



Full Length Article

Evaluating the Performance of Direct Seeded Rice in Different Intercropping Systems under Strip Plantation

ABDUL JABBAR¹, RIAZ AHMAD[†], IFTIKHAR HUSSAIN BHATTI[†], WASI-U-DIN, MUHAMMAD NADEEM AND MUHAMMAD MUJTABA KHAN

University of Agriculture Faisalabad, Sub-campus Depalpur, Okara, Pakistan

[†]Department of Agronomy, University of Agriculture, Faisalabad, Pakistan

¹Corresponding author's e-mail: jabbaruafap@yahoo.com

ABSTRACT

In a field study, the growth, grain yield and economic traits were studied under different intercropping systems in direct seeded rice under strip plantation 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. 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 dry matter of rice was decreased substantially due to intercropping of different forage legumes and non-legumes as compared to sole cropping of rice. Rice growth was more suppressed with a sesbania companion crop than with maize because of relatively thick shading effect of sesbania due to its vigorous vegetative growth rate. The results also revealed that rice grain yield was 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 against the minimum (10.94%) by maize intercrop. Among the intercrops, maize grown in association with rice produced significantly the highest forage yield (40.70 t ha⁻¹). In terms of total rice grain yield equivalent (TRGYE), the highest TRGYE (6.45 t ha⁻¹) was recorded for rice + forage maize intercropping system. 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. The dominance analysis showed that rice + maize, rice + cowpea and rice+pigeonpea intercropping systems are more profitable than growing rice alone and other intercropping systems. According to marginal rate of return, the highest MMR (2244%) was realized from rice + forage maize intercropping system followed by rice+cowpea (158%) against rice alone. It was also inferred from all sensitivity analysis options that rice+maize and rice+cowpea intercropping systems were economical and viable against sole rice. © 2010 Friends Science Publishers

Key Words: Intercropping; Direct-seeded rice; Grain yield equivalents; Economic benefits; Strip planting; Planting geometry

INTRODUCTION

Rice (*Oryza sativa* L.) being a staple food of the millions of people around the world particularly in South Asian countries including Pakistan, China, India, Bangladesh, Sri Lanka and Nepal. It is the second major foreign exchange earning source in Pakistan; hence its role in the economic development of Pakistan be overlooked. The major issue for rice production is the water shortage as more than 80% rice is produced under lowland conditions. The shifting of rice production from lowland to upland is not very old, however upland rice is becoming very popular in these countries and its acreage is increasing day by day (Saeed *et al.*, 1999a).

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 sub-tropical 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 (Saleem *et al.*, 2000, 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.*, 1999a). It also helps maintaining the soil fertility, making efficient use of nutrients (Aggarwal *et al.*, 1992; Nazir *et al.*, 1997; Ahmad & Saeed, 1998;

Maingi *et al.*, 2001), ensuring economic utilization of land, labour and capital (Morris & Garrity, 1993; Singh *et al.*, 1996; Jeyabal & Kuppuswamy, 2001) and controlling pest's population (Epidi *et al.*, 2008). Most legume crops stimulate upland rice yield, but the effect of upland rice on legume crop is different i.e., decreasing yield or no significant (Prajitno, 2007). In general, non-legume crop is considered a suppressing crop in legume associations.

Pakistan has arid to semi-arid sub-tropical 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 (Saeed *et al.*, 1999b).

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.

Reasonable research work has been done on maize, cotton, sugarcane and wheat based intercropping systems in Pakistan and elsewhere (Nazir *et al.*, 1997), yet research on rice-based intercropping systems is sketchy and negligible (Saeed *et al.*, 1999a). The lack of such information necessitates studies on rice-based intercropping systems, which may ensure sustained crop productivity and land use in the rice growing areas. So keeping in view the scope of intercropping in modern production system, the present study was conducted with the objective to study the effect of intercrops on growth and agro-economic traits of direct seeded rice in rice-based intercropping systems under agro-ecological conditions of Faisalabad in irrigated environment.

