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DIVERSIFICATION OF RICE-BASED CROPPING SYSTEMS TO IMPROVE SOIL FERTILITY, SUSTAINABLE PRODUCTIVITY AND ECONOMICS

R. I. Ali, T. H. Awan, M. Ahmad, M. U. Saleem and M. Akhtar
Rice Research Institute, Kala Shah Kaku
Corresponding Author: ranainayatali@yahoo.com)

ABSTRACT

Experiment on rice based cropping systems to improve soil fertility and sustainable crop productivity was conducted at Rice Research Institute, Kala Shah Kaku, Sheikhupura, Pakistan during 2007-08 in Randomized Complete Block Design with three replications. Seven cropping patterns viz; rice-berseem, rice-lentil, rice-canola, rice-wheat-mungbean, rice-wheat-cowpeas, rice-sunflower and rice-wheat-sesbania (rostrata) were compared with commonly practiced rice-wheat cropping pattern. Three crops viz; sesbania (dhancha) , mungbean and cowpeas were sown in the 4th week of April just one week after the harvest of succeeding wheat crop and their crop residues incorporated into the soil by rotavator before puddling for transplanting of rice crop. Berseem, lentil and canola were sown in the 3rd week of November after the harvest of rice crop (super basmati) while sunflower was sown in the 3rd week of February. The cropping systems were evaluated for their productivity & to assess their effect on the soil organic carbon contents and available soil NPK. The results revealed that the green manuring and leguminous cropping patterns gave higher paddy yield as compared to commonly practiced rice-wheat cropping pattern. The maximum paddy yield of rice (3.73 t/ha) was obtained from rice-wheat-sesbania cropping pattern where sesbania was sown and incorporated in the soil as green manuring crop just before rice transplanting. This increase in paddy yield was statistically at par with the paddy yields received from rice-wheat-mungbean (3.57 t/ha) and rice-berseem (3.52 t/ha) cropping pattern. The yield of succeeding wheat crop was also higher in case of green manuring (sesbania) and leguminous crops (mungbean and cowpeas) which yielded 2.81, 2.69 and 2.63 t/ha respectively. The yield in case of rice-wheat cropping pattern was only 2.59 t/ha. As regards cost benefit ratio, the highest ratio was received in case of rice-lentil (1:2.38) cropping system followed by rice-canola (1:1.96) and rice-wheat-mungbean (1:1.78) as against the existing cropping pattern (rice-wheat) which gave the ratio (1:1.56). The results further indicated that introduction of green manuring or leguminous crops in the existing rice-wheat system not only increased grain yields but also improved the physio-chemical properties, organic matter contents and nutrients availability in the soil. Increase of NPK over initial soil fertility was N (0.12 %), P (2.8 ppm), and K (52 ppm). Soil pH lowered from 8.2 to 7.8 and organic carbon increased from 0.67 % to 0.72 %.

Key words: Rice, cropping pattern, leguminous crops, green manuring, soil fertility, sustainable productivity, economics.

INTRODUCTION

Rice is one of the most important cereals of Pakistan and occupies second position after wheat. It is also an important source of foreign exchange earnings. Rice is grown on an area of 2.7 million hectares, with an annual production of 6.2 million tons giving an average yield of 3.10 t/ha Anonymous (2006). Despite huge efforts on the part of research work and the Government, its production has not been increased according to the genetic potential of varieties. Average yield of fine grain rice varieties is much below than its production potential. There are number of factors contributing to this yield gap. There is no alternative, than to use more plant nutrients for high productivity (Ahmad, 1992).

Since fertilizer is an expensive and precious input, determination of an appropriate dosage of application that would be both economical and appropriate to enhance productivity and consequent profit of the grower under given situation needs intensive study. At present the world is facing the problem of shortage of major fertilizer nutrients especially nitrogen and phosphorous. The developing countries like Pakistan are more sensitive to this shortage because the fertilizer production in these countries is expensive and less than its demand. Even when the fertilizer supply is satisfactory, the importance of increasing its efficient use cannot be underestimated. The application of nitrogen fertilizer either in excess or less than optimum rate affects both yield and quality of rice to remarkable extent, hence proper management of crop nutrition is of immense importance. (Kanade and Kalra, 1986; Marazi *et al.*, 1993; Dixit and Patro, 1994; Daniel and Wahab; 1994; Bali *et al.*, 1995; Spanu and Preneddu, 1997; Nawaz, 1999; Meena *et al.*, 2003).

