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Pigeonpea intercropping with some cereals and legumes in the plateau area of Eastern India

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ABSTRACT

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Field experiments were conducted during the rainy seasons of 1992-93 and 1993-94 at the agricultural experimental farm, Giridih, Bihar to evaluate the intercropping system of pigeonpea (*Cajanus cajan* L.) with cereals such as maize (*Zea mays* L.) and rice (*Oryza sativa* L.), and legumes such as greengram (*Phaseolus radiatus* L.) and groundnut (*Arachis hypogaea* L.). Pigeonpea + groundnut was the best system followed by pigeonpea + greengram with pigeonpea equivalent yields of 2.51 t ha^{-1} and 2.07 t ha^{-1}, respectively, compared with 1.97 t ha^{-1} from pigeonpea alone. The efficiency of intercrops was assessed on the basis of actual yield loss where yield per plant of the component crop was considered. Soil nitrogen enrichment through legume cultivation contributed to higher yield of the succeeding Indian mustard crop (*Brassica juncea* L. Crenz & Cosson).

Keywords: competition functions. follow-up crop. intercroping. residual soil nutrients.

INTRODUCTION

The purpose of intercropping is not only to grow more than one crop together but also to obtain more yield per unit area with superior economic returns. Scientific intercropping is ideal to sustain the yield of the main crop and at the same time obtain a bonus yield from the companion crop. In India,

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legumes or pulses have been grown with cereals for centuries under sub-marginal and aberrant weather conditions to safeguard against crop failure. In intercropping systems involving legume and non-legume, part of the nitrogen fixed in the root nodule of the legume may become available to the non-legume component. Thus, both as sole crop and as intercrop with cereals, legumes have been recommended not only for yield augmentation but also for the maintenance of soil health, particularly on degraded soils like those in the eastern plateau of India (Chatterjee and Bhattacharya, 1986; Banik and Bagchi, 1993 & 1994; Banik, 1996).

Therefore, an experiment was conducted to find out the suitability and advantage of legume and cereal association with rainfed pigeonpea in the subtropical uplands of Chotonagpur plateau of eastern India.

MATERIALS AND METHODS

Field experiments were conducted during the rainy seasons of both 1992-93 and 1993-94 at the agricultural experimental farm of the Indian Statistical Institute, Giridih, an eastern part of Chotonagpur Plateau, Bihar. The soil was sandy loam having a pH of 6.0-6.4, organic carbon of 0.33–0.41%, available P of 10–13 kg ha^{-1} and exchangeable K of 73–98 kg ha^{-1}. Pigeonpea (cv.T-21) was intercropped with maize (cv.Vijay), upland rice (cv.MW-10), groundnut (cv.K-3) and greengram (cv. Pusa Baishakhi). Treatments included sole crop of pigeonpea, maize, rice, groundnut and greengram sown at a normal seeding rate and spacing recommended for the plateau region (Mohsin *et al.*, 1986). Pigeonpea was sown at 60cm row spacing in both sole and intercrop treatments. In pigeonpea + maize and pigeonpea + groundnut, one row of either maize or groundnut was sown in between two rows of pigeonpea. In contrast, two rows of either rice or greengram were sown in between two rows of pigeonpea in pigeonpea + rice and pigeonpea + greengram intercropping systems. Thus the sown proportion of pigeonpea, maize, rice, groundnut and greengram in the intercropping systems were 100, 80, 60, 45 and 60% of their sole crops, respectively. Seeding rates of 20 for pigeonpea, 20 for maize, 100 for rice, 100 for groundnut and 20 for greengram (all in kg

ha^{-1}) were followed. Fertilizer nutrients applied at sowing time to both sole and intercropped plots were N at 20 kg ha^{-1}, P at 18 kg ha^{-1} and K at 17 kg ha^{-1}. Additional dose of N at 20 kg ha^{-1} was top dressed after one month along rice and maize lines only. Treatments were laid out in randomized complete block design with a plot size of 36 m^2 and replicated thrice. Rainy-season crops were sown in June 1992 and June 1993. The crops were grown rainfed and were weeded once after one month from sowing.

After the harvest of sole and intercrops, a succeeding crop of 'Varuna' Indian mustard at 7.0 kg ha^{-1} of seed was sown in November 1992 and 1993 with minimum tillage. It was grown entirely on residual soil fertility and aside from a light irrigation for germination, one life-saving irrigation at flowering stage was given in both cropping seasons.

Soil samples were collected from every plot at 0-15 cm depth after harvest of the rainy-season crop. They were analyzed for organic carbon (%), available P and exchangeable K (kg ha^{-1}) following standard procedures (Jackson, 1967). Amounts of rainfall received from June to March were 874.7 mm in 1992-93 and 955.9 mm in 1993-94.

