academicJournals

Vol. 9(20), pp. 1610-1617, 15 May, 2014
DOI: 10.5897/AJAR2013.7997
Article Number: 963854444696
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Productivity of maize-legume intercropping systems under rainfed situation

S. Kheroar[1]* and B. C. Patra[2]

[1]Regional Research and Technology transfer Station, Orissa University of Agriculture and Technology, Semiliguda, Post Box No. 10, Sunabeda, Odisha-763002, India.
[2]Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia-741252, West Bengal, India.

Received 28 September, 2013; Accepted 16 April, 2014

The present experiment was carried out to study the intercropping effect of green gram, black gram, soybean, groundnut and red gram with maize during *kharif* season of 2009 and 2010. Treatments consisted of sole crop of maize [rows spaced 60 cm apart (M_1) and paired rows (30 cm apart) spaced at 90 cm apart (M_2)], green gram (GG), black gram (BG), soybean (SB), groundnut (GN), and red gram (RG); intercropping of M_1+GG, M_1+BG, M_1+SB, M_1+GN and M_1+RG with 1:1 and M_2+2GG, M_2+2BG, M_2+2SB, M_2+2GN and M_2+2RG with 2:2 row proportions. Maize equivalent yield was always higher in all the intercropping situations as compared to pure stand yield of maize. The highest maize grain yield was obtained with maize + green gram intercropping (2783.11 kg ha^{-1}) in 1:1. The highest maize equivalent yield was observed with maize + red gram (5270.46 kg ha^{-1}) in 2:2 intercropping system. Values of land equivalent ratio, relative value total, relative net return and area time equivalent ratio were greater than unity and differed significantly in between both the groups of 1:1 and 2:2 proportions of intercropping. Highest gross and net return of Rs.55191.60 ha^{-1} and Rs.39950.30 ha^{-1} respectively was recorded in maize+red gram (2:2) intercropping.

Key words: Intercropping, maize, land equivalent ratio, area time equivalent ratio, sowing ratio, monetary advantage, net return, equivalent yield, rainfed.

INTRODUCTION

Intercropping is gaining popularity day by day among small growers as it provides yield advantage as compared to mono cropping through yield stability and fulfilling diversified domestic needs. Cereal-legume intercropping facilitates to maintain and improve soil fertility (Andrews, 1979). Intercropping is advocated due to its benefits for yield increase (Chen et al., 2004), conserving soil, control of weeds, control legume root parasite infections and high quality fodder. Cereal-legume intercropping plays an important role in subsistence food production in developing countries, especially in situations of limited water resources (Tsubo et al., 2005). Maize based intercropping system with legume helps in improving soil health as well as yield of main crop (Beedy et al., 2010). Maize-legume intercrops yielded more and were associated with less risk than the maize-legume rotations (Kamanga et al., 2010). Maize in association with legumes gives higher total yield and net return (Patra et al., 2000). Hence, the present investigation was carried out to evaluate intercropping advantages over the respective sole crop of maize with different legumes in different sowing proportions.

*Corresponding author. E-mail: kheroarshyamal@gmail.com

MATERIALS AND METHODS

A field experiment was conducted in humid tropics of Nadia, West Bengal during the *Kharif* seasons of 2009 and 2010. The experimental site was situated at approximately 22º56´N, 88º32´E and at an altitude of 9.75 m above mean sea level. The soil was typical gangetic alluvium with sandy-loam in texture. The soil leads to almost neutral pH (6.8) and with 0.051% nitrogen, 18.79 kg ha^{-1} available P and 90 kg ha^{-1} K. The experiment was laid out in an Augmented Randomized Block Design (RBD) having 17 treatment combinations replicated thrice with the plot size of 5.4 x 4 m. Treatments consisted of sole crop of maize (rows spaced 60 cm apart (M_1) and paired rows (30 cm apart) spaced 90 cm apart (M_2)], green gram (GG), black gram (BG), soybean (SB), groundnut (GN), and red gram (RG), intercropping of M_1+GG, M_1+BG, M_1+SB, M_1+GN and M_1+RG with 1:1 and M_2+2GG, M_2+2BG, M_2+2SB, M_2+2GN and M_2+2RG with 2:2 row proportions. The recommended dose of fertilizer for sole maize (80:40:40 kg N, P_2O_5 and K_2O ha^{-1}) and legumes (20:40:20 kg N, P_2O_5 and K_2O ha^{-1}) were applied separately.

