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ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

ISSN: 0976-3376

Asian Journal of Science and Technology
Vol. 5, Issue 3, pp. 233-237, April, 2014

RESEARCH ARTICLE

EVALUATION OF CEREAL-LEGUME INTERCROPPING SYSTEMS THROUGH PRODUCTIVITY AND COMPETITION ABILITY

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ARTICLE INFO

Article History:
Received 28^{th} January, 2014
Received in revised form
25^{th} February, 2014
Accepted 23^{rd} March, 2014
Published online 26^{th} April, 2014

Key words:
Competitive behavior;
Intercropping;
Groundnut;
Maize;
Soybean

ABSTRACT

A field experiment was carried out during *kharif* season of 2010 and 2011 at Sriniketan Research Farm, Visva-Bharati, West Bengal. Maize crop produced highest grain yield in sole cropping which was statistically at par with intercropping situations like maize + soybean (1:2) and maize + groundnut (2:4). The mean land equivalent ratio in two years ranged from 1.21 to 1.84, indicating biological sustainability of intercropping over sole cropping. The highest relative crowding coefficient, SPI and LER value was obtained in maize + groundnut (2:4) followed by maize + soybean (1:2), maize + groundnut (1:2) and maize + soybean (2:4) combinations, indicating that former system as a whole was more productive, giving more yield. The values of CR and MA were higher in maize-soybean intercropping than the maize-groundnut intercropping. Maize + groundnut and maize + soybean recorded area time equivalent ratio value more than one indicating better land utilization efficiency than their sole crops. Highest RVT value was obtained from maize + soybean (1:2) followed by maize + groundnut (1:2).

INTRODUCTION

Cereal-legume intercropping plays an important role in food production worldwide. Crop intercropping is commonly practiced because of various advantages such as greater yield stability, greater land-use efficiency, increased competitive ability toward weeds, improvement of soil fertility due to the addition of N by fixation, and some favorable exudates from legume species. Lithourgidis *et al*. 2006, demonstrated that yield production under intercropping is higher than in sole cropping systems. This is because resources such as water, light and nutrients can be utilized more efficiently than in the respective sole cropping systems. Almost all reported intercropping combinations with a significant yield advantage involved non legume/legume combinations (Ghosh *et al.* 2006). Producers and researchers carry out different cropping systems to increase productivity and sustainability by practicing crop rotations, relay cropping, and intercropping of annual cereals with legumes. Intercropping of cereals with legumes has been popular and rain-fed areas (Dhima *et al.* 2007) due to its advantages for soil moisture conservation, weed control (Banik *et al.* 2006), lodging resistance, yield increase. Different row ratios or planting patterns for cereal-legume intercropping have been practiced by many researchers (Karadag and Buyukburc 2004).

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Competition among mixtures is thought to be the major aspect affecting yield as compared with solitary cropping of cereals. Species or cultivar selections, row ratios, and competition capability within mixtures may affect the growth of the species used in intercropping systems in rain-fed areas (Banik *et al.* 2006, Dhima *et al.* 2007). A number of indices such as land equivalent ratio, land equivalent coefficient, relative crowding coefficient, competitive ratio and monetary advantage, have been proposed to describe competition within and economic advantages of intercropping systems (Banik *et al.* 2006, Dhima *et al.* 2007). The objectives of the present study were (i) to estimate the effect of competition within cereal-legume intercropping systems, e.g., maize-soybean and maize-groundnut intercropping; (ii) to examine different competition indices in these intercropping systems and, therefore (iii) to evaluate the systems for better management of resources to obtain less competition among higher productivity, sustainability.