MATERIALS AND METHODS

This study was conducted at the Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan 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 and Pratt (1961). The soil had an average fertility status of 0.042% N, 6.5 ppm P₂O₅ and 123 ppm K₂O with a pH of 8.6. The intercropping systems

comprised rice alone (*Oryza sativa* L.), rice+maize (*Zea mays* L.), rice+sesbania (*Sesbania sesban* L.), rice+mungbean (*Vigna radiata* L. Wilczek), rice+ricebean (*Vigna umbellata* L.), rice+cowpea (*Vigna unguiculata* L.) and rice+pigeonpea (*Cajanus cajan* L. Millspavgh). 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 field capacity 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 on June 16 in first year and June 19 in second 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 & pigeonpea 50 kg ha⁻¹). 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. A uniform basal dose of 100 kg N + 100 kg P₂O₅ 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. 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 said parameters of the component crops were recorded and the data obtained were analyzed statistically by using "MSTAT-C" statistical package on a computer (Fareed & Eisensmith, 1986). 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).

Fresh and dry weight per unit area of the component crops was recorded at fortnight interval. At each time period, an area (15 cm x 120 cm) was harvested at random from each plot at three different places, weighed and then chopped into small pieces. Chopped material was mixed thoroughly. Samples weighing 200 g each were taken in muslin cloth bags and then got dried at 80°C to the constant dry weight and weighed thereafter. The data pertaining to dry matter were used to calculate dry matter accumulation m⁻². The crop growth rate (CGR) was determined according to Beadle (1987).

The two years' average data were analyzed for economic parameters using the methodology prescribed in CIMMYT (1988). In economic analysis, net field benefits are calculated, but it does not compare the costs that vary with the net field benefits. For such a comparison, marginal

analysis is required. The marginal analysis involves the dominance analysis and marginal rate of return. For dominance analysis, treatments were arranged in order of increasing variable costs. A treatment was considered dominated (D) if its variable costs were higher than the preceding treatment, but its net field benefits were equal or low (CIMMYT, 1988). The marginal rate of return (MRR, percent) is the marginal net field benefits (MNB) i.e., the change in net field benefits divided by the marginal cost (MC) i.e., the change in costs expressed as percentage. MRR was determined by using the formula given by CIMMYT (1988).

The input and output prices of agricultural commodities keep on fluctuating from year to year and location to location in Pakistan. Therefore, in order to test its ability to withstand the possible price changes, "Sensitivity analysis" was performed. In this analysis, marginal analysis was done using an alternative set of input and output prices. Different scenarios assumed about the change in input and output prices were sensitivity analysis with constant input prices and output prices increased by 10% from the current level, sensitivity analysis with input prices increased by 10% and output prices kept constant and sensitivity analysis with input prices increased by 5% and output prices decreased by 5%.

RESULTS

Dry matter accumulation in rice: Periodic data pertaining to dry matter accumulation by rice as influenced by different intercropping systems recorded in both years are depicted in the Fig. 1. Rice grown alone or intercropped with forage legumes accumulated DM at a very slow rate up to 30 days after emergence because of slow growth rate and ultimately less initial plant biomass. Therefore, DM increased at a faster rate from 30 to 90 days after emergence. The data pertaining to dry matter production m^{-2} in rice as influenced by different intercropping systems recorded at 90 DAS are presented in the Table I. The data revealed that there was a significant variation in rice DM accumulation by the associated rice. Sesbania intercrop reduced the DM accumulation in the associated rice to the maximum ($916.79 m^{-2}$) preceded by pigeonpea and ricebean with DM accumulation of 1046.99 and 1049.64 $g m^{-2}$, respectively.

Mean crop growth rate (MCGR): Trends in the crop growth rate (CGR) of rice as influenced by different intercropping systems during both years are depicted in Fig. 2. During first year, regardless of intercropping systems, the CGR was slow up to 30 days after emergence (DAE) because of less initial plant biomass. Thereafter, CGR exhibited sharp increase up to 75 DAE followed by pronounced decline. The maximum CGR was recorded during 45-60 DAE, indicating the most active growth phase of rice. Almost similar trend on CGR was observed during second year. The crop growth rate was significantly higher in case of sole rice crop than the intercropped rice (Table I). Among the intercrops, sesbania caused the maximum

reduction in CGR of rice preceded by ricebean and pigeonpea. However, maize, mungbean and cowpea intercrops were at par with one another and decreased the CGR of the associated rice crop to a significant level.

