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EFFECT OF DIFFERENT RICE-BASED INTERCROPPING SYSTEMS ON RICE GRAIN YIELD AND RESIDUAL SOIL FERTILITY

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Abstract

In a field study the biological efficiency of intercropping in direct seeded upland rice and its effect on residual soil fertility was determined at the University of Agriculture, Faisalabad for two consecutive years. The intercropping systems comprised rice alone, rice + maize, rice + sesbania, rice + mungbean, rice + ricebean, rice + cowpea and rice + pigeonpea. The rice was seeded in 75 cm spaced 4-row strips (15/75 cm) while the intercrops as forage were seeded on the vacant spaces between the rice strips. The results revealed that rice grain yield decreased to a significant level by forage intercrops compared to monocropped rice which varied from 10.94 to 25.87%, with the maximum (25.87%) by sesbania followed by pigeonpea (16.67) against the minimum (10.94%) by maize intercrop. In terms of total rice grain yield equivalent (TRGYE), the highest TRGYE (6.45 ton ha^{-1}) was recorded for rice + forage maize intercropping system followed by rice + cowpea (5.08 ton ha^{-1}) and rice + sesbania (4.92 ton ha^{-1}) against the minimum (4.02 ton ha^{-1}) for monocropped rice clearly indicating yield advantages of intercropping over monocropping of rice. Similarly the net field benefits obtained from different intercropping systems were considerably higher than the sole cropping of rice. The maximum net benefit of Rs.42325 ha^{-1} was recorded for rice + maize which is 37.32% more than sole rice followed by rice + cowpea (Rs.30885 ha^{-1}) which is 14.03% higher than monocropping of rice (Rs.26526 ha^{-1}). The results also revealed that residual soil nitrogen and organic matter was improved in all the intercropping systems except rice + maize intercropping system. However, the maximum increase in soil nitrogen (7.14%) was recorded for rice + sesbania intercropping system while the residual soil phosphorus and potassium were depleted in all the intercropping systems as compared to initial soil analysis.

Introduction

In view of shrinkage resources like arable land, irrigation water and energy, there is a dire need to design and develop new methods and techniques of crop production to meet the increasing demand for food, feed and forage through effective utilization of available agricultural input resources. Under the present system of sole cropping, small farmers are unable to address their diversified domestic needs to sustain normal livings from their limited land, water and economic resources. This necessitates going for appropriate alternative and more efficient production systems such as multicropping (inter/relay cropping) which can ensure proper utilization of resources to obtain increased production per unit area and time on a sustainable basis (Trenbath, 1986).

Intercropping being a unique property of tropical and subtropical areas is becoming popular day by day among small farmers as it offers the possibility of yield advantage relative to sole cropping through yield stability and improved yield (Nazir *et al*., 2002; Bhatti *et al.,* 2006). Potential of raising other crops such as forage legumes and non-legumes in association with major staple food crops like rice could be substantially enhanced through intercropping (Saeed *et al*., 1999). It also helps maintaining the soil fertility (Patra & Chatterjee, 1986), making efficient use of nutrients (Aggarwal *et al*., 1992, Nazir *et al*., 1997, Ahmad & Saeed, 1998, Maingi *et al*., 2001) and ensuring economic utilization of land, labour and capital (Moris & Garrity, 1993, Singh *et al*., 1996, Jeyabel & Kuppuswamy, 2001). In general, non-legume crop is considered a suppressing crop in legume associations.

Pakistan has arid to semi-arid subtropical climate with high light intensity and favourable temperature ranges and an extensive canal irrigation system which translates into a large potential for raising two or more agricultural crops concurrently and/or in tandem. Small farmers constitute more than 70% of our farming community in the Punjab province, and their land holdings are continuously shrinking, which obviously suggests that the system of intercropping is their only bet to ensure efficient utilization of their resources for increased production and family income.

Rice (*Oryza sativa* L.) being a staple food of the millions of people, is the 2^{nd} major source of earning foreign exchange after cotton in Pakistan. Hence its role in the economic development of Pakistan can not be overlooked. At present, rice is grown on an area of 2.62 million hectares in Pakistan with total annual production of 5.54 million tonnes giving an average yield of 2110 kg ha^{-1} (Anon., 2006-07). Maize and other forage legumes such as sesbania, cowpea, pigeonpea, ricebean and mungbean are important short duration “summer” crops which provide more economic return to growers (Iqbal *et al*., 2006; Ahmad *et al*., 2007). The area under these crops cannot be increased as they compete with rice, a major kharif cereal of Pakistan. Moreover, during hot summer months, these fodders help to maintain animal health and milk production besides improving soil fertility through biological nitrogen fixation and sufficient organic matter (Wahla *et al.*, 2009). Thus one of the ways to supplement the summer fodder production is to grow these crops as forage in association with upland rice.