Rice- Wheat is one of the major cropping systems in Punjab adopted by 94% of the farmers and is prevalent in approximately 1.5 million hectares of land (Amir & Aslam, 1992). Rice is grown once a year in rotation with mainly wheat and to a lesser extent, with fodders, pulses and vegetables. Productivity of rice and the rabi (winter) crops in the system has stagnated despite increase in fertilizer use and other inputs. The soils are characterized by low organic matter content, poor soil structure and low native soil fertility (N, P, K and Zn deficiency is wide spread). Due to calcareous and alkaline nature of soils fertilizer use efficiency is low. Rice wheat cropping system is highly nutrient exhaustive and therefore, its continuous use has depleted inherent soil fertility, causing deficiency of several nutrients (Zia et.al.1997). Since sustainability of the production system depends on the sustainable use of soil recourses, it is necessary to develop and adopt soil management technologies that increase soil organic matter contents and biological activities, reduce salinity especially exchangeable sodium and improve soil physical conditions to keep lands productive on the sustainable basis. Induction of green manuring (dhancha) & leguminous crops in the existing rice-wheat cropping system can improve the soil fertility & crops productivity on sustainable basis.

The foremost quality of green manure crops should be its ability to yield substantial amount of nitrogen in a short period. A legume with leafy growth, succulent foliage, ability to suppress weeds and good nodulation activity is preferable. Thus fitting of sesbania, sunhemp, mungbean, guara and cowpeas in the rice-wheat- cropping system is quiet feasible. Organic manures provide a balance supply of nutrients and enhance soil organic matter. Now the other organic forms are scarce, green manures remain the only economical & alternative. In the past, to improve soil fertility, cultivation of green manuring crops was a part of crop husbandry but currently few farmers are practicing the green manuring cropping pattern in rice – wheat system.

The interest in the use of green manures in the rice-based cropping system has developed as a solution for sound ecosystem and substantially of rice production. Soils in the rice tract are found slightly alkaline in nature. The use of green manure can reduce soil pH, improves soil fertility, soil structure, porosity, water holding capacity and partially reduces the need of nitrogen fertilizer for rice crop. Besides green manuring being a part of integrated nutrient management system, would enhance the efficiency of applied fertilizer and helps in raising the organic matter contents in the soil. It also favourably improves the availability of other plant nutrients (Salim. *et al*. 2003). In Punjab wheat is usually harvested in the last fortnight of April or early May. The rice is transplanted during the month of June and July or early august. A fallow period of about 11 weeks does exist between wheat harvest and rice transplanting. This period is sufficient for the growth of short duration and fast growing green manuring legumes (Mann, 1987). In some countries of the world, many crops like chick pea, mung bean, sunflower, lentil, cowpeas, wheat, barley, maize, brassica and vegetables are being sown in rotation with rice to increase crop productivity, soil fertility and resource use efficiency. The rice yield is higher when grown after legumes (Singh & Verma, 1998). The present study was designed to add a suitable green manuring & profitable leguminous crops in the rice based cropping systems to improve soil fertility, crop productivity, resource use efficiency and income per unit area.

MATERIALS AND METHODS

The experiment was laid out during 2007-08 at Rice Research Institute, Kala shah Kaku, Sheikhupura, Punjab. Eight cropping systems viz; Rice-Wheat, Rice-Wheat-Mungbean, Rice- Wheat- Sesbania, Rice-Wheat-Cowpeas, Rice-Canola, Rice-Sunflower, Rice-Berseem and Rice-Lentil were studied in the experiment. Rice variety super basmati was transplanted on 1st July using completely randomized block design with three replications having a plot size of 10m × 14 m. Wheat variety Inqlab -91 was sown on 16th November and harvested in the 3rd week of April. The crops i.e. Mungbean, Cowpeas, sesbania were sown in the 4th week of April. The pods of crops (mungbean & cowpeas) were harvested in the end of June and the remaining biomass was incorporated into the soil by rotavator before puddling for transplanting of rice. Where as sesbania was incorporated in the soil seven days before transplanting. Berseem, lentil and canola were sown soon after the harvest of rice crop i.e. on 18.11.2007. Where as sunflower was sown on 16th February. Recommended fertilizer to each crop was applied at the appropriate time. Other agronomic practices for each crop were kept optimum. Data on yield of each crop was recorded and statistically analyzed using fisher's analysis of variance technique and treatment means were compared by LSD at 0.05 probability (Steel and Torrie, 1984). Cost of cultivation of each crop was worked out and income of crop yields were calculated on prevailing market prices. The cost benefit ratio of each cropping pattern was also calculated. Soil analysis was made before sowing and after harvest of each crop to determine the nutrient status (Table-1).