Aggressivity, competitive ratio (CR), land equivalent ratio (LER), land equivalent co-efficient (LEC), area-time equivalent ratio (ATER), relative value total (RVT), monetary advantage (MA) and relative net return (RNR) were calculated by using standard procedures. The prices of the inputs [seeds (Maize- Rs 61 kg^{-1}, Green gram- Rs 55 kg^{-1}, Black gram- Rs 45 kg^{-1}, Soybean- Rs 70 kg^{-1} and Peanut- Rs 40 kg^{-1}), fertilizers (Urea- Rs 5.50 kg^{-1}, Single Super Phosphate- Rs 4.50 kg^{-1} and Muriate of Potash- Rs 4.50 kg^{-1}), *Rhizobium* culture- Rs 100 kg^{-1}, Labour- Rs. 90 day^{-1}] that prevailed during experimentation were considered for working out of the cost of cultivation. Monetary return values were estimated on the basis of market price of the produce (maize grain- Rs 9 kg^{-1}, green gram- Rs 35 kg^{-1}, black gram- Rs 25 kg^{-1}, soybean- Rs 15 kg^{-1} and peanut- Rs 30 kg^{-1}) during harvest period. Net return (Rs. ha^{-1}) was calculated by deducting the cost of cultivation (Rs. ha^{-1}) from the gross return. Benefit-cost ratio (B:C) and per day return (PDR) were calculated by using the following formula:

B:C ratio = [Gross return (Rs. ha^{-1}) / Cost of cultivation (Rs. ha^{-1})]
PDR = [Net return (Rs. ha^{-1} / Cropping period (days)]

RESULTS AND DISCUSSION

Yield attributes

An increasing trend was observed with respect to the number of cobs $plant^{-1}$, number of grains cob^{-1} in intercropped maize due to the development of both temporal and spatial complementarity as a result of which there was no competition for nitrogen and there was a possibility of current transfer of fixed nitrogen to the cereal crop like maize, however, no significant change in 1000 grain weight was noticed (Table 1). There was decreasing trend of percentage of barren stalk in all the intercropping situations. Patra et al. (1999) reported increased number of cobs $plant^{-1}$ and grains cob^{-1} due to maize legume intercropping, however, 1000 grain weight of maize was not significantly influenced but there was an increasing trend.

Number of pods $plant^{-1}$ and seeds pod^{-1} in green gram, black gram, soybean and groundnut were significantly reduced due to intercropping. All the intercrops grown with maize were shorter in height and could utilize lower percentage of incoming solar radiation. Red gram was least affected due to its longer duration and taller stature (Table 2). Sole legumes always obtained higher 1000 seed/kernel weight than intercropped legumes though they were statistically at par.

Maize grain yield

Maize when planted with 60 cm row spacing always recorded higher grain yield as compared to paired rows spaced 90 cm apart both as sole crop as well as intercrop (Table 3). Grain yield of maize was increased when intercropped with legumes like green gram, black gram and soybean. The yield advantage of maize in intercropping systems with legumes probably occurred from the difference in the timing of utilization of resources by the different crops from different soil layers, especially during peak vegetative and reproductive stages of growth, thus resulting in both temporal and spatial complementarities. Also, the increase in grain yield of maize might be resulted from maize-legume association due to symbiotic nitrogen fixation by legumes and current transfer of nitrogen to the associated maize plants. In addition, there was bonus yield from legume component, which corroborated the findings of Rana et al. (2001). A decreasing trend in maize grain yield was recorded when intercropped with red gram and groundnut in both the proportions of sowing.

Intercrop yield

Yield of intercrops were reduced due to intercropping with maize (Table 2). Actual yield was slightly higher at 2:2 proportion of sowing than 1:1 proportion due to receipt of higher amount of solar radiation. Yield was mostly affected in the short statured under sown leguminous crops. Tall growing maize plants shaded the leguminous crops and the main reason for reduction in yield was probably due to the receipt of lower amount of incoming solar radiation which affected the rate of photosynthesis and thereby translocation of photosynthates from source to sink. Relatively tall growing crop like red gram was less affected with respect to receipt of incoming solar flux. Similar results were also obtained by Mandal and Mahapatra (1990), Patra et al. (1999) and Patra et al. (2000).