The present study was conducted with the objectives to develop sustainable and economically viable rice-based intercropping systems and to check their effects on residual soil fertility.

Materials and Methods

The proposed study was conducted at the agronomic research area, University of Agriculture, Faisalabad on sandy clay loam soils for two consecutive years. Prior to sowing of the component/representative crops, soil samples were collected to a depth of 30 cm and analyzed for its different chemical properties by employing the methods as described by Homer & Pratt (1961). The soil had an average fertility status of 0.042 % N, 6.5 ppm P_2O_5 and 123 ppm K_2O with a pH of 8.6. Similarly soil samples were also analyzed after the harvest of the experiment. The intercropping systems comprised rice alone (*Oryza sativa* L.), rice + maize (*Zea mays* L.), rice + sesbania (*Sesbania aculeata* L.), rice + mungbean (*Vigna radiata* (L.) Wilczen), rice + ricebean (*Vigna umbellata* L.), rice + cowpea (*Vigna unguiculata* L.) and rice + pigeonpea (*Cajanus cajan* L. Millspavgh). All the intercrops were grown as forage and harvested 45 days after sowing while rice crop was harvested at full physiological maturity as grain crop.

The experiment was arranged in randomized complete block design (RCBD) and replicated thrice. The net plot size measured 6.00 m x 3.60 m. Rice cultivar “Basmati 385” was direct seeded @ 50 kg ha^{-1} at optimum soil moisture on a finely prepared seed bed in 75 cm spaced 4-row strips with 15 cm space between the rows in a strip, with the help of a single row hand drill in the third week of June each year.

The respective intercrops were also seeded simultaneously on spaces between the rice strips on the same date using their recommended seed rates (maize 75 kg, sesbania 25 kg, mungbean 20 kg, ricebean 50 kg, cowpea 50 kg and pigeonpea 50 kg ha^{-1}). A uniform basal dose of 100 kg N + 100 kg P_2O_5 ha^{-1} was broadcast before seeding of rice crop while additional 50 kg N ha^{-1} was top dressed soon after the harvest of forage intercrops on the rice strips only.

Plant population density of the direct seeded rice crop was maintained by seeding the crop with a uniform seed rate in all the treatments. Pre-sowing soaking irrigation of 10 cm was given before sowing the rice and intercrops for the sake of seedbed preparation at optimum soil moisture while subsequent irrigations each of 7.5 cm were given as and when required according to the need of the rice crop. However, the first irrigation was applied a week after the sowing of the component crops at their full seedling emergence. The rice crop was kept free of weeds by hand weeding. Observations on desired parameters of the component crops were recorded using standard procedures and the data obtained were analyzed statistically by using “MSTAT-C” statistical package on a computer. The differences among treatment means were compared by Least Significant Difference (LSD) test at $P = 0.05$.The rice grain yield equivalent of each intercrop was computed by converting the yield of intercrops into grain yield of rice on the existing market price of each intercrop (Anjeneyulu *et al*., 1982).

Results

Rice grain yield: The rice grain yield was decreased to a significant level by intercropping forage legume and non-legume crops compared to monocropped rice (Table 1). However, the percent decrease in rice grain yield varied from 10.94 to 25.57% with the maximum (25.57%) for rice + sesbania followed by rice + pigeonpea (16.67%) and rice + mungbean (16.42%) intercropping systems. By contrast, the minimum decrease in rice grain yield over rice alone (10.94%) was recorded for rice + maize intercropping system.

Forage yield of intercrops: Significantly maximum fodder yield of 40.70 ton ha^{-1} was obtained when maize was intercropped in rice followed by fodder yield of sesbania (27.49 ton ha^{-1}) intercropped in rice and fodder yield of intercrop cowpea (23.69 ton ha^{-1}). The minimum fodder yield of 19.50 ton ha^{-1} was produced by intercrop of cowpea which was at par with fodder yield of intercrops pigeonpea and mungbean (20.76 & 20.60 ton ha^{-1}, respectively).

