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Residual Soil Fertility as Influenced by Diverse Rice-based Inter/Relay Cropping Systems

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ABSTRACT

A field experimented was conducted to study different direct seeded rice-based inter/relay cropping systems and their effect on residual soil fertility at the University of Agriculture, Faisalabad for two consecutive years (1998-1999 & 1999-2000). The intercropping systems comprised rice alone, rice + maize, rice + sesbania, rice + mungbean, rice + ricebean, rice + cowpea and rice + pigeonpea while wheat, lentil and Egyptian clover were sown as relay crops on residual soil moisture just after the harvest of rice previously intercropped with forage legumes and non-legumes at zero tillage. The results revealed that among the three sets of rice based inter/relay cropping systems, the overall production level of total rice grain yield equivalent (TRGYE) was higher for rice-based Egyptian clover set followed by lentil oriented to the lowest for wheat oriented set. Production level of TRGYE was highest (10.95 t ha^{-1}) for rice + maize - Egyptian clover inter/relay cropping system followed by rice + sesbania – Egyptian clover inter/relay cropping system (10.29 t ha^{-1}) compared to lowest (6.48 t ha^{-1}) for rice alone - wheat cropping system. However, rest of the cropping systems gave TRGYE ranging between 7.18 to 10.17 t ha^{-1}. Regarding residual soil fertility, residual soil nitrogen was improved in all leguminous inter/relay cropping systems as compared to sole rice as well as non-legume inter/relay cropping systems. Similarly residual soil organic matter was also improved in all inter/relay cropping systems. However, Egyptian clover oriented inter/relay cropping systems increased more residual nitrogen and organic matter as compared to lentil oriented inter/relay cropping systems, while wheat oriented inter/relay cropping systems either decreased or did not add nitrogen and organic matter in the soil. Residual soil phosphorus and potassium were depleted in all inter/relay cropping systems compared with the initial soil analysis. Similarly, as compared to rice alone, all intercropping systems showed similar trend in both years. Since rice-based leguminous inter/relay cropping systems proved to be more remunerative and sustainable than wheat-oriented inter/relay cropping systems, so some leguminous crop like lentil and Egyptian clover should be added in rice-based cropping system in place of wheat to sustain the yield of component crops of the cropping system and maintain the fertility status of the soil for long duration.

Key Words: Direct-seeded rice; Grain yield equivalents; Inter/relay cropping systems; Residual soil fertility

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 (Wahla *et al*., 2009; Jabbar *et al.*, 2010. This envisages to go for another appropriate and more efficient production system such as multiple cropping (inter/relay cropping), which may ensure proper utilization of resources towards increased production per unit area and time on a sustainable basis (Ahmad *et al*., 2007). 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 (Nazir *et al*., 2002; Malik *et al.*, 2002; Bhatti *et al.*, 2005). 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 (Jabbar *et al*., 2010). Wang *et al*. (1995) found that output values and input:output ratio were higher with intercropping of rice with *Pleurtus ostreatus* than without intercropping. Similarly, relay cropping is beneficial in terms of resolving time conflict for plantation of various crops. Relay cropping can also fetch certain other benefits such as usage of residual moisture from previous crop and reduced planting cost (Saleem *et al*., 2000; Malik *et al*., 2002; Jabbar *et al.*, 2005). Joshi (2002) reported that rice-vegetable and rice-pulses cropping systems were profitable substitutes for rice-rice cropping system. Hussain and Ghaffar (1991) found that berseem planted after rice increased the rice yield

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significantly as compared rice sown in chickpea, lentil and wheat fields. Sarkar *et al*. (1991) studied eleven crops sown in standing rice or after harvesting of rice and found that urdbean, chickpea, sunflower, linseed, wheat and transplanted cotton were remunerative crops for growing in rice. Akanvou *et al.* (2002) stated that *Cajanus cajan* was the most appropriate legume species to suit a relay intercropping with upland rice as it produced reasonable amounts of biomass at low levels of rice grain yield loss and improved fallow by *C. cajan* gave a significant increase in the yield of subsequent rice crop. 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 inter/relay cropping is their need of the time to ensure efficient utilization of their resources for increased production and family income (Saeed *et al*., 1999a). Pakistan has the distinction of being the single largest producer of fine, aromatic quality rice (Basmati) in the world. Research on rice-based inter/relay cropping system is sketchy and negligible (Saeed *et al*., 1999a). The lack of such information necessitates studies on rice-based inter/relay cropping systems, which may ensure sustained crop productivity and land use in the rice growing areas (Sleem *et al*., 2000; Malik *et al*., 2002). Keeping this in view, a new pattern of planting rice in widely spaced multi-row strips was developed (Nazir *et al*., 1988; Saeed *et al*., 1999b), which not only gives paddy yield comparable to the conventional planting in single rows, but also facilitates sowing of inter/relay crops, agronomic management and harvesting of intercrops without much damage to the base crop. This study was, therefore, planned to explore the production potential and feasibility of different rice-based inter/relay cropping systems and examine their effects on residual soil fertility.