Combined yield

Combined yield was always higher in intercropping situations both in 1:1 and 2:2 proportions of planting than mono cropping (Table 3). It might be attributed due to the inclusion of yield of maize with some yield of legumes. In maize legume association, maize was benefitted by nitrogen fixation of intercropped legumes.

Table 1. Effect of intercropping on cobs plant^{-1}, grains cob^{-1}, 1000 grain weight and barren stalk percentage of maize (pooled data of 2 years).

Treatments	Cobs plant^{-1}	Grains cob^{-1}	1000 grain weight (g)	Barren stalk (%)
M_1	1.43	314.33	215.43	17.90
M_2	1.38	307.79	214.22	19.65
SE m (±)	0.07	7.00	10.37	1.03
CD (P=0.05)	NS	NS	NS	NS
Maize (comb)	1.40	311.06	214.82	18.77
Legume (comb)	1.36	308.26	216.05	16.95
SE (diff.)	0.05	5.42	8.04	0.80
CD (P=0.05)	NS	NS	NS	NS
Group 1 (1:1)	1.38	311.18	216.65	16.20
Group 2 (2:2)	1.33	305.33	215.45	17.70
SE m (±)	0.03	3.13	4.64	0.46
CD (P=0.05)	NS	NS	NS	NS
Group 1 (1:1)				
M_1 + GG	1.50	320.79	216.59	15.83
M_1 + BG	1.48	316.88	216.70	15.35
M_1 + SB	1.45	315.48	216.25	14.82
M_1 + GN	1.25	304.66	217.21	17.20
M_1 + RG	1.22	298.12	216.49	17.81
SE m (±)	0.07	7.00	10.37	1.03
CD (P=0.05)	0.20	20.52	NS	NS
Group 2 (2:2)				
M_2 + 2GG	1.42	312.84	215.38	17.99
M2 + 2BG	1.40	311.09	215.22	17.53
M_2 + 2SB	1.39	310.39	215.21	17.81
M_2 + 2GN	1.24	301.23	216.40	17.39
M_2 + 2RG	1.20	291.12	215.04	17.80
SE m (±)	0.07	7.00	10.37	1.03
CD (P=0.05)	0.20	20.52	NS	NS

Details of treatments are given in materials and methods; NS, Non Significant.

Maize equivalent yield

Maize grain equivalent yield (Table 3) was recorded to be higher in all the cases of intercropping with respect to pure stand yield of maize which corroborated the findings of Patra et al. (1999, 2000). The highest maize grain equivalent yield was obtained in maize + red gram (2:2) intercropping (5270.46 kg ha^{-1}) due to higher yield and price of red gram.

Competition functions

Aggressivity and Competitive ratio

Aggressivity values were positive (+ve) in maize which obviously indicated that maize was the dominant crop, whereas the associated intercrops appeared to be the dominated ones having negative (-ve) values (Table 4). Between the two spatial arrangements, 1:1 proportion of intercropping resulted in higher values of aggressivity which denoted higher interspecific competition. Likewise, competitive ratio for maize was always higher as compared with the associated intercrops and higher competitive ratio of maize was observed at 1:1 proportion of intercropping than 2:2 proportions. Being a C_4 plant, maize appeared to be more competitive and the subsidiary intercrops were found to be less competitive with respect to utilization of available resources. Among the intercrops, red gram was more competitive and offered the highest competition to maize in both the proportions of sowing. Similarly, Sawargaonkar (2008) reported that the maize-based intercropping systems were more remunerative than sole maize; Maize + black gram and maize + green gram were superior to maize + soybean for grain yield and parameters related to

Table 2. Effect of intercropping on yield attributes and yields of associated legumes (pooled data of 2 years).

