

Studies on Cereal-Legume Intercrop Systems

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Abstract : Studies were conducted at Kundasale and Peradeniya to assess the agronomic and economic potential of some locally important cereal-legume intercrop systems. Total yield of the maize-soyabean intercrop increased although the yield of the component crops tended to be depressed. Maize-cowpea and maize-mung bean crop combinations appeared to be compatible. Land Equivalent Ratio (LER) and gross economic returns were increased by intercropping. The net protein utilization value of the intercrop systems were higher, highlighting the importance of such systems for the subsistence level farmers in developing countries.

1. Introduction

Results of preliminary studies on intercropping indicated that cereal-legume intercropped systems are superior to monocropped systems.⁴ Intercropping with compatible crop combinations increased both total economic yields as well as gross economic returns, thus providing for more efficient utilization of N, land and other inputs. Cereal-legume intercrop systems also appeared to enhance net protein utilization value of the system, highlighting the importance of such management practices for increasing the nutritional intake of subsistence level farming families in developing countries. In view of the preliminary findings, studies on intercropping were further developed to evaluate the yields and economics of intercropping cereal crops with legumes against their respective monocrop systems.

2. Materials and Methods

Six experiments were conducted in 1976/77 with three trials each at the University Farm, Kundasale and Peradeniya. The elevation of the locations were approximately 450 m. The rainfall during the experimental period varied widely between locations, ranging from 256 mm at Kundasale to 2516 mm at Peradeniya. The rainfall received during experimentation also showed considerable variation and the crops were supplementally irrigated as needed.

Augmented design^{4,6,7} was used to include several cereal-legume intercrop systems having a local potential in the study. Six treatments replicated three times formed the main experiment, while others were augmented or unreplicated. Replicated treatments consisting of maize (*Zea mays* L.)—soyabean (*Glycine max* (L) Merr.) intercrop system was included to systematically vary the row-intercrop species between locations for comparing the trends of treatments. The selection of maize (Var. Thai composite)

as the row crop and soyabean (Var. S. J. 2) as the legume in the main experiment was based on their performance in previous intercropping studies.⁸ In the augmented intercrop combinations, four locally grown legumes were intercropped with maize to identify compatible intercrop systems and to observe general trends. Maize (Var. Thai Composite) was used as the row crop as it has been found to be compatible with most legumes.³ Maize-cowpea (*Vigna unguiculata* L.) (Var. MI 35) and maize-mungbean (*Vigna radiata* L.) (Var. MI 1) intercrop systems were also selected based on previous experimentation⁸ while maize-groundnut (*Arachis hypogaea* L.) (Var. A 92) and maize-dwarf bean (*Phaseolus vulgaris* L.) (Var. Wade) intercrops were assumed to have potential for the mid-country wet zone.

Maize-soyabean intercrop system and the monocrop system was tested at three levels of N. N levels selected were 0.25 and 50 kg/ha, the highest level being the locally recommended rate for the row crop. Mono and intercrop systems were compared at 0 and 25 kg/ha only. The recommended N (50 kg/ha) applied to the row crop was used as a control treatment. N was band applied adjacent to the row crop. N was not applied to any of the other legumes grown in the augmented treatments. All plots received blanket applications of 56 kg P₂O₅ and K₂O/ha respectively and other cultural practices uniformly as per local recommendations. Maize was spaced 100 × 50 cm, while intercrop spacings were soyabean and mungbean 50 × 5 cm, and cowpea and groundnut 50 × 10 cm. Soybean seeds were inoculated with the commercial inoculant "Nitragin S" at 5 g per 60 kg of seed. It was assumed that indigenous rhizobia would be adequate to inoculate other legumes, as a commercial inoculant was not available. Both row and legume crops were planted at the same time.

3. Results and Discussion

The mean grain yields of maize and soyabean for both locations are given in Table 1.