Rice grain yield: The rice grain yield was decreased to a significant level by intercropping forage legume and non-legume cultures compared to monocropped rice. 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%). By contrast, the minimum (10.94%) was recorded for rice + maize intercropping system.

Forage yield of intercrops and their rice grain yield equivalents: There was a significant variation in forage yield of intercrops grown in association with rice under different intercropping systems (Table I). Among the intercrops, maize grown in association with rice produced significantly the highest forage yield ($40.70 t ha^{-1}$) and was followed by sesbania ($27.40 t ha^{-1}$) and cowpea ($23.69 t ha^{-1}$), which were significantly different from each other. However, statistically similar forage yield was obtained from pigeonpea, mashbean and ricebean, which amounted to 20.76, 20.60 and $19.50 t ha^{-1}$, respectively. Regarding rice grain yield equivalents (RGYE) of intercrops, the maximum RGYE was obtained by rice+maize intercropping system ($2.87 t ha^{-1}$) followed by rice+sesbania intercropping system ($1.94 t ha^{-1}$) against the minimum of $1.38 t ha^{-1}$ by rice+ricebean intercropping system.

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 ($6.45 t ha^{-1}$) was recorded for rice + maize followed by rice + cowpea intercropping systems ($5.08 t ha^{-1}$), while rest of the intercropping systems intermediated showing TRGYE ranging between 4.45 and $4.92 t ha^{-1}$ compared to the minimum ($4.02 t ha^{-1}$) for monocropped rice. 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.

Economic analysis: Pooled data were economically analyzed by partial budget analysis. The economic 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.

Dominance analysis of different rice-based intercropping systems: The dominance analysis of different intercropping systems (Table II) revealed that intercropping systems of rice + pigeonpea, rice + mungbean and rice + sesbania were dominated by rest of the intercropping systems under study. The dominated intercropping systems were actually less profitable than growing rice alone and other intercropping systems.

Table I: comparative bio-economic performance of different upland rice-based intercropping systems (2-year average data)

Intercropping systems	Dry matter accumulation (g m ⁻²)	Mean crop growth rate (gm ⁻² d ⁻¹)	Rice grain yield (t ha ⁻¹)	Forage yield of inter-crops (t ha ⁻¹)	Rice grain yield equivalents of intercrops (t ha ⁻¹)	Total rice grain yield equivalents of systems (t ha ⁻¹)	Net benefits (Rs. ha ⁻¹)
Rice alone	1348.08 a	17.75 a	4.02 a	-	-	4.02	26526
Rice + maize	1178.34 b	15.61 b	3.58 b (-10.94)	40.70 a	2.87	6.45 (+37.67)	42325 (+37.32)
Rice + sesbania	916.79 d	12.27 d	2.98 c (-25.87)	27.49 b	1.94	4.92 (+18.29)	28855 (+8.71)
Rice + mungbean	1178.26 b	15.52 b	3.36 b (-16.42)	20.60 d	1.45	4.81 (+16.42)	29352 (+9.63)
Rice + ricebean	1049.64 c	13.96 c	3.47 b (-13.68)	19.50 d	1.38	4.85 (+17.11)	29625 (+10.46)
Rice + cowpea	1208.15 b	15.98 b	3.41 b (-15.17)	23.69 c	1.67	5.08 (+20.87)	30885 (+14.03)
Rice + pigeonpea	1046.99 c	13.81 c	3.35 b (-16.67)	20.76 d	1.47	4.82 (+16.60)	29502 (+10.09)
LSD (P = 0.05)	76.55	1.04	0.26	2.79			

(+) = Percent increase over rice alone, (-) = Percent decrease over rice alone

Market prices of grain/green fodder

Maize fodder = Rs. 30/40 kg	Mungbean fodder = Rs. 30/40 kg
Sesbania fodder = Rs. 30/40 kg	Cowpea fodder = Rs. 30/40 kg
Ricebean fodder = Rs. 30/40 kg	
Pigeonpea fodder = Rs. 30/40	
Rice = Rs.425/40 kg	