Treatments	Pods plant^{-1}	Seeds pod^{-1}	1000 grain weight (g)	Seed yield (kg ha^{-1})	Harvest index (%)
Green gram	23.88	9.78	25.16	915.92	19.73
Black gram	29.05	6.24	34.38	979.33	22.12
Soybean	60.73	2.40	132.26	2245.07	36.09
Groundnut	13.25	1.80	367.21	1814.15	33.15
Red gram	95.20	3.51	31.94	1553.23	24.00
SE m (±)	2.36	0.25	10.96	69.34	0.31
CD (P=0.05)	6.85	0.73	31.74	200.83	0.89
Sole legume	44.42	4.75	118.19	1501.54	27.02
Intercrop legume	37.67	4.62	114.85	601.29	25.45
SE (diff.)	1.30	0.14	6.00	37.98	0.17
CD (P=0.05)	2.65	NS	NS	77.78	0.35
Group 1 (1:1)	36.85	4.57	114.38	569.50	24.83
Group 2 (2:2)	38.49	4.67	115.32	633.08	26.07
SE m (±)	1.06	0.11	4.90	31.01	0.14
CD (P=0.05)	NS	NS	NS	NS	0.40
Group 1 (1:1)					
M_1 + GG	16.67	9.51	24.34	323.27	21.11
M_1 + BG	21.58	5.94	32.33	358.28	19.98
M_1 + SB	53.08	2.35	129.28	691.27	32.03
M_1 + GN	7.89	1.58	358.62	563.15	28.87
M_1 + RG	85.05	3.48	27.34	911.51	22.18
SE m (±)	2.36	0.25	10.96	69.34	0.31
CD (P=0.05)	6.85	0.73	31.74	200.83	0.89
Group 2 (2:2)					
M_2 + 2GG	18.55	9.68	24.55	360.79	22.49
M_2 + 2BG	24.86	6.09	33.15	388.45	20.94
M_2 + 2SB	56.58	2.37	130.26	755.16	33.22
M_2 + 2GN	8.80	1.69	361.54	635.64	30.20
M_2 + 2RG	83.65	3.50	27.09	1025.35	23.53
SE m (±)	2.36	0.25	10.96	69.34	0.31
CD (P=0.05)	6.85	0.73	31.74	200.83	0.89

Details of treatments are given in materials and methods; NS, Non significant.

competitive ability.

Land equivalent ratio

LER values were always recorded to be higher than unity signifying yield advantages of intercropping over monoculture (Table 4). Yield advantages occurred due to the development of both temporal and spatial complementarities. The highest value of LER (1.418) was obtained from maize + black gram (2:2) intercropping which was closely followed by maize + green gram (2:2) intercropping (1.417). Sharma and Behera (2009) reported that, land equivalent ratio and other competitive functions were favourably influenced with intercropped maize + green gram and maize +cowpea.

Area time equivalent ratio

ATER values were also greater than unity in all the cases of intercropping. ATER values, similar to LER, were higher in cases of maize-legume combinations and at 2:2 proportion of sowing. So, the intercropping system was found to be advantageous in comparison to monoculture. Maize + black gram (2:2) intercropping recorded the highest ATER value (1.362), which was achieved probably due to the development of temporal as well as spatial complementarity (Table 4). The area time equivalent ratio was higher in maize + legume in 1:2

Table 3. Effect of intercropping on grain yield, harvest index, combined yield and equivalent yield of maize (pooled data of 2 years).

Treatments	Maize grain yield (kg ha^{-1})	Harvest index (%)	Combined yield (kg ha^{-1})	Maize equivalent yield (kg ha^{-1})
M_1	2690.96	31.58	2690.96	2690.96
M_2	2586.67	31.85	2586.67	2586.67
SE m (±)	219.00	0.25	122.21	355.35
CD (P=0.05)	NS	NS	NS	NS
Maize (comb)	2638.81	31.72	2638.81	2638.81
Legume (comb)	2521.56	31.11	3122.84	4281.29
SE (diff.)	169.64	0.19	94.67	275.25
CD (P=0.05)	NS	0.40	196.34	570.87
Group 1 (1:1)	2580.43	30.87	3149.92	4244.43
Group 2 (2:2)	2462.69	31.35	3095.76	4318.15
SE m (±)	97.94	0.11	54.66	158.92
CD (P=0.05)	NS	0.32	NS	NS
Group 1 (1:1)				
M_1 + GG	2783.11	31.33	3106.38	4040.26
M_1 + BG	2764.84	31.31	3123.12	3760.07
M_1 + SB	2752.33	31.58	3443.61	3904.45
M_1 + GN	2570.69	31.96	3133.85	4447.87
M_1 + RG	2031.16	28.15	2942.67	5069.52
SE m (±)	219.00	0.25	122.21	355.35
CD (P=0.05)	642.35	0.72	358.46	1042.27
Group 2 (2:2)				
M_2 + 2GG	2655.88	31.82	3016.67	4058.95
M2 + 2BG	2647.85	32.24	3036.29	3726.86
M_2 + 2SB	2635.21	32.20	3390.37	3893.81
M_2 + 2GN	2521.87	32.20	3157.51	4640.68
M_2 + 2RG	1852.63	28.31	2877.98	5270.46
SE m (±)	219.00	0.25	122.21	355.35
CD (P=0.05)	642.35	0.72	358.46	1042.27

