

ASSESSMENT OF YIELD ADVANTAGES, COMPETITIVENESS AND ECONOMIC BENEFITS OF DIVERSIFIED DIRECT-SEEDED UPLAND RICE-BASED INTERCROPPING SYSTEMS UNDER STRIP GEOMETRY OF PLANTING

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A field study to assess the yield advantage, competitiveness and economics of diversified direct-seeded upland rice-based intercropping systems under strip geometry of planting, was conducted on a sandy-clay loam soil at the University of Agriculture, Faisalabad. The intercropping treatments comprised rice alone, rice + maize, rice + sesbania, rice + mungbean, rice + rice bean, rice + cowpea and rice + pigeon pea. All the intercrops were grown as forage and harvested 45 days after sowing while the rice crop was harvested at its physiological maturity as a grain crop. The results revealed that all intercropping systems gave substantially higher yield advantages over monocropped rice in terms of total rice grain yield equivalent (16.42 to 37.67%) and land equivalent ratio (25 to 75%) and area time equivalent ratio (8 to 23%) with the maximum for rice + maize intercropping system. Similarly considerable economic benefits were achieved from the intercropped rice over monocropped rice with the highest from rice + maize (Rs.42325 ha⁻¹) followed by rice + cowpea (Rs.30885 ha⁻¹) and rice + rice bean (Rs.29625 ha⁻¹) compared to the minimum (Rs.26526 ha⁻¹) from sole crop of rice. The component crops in each intercropping system did not compete equally. All the intercrops indicated dominant behaviour over the base rice crop. Pigeon pea and cowpea were the least competitive intercrops while maize and sesbania appeared to be better competitive when grown in association with rice crop.

Keywords: Yield advantage, economic benefits, direct-seeded upland rice, diversified intercropping systems, strip planting geometry

INTRODUCTION

In Pakistan, under the present circumstances, the system of monocropping has failed to address the diversified domestic needs of small growers to sustain their normal livings from their limited land, water and economic resources. This envisages to go for another appropriate and more efficient production system which may ensure proper utilization of resources towards increased production per unit area and time on sustainable basis (Trenbath, 1986).

Intercropping offers the possibility of yield advantage relative to sole cropping through yield stability and improved yield and thus providing diversified needs of small farmers, stability of yield over different seasons, better control of weeds, insect pests and diseases as well as control of soil erosion (Willey, 1979). Besides, It helps maintaining soil fertility (Patra and chatterjee, 1986), making efficient use of nutrients (Aggarwal *et al.* 1992, Nazir *et al.* 1997, Ahmad and Saeed 1998) and ensuring economic utilization of land, labour and capital (Morris and Garrity, 1993; Singh *et al.*, 1996). Small farmers constitute more than 70% of our farming community in the Punjab province and their holdings

are continuously shrinking which obviously suggests that the system of intercropping is need of the time to ensure efficient utilization of their resources for increased production and family income.

Rice (*Oryza sativa* L.) is an important and economically viable cereal crop of Pakistan which is the second major source of earning foreign exchange after cotton. Punjab and Sindh are the leading rice growing provinces with about 92 per cent of the total area under rice. The main rice tract lies in the Punjab province covering more than one million hectares annually. Unfortunately there is, at present, no proper and economically viable cropping system in practice to make the best use of rice land for sustained productivity. Thus, it is imperative to explore new horizons and develop efficient methods and techniques of crop production for effective utilization of rice land and agricultural input resources, towards increased productivity per unit area and time.

Although sufficient research work has been done on maize, cotton, sugarcane and wheat-based intercropping systems in Pakistan and elsewhere, yet research on upland rice-based intercropping systems is scanty. The lack of such information necessitates streamlining the research on rice-based intercropping

systems which may ensure sustained crop productivity and land use in the rice growing areas. However, the conventional method of planting rice in 20x 20 cm hills does not permit intercropping because of narrow spacing and intensive binding of soil by root mass of closely growing rice plants. In view of this, a new geometry of planting rice in widely spaced multi-row strips at uniform plant population has been designed (Nazir *et al.*, 1988; Saeed *et al.*, 1999) that not only gives paddy yield comparable to the conventional planting in narrow rows but also facilitates interplanting, management and harvesting of intercrops without doing much damage to the base rice crop. It also facilitates easy relaying of other crops.

Keeping in view the scope and significance of intercropping technology in the modern production system, the present study was designed to evaluate the yield advantages, competitive functions and economics of diversified direct-seeded upland rice-based intercropping systems under the agro-ecological conditions of Faisalabad in irrigated environment.