MATERIALS AND METHODS

A field study to assess the yield advantages and economics of diversified direct-seeded rice-based inter/relay cropping systems and their effect on residual soil fertility was conducted at the University of Agriculture, Faislalabad for two consecutive years (1998-1999 & 1999-2000) on a sandy-clay loam soil. Prior to sowing of the component/representative crops, soil samples were collected to a depth of 30 cm and analyzed for its different physic-chemical properties by employing the methods as described by Homer and Pratt (1961). The physico-chemical characteristics of the experimental site are given in Table I. Similarly soil samples were also collected and analyzed after the harvest of the experiment to determine residual soil fertility status. The intercropping systems comprised rice alone (*Oryza sativa* L.), rice + maize (*Zea mays* L.), rice + sesbania (*Sesbania sesban* L.), rice + mungbean (*Vigna radiata* L. Wilczen), rice + ricebean (*V. umbellata* L.), rice + cowpea (*V. unguiculata* L.) and rice + pigeonpea (*C. cajan* L. Millspavgh). 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 @ seed rate of 37.5 kg ha^{-1} at optimum soil moisture ('wattar' condition) on a finely prepared 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 on June 16 in first year and June 19 in second year. The respective intercrops were also seeded simultaneously on the vacant spaces between the rice strips using their recommended seed rates ha^{-1}. All the intercrops were grown as forage and harvested 45 days after sowing, while the rice crop was harvested at its harvest maturity as a grain crop. Just after the harvest of rice crop, the field was divided into three parts, and in each part wheat (*Triticum aestivum* L.), lentil (*Lens culinaris* Medik.) and Egyptian clover (*Trifolium alexandrinum* L.) were relayed at zero tillage on space between the rice strips previously vacated by intercrops. Wheat and lentil were planted with a single row hand drill while Egyptian clover was sown by broadcast using their recommended seed rates of 100 kg, 20 kg and 25 kg ha^{-1}, respectively. A uniform recommended dose of 100-100 kg NP 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. The latter crops were managed as per recommendations. All other agronomic practices were kept normal and uniform for all the treatments except irrigation water which was applied as per requirements of each relay crop. The relay crops (Egyptian clover & lentil) were also fertilized @ 25 kg N + 50 kg P ha^{-1} at the time of planting while wheat crop was fertilized @ 100 kg N + 50 kg P ha^{-1}.

Observations on parameters of the component crops (inter/relay crops) were recorded and the data obtained were analyzed statistically using "MSTATC" statistical package on a computer (Farid & Eisensmith, 1986), while the differences among treatment means were compared by Least Significance Difference (LSD) test at P = 0.05. The yield advantages of different inter/relay cropping systems over mono-cropping of rice were determined in terms of total rice grain yield equivalents (TRGYE), which was computed by converting the yield of inter/relay crops into grain yield of rice on the existing market price of each inter/relay crop.

RESULTS

Rice: The rice grain yield was decreased to a significant level by intercropping forage legume and non-legume crops compared to monocropped rice (Table II). 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.

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

Relay crops: Wheat grown under rice - wheat relay cropping system yielded significantly less than that grown under rice + legumes intercrops – wheat cropping systems which were at par with one another. However, the difference between rice -wheat and rice + maize - wheat cropping systems was not significant. Wheat grain yield under rice + sesbania - wheat inter/relay cropping system was significantly maximum (3.54 t ha^{-1}), but was at par with other rice + legume intercrops - wheat cropping systems. Significantly minimum grain yield (2.99 t ha^{-1}) was recorded in case of rice - wheat relay cropping system which was statistically similar to rice + maize - wheat cropping system (3.22 t ha^{-1}).

Seed yield of lentil grown under rice + sesbania - lentil inter/relay cropping system was significantly higher (1.38 t ha^{-1}) followed by rice + mungbean - lentil and rice + ricebean - lentil cropping systems and these were at par with rice + cowpea - lentil and rice + pigeonpea - lentil cropping systems. Significantly the lowest seed yield of lentil (0.99 t ha^{-1}) was recorded in rice - lentil cropping system which was at par with rice + maize - lentil (1.03 t ha^{-1}).