Details of treatments are given in materials and methods; NS, Non significant.

proportion than in 1:1 proportion (Mohan et al. 2005).

Land equivalent coefficient

Land equivalent co-efficient values were always recorded to be greater than 0.25 which indicated yield advantages in maize + legume intercropping situations in both the proportions of intercropping (1:1 and 2:2). The highest LEC (0.47) was recorded with maize + red gram (2:2) intercropping (Table 4).

Relative value total

The values of RVT were always greater than unity. The highest value of RVT was obtained with maize + red gram (2:2) intercropping (2.033) due to higher market price of red gram (Table 4). Maize + legume intercropping brought about higher RVT value probably due to higher combined yield in maize-legume association, which was in agreement with the findings of Patra et al. (1999).

Monetary advantage

Higher monetary advantages were always obtained when maize was intercropped with leguminous crops. Maize + red gram (2:2) intercropping gave rise to the highest monetary advantage (Rs. 13,011.22). The lowest monetary advantage (Rs. 8,424.99) was found in maize + soybean (1:1) intercropping (Table 4). Similar observation was also made by Refey and Prasad (1992).

Relative net return

It was found that growing of legumes in between the

Table 4. Effect of intercropping on aggressivity value, competitive ratio, land equivalent ratio, area time equivalent ratio, monetary advantage, land equivalent coefficient, relative value total and relative net return of maize and associated legumes (pooled data of 2 years).

Treatments	Aggressivity value		Competitive ratio		Land equivalent ratio	Area time equivalent ratio	Monetary advantage	Land equivalent co-efficient	Relative value total	Relative net return
	A_{ab}	A_{ba}	CR_a	CR_b						
Group 1 (1:1)	0.591	-0.591	2.805	0.499	1.344	1.234	9708.63	0.36	1.578	1.726
Group 2 (2:2)	0.265	-0.265	2.500	0.493	1.378	1.266	10644.23	0.39	1.667	1.844
SE m (±)	0.040	0.040	0.190	0.039	0.006	0.006	261.42	0.003	0.007	0.020
CD (P=0.05)	0.119	0.119	NS	NS	0.018	0.018	776.75	0.011	0.020	0.059
Group 1 (1:1)										
M_1 + GG	0.701	-0.701	3.015	0.348	1.389	1.255	10162.34	0.36	1.506	1.645
M_1 + BG	0.683	-0.683	2.911	0.365	1.393	1.341	9559.79	0.37	1.399	1.417
M_1 + SB	0.730	-0.730	3.594	0.663	1.333	1.286	8736.18	0.32	1.455	1.641
M_1 + GN	0.673	-0.673	3.199	0.331	1.261	1.221	8424.99	0.29	1.651	1.879
M_1 + RG	0.168	-0.168	1.307	0.787	1.341	1.069	11659.86	0.44	1.878	2.047
SE m (±)	0.089	0.089	0.426	0.087	0.013	0.013	584.56	0.01	0.015	0.044
CD (P=0.05)	0.265	0.265	1.265	0.258	0.040	0.040	1736.87	0.03	0.045	0.131
Group 2 (2:2)										
M_2 +2GG	0.319	-0.319	2.719	0.400	1.417	1.268	10825.50	0.40	1.567	1.711
M_2 +2BG	0.318	-0.318	2.663	0.396	1.418	1.362	9929.30	0.40	1.440	1.580
M_2 +2SB	0.347	-0.347	3.040	0.332	1.354	1.308	9184.98	0.34	1.505	1.698
M_2 +2GN	0.319	-0.319	2.950	0.370	1.322	1.278	10270.14	0.34	1.789	2.026
M_2 +2RG	0.021	-0.021	1.127	0.966	1.378	1.118	13011.22	0.47	2.033	2.208
SE m (±)	0.089	0.089	0.426	0.087	0.013	0.013	584.56	0.01	0.015	0.044
CD (P=0.05)	0.265	0.265	1.265	0.258	0.040	0.040	1736.87	0.03	0.045	0.131