MATERIALS AND METHODS

A field study to assess the yield advantages, competitiveness and economics of diversified direct-seeded upland rice-based intercropping system was conducted at the University of Agriculture, Faisalabad for two consecutive years on a sandy-clay loam soil with an average fertility status of 0.42% N, 6.93 ppm P₂O₅ and 138 ppm K₂O. The intercropping systems comprised rice alone (*Oryza sativa* L.), rice + maize (*Zea mays* L.), rice + sesbania (*Sesbania sesbane* L.), rice + mungbean (*Vigna radiata* L. Wilezen), rice + ricebean (*Vigna umbellata* L.), rice + cowpea (*Vigna unguiculata* L.) and rice + pigeonpea (*Cajanus cajan* L. Millspergh). All the intercrops were grown as forage and harvested 45 days after sowing while the rice crop was harvested at its full physiological maturity as a grain crop. The experimental treatments were arranged in a randomized complete block design (RCBD) and replicated thrice. The net plot size measured 3.60 m x 6.00 m. Rice cultivar "Basmati-385" was direct seeded at optimum soil moisture ('wattar' condition) on a fine seedbed 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 the vacant spaces between the rice strips using their recommended seed rates ha⁻¹. A fertilizer dose of 100 kg N ha⁻¹ + 100 kg P₂O₅ ha⁻¹ was applied at the time of seeding rice crop while additional dose of 50 kg N ha⁻¹ was top dressed soon after the harvest of forage crops on the rice strips only. Normal

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 intercrops for the sake of seedbed preparation at optimum soil moisture while subsequent irrigations 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 as and when a need was felt up till its final harvest. Observations on desired parameters of the component crops were recorded using standard procedures and the data obtained were analyzed statistically using "MSTATC" statistical package on a computer while the differences among treatment means were compared by Least Significance Difference (LSD) test at P = 0.05.

The yield advantages of different intercropping systems over monocropping of rice were determined in terms of total rice grain yield equivalent (TRGYE), land equivalent ratio (LER) and area time equivalent ratio (ATER).

Total rice grain yield equivalent (TRGYE)

Total rice grain yield equivalent (TRGYE) of each intercrop was computed by converting the yield of intercrops into grain yield of rice on the basis of the existing market price of each intercrop (Anjeneyula *et al.*, 1982).

Land equivalent ratio (LER)

Land equivalent ratio (LER) was computed using the following formula described by Willey (1980).

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

Where

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

Yab = Intercrop yield of crop 'a'

Yba = Intercrop yield of crop 'b'

Yaa = Pure stand crop yield of 'a'

Ybb = Pure stand crop yield of 'b'

Area time equivalent ratio (ATER)

Area time equivalent ratio (ATER) was determined by the formula proposed by Hiebsch (1987) as follows:

$$ATER = \frac{(Ryc \times tc) \times (Ryp \times tp)}{T}$$

Where

Ryc = Relative yield of crop c (main crop)

Ryp = Relative yield of crop p (intercrop)

tc = Growth duration (days) for crop 'c'
tp = Growth duration (days) for crop 'p'
T = Growth duration (days) for the whole system

Competition functions

The competitive functions were computed in the form of relative crowding coefficient, aggressivity and competitive ratio.

Relative crowding coefficient (RCC)

As proposed by Dewit (1960) relative crowding coefficient (K) was calculated by the following formula as under:

$$K_{ab} = \frac{Y_{ab}}{Y_{aa} - Y_{ab}} - \frac{Z_{ba}}{Z_{ab}}$$

Where

Yab = Intercrop yield of crop 'a'

Yaa = Pure stand yield of crop 'a'

Zba and Zab are sown proportions of crop 'a' and 'b' in an intercropping system

RESULTS AND DISCUSSION

Total rice grain yield equivalent (TRGYE)

Total rice grain yield equivalent (TRGYE) is the best tool to determine the overall productivity potential of an intercropping system. The data presented in Table 1 reflected visible variation in TRGYE among the intercropping systems showing the highest TRGYE (6.45 t ha⁻¹) for rice + maize followed by rice + cowpea (5.08 t ha⁻¹) and rice + sesbania (4.92 t ha⁻¹) compared to 4.85, 4.82 and 4.81 t ha⁻¹ for rice + ricebean, rice + pigeonpea and rice + mungbean intercropping system, respectively against the minimum (4.02 t ha⁻¹) for sole rice crop. The percentage increase over sole cropping of rice as a result of different intercropping systems, however, varied from 16.42, to 37.67 % clearly indicating substantial yield advantage of intercropping. The variation in TRGYE under different cropping systems was ascribed to their variable utilization of soil and agro resources. Higher yield benefit in terms of TRGYE of intercropping over monocropping of rice has