The forage yield of Egyptian clover in rice + sesbania - Egyptian clover inter/relay cropping system was significantly maximum (76.05 t ha^{-1}). However, it was at par with all other inter/relay cropping systems except rice + maize - Egyptian clover cropping system which was at par with forage yield of rice alone - Egyptian clover relay cropping system.

Total rice grain yield equivalents (TRGYE): The highest TRGYE (9.33 t ha^{-1}) was recorded for rice + maize - wheat cropping system against the lowest (6.48 t ha^{-1}) for rice-wheat relay cropping system. The other rice + legumes - wheat inter/relay cropping systems gave TRGYE ranging between 7.18 and 7.99 t ha^{-1}. Similarly among the rice + intercrops - lentil cropping system, the maximum TRGYE (10.07 t ha^{-1}) was obtained for rice + maize - lentil followed by rice + sesbania - lentil (9.47 t ha^{-1}) compared to the minimum (7.28 t ha^{-1}) for rice-lentil relay cropping system. The TRGYE for rest of cropping systems varied from 8.74 to 9.0 t ha^{-1}.

As regards rice + intercrops - Egyptian clover inter/relay cropping systems, the production level of TRGYE was higher than rice + intercrops - lentil cropping system with the highest (10.45 t ha^{-1}) for rice + maize - Egyptian clover followed by rice + sesbania - Egyptian clover cropping system (10.29 t ha^{-1}) compared to the lowest (8.30 t ha^{-1}) for rice - Egyptian clover relay cropping system. However, rest of the cropping systems gave TRGYE ranging between 9.84 to 10.17 t ha^{-1}.

Table I: Physico-chemical properties of the experimental site

Determination	Unit	1998-1999	1999-2000
Mechanical analysis			
Sand	%	59.7	60.5
Silt	%	18.5	17.6
Clay	%	21.8	21.9
Textural class		Sandy-clay loam	Sandy-clay loam
Chemical analysis			
Ece	$dScm^{-1}$	1.11	1.12
pH		7.8	7.7
Organic matter	%	0.75	0.74
Total nitrogen	%	0.042	0.041
Available phosphorus	ppm	6.93	7.10
Available potassium	ppm	138	137

Residual Soil Fertility

Residual soil organic matter (O.M): In wheat oriented inter/relay cropping systems, the residual soil organic matter was slightly improved (1.33%) in rice + forage legume - wheat inter/relay cropping systems, while the organic matter level was reduced by 6.67 and 4.00 % in rice - wheat and rice + maize - wheat inter/relay cropping systems, respectively in the first year. Similarly during the 2^{nd} year, the residual soil organic matter was reduced to the extent of 8.11 and 5.11 in case of rice - wheat and rice + maize - wheat inter/relay cropping systems, respectively while in rest of the inter/relay cropping systems, the level of residual organic matter was neither improved nor reduced (Table III). As compared to rice alone, there was a slight increase in residual soil organic matter to the extent of 2.70 and 2.78%, respectively in rice + legume intercrops - wheat in both years (Table IV), while there was a decrease in residual organic matter to the extent of 5.40 and 2.70 % in the 1^{st} year and 5.55 and 2.78 % in the 2^{nd} year for rice alone - wheat and rice + maize - wheat inter/relay cropping systems, respectively.

Regarding lentil-oriented inter/relay cropping systems, all cropping systems had a profound effect on the residual soil fertility. The maximum improvement occurred due to rice + sesbania - lentil inter/relay cropping system (10.67%) followed by rice + ricebean - lentil, rice + cowpea - lentil, rice + pigeonpea - lentil and rice alone-lentil, which were at par with each other (8.00%) against the minimum of 5.33% due to rice + mungbean - lentil relay cropping system. The same trend was noted in the 2^{nd} year. Similarly as compared to rice alone, there was also a measurable increase in soil organic matter due to different lentil oriented inter/relay cropping systems in both years (Table IV).

A pronounced effect of all the clover-oriented inter/relay cropping systems was observed on residual soil O.M. The maximum improvement in soil O.M. was observed in case of rice + sesbania - clover inter/relay cropping system (13.33%) closely followed by rice + ricebean - clover. Rice + cowpea - clover, rice + pigeonpea -

Table II: Total rice grain yield equivalent as affected by different direct seeded rice-based inter/relay cropping system (two-year average data)