MATERIALS AND METHODS

The field experiment was conducted during two consecutive *kharif* seasons of 2010 and 2011 at Sriniketan Research Farm ($23^{0}39'$ N latitude, $87^{0}42'$ E longitude and 58.9 m above mean sea level) of Institute of Agriculture, Visva-Bharati, Birbhum, West Bengal. The experiment was laid out in a randomized block design with 7 treatments replicated thrice. Treatments comprised of seven cropping situations namely, T_1: sole maize, T_2: sole groundnut, T_3: sole soybean, T_4: Maize + groundnut (1:2), T_5: Maize + soybean (1:2), T_6: Maize +

groundnut (2:4) and T_7: Maize + soybean (2:4). Under this experiment the main crop was maize var. 'Shakti hybrid' and the intercrops were groundnut var. 'TAG 24' and Soybean var. 'Birsa Soybean1'. Maize was sown with a seed rate of 18-20 kg/ha on 3rd week of July with spacing 75 cm x 25 cm in sole maize and for paired row spacing was 50 cm x 25 cm. Intercrops i.e. groundnut and soybean was sown with 25 cm x 10 cm spacing. The fertilizer doses for maize and grain legumes were 150 kg N + 75 kg P_2O_5 + 75 kg K_2O/ha and 40 kg N + 80 kg P_2O_5 + 80 kg K_2O/ha respectively. The other management operations were done as per recommended package of practices for both main and intercrops. The competitive functions were computed in the form of aggressivity, competitive ratio, land equivalent ratio, area time equivalent ratio, monetary advantage and relative value total. Abbreviations used to calculate different competitive functions were Yaa- pure stand yield of crop "a", Yab- intercrop yield of crop "a", Ybb-pure stand yield of crop "b", Yba- intercrop yield of crop "b". Zab and Zba are sown proportions of crop "a" and "b" in an intercropping system. The aggressivity (A) shows the degree of dominance of one crop over other when sown together.

Aggressivity value was calculated by Aab=(Yab/Yaa x Zab) – (Yba/Ybb x Zba), where Aab is aggressivity value for the component crop "a". Relative crowding coefficient (K) was calculated Kab=(Yab/Yaa–Yab) – (Zba/Zab), where Kab is relative crowding coefficient for the component crop "a".Competitive ratio (CR) was calculated by the formula as CRa=(LERa/LERb) (Zba/Zab), where CRa is competitive ratio for the component crop "a". All the other abbreviations have been described above in this section. LER is defined as the relative land area under sole crop that is required to produce the yield achieved in intercropping. LER= Yab/Yaa + Yba/ Ybb. Land equivalent coefficient (LEC), a measure of interaction related to the relationship strength was calculated as: LEC = La × Lb (Lithourgidis *et al.* 2006), Where, La = LER of main crop and Lb = LER of intercrop. For a two crop mixture the minimum expected productivity coefficient (PC) was 25% which means that a yield advantage is obtained if LEC value exceeds 0.25. System productivity index (SPI) was calculated as: SPI = (Sa/Sb) Yb + Ya, where S is the mean yield of each plant in sole culture and Y is the mean yield of each plant in mixed culture. Monetary advantage as suggested by (Willey 1979) was calculated as follows:

Monetary advantage = LER-1/LER × Value of combined intercrop yield. The values of produces were estimated on the basis of price rate available in local market. LER can only consider the profitability of intercropping in terms of land area but not the time. So, unlikely of LER, the measure of Area Time Equivalent Ratio (ATER) can consider both land area as well as the time for which the crops were on the land. According to him, ATER is calculated as follows: ATER = (R_{ya} × ta) + (R_{yb} × t_b)/ T, Where, R_y = Relative yield of species 'c' or 'p', t = duration (day) for species 'a' or 'b', T = duration (days) of the intercropping system. The LER combined the two crops according to their yields. Alternative methods of combination could be based on their relative monetary value. For this purpose, the RVT for intercrop was calculated using the formula. RVT = (V_a +V_b)/Vs. Where, V_a and V_b are the monetary values of species 'a' and 'b' from the intercrop treatment and appropriate sole crop monetary value.