Table II: Dominance analysis of different intercropping systems

Intercropping systems	Cost that vary (Rs. ha ⁻¹)	Net benefits (Rs. ha ⁻¹)
Rice alone	3330	26526
Rice + pigeonpea	6149	29625
Rice + ricebean	6365	29502 D
Rice + mungbean	6432	29352 D
Rice + sesbania	6592	28855 D
Rice + cowpea	6944	30885
Rice + maize	7412	42325

Table III: Marginal analysis of different intercropping systems

Cropping systems	Cost that vary (Rs. ha ⁻¹)	Marginal cost (Rs. ha ⁻¹)	Net benefits (Rs. ha ⁻¹)	Marginal net benefits (Rs. ha ⁻¹)	Marginal rate of return (%)
Rice alone	3330	-	26526	-	-
Rice + pigeonpea	6149	2819	29625	3099	110
Rice + cowpea	6944	795	30885	1260	158
Rice + maize	7412	468	42325	11440	2444

Table IV: Sensitivity analysis with input prices increased by 10% and output prices kept constant (Dominance analysis)

Intercropping systems	Cost that vary (Rs. ha ⁻¹)	Net benefits (Rs. ha ⁻¹)
Rice alone	3663	26193
Rice + ricebean	6764	29010
Rice + pigeonpea	7002	28865 D
Rice + mungbean	7075	28709 D
Rice + sesbania	7251	28196 D
Rice + cowpea	7638	30191
Rice + maize	8153	41584

Marginal analysis of different rice-based intercropping systems: Marginal analysis revealed that the highest MRR of 2444% was realized from the rice + maize intercropping system followed by rice + cowpea (158%), rice + pigeonpea (110%) against rice alone. In conclusion, this analysis suggested that rice + ricebean gave 110% increase in cost involved in this intercropping system as against a sole rice crop. Rice + cowpea intercropping system resulted in a further 158% increase in marginal returns per unit of increase in marginal cost over rice + ricebean. By contrast, shifting

from rice + cowpea intercropping system to rice + maize intercropping system gave 2244% marginal benefit for a change in marginal cost of the previous intercropping system.

Sensitivity analysis of different intercropping systems: The dominance analysis evinced that all the intercropping systems except rice + pigeonpea, rice + mungbean and rice + sesbania still gave higher net benefits, which varied from Rs. 29010 to 41584 ha⁻¹ against the minimum of 26193 ha⁻¹ for rice alone, when the prices of all inputs were increased by

Table V: Sensitivity analysis with input prices increased by 10% and output prices kept constant (Marginal rate of return MRR)

Cropping systems	Cost that vary (Rs. ha ⁻¹)	Marginal cost (Rs. ha ⁻¹)	Net benefits (Rs. ha ⁻¹)	Marginal net benefits (Rs. ha ⁻¹)	Marginal rate of return (%)
Rice alone	3663	-	26193	-	-
Rice + ricebean	6764	3101	29010	2817	91
Rice + cowpea	7638	874	30191	1181	135
Rice + maize	8153	515	41584	11393	2212

Table VI: Sensitivity analysis with constant input prices and output prices increased by 10% (Dominance analysis)

Intercropping systems	Cost that vary (Rs. ha ⁻¹)	Net benefits (Rs. ha ⁻¹)
Rice alone	3330	29179
Rice + ricebean	6149	32588
Rice + pigeonpea	6365	32452 D
Rice + mungbean	6432	32287 D
Rice + sesbania	6592	31741 D
Rice + cowpea	6944	33974
Rice + maize	7412	46557

Table VII: Sensitivity analysis with constant input prices and output prices increased by 10% (Marginal rate of return MRR)

Cropping systems	Cost that vary (Rs. ha ⁻¹)	Marginal cost (Rs. ha ⁻¹)	Net benefits (Rs. ha ⁻¹)	Marginal net benefits (Rs. ha ⁻¹)	Marginal rate of return (%)
Rice alone	3330	-	29179	-	-
Rice + pigeonpea	6149	2819	32588	3409	121
Rice + cowpea	6944	795	33974	1386	174
Rice + maize	7412	468	46557	12583	2689

Table VIII: Sensitivity analysis with input prices increased by 5% and output prices kept constant (Dominance analysis)