Inter/relay cropping systems	Grain//forage yield of inter/relay crops ($t\ ha^{-1}$)			Rice equivalent yield of inter/relay crops ($t\ ha^{-1}$)		Total rice grain yield equivalent of the system ($t\ ha^{-1}$)
	Rice	Intercrops	Relay crops	intercrops	Relay crops	
Wheat oriented set						
Rice alone- wheat	4.02 a	-	2.99 c	-	2.46	6.48
Rice + Maize- wheat	3.81 b	40.70 a	3.22 bc	2.87	2.65	9.33
Rice + Sesbania- wheat	2.98 c	27.49 b	3.54 a	1.94	2.92	7.84
Rice +Mungbean- wheat	3.36 b	20.60 d	3.46 ab	1.45	2.85	7.66
Rice + Ricebean- wheat	3.47 b	19.50 d	3.49 ab	1.38	2.67	7.72
Rice + Cowpea- wheat	3.41 b	23.69 c	3.43 ab	1.67	2.82	7.99
Rice + Pigeonpea- wheat	3.35 b	20.76 d	3.32 ab	1.46	2.73	7.18
Lentil oriented set						
Rice alone- lentil	4.02 a	-	0.99 c	-	3.26	7.28
Rice + Maize- lentil	3.81 b	40.70 a	1.03 c	2.87	3.39	10.07
Rice + Sesbania- lentil	2.98 c	27.49 b	1.38 a	1.94	4.55	9.47
Rice +Mungbean- lentil	3.36 b	20.60 d	1.20 b	1.45	3.96	8.77
Rice + Ricebean- lentil	3.47 b	19.50 d	1.20 b	1.38	3.95	8.80
Rice + Cowpea-lentil	3.41 b	23.69 c	1.19 b	1.67	3.92	9.00
Rice + Pigeonpea -lentil	3.35 b	20.76 d	1.19 b	1.47	3.92	8.74
Egyptian clover oriented set						
Rice alone-Egyptian clover	4.02 a	-	66.70 b	-	4.28	8.30
Rice + Maize-Egyptian clover	3.81 b	40.70 a	66.52 b	2.87	4.27	10.95
Rice + Sesbania-Egyptian clover	2.98 c	27.49 b	76.05 a	1.94	5.37	10.29
Rice+Mungbean-Egyptian clover	3.36 b	20.60 d	73.34 a	1.45	5.18	9.99
Rice+ Ricebean- Egyptian clover	3.47 b	19.50 d	73.70 a	1.38	5.20	10.05
Rice + Cowpea-Egyptian clover	3.41 b	23.69 c	72.15 ab	1.67	8.09	10.17
Rice+Pigeonpea-Egyptian clover	3.35 b	20.76 d	73.28 a	1.46	5.03	9.84

Market prices of green fodder

Wheat = Rs. 350/40 kg
Lentil = Rs. 1400 /40 kg
Egyptian clover fodder = Rs. 30/40 kg
Sesbania fodder = Rs. 30/40 kg
Ricebean fodder = Rs. 30/40 kg
Pigeonpea fodder = Rs. 30/40 kg
Maize fodder = Rs. 30/40 kg
Mungbean fodder = Rs.30/40 kg
Cowpea fodder = Rs. 30/40 kg

clover and rice alone - egyptian clover, which were at par with one another and recorded an increase of 10.67% (Table III). The same trend was noted during the 2nd year of the experiment while comparing to rice alone, a sufficient increase in soil O.M. content was noted in all rice-based inter/relay cropping systems during both years (Table IV).

Residual soil nitrogen (N): Residual soil nitrogen generally declined in all the wheat oriented inter/relay cropping system with the maximum (9.52%) in rice-wheat cropping system closely followed by rice + maize - wheat inter/relay cropping system (7.14%). However, there was a considerably less decline in soil nitrogen (2.38%) in all rest of the rice + legumes -wheat inter/relay cropping systems (Table III). Similar trend was observed in the 2nd year. By contrast, when residual soil nitrogen was compared with rice alone, a slight increase was observed in all rice + legumes - wheat inter/relay cropping systems in both years (Table IV).

In lentil oriented inter/relay cropping systems, the maximum improvement of soil nitrogen (7.14%) was recorded for rice + sesbania - lentil inter/relay cropping system followed by rice + ricebean - lentil, rice + cowpea - lentil, rice + pigeonpea - lentil and rice alone-lentil inter/relay cropping systems (4.76%) against the minimum improvement of 2.38% in case of rice + maize - lentil and rice - mungbean-lentil inter/relay cropping systems. Similar trend was observed in the 2nd year. There was also a reasonable increase in residual soil N due to all lentil-oriented inter/relay cropping system in relation to rice alone in both years of the study (Table IV).

