AGRONOMIC APPROACHES FOR PRODUCTIVITY ENHANCEMENT OF UPLAND RICE-BASED INTERCROPPING SYSTEMS UNDER STRIP PLANTATION

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In a field study conducted for two consecutive years on a sandy-clay loam soil at the University of Agriculture, Faisalabad, the comparative agro-economic performance of different upland rice-based intercropping systems was investigated in upland environment. The intercropping systems comprised rice + forage maize, rice + sesbania, rice + mungbean, rice + ricebean, rice + cowpea, rice + pigoenpea and rice alone. The base rice crop was direct-seeded in 75 cm spaced 4-row strips (15/75 cm) and the forage intercrops were seeded on the vacant space between the rice strips. The results revealed that although the rice grain yield was reduced by 10.94 to 25.87% by different forage intercrops but in terms of total rice grain yield equivalent, all the intercropping systems gave 16.42 to 37.67 % higher grain yield than the monocropped 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 followed by rice + cowpea (Rs.30885 ha^{-1}) compared to the minimum of Rs.26526 ha^{-1} in case of monocropping of rice. Whereas almost similar net field benefits ha^{-1} were achieved from rice + ricebean, rice + pigeonpea, rice + mungbean and rice + sesbania which varied from Rs.28855 to 29625 ha^{-1}.

Key words: Agronomic approaches, productivity enhancement, rice-based intercropping systems, strip plantation.

INTRODUCTION

In view of shrinkage resources particularly arable land area, irrigation water and energy, the only option left is to increase the production per unit area/time in order to cope with the ever increasing demand for food, feed and forage during the next two decades which will be a very challenging task. Of the possible agronomic approaches to meet this challenge, an intercropping technology is an immediate option since it has been a proven technology for the last many years in Indo-Pak subcontinent and is now showing commercial prospects.

For increasing production per unit area/time and to cover the risk of total crop failure, the practice of intercropping is a unique technology provided both the component crops are grown in independent multi-row strips in order to avoid direct competition between the two species. Although the practice of intercropping in other cereals like wheat, maize etc. is very common among the growers but intercropping of upland crops like rice is a new trend in cropping system research in Pakistan. Introducing upland crops such as maize, ricebean, cowpea, sesbania, mungbean and pigeonpea as forage intercrops into the upland rice-based intercropping systems may show its effects on improving the soil physical properties, reducing its volume and weight, increasing its porosity and enhancing the residual soil nitrogen content.

Under the present circumstances, the rice growers with small holdings are seriously constrained by low crop income due to very low crop yields and sometimes complete crop failure. Hence, there is an urgent need to develop an appropriate, economically viable and sustainable rice-based intercropping system for upland environment that may promote full/efficient utilization of solar radiation, land, water and input resources. The present study was, therefore, designed accordingly to achieve the said objectives.

MATERIALS AND METHODS

A field study on the agro-economic assessment of different upland rice-based intercropping systems was conducted for two consecutive years (1998-1999) at the research area of Agronomy Department, University of Agricultue, Faisalabad on a sandy-clay loam soil with an average fertility status of 0.75 % organic matter, 0.042 % N, 6.93 ppm P_2O_5 and 138 ppm K_2O having a pH value of 7.8. The intercropping systems comprised rice alone (*Oryza sativa* L.), rice + maize (*Zea mays* L.), rice + sesbania (*Sesbaina sesbane* L.), rice + mungbean (*Vigna radiata* L. wilezen), rice + ricebean (*Vigna umbellate* L.), rice + cowpea (*Vigna senensis* L.) and rice + pigeonpea (*Cajanus cajan* L. Millspargh). All the intercrops were grown as fodder and harvested 45 days after sowing while the rice crop was harvested at its full physiological maturity as a grain crop.

The experiment was laid out in a randomized complete block design (RCBD) with three replications. The net plot size was 3.6 m x 6.0 m. Rice cultivar Basmati-385 was direct seeded on a well prepared seed bed in 75 cm spaced 4-row strips with 15 cm space between the rows in a strip (15/75 cm) 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. A uniform basal dose of 100 kg N + 100 kg P_2O_5 ha^{-1} was applied at seeding of the rice crop while 50 kg N ha^{-1} was top-dressed soon after the harvest of forage intercrops to the rice strips only. Plant population of the direct seeded rice crop was maintained by seeding the crop with a uniform seed rate of 37.5 kg ha^{-1} in all the treatments.

Pre-sowing irrigation "Rauni irrigation" of 10 cm was given before sowing the rice and component crops (intercrops) for the sake of seed bed preparation at optimum soil moisture while subsequent irrigations each of 7.5 cm were given as and when needed 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 as and when a need was felt uptill its final harvest. The observations on desired parameters of the component crops were recorded using standard procedures and the data were analysed statistically by using "MSTATC" statistical package on a computer and the differences among treatments' means were compared by the Least Significance Difference (LSD) test at P = 0.05.

Land equivalent ratio(LER) was computed using the formula described by Willey (1979).

La and Lb are the LERs for the individual crops of the system.

Yaa = Pure stand yield of crop 'a'

Ybb = intercrop yield of crop 'b'

Yab = Intercrop yield of crop 'a'

Yba = Intercrop yield of crop 'b'

$$LER = La + Lb = \frac{Yab}{Yaa} + \frac{Yba}{Ybb}$$

Area time equivalent ratio (ATER) was determined by the formula proposed by Hiebsch (1980) as follows.

$$ATER = \frac{(RYC \times tC) \times (RYP \times tP)}{T}$$

Where

RYC = Relative yield of crop C

RYP = Relative yield of crop P

TC = Duration (days) for crop 'C'

TP = Duration (days) for crop 'P'

T = Duration (days) for the whole system

Rice grain yield equivalent (RGYE) was computed by converting the yield of intercrops into grain yield of rice, based on the existing market price of each intercrop (Anjeneyubu *et al.* 1982).