Intercropping systems	Cost that varies (Rs. ha ⁻¹)	Net benefits (Rs. ha ⁻¹)
Rice alone	3163	25033
Rice + ricebean	5841	27837
Rice + pigeonpea	6047	27709 D
Rice + mungbean	6110	27562 D
Rice + sesbania	6262	27082 D
Rice + cowpea	6597	28994
Rice + maize	7041	39838

Table IV: Sensitivity analysis with input prices increased by 5% and output prices kept constant (Marginal rate of return MRR)

Cropping systems	Costs that vary (Rs. ha ⁻¹)	Marginal cost (Rs. ha ⁻¹)	Net benefits (Rs. ha ⁻¹)	Marginal net benefits (Rs. ha ⁻¹)	Marginal rate of return (%)
Rice alone	3163	-	25033	-	-
Rice + ricebean	5841	2678	27837	2804	105
Rice + cowpea	6597	756	28994	1157	153
Rice + maize	7041	444	39838	10844	2442

10% over the current prices. However, rice + pigeonpea, rice + mungbean and rice + sesbania intercropping systems were dominated (D) by these systems.

The marginal rate of return (MRR) from intercropping systems of rice + ricebean, rice + cowpea and rice + maize were recorded as 91, 135 and 2212%, respectively compared to that with actual costs of inputs. This analysis revealed that in the future if the prices of all input commodities are increased by 10% even then the superiority of intercropping systems of rice + ricebean, rice + cowpea and rice + maize over sole would not change. Therefore, it is safe to recommend the intercropping systems as a better alternative of sole cultivation.

The dominance analysis indicated that the net profit increased with increase in output prices. Among the different

intercropping systems, rice + maize showed the highest net benefit (Rs. 46557 ha⁻¹) followed by rice + cowpea (Rs. 33974 ha⁻¹) and rice + ricebean (Rs. 32588 ha⁻¹) compared to Rs. 32452, 32287 and 31741 ha⁻¹ in rice + pigeonpea, rice + mungbean and rice + sesbania intercropping systems, respectively against the minimum of Rs. 29179 ha⁻¹ in monocropped rice. The analysis further revealed that net profit from rice + pigeonpea, rice + mungbean and rice + sesbania were dominated "D".

The marginal rate of return (MRR) calculated for dominant intercropping system given in Table indicated that the MRR for rice + ricebean, rice + cowpea and rice + maize increased by 121 to 174 and 2689%, respectively when prices of all the output commodities were increased by 10%, while keeping the prices of all inputs at constant rates.

Fig. 1: Dry matter accumulation of rice at various development stages (DAE) as influenced by different intercropping systems

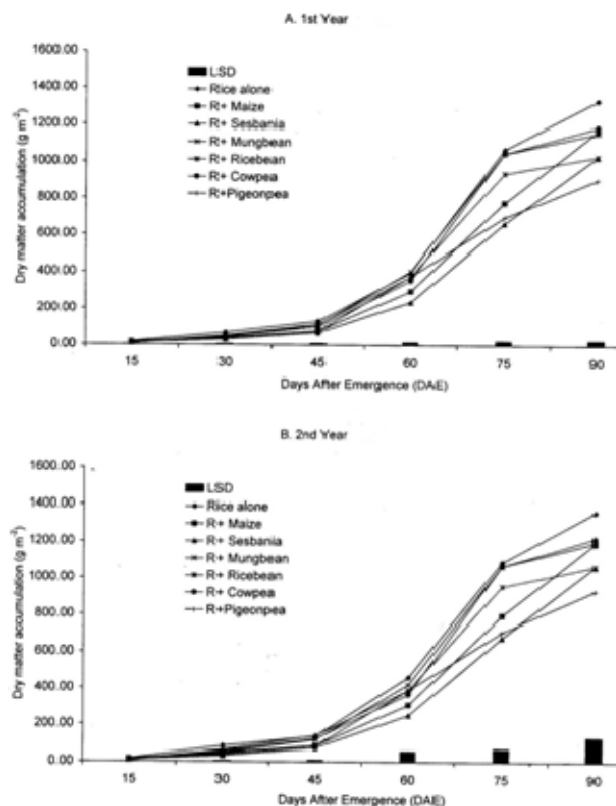
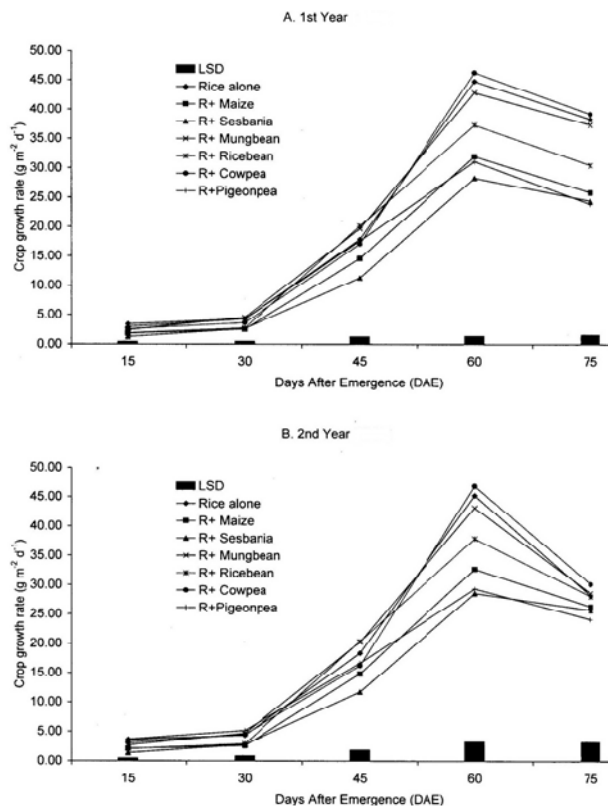