Rice grain yield equivalents of intercrops: The fodder yield of all intercrops was converted into rice grain yield equivalent (RGYE) on the basis of existing market price of each intercrop (Anjeneyubu *et al*., 1982) and RGYE ranged between 1.38 and 2.87 ton ha^{-1}. The maximum RGYE was recorded for rice + maize (2.87 ton ha^{-1}) followed by rice + sesbania (1.94 ton ha^{-1}), rice + cowpea (1.67 ton ha^{-1}), rice + pigeonpea (1.47 ton ha^{-1}) and rice + mungbean (1.45 ton ha^{-1}) compared to the minimum of 1.38 ton ha^{-1} in rice + ricebean intercropping systems.

Total rice grain yield equivalent (TRGYE): All the intercropping treatments resulted in substantially higher total rice grain yield equivalent than sole crop of rice. However, the highest TRGYE (6.45 ton ha^{-1}) was recorded for rice + maize followed by rice + cowpea intercropping systems (5.08 ton ha^{-1}) while rest of the intercropping systems intermediated showing TRGYE ranging between 4.45 and 4.92 ton ha^{-1} compared to the minimum (4.02 ton ha^{-1}) for monocropped rice

Table 1. Comparative bio-economic performance of different upland rice-based intercropping systems (2-year average data).

Intercropping systems	Rice grain yield (ton ha^{-1})	Percent decrease over mono cropping	Forage yield of inter-crops (ton ha^{-1})	Rice grain yield equivalents of intercrops (ton ha^{-1})	Total rice grain yield equivalents of the systems (ton ha^{-1})	Percent increase over rice alone	Net benefits (Rs. ha^{-1})	Percent net benefit increase over sole rice
Rice alone	4.02 a	-	-	-	4.02	-	26526	
Rice + maize	3.58 b	10.94	40.70 a	2.87	6.45	37.67	42325	37.32
Rice + sesbania	2.98 c	25.87	27.49 b	1.94	4.92	18.29	28855	08.71
Rice + mungbean	3.36 b	16.42	20.60 d	1.45	4.81	16.42	29352	09.63
Rice + ricebean	3.47 b	13.68	19.50 d	1.38	4.85	17.11	29625	10.46
Rice + cowpea	3.41 b	15.17	23.69 c	1.67	5.08	20.87	30885	14.03
Rice + pigeonpea	3.35 b	16.67	20.76 d	1.47	4.82	16.60	29502	10.09
LSD (p=0.05)	0.26		2.79					

Economic analysis: Economic analysis (Table 1) is done to see profits and costs of a newly evolved technology and to know about risks involved in the adoption of new practices. Pooled data were analyzed by partial budget analysis. This analysis showed that rice + maize and rice + cowpea gave maximum net benefits of Rs.42325 and Rs.30885 ha^{-1} which were 37.32 and 14.03% higher than sole rice (Rs.26526 ha^{-1}), respectively. However, the net benefits of all intercropping systems were higher than that achieved from monocropping of rice.

Residual soil fertility after the harvest of different rice-based intercropping systems

Residual soil organic matter: There was a considerable effect of even short term intercropping in rice on the residual soil fertility (Table 2). All the intercrops except maize had a positive effect on residual soil organic matter especially where forage legumes were intercropped. The maximum improvement occurred for sesbania (10.67%) followed by cowpea and pigeonpea which were similar to each other (8.00%) compared to the minimum (5.33%) for ricebean and mungbean. There was a decrease in residual soil organic matter due to forage maize (non-legume) (9.33%) and sole rice (1.33%). During 2^{nd} year all legume intercrops improved the soil organic matter, maximum for sesbania (9.46%) followed by pigeonpea (6.76%) while mungbean, ricebean and cowpea each improved the organic matter by 4.10%. By contrast, rice alone and forage maize intercrop decreased the soil organic matter to the extent of 2.70 and 10.81%, respectively.

The soil organic matter also increased due to all legume intercrops in relation to rice alone during both years (Table 3). There was, however, a decrease in soil organic matter due to forage maize intercrop in relation to rice alone.