RESULTS AND DISCUSSION

The data pertaining to grain yield of rice and forage yield of intercrops along with total rice grain yield equivalent of the systems and their economic benefits are presented in Tabble 1. The grain yield of rice was reduced to a significant level by different forage intercrops which varied from 10.94 to 25.87 percent over monocropped rice. The maximum decrease (25.87%) was recorded for rice intercropped with sesbania followed by rice + pigeonpea (16.67%) and rice + mungbean (16.42%) compared to the minimum reduction of 10.97% in case of rice intercropped with forage maize while rest of the two intercropping systems i.e. rice + ricebean & rice + cowpea intermediated and reduced the rice grain yield to the extent of 13.68 and 15.17%, respectively. The maximum reduction in rice grain yield due to sesbania intercropping was attributed to its luxuriant growth rate and dominant plant stature as a result of which the base rice crop remained overshaded for most of the period and ultimately produced poor grain yield. Adverse effects of intercropping rice, wheat and cotton with different legumes and non-legumes has also been reported by Banik and Bagchi(1990), Saeed *et al.* (1999), Ahmad & Saeed (1998) and Khan (2000), respectively.

Total rice grain yield equivalent (TRGYE)

In terms of total rice grain yield equivalent (TRGYE), all the intercropping systems gave substantially higher grain yield of rice varying from 4.81 to 6.45 t ha^{-1} than the sole crop of rice (4.02 t ha^{-1}). The percentage increase, however, ranged between 16.42 and 37.67 %. The maximum increase (37.67%) was recorded for rice + maize followed by rice + cowpea (20.87%), rice + sesbania (18.29%) and rice + ricebean (17.11%) compared to the minimum of 16.42% in rice + mungbean intercropping systems. These results led to the conclusion that the intercropping systems utilized the agronomic resources more effectively and efficiently towards increased production. These results corroborate the findings of Banik and Bagchi (1991) and Saeed *et al.* (1999).

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

Intercropping systems	Rice grain yield (t ha^{-1})	Percent decrease over mono cropping	Forage yields of inter-crops (t ha^{-1})	Rice grain yield equivalent of intercrops t ha^{-1})	Total rice grain yield equiva-lents of the system (t ha^{-1})	Percent increase over rice alone	Land equivalent ratio	Area time equivalent ratio	Yield advantage over sole rice crop (%)	Net benefits (Rs. ha^{-1})
Rice alone	4.02 a	-	-	-	4.02	-	-	-	-	26526
Rice + maize	3.58 b	10.94	40.70	2.87	6.45	37.67	1.75	1.23	23	42325
Rice + sesbania	2.98 c	25.87	27.44	1.94	4.92	18.29	1.39	1.08	08	28855
Rice + mungbean	3.36 b	16.42	20.60	1.45	4.81	16.42	1.27	1.16	16	29352
Rice + ricebean	3.47 b	13.68	19.5	1.38	4.85	17.11	1.25	1.19	14	29625
Rice + cowpea	3.41 b	15.17	21.60	1.67	5.08	20.87	1.34	1.17	17	30885
Rice + pigeonpea	3.35 b	16.67	20.76	1.47	4.82	16.60	1.27	1.14	14	29502
LSD (P = 0.05)	0.26									

Land equivalent ratio (LER) and area time equivalent ratio (ATER)

The data on land equivalent ratio (LER) and area time equivalent ratio (ATER) revealed that all the intercropping systems showed yield advantage over monocropped rice to the extent of 25 to 75 and 8 to 23% in terms of LER and ATER, respectively. On the basis of ATER, the maximum yield advantage (23%) was recorded for rice + forage maize followed by rice + ricebean (19%), rice + cowpea (17%) and rice + mungbean (16%) against the minimum of 8% for rice + sesbania intercropping system. This clearly indicated the higher level of resouce utilization of intercropping over sole cropping of rice for increased production. These results are in consonance with those of Saeed *et al.* (1998) and Khan (2000) who also reported yield advantages of intercropping rice, wheat and cotton with legumes and non-legumes over their monocropping, respectively.

Economic benefits

Considering the economic benefits, the net field benefits from all the intercropping system were substantially higher than that achieved from monocropping of rice. Among the intercropping systems, rice + maize and rice + cowpea generated the maximum net benefit of Rs.42325 and 30885 ha^{-1}, respectively while rice + ricebean, rice + pigeonpea and rice + mungbean gave almost similar net income of Rs.29925, 29502 and 29352 ha^{-1}, respectively compared to Rs.28855 ha^{-1} for rice + sesbania intercropping system against the lowest of Rs.26526 ha^{-1} in case of sole cropping of rice. Significantly higher net field benefits of intercropping rice, wheat and cotton with legumes and non-legumes has also been reported by saeed *et al.* (1992), Saeed *et al.* (1999) and Khan (2000), respectively.

The results led to the conclusion that intercropping direct-seeded rice with forage maize and different forage legumes under 4-row strip plantation not only proved to be feasible and economically viable but also yielded 16.42 to 57.60 % higher than the monocropping of rice in terms of their total rice grain yield equivalents. Similarly the net income ha^{-1} from all the intercropping systems was considerably higher than the mono cropped rice which varied from Rs.28855 to 42325 ha^{-1} against 26526 ha^{-1} in sole cropping of rice.

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