Fig. 2: Crop growth rate of rice at various development stages (DAE) as influenced by different intercropping systems



The dominance analysis indicated that although the net benefits decreased in all the intercropping systems as against the current prices of inputs and outputs, but the intercropping systems of rice+ricebean, rice+cowpea and rice+maize still gave the highest net returns of Rs. 27837, 28994 and 39838 ha⁻¹ compared to lowest of Rs. 27709, 27562 and 27082 ha⁻¹ for rice+pigeonpea, rice+mungbean and rice+sesbania, which were dominated “D”. However, these benefits were 6.04, 6.12 and 8.00% lower than those realized, when the prices of all inputs and outputs were considered at current rates (Table II) for the aforesaid intercropping systems.

The marginal rate of return (MRR) calculated for dominant intercropping systems given in the table indicated that MRR for rice + ricebean, rice + cowpea and rice + maize increased by 105, 153 and 2442%, respectively when prices of all the output commodities were 5% and the prices of outputs decreased by 5%.

DISCUSSION

The first prerequisite for high yield is high total dry matter (DM) production per unit area. Dry matter production depends on photosynthesis for which adequate supply of solar radiation, CO₂ and favourable environment are necessary. Economic yield depends on as to how the net DM is distributed among different organs of the plant. Dry matter

accumulation in associated rice was low probably because of competition between the component crops for different growth factors such as water, nutrients etc. that resulted in slow crop growth rates of the intercropped rice compared to sole rice. Mandal *et al.* (1989), Chauhan *et al.* (1994) and Saha (1994) also attributed reduction in rice DM to quick growth and more competition of intercrops, when intercropped with soybean, peanut, ricebean and other crops. The crop growth rate is the gain in dry matter production on a unit of land in a unit of time. Crop growth rate is affected by a range of factors including temperature, level of solar radiation, water, nutrients supply, crop, cultivar and its age. These factors influence the size and efficiency of leaf canopy and hence the ability of the crop to convert solar energy into economic growth. Variable CGR of rice in different intercropping systems might be attributed to the variation in total above ground plant biomass (DM) of rice. Banik and Bagchi (1994) also observed that CGR of rice was decreased by intercropping legumes compared with that of the sole crop of rice due to quick growth and more leaf area of intercrops. Ahmad and Saeed (1998) attributed decrease in CGR of wheat by intercropping legumes and non-legumes to more biomass of intercrops.