RESULTS AND DISCUSSION

Yield of maize and intercrops

Maize crop produced highest grain yield in sole cropping which was statistically at par with intercropping situations (Table 1) like maize + soybean (1:2) and maize + groundnut (2:4). The lowest grain yield was observed in maize +soybean (2:4) which may be due to higher competition faced by the crop in 2: 4 row ratio due to presence of more number of plants per unit area. The presence of groundnut in the paired row system probably had more synergistic effect as compared to antagonistic effect and therefore the maize crop in association with groundnut in the paired row system reported comparable yield. This might be due to more competition among plants due to higher plant population which might have caused reduction in availability of growth factors for the legume component and finally there was yield reduction. On the other hand, the sole crop enjoyed higher availability of nutrient, moisture, light, space etc and produced more number of pods/plant, seeds/pod and finally gave higher grain yield. This corroborates with the findings of Pandey *et al.* 2003.

Maize equivalent yield and economies

Among all the treatments under study, in terms of maize equivalent yield, maize + soybean (1:2) gave the highest maize equivalent yield (5.48 t/ha) and high return per rupee invested (Table 1). Maize and soybean intercropping systems recorded significantly more maize equivalent yields compared to sole maize. Further, pure groundnut and pure soybean crop gave maize equivalent yield higher than sole maize but lower than the intercropping systems. The maize + groundnut (1:2) intercropping system produced highest cost of cultivation, gross return, net return value as well as the highest return per rupee invested. All the treatments were found profitable although sole maize gave least return per rupee invested. The data showed that the highest total cost of cultivation of Rs. 23383.36 in both years was incurred in maize + groundnut (1:2) intercropping system. The lowest total cost of cultivation was observed in sole maize. The cost of cultivation increased in the intercropping systems compared with respective sole crop of maize, groundnut and soybean. It might be due to additional inputs and management require for groundnut and soybean in the intercropping treatments.

These results are in agreement with those of (Patel and Rajagopal 2001) under cereal + legume intercropping system. To monetary return of maize + groundnut intercropping system indicated that higher total gross return was obtained from (two row groundnut in between one paired rows of maize) than sole crop of maize, groundnut and soybean in consecutive two years. (Razzaque *et al*. 2007) also reported higher monetary advantages from different intercropping systems than their respective sole crops. Two year's results revealed that the highest total net return and return per rupee invested was obtained from maize + groundnut (1:2) intercropping system. It might be due to better utilization of different growth resources in maize + groundnut and maize + soybean intercropping system. Many investigators also reported higher net return obtained intercropping system than sole crop (Razzaque *et al.* 2007). Maize as sole crop gave

Table 1. Yield, equivalent yield and economics of sole and intercropping system (Pooled data of 2 years)

Treatment	Grain yield (t/ha)			Maize Equivalent Yield (t/ha)	Cost of cultivation (Rs./ha)	Gross return (Rs./ ha)	Net return. (Rs./ ha)	Return per rupee invested (Rs.)
	Maize	Intercrop	Total					
Sole maize	2.48	-	2.48	2.48	16708.56	33415.00	16706.44	1.00
Sole groundnut	-	2.02	2.02	2.78	23270.83	76316.00	53045.17	2.28
Sole soybean	-	2.08	2.08	3.54	23420.83	46948.00	23527.17	1.01
Maize + groundnut (1 :2)	2.06	1.93	3.99	4.71	23383.36	99103.3	75719.94	3.24
Maize + soybean (1:2)	2.23	1.91	4.14	5.48	23300.92	98751.00	75450.08	3.23
Maize + groundnut (2:4)	2.26	1.88	4.14	4.85	22750.36	71716.50	48966.14	2.15
Maize + soybean (2:4)	1.87	0.95	2.82	3.49	22818.84	45763.50	22944.66	1.01
SEm ±	0.09	0.10						
CD(P=0.05)	0.28	0.30						

Table 2. Land equivalent ratio (LER), land equivalent coefficient (LEC) and relative crowding coefficient (K) for sole stand and intercrop of maize with groundnut and soybean in different intercropping system