As far as clover-oriented inter/relay cropping systems are concerned, residual soil N generally increased in all cropping systems to a variable degree ranging from 4.76 to 9.52% (Table III). The maximum increase in residual soil N (9.52%) was recorded for rice + sesbania - clover inter/relay cropping system closely followed by rice-clover, rice + ricebean - clover, rice + cowpea - clover and rice + pigeonpea - clover, which were at par with one another and recorded an increase of 7.14% against the minimum increase of 4.76% in case of rice + maize - clover and rice + mungbean - clover inter/relay cropping systems. The same trend was observed in the 2nd year. There was also reasonable increase in residual soil N in all the clover-oriented inter/relay cropping systems in relation to rice alone in both years (Table IV).

Residual soil phosphorus (P) and potassium (K): Phosphorus and potassium depletion occurred in all the wheat, lentil and Egyptian clover oriented inter/relay cropping systems at almost uniform rate during both years. In wheat oriented inter/relay cropping systems, P and K depletion ranged from 14.00 to 14.86% and 6.52 to 7.97%, respectively during the 1st year and 13.80 to 15.49% and 6.57 to 8.03% respectively in the 2nd year, while in lentil-

Table III: Post harvest fertility status of the experimental soil with respect to initial soil analysis before planting

Intercropping systems	1998-1999				1999-2000			
	N (%)	P (ppm)	K (ppm)	OM (%)	N (%)	P (ppm)	K (ppm)	OM (%)
Rice alone	0.040 (-4.76)	6.99 (+0.87)	134 (-2.90)	0.74 (-1.33)	0.039 (-4.88)	7.19 (+1.27)	133 (-2.99)	0.73 (-2.70)
Wheat oriented inter/relay cropping systems								
Rice alone-wheat	0.038 (-9.52)	5.90 (-14.86)	129 (-6.52)	0.70 (-6.67)	0.037 (-9.76)	6.00 (-15.49)	128 (-6.67)	0.66 (-8.11)
Rice + maize – wheat	0.039 (-7.14)	5.91 (-14.72)	129 (-6.52)	0.72 (-4.00)	0.038 (-7.32)	6.04 (-14.93)	128 (-6.57)	0.70 (-5.11)
Rice + sesbania – wheat	0.041 (-2.38)	5.93 (-14.43)	128 (-7.25)	0.76 (+1.33)	0.040 (-2.44)	6.10 (-14.08)	127 (-7.30)	0.74 (0.00)
Rice + mung bean – wheat	0.041 (-2.83)	5.94 (-14.29)	128 (-7.25)	0.76 (+1.33)	0.040 (-2.44)	6.11 (-13.94)	127 (-7.30)	0.74 (0.00)
Rice + rice bean – wheat	0.041 (-2.38)	5.95 (-14.14)	127 (-7.97)	0.76 (+1.33)	0.040 (-2.44)	6.12 (-13.80)	126 (-8.03)	0.74 (0.00)
Rice + cowpea – wheat	0.041 (-2.38)	5.96 (-14.00)	128 (-7.25)	0.76 (+1.33)	0.040 (-2.44)	6.11 (-13.94)	127 (-7.30)	0.74 (0.00)
Rice + pigeonpea – wheat	0.041 (-2.38)	5.95 (-14.14)	129 (-6.52)	0.76 (+1.33)	0.040 (-2.44)	6.11 (-13.94)	128 (-6.57)	0.74 (0.00)
Lentil oriented inter/relay cropping systems								
Rice alone – lentil	0.044 (+4.76)	5.72 (-17.46)	128 (-7.25)	0.81 (+8.00)	0.043 (+4.88)	5.83 (-17.89)	127 (-7.30)	0.79 (+6.76)
Rice + maize – lentil	0.043 (+2.38)	5.74 (-17.17)	129 (-6.25)	0.79 (+5.33)	0.042 (+2.44)	5.84 (-17.75)	128 (-6.57)	0.77 (+4.10)
Rice + sesbania – lentil	0.045 (+7.14)	5.78 (-16.58)	128 (-7.25)	0.83 (+10.67)	0.044 (+7.31)	5.86 (-17.47)	127 (-7.30)	0.81 (+9.46)
Rice + mungbean- lentil	0.043 (+2.38)	5.76 (-16.88)	128 (-7.25)	0.79 (+5.33)	0.042 (+2.44)	5.87 (-17.32)	127 (-7.30)	0.77 (+4.10)
Rice + rice bean – lentil	0.044 (+4.76)	5.75 (-17.03)	129 (-6.52)	0.81 (+8.00)	0.043 (+4.88)	5.89 (-17.04)	128 (-6.57)	0.79 (+6.76)
Rice + cowpea – lentil	0.044 (+4.76)	5.76 (-16.88)	128 (-7.25)	0.81 (+8.00)	0.043 (+4.88)	5.86 (-17.47)	127 (-7.30)	0.79 (+6.76)
Rice + pigeonpea – lentil	0.044 (+4.76)	5.73 (-17.32)	129 (-6.52)	0.81 (+8.00)	0.043 (+4.88)	5.86 (-17.47)	128 (-6.57)	0.79 (+6.76)
Egyptian clover oriented inter/relay cropping systems								
Rice alone–Egyptian Clover	0.045 (+7.14)	5.81 (-16.16)	127 (-7.97)	0.83 (+10.67)	0.044 (+7.31)	5.91 (-16.76)	126 (-8.03)	0.81 (+9.46)
Rice+maize–Egyptian Clover	0.044 (+4.76)	5.82 (-16.02)	129 (-6.52)	0.81 (+8.00)	0.043 (+4.88)	5.94 (-16.34)	128 (-6.57)	0.79 (+6.67)
Rice + sesbania – Egyptian Clover	0.046 (+9.52)	5.89 (-15.00)	129 (-6.52)	0.85 (+13.13)	0.045 (+9.76)	5.96 (-16.06)	128 (-6.57)	0.83 (+12.17)
Rice+mung bean–Egyptian Clover	0.044 (+4.76)	5.84 (-15.73)	128 (-7.24)	0.81 (+8.00)	0.043 (+4.88)	5.97 (-15.92)	127 (-7.30)	0.79 (+6.76)
Rice+rice bean –Egyptian Clover	0.045 (+7.14)	5.85 (-15.58)	128 (-7.25)	0.83 (+10.67)	0.044 (7.31)	5.98 (-15.77)	127 (-7.30)	0.81 (+9.46)
Rice+cowpea–Egyptian Clover	0.045 (+7.14)	5.83 (-15.87)	128 (-7.25)	0.83 (+10.67)	0.044 (+7.31)	5.97 (-15.92)	127 (-7.30)	0.81 (+9.46)
Rice+pigeonpea –Egyptian Clover	0.045 (+7.14)	5.84 (-15.73)	128 (-7.25)	0.83 (+10.67)	0.044 (+7.31)	5.97 (-15.92)	128 (-6.57)	0.81 (+9.46)
Original values	0.042	6.93	138	0.75	0.041	7.10	137	0.74