3.1 Yield of Maize—i. Effect of N—Whether intercropped or not, maize showed a positive response to N. In both locations, under the monocrop system, yield increased in the zero and 25 kg N levels, the differences being significant in Kundasale (2) and (3); Peradeniya (4) and (5). The yields however varied widely, from 0.35 t/ha in Peradeniya (4) to 3.11 t/ha in Kundasale (1) with zero N, and from 1.72 t/ha in Peradeniya (5) to 3.69 t/ha in Kundasale (3) with 25 kg N. The yield differences between 25 and 50 kg N were significant in 3 locations: Kundasale (3), Peradeniya (4) and (5). The highest yield at the 50 kg N/ha recommended level of N was reported in Kundasale (3) (4.87 t/ha) and lowest for Peradeniya (6) (2.4 t/ha). Under intercropping yield differences between zero and 25 kg N were significant in 5 cases, Kundasale (1), (2) and (3), Peradeniya (4) and (5). The highest and lowest

yields for zero and 25 kg N levels were : 0.32 t/ha in Peradeniya (4) and 2.56 t/ha in Kundasale (2), respectively. As evident, wide yield variations have been reported for various experiments in both locations. Gunasena *et al*⁸ reported similar yield variations in the previous intercropping studies. Such variations could be expected to result from agroclimatic variations among locations,⁵ as the differences in the total N contents among locations varied only slightly.

TABLE 1. Mean grain yield of maize and soyabean under various levels of nitrogen, t/ha.

		Monocrop System				Intercrop System		LSD P=0.05	CV %
		Rate of N, kg/ha				25	0		
		50	25	0					
Kundasale (1)	Maize	3.64	3.38	3.11		3.41	2.45	0.29	16.4
	Soyabean	—	—	—	0.36	0.46	0.40	0.16	7.7
	Total	3.64	3.38	3.11	0.36	3.87	2.85	0.46	14.9
Kundasale (2)	Maize	3.33	3.27	2.75		3.29	2.46	0.30	20.4
	Soyabean	—	—	—	0.21	0.27	0.26	0.11	6.3
	Total	3.33	3.27	2.75	0.21	3.56	2.72	1.08	20.3
Kundasale (3)	Maize	4.87	3.59	2.51		3.89	1.99	0.71	16.8
	Soyabean	—	—	—	0.86	0.49	0.60	0.92	10.4
	Total	4.87	3.59	2.51	0.86	4.38	2.59	0.63	16.0
Peradeniya (4)	Maize	3.97	1.98	0.34		2.01	0.31	0.31	10.9
	Soyabean	—	—	—	3.03	1.94	1.92	0.82	32.6
	Total	3.97	1.98	0.34	3.03	3.95	2.23	0.56	12.0
Peradeniya (5)	Maize	4.51	3.41	1.19		3.72	2.12	0.63	13.6
	Soyabean	—	—	—	2.21	0.69	0.85	0.25	18.0
	Total	4.51	3.41	1.19	2.21	4.41	2.97	0.53	7.5
Peradeniya (6)	Maize	2.40	1.72	0.82		1.73	1.18	0.61	24.9
	Soyabean	—	—	—	0.84	0.28	0.19	0.29	26.8
	Total	2.40	1.72	0.82	0.84	2.01	1.37	0.71	19.5

ii. *Effect of Cropping System*— At zero N, maize yields were somewhat depressed by intercropping except in two cases; Peradeniya (5) and (6). However the reduction was not significant. The yield gap between mono and intercropped maize tended to decrease at 25 kg N. Although the differences were non-significant, yield tended to increase in most of the trials. This may probably be due to the inability of maize to compete with the soyabean for available nutrients and other resources. Similar conclusions have also been reported by Harwood and Banta.¹⁰ However, the treatment trends suggest that maize could withstand intercropping with soyabean. Beets³ and Gunasena *et al*⁸ reported similarly. This would indicate that there is competition between maize and interplanted legume for nutrients or other resources and that the competitive effects decrease as N level increases. The results also suggest that future experimentation should include higher rates of N under intercropping.

3.2 Yield of Soyabean—Except in a few cases, intercropping depressed the yield of soyabean. Monocropped soyabean at zero N out-yielded intercropped soyabean at the same level of N in four out of six locations. Exceptions were : Kundasale (1) and (2). The yield increase was significant in two locations, Peradeniya (4) and (5). However, intercropping at 25 kg N decreased the magnitude of yield reduction and in four locations yield increased over intercropped soyabean at zero N. This would suggest that at low N levels, the shading effect due to the row crops is less severe. At high N levels, however, reductions in legume yields have been reported.¹⁵