Table 1. Total rice grain yield equivalent, land equivalent ratio, area-time equivalent ratio, competitive functions and net monetary returns under different upland rice-based intercropping systems

Intercropping systems	Total rice grain yield equivalent of the system (t ha ⁻¹)	% increase over rice alone	Land equivalent ratio of the system (LER)	Area time equivalent ratio of systems (ATER)	Relative crowding coefficient (RCC)	Aggressivity (A)		Competitive ratio (CR)		Net monetary returns (Rs.ha ⁻¹)
						Rice (Aab)	Intercrop (Aba)	Rice	Intercrops	
Rice alone	4.02	-	1.00	1.00	-	-	-	-	-	26526
Rice + maize	6.45	37.67	1.75	1.23	76.94	- 0.55	+ 0.55	0.55	1.82	42325
Rice +sesbania	4.92	18.29	1.39	1.08	19.80	- 0.64	+ 0.64	0.47	2.14	28855
Rice +mungbean	4.81	16.42	1.27	1.16	21.38	- 0.49	+ 0.49	0.56	1.78	29352
Rice +rice bean	4.85	17.11	1.25	1.19	37.48	- 0.51	+ 0.51	0.56	1.78	29625
Rice +cowpea	5.08	20.87	1.34	1.17	23.39	- 0.48	+ 0.48	0.57	1.75	30885
Rice +pigeon pea	4.82	16.60	1.27	1.14	18.56	- 0.47	+ 0.47	0.57	1.75	29502

Aggressivity (A)

The aggressivity (A) was calculated by the following formula proposed by McGilchrist (1965):

$$A_{ab} = \frac{Y_{ab}}{Y_{aa} \times Z_{ab}} - \frac{Y_{ba}}{Y_{bb} \times Z_{ba}}$$

Competitive Ratio (CR)

The competitive ratio was calculated by the following formula as proposed by Willey *et al* (1980).

$$CR_a = \frac{Y_{ab}}{Y_{aa} \times Z_{ab}} \div \frac{Y_{ba}}{Y_{bb} \times Z_{ba}}$$

Economic analysis

The two year average results were analyzed for economic benefits using the methodology prescribed by CIMMYT (1988).

also been reported by Banik and Bagchi (1994), Saeed *et al.* (1999) and Ahmad *et al.* (2007). Similarly Qayyum *et al.* (1995) stated that maize + rice intercropping gave the highest grain equivalent yield of 3.35 t ha⁻¹.

Land equivalent ratio (LER)

The land equivalent ratio (LER) is the relative area of a sole crop required to produce the yield achieved in intercropping. If LER value is equal to one, it means that there is no yield advantage but when LER is more than one, then there is yield advantage. The data on LER of different intercropping systems indicated that LER values were greater than one in all the intercropping treatments and the range of yield advantage over sole cropping of rice was between 25 and 75 % with the highest in case of rice + maize (75 %) followed by rice + sesbania (39%). The rest of the intercropping systems intermediated showing yield

advantage from 25 to 34%. Among the rice + forage legume intercropping systems, rice + sesbania and rice + cowpea proved to be the best because of their relatively higher yield potential and mutual complementation. Higher LER in intercropping treatments compared to monocropping of rice was attributed to better utilization of natural (land, CO₂ and light) and added (fertilizer and water) resources. Higher LER in intercropping compared to monocropping of rice was also reported by Mishra (1992), Mondal *et al.* (1993), Prasad and Singh (1992), Aziz *et al.* (1994), Saeed *et al.* (1999), Ibni Zamir *et al.* (2005) and Bhatti *et al.* (2006).

Area time equivalent ratio (ATER)

As LER does not take into account the time for which land is occupied by the component crops of an intercropping system, area-time equivalent ratio (ATER) was also calculated. The ATER provides a more realistic comparison of the yield advantage of intercropping over that of the sole cropping that the LER as it considers variation in time taken by the component crops of different intercropping systems. The ATER values shown in Table 1 revealed that ATER in all the intercropping systems was smaller than LER values indicating the over estimation of resource utilization in the latter. Hence contrary to LER, the ATER is free from the prediction of over estimation of resources utilization. Based on two-year average data, ATER value exhibited an average of one to twenty three per cent in intercropping systems compared to sole cropping of rice. The highest ATER (1.23) was recorded for rice + maize followed by rice + ricebean (1.19) and rice + cowpea (1.17) against the lowest (1.08) in case of rice + sesbania compared to 1.16 and 1.19 for rice + mungbean and rice + pigeonpea, respectively. Variable ATER of different rice-based intercropping system has also been reported by Banik and Bagchi (1994) and Saeed *et al.* (1999).