% increase (+) decrease (-) over original values of soil analysis before sowing of rice and intercrops

oriented inter/relay cropping systems, they varied from 16.59 to 17.46% and 6.52 to 7.25%, respectively (Table III). In clover oriented inter/relay cropping systems, the decline in P varied from 15.00% to 16.16% while K varied from 6.52 to 7.97% during 1st year and same trend was noted during 2nd year. The soil P and K also declined to a notable extent in all inter/relay sequences with respect to rice alone in both years (Table IV).

DISCUSSION

It is clear from the results that reduction in rice grain yield was maximum due to sesbania intercropping, which was attributed to its luxuriant growth and thick shading effect on the associated rice crop and it ultimately resulted in poor growth and low yield of the rice crop (Table I). Reduction in rice grain yield may be attributed to more leafy growth and spread behavior of intercrops (Chandra *et al.*, 1992; Saeed *et al.*, 1999b; Joshi, 2002). Quick growth and overshading of legumes can cause svere reduction in rice biomass and grain yield (Akanvou *et al.*, 2002). Low yield of major crop may be due to inhibitory effect of intercrops on root proliferation of main crop and malfunctioning of roots and ultimately a decrease in tissue water concentration of the intercrop (Gill *et al.*, 2009) as significant variation in growth behavior and resource utilization potential exists among intercrops (Ahmad *et al.*, 2007).

In contrary, maximum fodder yield of maize intercropped in rice was due to its solid stem and more leaf area as compared to other intercrops (Saeed *et al*., 1999b). Higher yield of wheat after rice + legumes intercropping as compared to wheat sown after rice alone or rice + maize intercropping was probably due to availability of more nitrogen due to biological nitrogen fixation by nodules formed in the roots of legume intercrops, while less wheat yield in rice alone and rice + maize intercropping was probably due to exhaustive residual effect of maize intercrop and intensive leaching of nutrients from the vacant spaces in case of alone rice crop. Same is in the case of lentil and Egyptian clover as that of wheat. Similar results were reported by Kumar and Goh (2002), who attributed more wheat yield in the field vacated by white clover and peas as compared to fallow-wheat to more contribution of roots- nitrogen by legume crops.