Yield data were taken after each harvest of legume and cereal leaving border rows. Competition functions like Land Equivalent Ratio (Mead and Willey, 1980), Monetary Advantage (Willey, 1979), Relative Crowding Coefficient (De Wit, 1960), Competition Ratio (Willey and Rao, 1980), Actual Yield Loss (Banik and Bagchi, 1996) and Area Time Equivalent Ratio (Hiebsch, 1980) were computed as follows:

Land Equivalent Ratio (LER)

LER is the relative land area of a sole crop required to produce the yield achieved in intercropping. The LERs of intercropped plots were calculated for each component crop separately. By adding them, the total of two crops was estimated. LER of the sole crop was taken as unity.

$$LER = L_a + L_b = (Y_{ab}/Y_{aa}) + (Y_{ba}/Y_{bb})$$

where: L_a and L_b are the LERs for the individual crops

Relative Crowding Coefficient (RCC)

RCC assumes that mixture treatments formed a replacement series. Each species has its own coefficient (K) which gives a measure of whether or not that species has produced any yield as expected. For species 'a' in a 50:50 mixture with species 'b', K stands as:

$$K_{ab} = Y_{ab}/(Y_{aa}-Y_{ab})$$

But for a mixture differing from 50:50, it could be generalized as:

$$K_{ab} = Y_{ab} \times Z_{ba}/(Y_{aa}-Y_{ab}) \times Z_{ab}$$

If a species has a coefficient of less than, equal to, or greater than 1.0, it has produced less yield, the same yield, or more yield than "expected", respectively. The component with the higher coefficient was the dominant one. To determine if there was any yield advantage of mixing, the product of the coefficient was formed and designated as K. If K>1, there was a yield advantage, if K=1, there was no difference and if K<1, there was a yield disadvantage.

Actual Yield Loss (AYL)

AYL is the proportionate yield loss or gain relative to the respective sole crops:

$$AYL = AYL_a + AYL_b$$
$$= [(Y_{ab}/Z_{ab})/(Y_{aa}/Z_{aa})-1] + [(Y_{ba}/Z_{ba})/(Y_{bb}/Z_{bb})-1]$$

Competitive Ratio (CR)

CR was put forward by Willey and Rao (1980) in order to estimate the nature of relative competition function for two crops when grown in mixture or under intercropping system.

$$CRa = (Y_{ab}/Y_{aa}) / (Y_{ba}/Y_{bb}) \times (Z_{ba}/Z_{ab})$$

$$CRb = (Y_{ba}/Y_{bb}) / (Y_{ab}/Y_{aa}) \times (Z_{ab}/Z_{ba})$$

where: CR_a = Competition Ratio of species a

CR_b = Competition Ratio of species b

Other notations used for the above competition functions

Y_{aa} = yield of pure or sole crop species, a

Y_{bb} = yield of pure or sole crop species, b

Y_{ab} = yield of species a (in combination of species b)

Y_{ba} = yield of species b (in combination of species a)

Z_{ab} = sown proportion of species a (in mixture with species b)

Z_{ba} = sown proportion of species b (in mixture with species a)

Monetary Advantage (MA)

MA was calculated in order to estimate the preferential economics of growing two or more crops at a time under mixed or intercropping system as proposed by Willey (1979).

MA = Value of combined intercrop yield x (LER-1)/LER

Area-Time Equivalent Ratio (ATER)

To overcome the limitation of the LER method, which gives emphasis on land area without considering the time the field is used for production, a new concept, area-time equivalent ratio (ATER) was evolved by Hiebsch (1980). In this new concept, LER method was modified to include the duration the crop is occupying the land from planting to harvest. It is the ratio of the number of hectare-days used in intercropping to produce identical output of each of the component crops. ATER value was calculated by using the following formula:

$$ATER = (LER_a \times t_a + LER_b \times t_b) / T$$

where: t_a & t_b are the duration in days for species a & b

T is the total duration of the intercropping system

RESULTS AND DISCUSSION

Grain yield

Table 1 reveals that crops under sole cropping (pure stand) gave higher grain yield than under intercropping in both cropping seasons. This can be attributed to the limited habitat disturbance and interactional competition under sole cropping environment (Grime, 1977) than under intercropping systems. Pigeonpea yield of 2.05 and 1.89 t ha^{-1} were obtained under sole cropping in 1992-93 and 1993-94, respectively. When intercropped with maize and greengram, pigeonpea yielded 61.57% and 94.59%, respectively, relative to