Competition functions

Competitive behaviour of the component crops across different intercropping systems was determined in terms of relative crowding coefficient, aggressivity and competitive ratio.

Relative crowding coefficient (RCC)

Relative crowding coefficient (RCC) plays an important role in determining the competition effects and advantages of intercropping. According to Willey (1979), in an intercropping system, each crop has its own RCC (K). The component crop with higher "K" value is the dominant and that with low "K" value is dominated. To determine if there is a yield advantage

in intercropping, the product of the coefficient of both component crops is obtained and that is usually designated as "K". If the product of RCC of the two species is equal, less or greater than one it means that the intercropping system has no advantage, disadvantage or advantage, respectively. In all the intercropping systems included in this study, ricebean, cowpea and pigeonpea intercrops appeared to be dominant as they had higher values for "K" than the intercrops in rest of the intercropping systems (Table 1). It may be inferred that the respective intercrops utilized the resources more competitively than rice which appeared to be dominated. However, in rice + ricebean, rice + cowpea and rice + pigeonpea intercropping systems, rice had a dominant effect in the utilization of resources and the intercrops were dominated.

The product of the component crops were greater than one. All the intercropping systems had yield advantage. Across the intercropping systems, the maximum rice yield advantage was recorded for rice + maize as indicated by its maximum value of "K" (76.64). Wheat + fenugreek, wheat + gram (Shahid and Saeed, 1997) and wheat + Egyptian clover intercropping systems (Ahmad, 1990) and sesame + mungbean intercropping (Bhatti *et al.*, 2006) have also been reported for grain yield advantage over their respective monoculture as determined on the basis of "RCC".

Aggressivity (A)

Aggressivity is an important competition function to determine the competitive ability of a crop when grown in association with another crop. An aggressivity value of zero indicated that component crops are equally competitive. For another situation, both crops will have the same numerical value but the sign of the dominant species will be 'positive' and that of dominated 'negative'. The greater the numerical value, the higher is the difference in competitive abilities and the higher the differences between actual and expected yields. The data shown in Table 1 revealed that component crops did not compete equally. All the intercrops indicated dominant behaviour over the base rice crop as indicated by their positive (+) sign against negative (-) sign for rice crop. Aggressivity values was the highest (+0.64) for rice + sesbania followed by rice + maize (+0.55) and rice + ricebean (+0.51) compared to the minimum (+0.47 and 0.48) for rice + pigeonpea and rice + cowpea, respectively which indicated that pigeonpea and cowpea were the least competitive crops to rice. Mungbean also appeared to be comparatively less competitive showing an aggressivity value of (+0.49). Many other research workers like

Gomma (1991), Shahid and Saeed (1997) also reported the dominant effect of mungbean, cowpea, mashbean and linseed when grown in association with other crops having a positive (+) aggressivity values.

Competitive ratio (CR)

Competitive ratio (CR) is another way to know the degree with which one crop competes with the intercrop. Higher CR values for intercrops than the base rice crop indicated that all intercrops like maize, sesbania, mungbean, ricebean, cowpea and pigeonpea were more competitive than rice when grown in association with each other (Table 1). Among intercrops, the competitive ratio was higher for sesbania (2.14) followed by maize (1.82) compared to the minimum of 1.75 for cowpea and pigeonpea while rest of the intercrops intermediated showing CR of 1.78. It is thus apparent from the data regarding RCC and CR that rice in each intercropping system was the dominated crop. Among the intercrops, sesbania and maize proved to be better competitive when grown in association with rice. As reported earlier by Shahid and Saeed (1997), lentil was a better competitor than other crops when grown in association with wheat.

Economic analysis

Economic analysis is essential as the farmers are often interested in profits and costs of a newly evolved technology. They also like to know about risks involved in the adoption of new practices. Pooled data were economically analyzed. The partial budget analysis revealed that rice + maize and rice + cowpea intercropping systems gave the maximum net benefits of Rs.42325 and 30885 ha⁻¹, respectively while rice + ricebean, rice + pigeonpea and rice + mungbean gave almost similar net benefits of Rs.29625, 29502 and 29352 ha⁻¹, respectively. By contrast, the lowest net benefit of Rs.28885 ha⁻¹ was recorded for rice + sesbania intercropping system (Table 1). However, the net benefits of all intercropping systems were higher than that achieved from monocropping of rice.

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