Rao *et al.* (1983) also attributed more maize grain yield after pigeonpea alone or intercropped with sorghum as compared to fallow- maize to more residual effect of nitrogen fixed by pigeonpea crop. Among legume intercropping systems, the grain yield of wheat, seed yield of lentil and fodder yield clover were more after rice + sesbania intercropping as compared to other intercrops probably due to more nodules formation and ultimately more nitrogen fixation by sesbania intercrop. Toomsan *et al.* (2000) also ascribed more rice yield benefits sown after sesbania to increased soil fertility status due to more nitrogen fixation and improved nutrient availability by it. Asibuo *et al.* (2008) also stated that best maize grain yield sown after valvet bean (*Mucuna pruriens* L.) was due to addition or more organic matter and nitrogen by valvet bean.

Table IV: Post harvest fertility status of the experimental soil with respect to rice alone

Intercropping systems	1998-1999				1999-2000			
	N (%)	P (ppm)	K (ppm)	OM (%)	N (%)	P (ppm)	K (ppm)	OM (%)
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)
Wheat oriented inter/relay cropping systems								
Rice alone-wheat	0.038 (-9.52)	5.90 (-14.86)	129 (-6.52)	0.70 (-6.67)	0.037 (-9.76)	6.00 (-15.49)	128 (-6.67)	0.66 (-8.11)
Rice + maize – wheat	0.039 (-7.14)	5.91 (-14.72)	129 (-6.52)	0.72 (-4.00)	0.038 (-7.32)	6.04 (-14.93)	128 (-6.57)	0.70 (-5.11)
Rice + sesbania – wheat	0.041 (-2.38)	5.93 (-14.43)	128 (-7.25)	0.76 (+1.33)	0.040 (-2.44)	6.10 (-14.08)	127 (-7.30)	0.74 (0.00)
Rice + mung bean – wheat	0.041 (-2.83)	5.94 (-14.29)	128 (-7.25)	0.76 (+1.33)	0.040 (-2.44)	6.11 (-13.94)	127 (-7.30)	0.74 (0.00)
Rice + rice bean – wheat	0.041 (-2.38)	5.95 (-14.14)	127 (-7.97)	0.76 (+1.33)	0.040 (-2.44)	6.12 (-13.80)	126 (-8.03)	0.74 (0.00)
Rice + cowpea – wheat	0.041 (-2.38)	5.96 (-14.00)	128 (-7.25)	0.76 (+1.33)	0.040 (-2.44)	6.11 (-13.94)	127 (-7.30)	0.74 (0.00)
Rice + pigeonpea – wheat	0.041 (-2.38)	5.95 (-14.14)	129 (-6.52)	0.76 (+1.33)	0.040 (-2.44)	6.11 (-13.94)	128 (-6.57)	0.74 (0.00)
Lentil oriented inter/relay cropping systems								
Rice alone – lentil	0.044 (+4.76)	5.72 (-17.46)	128 (-7.25)	0.81 (+8.00)	0.043 (+4.88)	5.83 (-17.89)	127 (-7.30)	0.79 (+6.76)
Rice + maize – lentil	0.043 (+2.38)	5.74 (-17.17)	129 (-6.25)	0.79 (+5.33)	0.042 (+2.44)	5.84 (-17.75)	128 (-6.57)	0.77 (+4.10)
Rice + sesbania – lentil	0.045 (+7.14)	5.78 (-16.58)	128 (-7.25)	0.83 (+10.67)	0.044 (+7.31)	5.86 (-17.47)	127 (-7.30)	0.81 (+9.46)
Rice + mung bean – lentil	0.043 (+2.38)	5.76 (-16.88)	128 (-7.25)	0.79 (+5.33)	0.042 (+2.44)	5.87 (-17.32)	127 (-7.30)	0.77 (+4.10)
Rice + rice bean – lentil	0.044 (+4.76)	5.75 (-17.03)	129 (-6.52)	0.81 (+8.00)	0.043 (+4.88)	5.89 (-17.04)	128 (-6.57)	0.79 (+6.76)
Rice + cowpea – lentil	0.044 (+4.76)	5.76 (-16.88)	128 (-7.25)	0.81 (+8.00)	0.043 (+4.88)	5.86 (-17.47)	127 (-7.30)	0.79 (+6.76)
Rice + pigeonpea – lentil	0.044 (+4.76)	5.73 (-17.32)	129 (-6.52)	0.81 (+8.00)	0.043 (+4.88)	5.86 (-17.47)	128 (-6.57)	0.79 (+6.76)
Egyptian clover oriented inter/relay cropping systems								
Rice alone – Egyptian Clover	0.045 (+7.14)	5.81 (-16.16)	127 (-7.97)	0.83 (+10.67)	0.044 (+7.31)	5.91 (-16.76)	126 (-8.03)	0.81 (+9.46)
Rice + maize – Egyptian Clover	0.044 (+4.76)	5.82 (-16.02)	129 (-6.52)	0.81 (+8.00)	0.043 (+4.88)	5.94 (-16.34)	128 (-6.57)	0.79 (+6.67)
Rice + sesbania – Egyptian Clover	0.046 (+9.52)	5.89 (-15.00)	129 (-6.52)	0.85 (+13.13)	0.045 (+9.76)	5.96 (-16.06)	128 (-6.57)	0.83 (+12.17)
Rice+mung bean –Egyptian Clover	0.044 (+4.76)	5.84 (-15.73)	128 (-7.24)	0.81 (+8.00)	0.043 (+4.88)	5.97 (-15.92)	127 (-7.30)	0.79 (+6.76)
Rice+rice bean –Egyptian Clover	0.045 (+7.14)	5.85 (-15.58)	128 (-7.25)	0.83 (+10.67)	0.044 (7.31)	5.98 (-15.77)	127 (-7.30)	0.81 (+9.46)
Rice + cowpea – Egyptian Clover	0.045 (+7.14)	5.83 (-15.87)	128 (-7.25)	0.83 (+10.67)	0.044 (+7.31)	5.97 (-15.92)	127 (-7.30)	0.81 (+9.46)
Rice+pigeonpea –Egyptian Clover	0.045 (+7.14)	5.84 (-15.73)	128 (-7.25)	0.83 (+10.67)	0.044 (+7.31)	5.97 (-15.92)	128 (-6.57)	0.81 (+9.46)