Residual soil nitrogen: Residual soil nitrogen was depleted in rice alone (4.76%) and rice + forage maize (11.90%) intercropping systems (Table 2). Residual soil nitrogen was found improved in all the rice + legumes intercropping systems with the maximum (7.14%) in rice + sesbania followed by rice + cowpea (4.76%), rice + pigeonpea (4.76%) compared to the minimum in rice + mungbean and rice + ricebean (2.38%). During the 2^{nd} year of study, although similar trend was noted but the level of improvement was somewhat different with the maximum (7.32%) in rice + sesbania followed by rice + pigeonpea (4.88%) while the same level of improvement was found in rice + mungbean, rice + ricebean and rice + cowpea (2.44%). Residual soil nitrogen in relation to rice alone was also increased in all the rice-based forage legumes intercropping systems but declined in the rice + forage maize intercropping system during both years (Table 3).

Residual soil phosphorus (P_2O_5): During first year, the maximum P_2O_5 decline occurred for pigeonpea intercrop (16.16%) closely followed by cowpea (15.58%) and ricebean (15.00%) and with the same level of 14.43% for maize and sesbania against 14.83% due to mungbean. Similar trend was observed during 2^{nd} year but with comparatively low values. The maximum decline occurred due to pigeonpea (9.72%) followed by maize (9.01%), sesbania (8.73%), mungbean (7.89%), ricebean (7.61%) and cowpea (7.04%). Phosphorus also declined for all the intercrops compared to that with rice alone (Table 3). The maximum depletion occurred in rice + pigeonpea (16.88%) in the 1^{st} year and 10.85% during the 2^{nd} year closely followed by cowpea, ricebean, mungbean, ricebean, cowpea and maize, respectively during the 2^{nd} year.

Table 2. Post harvest fertility status of soil under different direct seeded rice-based intercropping systems with respect to initial soil analysis before planting.

Intercropping systems	1st year				2nd year			
	N (%)	P (ppm)	K (ppm)	O.M. (%)	N (%)	P (ppm)	K (ppm)	O.M. (%)
Rice alone	0.040	6.99	134	0.74	0.039	7.19	133	0.72
	(-4.76)	(+0.87)	(-2.90)	(-1.33)	(-4.88)	(+1.27)	(-2.92)	(-2.70)
Rice + Maize	0.037	5.93	128	0.68	0.036	6.46	125	0.66
	(-11.90)	(-14.43)	(-7.25)	(-9.33)	(-12.20)	(-9.01)	(-8.76)	(-10.81)
Rice + Sesbania	0.045	5.92	126	0.83	0.044	6.48	128	0.81
	(+7.14)	(-14.43)	(-8.70)	(+10.67)	(+7.32)	(-8.73)	(-6.58)	(+9.46)
Rice + Mung bean	0.043	5.90	127	0.79	0.042	6.54	130	0.77
	(+2.83)	(-14.86)	(-7.97)	(+5.33)	(+2.44)	(-7.89)	(-5.11)	(+4.10)
Rice + Rice bean	0.043	5.89	125	0.79	0.042	6.56	124	0.77
	(+2.38)	(-15.01)	(-9.42)	(+5.33)	(+2.44)	(-7.61)	(-9.49)	(+4.10)
Rice + Cowpea	0.044	5.85	129	0.81	0.042	6.60	131	0.77
	(+4.76)	(-15.58)	(-6.52)	(+8.00)	(+2.44)	(-7.04)	(-4.38)	(+4.10)
Rice + Pigeonpea	0.044	5.81	124	0.81	0.043	6.41	127	0.79
	(+4.76)	(-16.16)	(-10.14)	(+8.00)	(+4.88)	(-9.72)	(-7.30)	(+6.76)
Original values	0.042	6.93	138	0.75	0.041	7.10	137	0.74

% increase (+) decrease (-) over original values

Table 3. Post harvest fertility status of soil under different direct seeded rice-based intercropping systems with respect to rice alone.