Treatments	Land equivalent ratio (LER)			Relative crowding coefficient (K)			Land equivalent coefficient (LEC)
	Maize	Intercrop	Total	Ka	Kb	K_{total}=(Ka × Kb)	
Sole maize	1.0	1.0	1.0	-	-	-	1.0
Sole groundnut	1.0	1.0	1.0	-	-	-	1.0
Sole soybean	1.0	1.0	1.0	-	-	-	1.0
Maize + groundnut (1:2)	0.83	0.96	1.79	0.90	21.19	19.07	0.80
Maize + soybean (1:2)	0.90	0.92	1.82	4.92	10.99	54.07	0.82
Maize + groundnut (2:4)	0.91	0.93	1.84	6.27	13.18	82.64	0.85
Maize + soybean (2:4)	0.75	0.46	1.21	-0.93	0.59	-0.52	0.35

Table 3. Aggressivity (A), competitive ratio (CR) system productivity index (SPI), monetary advantage (MA), area time equivalent ratio (ATER) and relative value total (RVT) for maize and legumes in different intercropping system

Treatments	Aggressivity (A)		Competitive ratio (CR)		System productivity index (SPI)	Monetary advantage (MA)	Area time equivalent ratio (ATER)	Relative value total (RVT)
	Aab	Aba	CRab	CRba				
Maize + groundnut (1:2)	1.18	-1.18	3.46	0.29	49.08	82962.00	1.63	1.90
Maize + soybean (1:2)	1.34	-1.34	3.91	0.26	49.27	98586.00	1.67	2.21
Maize + groundnut (2:4)	1.35	-1.35	3.91	0.26	50.92	89148.00	1.67	1.05
Maize + soybean (2:4)	1.28	-1.28	6.52	0.15	33.56	23698.00	1.09	1.41

reasonable good yield and economic return but due to sustaining of soil fertility as well as ensures productivity from hybrid maize, intercropping with legumes is one of the way which could help in yield stability. In this situation, four rows of groundnut in between one paired rows of maize would be better option in *kharif* season.

Land equivalent ratio, land equivalent coefficient and relative crowding coefficient

Various competitive relationship of intercropping were computed and presented in Table 2. The mean land equivalent ratio in two years ranged from 1.21 to 1.84, indicating biological sustainability of intercropping over sole cropping. These results indicate that 21 to 84%, greater area would be required by a sole cropping system to recover the yield of intercropping system (Miyda *et al*. 2005). The highest LER value was obtained in maize + groundnut (2:4) followed by maize + soybean (1:2), maize + groundnut (1:2) and maize + soybean (2:4) combinations, indicating that former system as a whole was more productive, giving more yield. All mixing ratios had higher LER than 1, which shows intercropping advantages. The advantages accrued from intercropping systems, as evident from competitive functions, is due to better utilization of growth resources under cereal–legume intercropping system.

Land equivalent coefficient values ranged from 0.85 to 0.35. Others treatments had LEC values of 0.82, 0.80 and 0.35 for maize + soybean (1:2), maize + groundnut (1:2) and maize + soybean (2:4) respectively (Table 2). Land equivalent coefficient (LEC) was greater than 0.25 under all treatments. According to Adetiloye *et al*. 1983, for a two-crop mixture, the minimum expected productivity coefficient (PC) is 25%. This indicates that soybean and groundnut can grow in mixture with maize under all treatments without major adverse effects. In fact, in the present study, intercropping yield advantage was observed under all the treatments, indicating an absolute yield advantage of groundnut, soybean when intercropped with maize. Yilmaz *et al*. 2008 had reported similar findings in maize- legume intercropping systems in the East Mediterranean region. Maize + groundnut (2:4) recorded the highest relative crowding coefficient (82.64), followed by maize + soybean (1:2) and maize + groundnut (1:2). In all intercropping system, relative crowding coefficient value recorded more than one except maize + soybean (2:4) showing better utilization of land with intercropping than sole crops (Table 2). The lowest RCC (-0.52) was recorded in maize + soybean (2:4). RCC lesser than 1 which shows sometimes, differences in growth patterns of the intercrops also improve light interception pattern, leaf area index and leaf area duration (Yellamanda and Reddi 1995). The accompanying crops in mixtures ought to be planted in such a way as to minimize competition for light and other resources, and manipulating spatial arrangement is one way of attaining this. Partial K values of legumes were higher than partial K values of maize in the maize +soybean (2:4) planting pattern. In addition, a K value for groundnut was higher compared to soybean, indicating that groundnut was more competitive than common bean in cereal-legume mixtures. In a groundnut-cereal mixtures, cereals over crowded groundnut (Kcereal values > 1;Ghosh 2004). When maize-legume intercropping was considered in close rates such as 1:2, 2:4 ratio, competition among the plants seemed to be against maize while it was in favor of groundnut.