% increase (+) decrease (-) with respect to soil analysis values after harvest of rice

The productive efficiency and profitability of inter/relay cropping system is ultimately determined by its total yield equivalents (Jabbar *et al.*, 2010). All the rice-based wheat, lentil and Egyptian clover inter/relay cropping systems gave much higher total rice grain yield equivalent (TRGYE) than their respective rice - wheat, rice - lentil and rice - Egyptian clover relay cropping systems. The variations in different types of inter/relay cropping system caused significant differences in TRGYE. Among the three sets of rice-based inter/relay cropping systems, the overall production level of TRGYE was higher for the rice based Egyptian clover set followed by lentil oriented compared to the lowest for wheat oriented set. However, maximum TRGYE obtained from rice + maize - Egyptian clover was due to more fodder yield of inter and relay crops and as a result more economic return was obtained from maize and clover fodder as compared to other inter/relay crops as reported (Seed *et al*., 1999a; Joshi, 2002). Residual soil organic matter and nitrogen declined in all the wheat oriented inter/relay cropping systems with the maximum in rice-wheat and rice + maize - wheat inter/relay cropping systems probably because of the exhaustive nature of the component crops in both cropping systems. Contrary to it, all lentil and Egyptian clover oriented inter/relay cropping systems increased soil organic matter and nitrogen level. Maximum improvement was observed in rice + sesbania - Egyptian clover inter/relay cropping system closely followed by rice + sesbania - lentil inter/relay cropping system. This increase in soil organic matter and nitrogen might be attributed to more formation of nodules and ultimately more biological nitrogen fixing by legume inter/relay crops (Kumar & Goh, 2002; Toomsan *et al*., 2000; Bhattacharyya *et al.*, 2009). Shah *et al.* (2003) attributed improved soil organic matter and nitrogen to more N-fixation by legumes, when they studied mungbean-wheat and lentil-maize cropping systems. Improvement in residual organic matter and nitrogen as result of legume inter/relay cropping in wheat, cotton, sesame and barley was also reported by Ahmad and Saeed (1998) and Bhatti (2005), respectively. Residual soil phosphorus was found declined in all wheat, lentil and Egyptian clover oriented inter/relay cropping systems compared to rice alone but it was comparatively more in case of legume inter/relay cropping. Ahmad and Saeed (1998) and Bhatti *et al.* (2005) also ascribed depletion of phosphorus by different legumes to higher uptake of P by these crops. Similarly depletion of potassium in all inter/relay cropping systems might be ascribed to its uptake by different crop plants in variable quantities. Another reason might be non-application of potassium at the timing of sowing. Gami *et al.* (2001) attributed decrease in potassium balance in rice-wheat cropping system to more absorption of k by these crops. Bhattacharyya *et al.* (2009) ascribed decrease in soil potassium balance in wheat-soybean cropping system to more absorption of K by soybean crop.

CONCLUSION

It is concluded that clover-oriented inter/relay cropping systems was superior to wheat and lentil-oriented inter/relay cropping systems both in terms of yield and residual soil fertility. Among clover-oriented cropping systems, rice + maize - clover and rice + sesbania - clover inter/relay cropping systems were proved to be more reliable, economical and sustainable than lentil and wheat-oriented inter/relay cropping systems under upland rice environment of Faisalabad region.

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