Table 1. Grain yield and pigeonpea yield equivalent of sole and intercrops

Treatments	Grain Yield (t ha^{-1}) 1992-93 Pigeonpea	1992-93 Intercrops	1993-94 Pigeonpea	1993-94 Intercrops	Pigeonpea yield equivalent (t ha^{-1}) 1992-93	1993-94
Pigeonpea sole	2.05	-	1.89	-	2.05	1.89
Maize sole	-	1.92	-	2.21	0.96	1.11
Rice sole	-	2.93	-	2.58	1.30	1.15
Groundnut sole	-	0.98	-	1.21	1.64	2.01
Greengram sole	-	0.52	-	0.52	0.52	0.52
Pigeonpea + maize	1.12	1.23	1.29	1.13	1.74	1.86
Pigeonpea + rice	1.71	0.97	1.47	1.07	2.14	1.95
Pigeonpea + groundnut	1.83	0.37	1.68	0.53	2.45	2.57
Pigeonpea + Greengram	1.95	0.21	1.78	0.22	2.16	1.99
SE (±)	0.83	-	0..07	-	0.19	0.22
CD $_{(p=0.05)}$	0.19	-	0.16	-	0.40	0.46

the sole crop of pigeonpea. Moreover, pigeonpea yielded, relative to its sole crop, 80.58% when grown with rice and 88.98% with groundnut. Reduction in the yield of pigeonpea due to intercropping was also reported earlier (Sarkar *et al*., 1995; Giri *et al*., 1980; Ali, 1985; Sarma *et al*., 1995). Among the intercrops, highest yield reduction (62.98%) was noted in rice followed by groundnut (58.90%), greengram (58.65%) and maize (42.86%) when grown with pigeonpea. The less yield reduction in maize when intercropped with pigeonpea was probably due to the faster growth habit of maize than that of pigeonpea. As a result, the competition offered by pigeonpea was less during the peak growth stages of maize. Pigeonpea-yield equivalent indicated better performance of pigeonpea when intercropped with legumes than with cereals. Pigeonpea + groundnut intercropping treatment gave the highest pigeonpea yield equivalent value (2.51 t ha^{-1}) followed by pigeonpea + greengram (2.07 t ha^{-1}).

Competition and other indices for yield advantages

Table 2 shows that the land equivalent ratio was more than unity in all the intercropping systems indicating high biological efficiency of intercropping (Banik, 1996). Highest land equivalent ratio (1.353) was recorded in pigeonpea + greengram, followed by pigeonpea + groundnut (1.297). Thus, the land use efficiency was 35.3% higher in the intercropping system of pigeonpea with greengram, and 29.7% higher for pigeonpea with groundnut. In other words, to produce the combined mixture yield by growing pure stands will require 35.3% and 29.7% more land area.

Intercropped pigeonpea always showed higher competition ratio (CR_a) values than the intercrops except in the pigeonpea + maize intercropping system. Based on yield and space assigned to each species in the intercropping systems, the values of competition ratio indicated that pigeonpea was more competitive than the intercrops except maize. The relative crowding coefficient values (K_{ab}) also showed the same trend implying that pigeonpea was dominant over the component intercrops except maize. In addtion, the product value of relative crowding coefficient (K) was always more than 1 indicating a definite yield advantage due to intercropping probably because of the compatible and complementary nature of the crop components.

Table 2. Different competition functions measured for pigeonpea-based intercropping systems (average of 2-year results)

Treatments	Land Equivalent Ratio			Actual Yield Loss		Monetary Advantage (Rs. ha^{-1})	Competition Ratio		Relative Crowding Coefficient			ATER
	L_a	L_b	Total	AYL_a	AYL_b		CR_a	CR_b	K_{ab}	K_{ba}	K	
Pigeonpea + Maize	0.61	0.57	1.18	-0.39	-0.28	2514	0.97	1.13	1.49	1.84	2.74	0.94
Pigeonpea + Rice	0.81	0.37	1.18	-0.19	-0.40	2754	1.46	0.73	2.81	0.97	2.73	1.08
Pigeonpea + Groundnut	0.89	0.41	1.30	-0.11	-0.08	5170	1.05	0.97	4.81	1.78	8.56	1.22
Pigeonpea + Greengram	0.95	0.40	1.35	-0.05	-0.30	4879	1.53	0.66	24.05	1.81	43.53	1.11

On the basis of area-time equivalent ratio, where crop growing period was considered, pigeonpea + groundnut and pigeonpea + greengram intercropping combinations gave higher values indicating more efficient use of area and growing period (time) by the intercrops. This result also reflected a higher biological efficiency of such crop mixture. This is probably due to less competition for growth factors experienced by the component crops with different growth habits.