Aggressivity, competitive ratio, and system productivity index

In all planting patterns, positive Aab values showed that maize was the dominant species (Table 3). Considering all the intercropping system Aab values were always positive and Aba values were all negative, showing that maize was the dominant species and while intercrops were dominated as reported by previous cereal-legume mixture studies (Ghosh 2004, Dhima *et al.* 2007). Banik *et al.* 2000 and Ghosh 2004 reported that in groundnut maize intercropping system, the aggressivity of groundnut was negative; thus, it is considered as the less-dominant crop in the system. Associated maize was the dominant crop as measured by the positive value of aggrresivity.

The highest CR value for maize was obtained in maize +soybean (2:4) ratio (Table 3).On the other hand groundnut had higher CR values than those of soybean. The results of competitive ratio (CR) index were also in corroboration with those of the aggressivity index. The values of A and CR for groundnut were greater than those of soybean. This indicated that groundnut was more competitive than soybean in maize mixtures. Greater competitive ability of cereal to exploit resources in association with some legumes has been reported by other researchers (Banik *et al.* 2006) the advantages accrued from intercropping systems, as evident from competitive functions, is due to better utilization of growth resources under cereal-legume intercropping system. The SPI for 2:4 ratio of maize: groundnut intercropping system was higher than all other intercropping treatments (Table 3). The maize + groundnut (1:2) and maize + soybean (1:2) intercropping treatment had a fairly same SPI value. However the maize + groundnut intercropping system generally had greater SPI then Maize + soybean intercropping.

Area time equivalent ratio, monetary advantage and relative value total

The monetary advantage (MA) values were positive in intercropping system, which shows definite yield and economic advantages compared to the sole cropping systems tested in our study. The values of MA was higher in maize-soybean intercropping than the maize-groundnut intercropping and the highest MA was observed for maize + soybean (1:2) intercropping followed by Maize + groundnut (2:4), maize + groundnut (1:2)and maize + soybean (1:2) respectively (Table 3). Ghosh (2004) and Dhima *et al*. (2007) reported that if LER and K values were higher, there was also economic benefit expressed with MA values. Maize + groundnut and maize + soybean recorded area time equivalent ratio value more than one indicating better land utilization efficiency than their sole crops (Table 3). Intercropping of maize with groundnut was beneficial regarding ATER irrespective of row arrangements. The highest value obtained in maize + soybean (1:2) and maize + groundnut (2:4) were followed by maize + groundnut (1:2). ATER values produced under all the treatments were higher than 1.0, confirming further advantage of intercropping of groundnut and soybean with maize. Highest RVT value was obtained from maize + soybean (1:2) followed by maize + groundnut (1:2) while lowest was obtained from maize + groundnut (2:4) row ratio. In both the row ratios, the RVT of maize + soybean was found to be superior over that of maize +groundnut. One reason for the preference of the intercropping over the pure cropping, is the lesser intra-species competition of the crops of intercropping compared to the inter-species competition of the crops of pure cropping; this discrepancy results from the nutritional requirements of the two kind of plants, their root systems, their photosynthetic systems, the length of their growth phase and their height.