In case of rice grain yield, the maximum reduction in rice grain yield due to sesbania intercropping 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. Chandra *et al.* (1992), Saeed *et al.* (1999a) and Joshi (2002) also narrated that reduction in grain yield of rice was due to more leafy growth and spreading behavior of intercrops. Dhimmarr *et al.*, 2009 caused chickpea, green gram and Indian bean intercrops to severe reduction in yield and yield attributes of cater with the maximum loss by Indian beans. The significant variation in forage yield among different intercrops was probably attributed to their variable growth behavior and resource utilization potential under different intercropping associations. Qayyum and Muniruzzaman (1995) and Saeed *et al.* (1999a) stated that variation in forage yield of different legume intercrops grown in association with rice and other cereal crops was due to different growth habit of intercrops and their varied capacity to use inputs applied. Khan and Khaliq (2004) stated that smaller fresh weights of fodder intercrops in cotton were due to more and spreading growth behavior of cotton. Similarly, Gill *et al.* (2009) ascribed low grain yield of chickpea intercropped with wheat to inhibitory effect of wheat on root proliferation of chickpea and malfunctioning of roots and ultimately significant decrease in tissue water concentration of the intercrop.

Maximum rice grain yield equivalents (RGYE) obtained from rice + maize intercropping system was due to more fodder yield of the intercrop. Banik and Bagchi (1994), Qayyum and Muniruzzaman (1995), Saeed *et al.* (1999a) and Joshi (2002) also ascribed increase in TRGYE to the additional income obtained from intercrops. Economic analysis is done to see profits and costs of a newly evolved technology and to know about risks involved in the adoption of new practices. Maximum net benefits obtained from rice + maize intercropping system was probably due to more fodder yield of the maize intercrop as compared to other intercrops. Significantly higher net field benefits of intercropping rice and wheat with legumes and non-legumes has also been reported by Saeed *et al.* (1999 a & b). Khan and Khaliq (2004) stated that additional production from intercrops obtained from cotton + maize, cotton + sorghum and cotton + cowpea compensated more in monetary terms than the losses in cotton production. Asmatullah *et al.* (2007) reported that all maize based intercropping systems gave substantially higher net income over mono-cropping of maize due to additional income from yield of intercrops. A partial budget analysis (economic analysis) gave an insight into the total costs that vary and the net gains from any intercropping system. It did not give information on relative/comparable gains in extra (marginal) benefits from the extra (marginal) costs involved for different intercropping systems. For this purpose dominance analysis was carried out first by listing the intercropping systems in order to increasing costs that vary. The dominance analysis showed that rice + maize, rice + cowpea and rice + pigeonpea are dominant over rest of the intercropping systems under study. It means that these intercropping systems were more profitable than growing

rice alone and other intercropping systems.

Marginal analysis was done to reveal first how the net benefits from an investment on different intercropping systems increased as the amount invested on the same increased. The intercropping systems, which were dominated in a dominance analysis, were dropped from the marginal analysis. The maximum marginal rate of return obtained from rice + maize intercropping system was probably due to more biomass of maize intercrop from which more marginal benefit was obtained at the same cost. Although dominance and marginal analysis showed the superiority of some of the intercropping systems over the others, the farmers' choice will still depend on sensitivity in returns and risk attitudes, as well as average level of returns. In Pakistan, the output and input prices are subject to change from year to year and location to location. To determine how sensitive are the net benefits of these intercropping systems to change in the prices of inputs and outputs and to make a certain intercropping system acceptable to farmers, sensitivity analysis was carried out. This analysis was performed by changing one price or combination of prices to see their impact on the benefits and marginal rate of return under different intercropping systems in this study. It is inferred from all sensitivity analysis options that all the above mentioned intercropping systems were economical and viable against sole rice. With different assumptions in change of output and input prices, the results proved the superiority of rice + maize intercropping system probably due to less adverse effect of maize intercrop on rice yield, as well as its more fodder yield and ultimately more economic return. Bhatti *et al.* (2008) attributed superiority of sesame + mungbean intercropping system to less adverse effect of mungbean intercrop on sesame and its more grain yield as compared to other sesame based intercropping systems. Similarly Wahla *et al.* (2009) also ascribed the highest advantage of barley + fenugreek intercropping system to more yield of intercrop and its less competition for growth factors with main crop.

CONCLUSION

It is concluded after detailed economic analysis that intercropping direct-seeded rice with forage maize under 4-row strip plantation proved to be feasible and economically more viable than other rice-based intercropping systems and monocropping of rice.

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