Intercropping systems	1st year				2nd year			
	N (%)	P (ppm)	K (ppm)	O.M. (%)	N (%)	P (ppm)	K (ppm)	O.M. (%)
Rice alone	0.040 (0.00)	6.99 (0.00)	134 (0.00)	0.74 (0.00)	0.039 (0.00)	7.19 (0.00)	133 (0.00)	0.72 (0.00)
Rice + Maize	0.037 (-7.50)	5.93 (-15.16)	128 (-4.48)	0.68 (-8.11)	0.036 (-7.69)	6.46 (-3.19)	125 (-6.02)	0.66 (-8.33)
Rice + Sesbania	0.045 (+12.50)	5.92 (-15.13)	126 (-5.97)	0.83 (+12.16)	0.044 (+12.82)	6.48 (-9.87)	128 (-3.76)	0.81 (+12.50)
Rice + Mung bean	0.043 (+7.50)	5.90 (-15.59)	127 (-5.22)	0.79 (+6.76)	0.042 (+7.69)	6.54 (-9.04)	130 (-2.26)	0.77 (+6.94)
Rice + Rice bean	0.043 (+7.50)	5.89 (-15.74)	125 (-6.72)	0.79 (+6.76)	0.042 (+7.69)	6.56 (-8.76)	124 (-6.77)	0.77 (+6.94)
Rice + Cowpea	0.044 (+10.00)	5.85 (-16.31)	129 (-3.73)	0.81 (+9.46)	0.042 (+7.69)	6.60 (-8.21)	131 (-3.01)	0.77 (+6.94)
Rice + Pigeonpea	0.044 (+10.00)	5.81 (-16.38)	124 (-7.46)	0.81 (+9.46)	0.043 (+10.26)	6.41 (-10.85)	127 (-4.51)	0.79 (+9.72)

% increase (+) and decrease (-) over rice alone

Residual soil potassium (K_2O): Depletion of potassium occurred with all the intercropping systems including rice alone (Table 2). However, maximum reduction was found with pigeonpea (10.14%) followed by ricebean (9.42%), sesbania (8.70%), mungbean (7.79%) and maize (7.23%) against 2.90% due to rice alone. Almost similar trend was exhibited during 2nd year of studies with a maximum depletion by ricebean (9.49%) followed by maize (8.76%) against the minimum (2.92%) in case of sole crop of rice while rest of the intercrops intermediated. The soil potassium was also depleted for all the intercropping systems in relation to sole crop of rice during both the years.

Discussion

It is evident from the results that maximum reduction in rice grain yield was due to sesbania intercropping and it was attributed to the luxuriant growth of sesbania and its thick shading effect on the associated rice crop which ultimately resulted in poor growth and low yield of the rice crop. Reduction in grain yield of rice due to intercropping was also reported by Chandra *et al*., (1992), Saeed *et al*., (1999) and Joshi (2002). The maximum fodder yield and rice grain yield equivalent of maize intercrop is due to its solid stem and more leaf area as compared to other forage intercrops (Saeed *et al*., 1999). The overall increase in TRGYE of intercropping treatments over sole crop of rice varied from 16.42 to 37.67% with the maximum (37.67%) in rice + maize and the minimum (16.42%) in rice + mungbean intercropping system. Increase in TRGYE as a result of intercropping was also reported by Banik & Bagchi (1994), Qayyum & Muniruzzaman (1995), Saeed *et al*., (1999) and Joshi (2002). Similarly maximum net benefit obtained from rice + maize intercropping system might be due to maximum fodder yield of maize. Similar results were reported by Saeed *et al*., (1999). Grain legumes intercropping in rice had remarkable effect on the residual soil fertility by increasing organic matter and nitrogen in the soil. The maximum improvement occurred for sesbania (10.67%). It might be due to more nodule formation by roots of sesbania as compared to other legume forage intercrops. Similarly residual soil nitrogen contents increased by legume forage crops and decreased by non-legume intercrops. This increase in nitrogen could be attributed in biological nitrogen fixation by legumes. Legumes generally find a place in intercropping systems because of their capacity to fix atmospheric nitrogen and are reported to contribute nitrogen to the associated non-legumes (Balasubramaniyan & Palaniappan, 2001). Improvement in residual soil nitrogen as a result of legumes intercropping in wheat, cotton, sesame and barley has also been reported by Ahmad (1990), Khan (2000), Bhatti (2005) and Wahla (2008), respectively. The residual soil P_2O_5 was found declined in all the intercropping systems compared to rice alone (Table 2) and it was more in case of legume intercrops because they have been reported to extract insoluble forms of soil phosphorus (Balasubramaniyan & Palaniappan, 2001). Decline in phosphorus as compared to rice alone might be attributed to higher uptake of P_2O_5 by these crop plants. Depletion of P_2O_5 by different legumes and non-legumes intercropped in wheat, sesame and barley has also been reported by Ahmad & Saeed (1998). Similarly depletion of potassium in all intercropping systems might be ascribed to its uptake by different crop plants in variable quantities. No application of potassium might be another reason for depletion. These results are in consonance with the findings of Khan (2000), Bhatti (2005) and Wahla (2008) who reported potassium depletion of soil in cotton-legumes, sesame-legumes and barley-legumes intercropping, respectively.

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