Details of treatments are given in materials and methods; NS, Non significant.

maize rows at both the sowing ratios 1:1 and 2:2 were profitable in comparison to sole cropping of maize when differential cost of cultivation was taken into consideration (Table 4). Maize + red gram (2:2) intercropping gave the highest RNR values (2.208). This might be due to the spatial as well as temporal complementarity which resulted in substantial yield advantages from intercropping. Similar results were also obtained by Mandal et al. (1986b, 1990a and 1991a).

Economic analysis

Intercropping in paired rows of maize spaced at 90 cm was advantageous than 60 cm row to row spacing of maize (Table 5). 2:2 proportion of intercropping brought about higher gross returns as compared to 1:1 proportion of intercropping. The highest gross and net return was obtained from maize + red gram (2:2) amounting to Rs. 55,191.60 and Rs. 39,950 ha^{-1} respectively. From the pooled data, it was observed that 2:2 proportion of intercropping always fetched net

Table 5. Effect of intercropping on gross return, net return, B:C ratio and Per day return of maize and associated legumes (pooled data of 2 years).

Treatments	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B : C ratio	Per day return (Rs.)
Group 1 (1:1)	41448.54	25521.24	2.60	215.63
Group 2 (2:2)	42814.85	27438.93	2.80	229.32
SE m (±)	1006.12	960.78	0.18	9.06
CD (P=0.05)	NS	NS	NS	NS
Group 1 (1:1)				
M_1 + GG	39362.31	24457.11	2.64	232.92
M_1 + BG	36840.60	22019.40	2.48	209.71
M_1 + SB	38140.08	21108.88	2.24	191.90
M_1 + GN	43030.84	26349.64	2.58	239.54
M_1 + RG	49868.88	33671.18	3.08	204.07
SE m (±)	2012.24	1921.56	0.35	18.12
CD (P=0.05)	5977.99	5708.60	NS	NS
Group 2 (2:2)				
M_2 + 2GG	39530.54	25050.34	2.73	238.57
M_2 + 2BG	36541.73	22195.53	2.55	211.39
M_2 + 2SB	38044.28	21475.38	2.30	195.23
M_2 + 2GN	44766.08	28523.08	2.76	259.30
M_2 + 2RG	55191.60	39950.30	3.65	242.12
SE m (±)	2012.24	1921.56	0.35	18.12
CD (P=0.05)	5977.99	5708.60	1.04	53.83

Details of treatments are given in materials and methods; NS, Non significant.

return than 1:1 proportion. It was also noticed that 2:2 proportion of intercropping always recorded higher B: C ratio than 1:1 proportion and the highest (3.65) B:C ratio was recorded in maize + red gram (2:2). Maize + groundnut (2:2) gave the highest Per day return of Rs. 259.30. Bharati et al. (2007) reported that maize based intercropping generated higher net return than sole crop of maize. Kamanga et al. (2010) opined maize + legume intercropping was more productive and remunerative as compared to sole cropping which was in close agreement with the present findings.

Conclusion

Maize when intercropped with legumes found to be beneficial and profitable. Maize- legume intercropping were found to be more advantageous (in additive series) with respect to maize grain equivalent yield and monetary returns in both the proportions of sowing (1:1 and 2:2) but 2:2 proportion was appeared to be more remunerative.