Table 1: Some physical & chemical properties of soil used for the study

Parameter	0-6 inch depth	6-12 inch
E.C (ms/cm)	1.2	0.8
Soil pH	8.2	8.3
Organic Matter (%)	0.67	0.56
Nitrogen (%)	0.48	0.28
Available Phosphorus (ppm)	5.4	5.0
Available Potash (ppm)	100	80
Saturation (%)	42	37
Texture	Clay loam	Clay loam

RESULTS AND DISCUSSION

Effect of green manuring and legume crops on soil health: The results of the study indicated that use of green manuring or legumes improved the physio-chemical status of the soil (Table 2). Initial soil analysis showed organic matter contents of 0.67%, N 0.48%, available P 5.4 ppm, available K 100 ppm and pH 8.2. After harvest of dhancha & legume crops, the soil analysis showed average organic matter contents 0.72%, N 0.60%, available P 6.3 ppm, available K 152 ppm and pH 7.8. Where as the higher contents of organic matter 0.79%, N 0.65%, available P 8.2 ppm and available K 198 ppm were found in case of sesbania was incorporated into the soil as green manuring crop which indicates that sesbania is much more beneficial to soil health than any other legume crop.

The primary value of green manure and legume crops residues as a source of N is realized when green or organic manure decomposes and its organic N is transformed into available form. If a green manure or legume crops residues decomposes rapidly and releases its N quickly, it is an excellent source of N for the first crop following its incorporation. It was proposed that 6.5% of the added green manure nitrogen mineralizes during 1st crop, 14% mineralizes during the second crop and so on (Bouldin, 1998). For higher crop yield, peak N releases pattern from the green manure or legume must coincides with the peak N requirement of the rice crop. Nitrogen mineralization from the green manure take place 5 days after its incorporation with a peak around 20 days, afterwards it declined to a minimum level at 45 days (Morris *et al*.1985). A supplement dose of 40 kg N/ha applied at 45 – 50 days (panicle initiation stage) was effective to support plant growth when organic manure – N had been exhausted. The organic manure – N, with an effect similar to basal N application, increased plant growth and tillering in rice while the supplemental N application at the panicle initiation stage lead to increase grain size & weight. Porpavai *et al*; (2011) also reported that legumes were potentially important to diversify cereal based mono cropping into cereal-legume sequences which had nutrient cycling advantages. Kanwarkamla (2000) concluded that cultivation of legume crops were viewed more as a soil fertility improver than as independent crops grown for their grain output. This is because legume crops are self sufficient in N supply. Singh *et al.* (1997) reported that multiple cropping systems with legumes offer special advantage to farmer. Similar results have also been reported by Saroch *et al.* (2005). Rice.

Table 2: Effect of leguminous crops on soil fertility in rice based cropping systems

Cropping System	Residues added (t/ha)	Soil fertility after green manure leguminous crops			
		Organic matter (%)	Nitrogen (%)	Available Phosphorus (ppm)	Available Potash (ppm)
Rice-Wheat	-	0.65	0.50	5.5	110
Sesbania-Rice-Wheat	4.7	0.79	0.65	8.2	198
Mungbean-Rice-Wheat	1.4	0.72	0.61	6.4	163
Cowpeas-Rice-Wheat	1.7	0.70	0.60	6.0	149
Rice-Berseem	-	0.74	0.63	6.2	165
Rice-Lentil	-	0.70	0.58	5.9	127
Average		0.72	0.60	6.3	152

The results are in conformity with Mann *et al* – 2000, who reported that after continuous green manuring for three years, the soil organic matter and NP increased up to 1.09%, 0.37% and 10.2ppm respectively. Tiwari *et al* (1980) found a significant residual effect of green manuring on wheat crop in rice – wheat system. Meelu and Rekhi (1983) and Bhordwaj *et al* (1981) also obtained similar results from green manuring in rice-wheat cropping system. The results are also inline as obtained by Tiwari *et al* (1980), Meelu and Rekhi (1981). While Singh (1981), was found no significant residual effect of preceding rice green manures on wheat. Nevertheless, it can be assumed that the amount of residual N is limited. But the evidence indicates that continued use of organic manure (preferably for 2-3 years) would accumulate modest amounts of N in the soil (Mann *et al*, 2000) and thus, show a considerable effect, either by rising yields of subsequent crops or by reducing fertilizer N requirement.

