive Rice-Wheat-Mungbean (RWM) cropping systems. Lignified residual straw and roots added more organic matter and nutrients into the soils under residue retained plots, resulting in increased nutrient uptake by the crops. Crop productivity on UPTPR in paired row with residue retention rose by 6.2 to 14.9% for rice and Wheat planted by ZT paired row with residue retained 6 to 8% and total system productivity increased by 10-13% in residue retained with permanent wide raised beds system over conventional. Thus results showed that permanent wide raised beds with residue retention can help to sustain and intensify RW system to RWM systems with proper management. We propose that soil management can be one of our best tools for improving income and nutrition of the burgoining population. The way we manage soils and crop residue now will have an impact on the quality of soil and water resources that future generations will need for food security.

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