Conclusions

The present study concludes that intercropping of maize with groundnut and soybean indifferent planting ratios had influence on grain yield, equivalent yield and economies, competition between species and economics advantages as compared to sole cropping of the crops. The maize: groundnut mixture and maize: soybean mixture had the best intercropping total grain yield and economic advantageous, respectively. Furthermore, soybean intercropped with maize was more competitive than groundnut with maize. Therefore, maize was the dominant species in maize: groundnut mixture at all the intercropping system. Yield of all maize intercropping were less than it was in mono cropping. However, results obtained from competition indices and LERs of the maize: groundnut and maize: soybean mixtures indicated a significant advantage from maize intercropping than the sole cropping system.

REFERENCES

Adetiloye PO, Ezedinma FOC and Okigbo BN. 1983. A land equivalent coefficient concept for the evaluation of competitive and productive interactions on simple complex mixtures. *Ecol. modelling.*19: 27-39.

Banik P, Midya A, Sarkarand BK and Ghose SS. 2006. Wheat chickpea intercropping systems in an additive series experiment: Advantages and weed smothering. *Eur. J. Agron*. 24: 325-332.

Banik P, Sasmal T, Ghosal PK and Bagchi DK. 2000. Evaluation of mustard *(Brassica compestris* Var.Toria) and legume intercropping under 1:1 and 2:1 Row Replacement Series Systems. *J. Agron. Crop Sci*. 185: 9-14.

Dhima KV, Lithourgidis AA, Vasilakoglou IB and Dordas CA. 2007. Competition indices of common vetch and cereal intercrops in two seeding ratio. *Field Crop Res*. 100: 249-256.

Ghosh PK, Manna MC, Bandyopadhyay KK, Ajay TAK, Wanjari RH, Hati KM, Misra A K, Acharya C and Rao AS. 2006. Interspecific interaction and nutrient use in soybean/sorghum intercropping system. *Agron. J.* 98: 1097-1108.

Ghosh PK. 2004. Growth, yield, competition and economics of groundnut/cereal fodder intercropping systems in the semi-arid tropics of India. *Field Crops Res*. 88: 227-237.

Karadag Y and Buyukburc U. 2004. Forage qualities, forage yields and seed yields of some legume-triticale mixtures under rainfed conditions. *Acta Agri. Scan., Sec. B, Soil and Plant Sci*. 54: 140- 148.

Lithourgidis AS, Vasilakoglou IB, Dhima KV, Dordas CA and Yiakoulaki MD. 2006. Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratios. *Field Crops Res*. 99: 106–113.

Miyda A, Bhattacharjee K, Ghose SS and Banik P. 2005. Deferred seeding of blackgram (Phaseolus mungo L.) and rice (Oryza sativa L.) field on yield advantages and mothering of weeds. *J. Agron. Crop Sci*. 191: 195-201.

Pandey IB, Bharati V and Mishra SS. 2003. Effect of maize *(Zea mays* L.) -based intercropping systems on maize yield and associated weeds under rainfed condition. *Indian J. Agron.* 48(1): 30-33.

Patel JR and Rajagopal S. 2001. Production potential of forage maize (Zea mays L.) with legumes under intercropping system. *Indian J. Agron*. 46(2): 211-215.

Razzaque MA, Rafiquzzaman S, Bazzaz MM, Ali MA and Talukdar MMR. 2007. Study on the intercropping groundnut with chilli at different plant populations. *Bangladesh J. Agril. Res.* 32(1): 37-43.

Willey RW. (1979). Intercropping its importance and research needs Part I. Competition and yield advantages. *Field Crop Abst*., 32: 1-10.

Yellamanda TR and Reddi GHS. 1995. Principles of agronomy. Second edition. Kalyani Publishers.

Yilmaz S, Atak M and Erayman M. 2008. Identification of advantages of maize-legume intercropping over solitary cropping through competition indices in the East Mediterranean region. *Turk. J. Agric. For*. 32:111-119.

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