Conflict of Interests

The author(s) have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors thank Bidhan Chandra Krishi Viswavidyalaya for all kinds of support relating to the experimentation. We offer special thanks to Department of Agronomy, Department of Agricultural Statistics and field staffs of University Research Farm for their kind assistance during the period of experimentation and analyses of data.

REFERENCES

Andrews RW (1979). Intercropping: Its importance and research needs I. Competition and yield advantages. Agronomy and research approaches. Field Crops Abs. 32:73-85.

Beedy TL, Snapp SS, Akinnifesi FK, Sileshi GW (2010). Impact of Gliricidia sepium intercropping on soil organic matter fractions in a maize-based cropping system. Agric. Ecosyst. Environ. 138(3/4):139-146. http://dx.doi.org/10.1016/j.agee.2010.04.008

Bharati V, Nandan R, Kumar V, Panday IB (2007). Effect of irrigation levels on yield, water use efficiency and economics of winter maize (Zea mays L.) based intercropping systems. Indian J. Agron. 52(1):27-30.

Chen C, Westcott M, Neill K, Wichman D, Knox M (2004). Row configuration and nitrogen application for barley-pea intercropping in Montana. Agron. J. 96:1730-1738. http://dx.doi.org/10.2134/agronj2004.1730

Kamanga BCG, Waddington SR, Robertson MJ, Giller KE (2010). Risk analysis of maize-legume crop combinations with smallholder farmers varying in resource endowment in central Malawi. Exp. Agric. 46(1):1-21. http://dx.doi.org/10.1017/S0014479709990469

Mandal BK, Mahapatra SK (1990). Barely, lentil and flax yield under different intercropping systems. Agron. J. 82:1066-1068. http://dx.doi.org/10.2134/agronj1990.00021962008200060007x, http://dx.doi.org/10.2134/agronj1990.00021962008200060006x

Mandal BK, Dasgupta S, Ray PK (1986b). Yield of wheat, mustard and chickpea grown as sole and intercrops with four moisture regimes. Indian J. Agric. Sci. 56(8):577-583.

Mandal BK, Dhara MC, Mandal BB, Bhunia SR, Dandapat A (1991a). Nodulation in some legumes grown as pure and intercrops. Indian Agric. 35(1):15-19.

Mandal BK, Dhara MC, Mandal BB, Das S, Nandy R (1989). Effect of intercropping on the yield components of rice, Mungbean, soybean, peanut, rice bean and blackgram yields under different intercropping systems. Agron. J. 82:1063-1066. http://dx.doi.org/10.2134/agronj1990.00021962008200060006x

Mohan HM, Chittapur BM, Hiremath SM, Chimmad VP (2005). Performance of maize under intercropping with grain legumes, Karnataka J. Agric. Sci. 18(2):290-293.

Patra BC, Mandal BB, Mandal BK, Padhi AK (1999). Suitability of maize (*Zea mays*) based intercropping systems. Indian J. Agric. Sci. 69(11):759-762.

Patra BC, Mandal BK, Padhi AK (2000). Production potential of winter maize (*Zea mays*) – based intercropping systems. Indian J. Agric. Sci. 70(4):203-206.

Rana RS, Singh B, Negi SC, Singh B (2001). Management of maize/legume intercropping under mid-hill sub-humid conditions. Indian J. Agric. Res. 35:100-103.

Refey A, Prasad NK (1992). Biological potential and economic feasibility of maize (*Zea mays*) + pigeonpea (*Cajanus cajan*) intercropping system in dry lands. Indian J. Agric. Sci. 62:110-113.

Sawargaonkar GL, Shelke DK, Shinde SA, Shilpa K (2008). Performance of kharif based legumes intercropping systems under different fertilizer doses. Int. J. Agric. Sci. 4(1):152-155.

Sharma AR, Behera UK (2009). Recycling of legume residues for nitrogen economy and higher productivity in maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system. Nutrient Cycling in Cropping Syst. 83(3):197-210. http://dx.doi.org/10.1007/s10705-008-9212-0

Tsubo M, Walker S, Ogindo HO (2005). A simulation model of cereal-legume intercropping systems for semi-arid regions II. Model application. Field Crops Res. 93:23-33. http://dx.doi.org/10.1016/j.fcr.2004.09.003, http://dx.doi.org/10.1016/j.fcr.2004.09.002