Monetary advantages (based on land equivalent ratio) obtained in the intercropping systems indicated a definite gain. Highest monetary advantage (RS. 5169.79 ha^{-1}) was recorded in the pigeonpea + groundnut intercropping system due to the higher values of the combined yields of the intercrops.

Partial actual yield loss (AYL_a), which is the proportionate yield loss or gain relative to the respective sole crops, gave negative values indicating a yield loss due to intercropping. The data also revealed that the yield loss of pigeonpea was highest when grown with maize whereas it was lowest when grown with greengram. The partial AYL_b values of rice and greengram were higher than the partial AYL_a of pigeonpea when grown in association with the intercrops. The minimum yield loss of groundnut (AYL_b = -0.0815) was noted when grown with pigeonpea indicating that it is more competitive than pigeonpea. The AYL value of pigeonpea + groundnut was minimum. It indicated the superiority of this intercropping system over the others.

Residual effect of legumes on soil fertility and succeeding crop

Soil test values in sole and intercropped treatments were significantly different for organic carbon but not for available P and exchangeable K (Table 3). Higher contents of organic carbon were noted in all the legume plots, either sole or with an intercrop, than in the plots of sole maize and rice. Highest soil organic carbon value was noted in pigeonpea + greengram (0.639) followed by pigeonpea + groundnut (0.610) due to the increased number of plants which probably resulted in more biomass turnover and increased the soil nitrogen status (Adhikary *et al.*, 1991; Banik and Bagchi, 1993; 1994). Although statistically insignificant, there was an increase of available P and exchangeable K in the soil due to the incorporation of groundnut in the intercropping system. Thus intercropping appears to have not caused nutrient

Table 3. Yield of follow-up Indian mustard crop and residual soil nutrients after kharif crops

Treatments	Yield of Indian mustard (t ha^{-1})		Organic carbon (%)		Available P (kg ha^{-1})		Exchangeable K (kg ha^{-1})	
	I	II	I	II	I	II	I	II
Pigeonpea sole	0.538	0.515	0.437	0.477	11.77	13.47	123.00	134.13
Maize sole	0.407	0.533	0.360	0.350	11.27	12.77	119.20	132.40
Rice sole	0.386	0.444	0.373	0.363	10.40	12.37	111.73	128.27
Groundnut sole	0.614	0.817	0.460	0.653	12.77	13.97	126.67	137.60
Greengram sole	0555	0.586	0.520	0.570	12.63	13.70	122.00	136.47
Pigeonpea + maize	0.536	0.542	0.520	0.553	14.33	15.07	130.27	140.93
Pigeonpea + rice	0.541	0.646	0.567	0.613	11.70	14.90	130.40	140.00
Pigeonpea + groundnut	0.631	0.803	0.543	0.677	16.23	16.13	139.87	147.60
Pigeonpea + Greengram	0.606	0.663	0.607	0.670	14.70	15.17	134.40	144.53
SE (±)	0.101	0.101	0.034	0.30	3.41	3.77	33.47	28.39
CD $_{(p=0.05)}$	n.s.	n.s.	0.072.	0.064	n.s.	n.s.	n.s.	n.s.

n.s. - not significant

depletion in this soil with low fertility status.

Indian mustard [*Brassica juncea* (L.) Czernj & Cosson], is commonly grown in the eastern parts of India. It is an annual herb ranging in height from 0.45 to 1.75 m and which matures in 75-130 days. It is moderately fertilizer-responsive (40-60 kg N ha^{-1}) and yields 0.8 to 1.0 t ha^{-1}. Results of this study showed that when this crop was grown as a succeeding crop in the experimental area with moderate residual soil fertility, it gave a grain yield of 0.42–0.72 t ha^{-1} with minimum water.addition. The lowest grain yield of the crop (0.42 t ha^{-1}) was obtained when it was grown after sole rice. On the other hand, highest grain yield was obtained when Indian mustard was grown after pigeonpea + groundnut (0.72 t ha^{-1}) followed by pigeonpea + greengram (Rajput *et al.*, 1995). The results thus suggest the beneficial role of legumes in the succeeding crop corroborating earlier studies by other researchers (Singh, 1985; Chatterjee and Bhattacharya, 1986; Adhikary *et al.*, 1991; Ofori and Stern, 1987 and Banik and Bagchi, 1993).

CONCLUSION

On the basis of the results of this experiment, pigeonpea + groundnut and pigeonpea + greengram may be recommended for the rainfed uplands of the subtropical plateau of Eastern Indian and for other areas with comparable agro-climatic conditions.

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