Effect of green manuring and legume crops on rice & wheat grain yield: Green manuring of sesbania rostrata and legume crops (mungbean, cowpeas and lentil) produced significantly better grain yield of rice and wheat than the other crops (Table 3). Maximum paddy yield of 3.73 t/ha was produced by rice – wheat – sesbania cropping system followed by 3.57, 3.52, 3.40 and 3.39 t/ha produced by rice – wheat – mungbean, rice – berseem, rice – wheat – cowpeas and rice – lentil cropping systems respectively and these were statistically at par with each other. The other cropping patterns gave significantly lower yields. Rice - wheat system produce paddy yield of 3.34 t/ha. Sowing of sesbania rostrata increased rice yield by 12%, mungbean (7.2 %), Berseem (5.3 %), cowpeas (1.8 %) over the traditional rice – wheat cropping system. Almost similar yield trends were found in case of wheat crop. Rice – wheat – sesbania increased wheat yield (2.81 t/ha), rice – wheat – cowpeas (2.69 t/ha) and rice – wheat – mungbean (2.63 t/ha) while the prevailing rice – wheat system produced wheat grain yield of 2.59 t/ha. Rice – wheat – sesbania cropping system increased wheat yield by 7.8 %, cowpeas (3.9 %), mungbean (3.5 %) over traditional rice – wheat cropping system. The paddy yield was slightly decreased in case of sunflower and canola crops (3.32 & 3.21 t/ha respectively) than rice wheat system where the yield was 3.34 t/ha which may be that these crops are nutrients exhaustive. Singh & Verma (1998) reported similar results that rice – wheat yield increased after legume pulses e.g. chickpea and lentil. The results are also in line with Khawara *et al*; (1987) who reported that the best one year crop rotation was rice – wheat – mungbean. It is evident from the results that mungbean and cowpeas which are pulses as well as leguminous crops can be adjusted in the rice - wheat cropping system for increasing income per unit area and improving soil health. It is short duration (65 - 70 days) crops and can be grown easily during the fallow period between wheat and rice crop. The results are similar as obtained by D.K. Bastia *et al*; (2008).

Table 3: Crop yields under different rice - based cropping systems

Cropping System	Yield (t/ha)		
	Rice	Rabi Crops	Summer Crops
Rice – Wheat	3.34b	2.59b	-
Rice – Berseem	3.52a	28.50a	-
Rice – Lentil	3.39ab	0.71c	-
Rice – Canola	3.21b	0.53c	-
Rice – Wheat -Mungbean	3.57a	2.63b	0.78
Rice – Wheat - Cowpeas	3.40ab	2.69b	0.98
Rice – Sunflower	3.32b	-	1.08
Rice – Wheat - Sesbania	3.73a	2.81b	-
LSD	0.3163	1.073	NS

Table 4: Economics and cost-benefit ratio of different rice based cropping systems

Cropping System	Cost (Rs/ha)				Income (Rs/ha)				Net Income (Rs/ha)	C:B Ratio
	Rice	Wheat/ Rabi	Other Crop	Total Cost	Rice	Wheat/ Rabi	Other Crop	Total Income		
Rice-wheat	52296	32423	-	84719	91795	40469	-	132264	47545	1:1.56
Rice-bersem	55115	24898	-	80013	96800	42750	-	139550	59537	1:1.74
Rice-canola	50281	11232	-	61513	88275	32240	-	120515	59002	1:1.96
Rice-sunflower	51983	24484	-	76467	91300	-	43200	134500	58033	1:1.76
Rice-lentil	53079	15569	-	68648	93225	60435	-	153660	85012	1:2.38
Rice-wheat-mungi	55898	32924	16676	105498	98175	41094	48900	188169	82671	1:1.78
Rice-wheat-cowpeas	53236	33675	20380	107291	93500	42017	29340	164857	57566	1:1.54
Rice-wheat-sesbania	58403	35177	14820	108400	102575	43890	-	146465	38065	1:1.35

Economics &Cost Benefit Ratio (CBR): Economics of the rice-based cropping systems showed that the highest profit (Rs 85,012/-) was found in case of rice - lentil followed by rice – wheat - mungbean which gave Rs 82,671/- per hectare. The lowest profit (Rs 38,065/-) was obtained in case of rice-wheat-sesbania cropping pattern. It was due to inclusion of cost of production of sesbania, although this pattern has no additional monetary benefit but in the long run has a great effect on the soil health resulting increase in crop yields. The income in case of prevailing rice-wheat cropping system was Rs.47545/- per hectare. As regards cost-benefit ratio, it was highest in case of rice-lentil (1:2.38) due to high price of lentil and less cost of production followed by rice-canola system (1:1.96) because it also involves less cost of production and more income of canola crop. The cost benefit ratio, in case of rice – wheat – mungbean (1:1.78), rice – sunflower (1:1.76) and rice – berseem were also better than the other cropping systems. This was due to high prices of mungbean & sunflower. The results were similar as obtained by D.K. Bastia *et al*; (2008). These results are also in line with Shahid I.Z (2006) who concluded that rice – chickpea & rice – sunflower were superior economically among different rice - based cropping systems.

Conclusion: The adoption of green manuring / leguminous crops such as mungbean, cowpeas and sesbania rostrata (dhancha) can tremendously benefit the nutrient exhaustive rice - wheat cropping system through nitrogen fertilizer saving, increase in crop yields and higher income per unit area as these crops increases the level of NPK, decreases the soil pH and improves the soil structure. As regards other rice - based cropping systems such as rice – lentil and rice – sunflower can be adopted as these are profitable but these patterns are suitable for loam soils.

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