3.3 Yield of Total System—In general, total yield of the intercropped system increased and depended considerably on N level used. Thus, at 25 kg N total yield increased under intercropping in all six locations, the differences being significant in Kundasale (3) and Peradeniya (4) and (5). Intercropping at 0 N level increased total yield over monocropped soyabean in all except Peradeniya (4). In the case of maize, however, total yield of the system exceeded only in two locations. This could be expected as monocropped maize at zero N will have better competitive ability over the intercropped system. The magnitude of the differences varied widely depending on locations. In general, this would indicate that intercropping makes better overall resource use than when the same crops are grown separately. The results of these and previous studies⁸ show a potential for a total production system if plant types of a complementary nature could be selected to exploit those specific environments. Similar results have been reported for maize-soyabean combination,¹¹⁻¹² for maize-groundnut and maize-mungbean combinations¹⁴ and for rice-soyabean and maize-soyabean combinations.²

3.4 Augmented Intercrop Systems—Four different augmented intercrop systems with the corresponding monocrops were tested. There were three augmented intercrop systems in Kundasale and two at Peradeniya with the locally potential legumes used in the combination. The mean yield of monocrop maize at zero N level from the main experiment have been used for comparison with intercropped maize, in the respective experiments. The mean yield data of the cropping systems is indicated in Table 2.

3.5.1 Maize-Cowpea Intercrop system

Maize-cowpea intercrop system was augmented in 5 experiments with three trials at Kundasale (1, 2 and 3) and two trials (4) and (5) at Peradeniya. Intercropped maize out-yielded monocropped maize in three trials, with yield increases as high as 78% and 103% in Kundasale (1) and (2), respectively. In Peradeniya (5), intercropping decreased maize yield by 54% while equal yields were reported under both cropping systems in Kundasale (3). Similar results have been reported by Haizel⁹ when

maize was intercropped with cowpea in two cropping seasons. This indicates the compatibility of the maize-cowpea intercrop system suggesting the insignificant competitiveness for available soil nutrients and other resources, perhaps due to differences in the rooting habit of the crops. On the other hand, Agboola and Fayemi¹ studied the effect of intercropping maize with cowpea at varying levels of N and found that maize yield decreased only at lower levels of N, suggesting competition between maize and interplanted cowpea for N and that the competitive effect decreased as N level increases.

As a general trend, cowpea yields were depressed by intercropping. The highest reductions were in Kundasale trials 1 and 2 (56% to 74%) while in others, the magnitude ranged from 14% to 26%. The poor yields reported for cowpea could have been due to shading effect of the row crop, although this argument may have been more appropriate, if N was applied to the row crop and not grown at zero level of N.

As indicated in Table 2, except in Peradeniya (5), yield of the total system was higher than the monocrop of either maize or cowpea. The magnitude of the difference, however, varied with location.

TABLE 2. Mean grain yield of augmented (unreplicated) intercrop systems, t/ha

Crop used	Kundasale 1		Kundasale 2		Kundasale 3		Peradeniya 4		Peradeniya 5	
	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono
Maize	0.70	0.35	2.12	1.19	0.82	0.82	6.15	5.80	2.06	4.50
Cowpea	0.75	1.30	0.46	1.05	0.17	0.20	1.05	1.08	0.71	0.85
Total	1.45		2.58		0.99		7.20		2.77	
Maize	0.40		2.17	1.19	1.34	0.82			2.32	4.50
Mungbean	0.44	1.00	0.45	1.09	0.54	5.6			1.16	1.60
Total	0.84		2.62		1.88				3.48	
Maize	0.49		1.39	1.19						
Bush bean	0.11		0.21	0.97						
Total	0.60		1.60							
Maize					1.37	0.82				
Groundnut					0.82	1.39				
Total					2.19					

3.5.2 Maize-mungbean Intercrop System

Maize-mungbean intercrop system was tested in Kundasale (1), (2) and (3) and Peradeniya (5) only. Intercropped maize increased yield over its monocropped counterpart in three out of four trials, with increases ranging from 16% to 82%. Intercropping decreased maize yield by 48% in Peradeniya (5) only.

As reported in maize-cowpea intercrop system, mungbean yield was depressed under intercropping in all trials. The magnitude of yield reduction varied from 27% to 58%, the highest being for Kundasale trials (1) and (2) (56% to 58%).

The total yield of the system was higher in Kundasale (2) and (3) compared to maize or mungbean monocrop systems. The exceptions were in Kundasale (1) and Peradeniya (5) where mungbean and maize monocrops exceeded the total yield of the system.

3.5.3 Maize-dwarf bean Intercrop System

This intercrop system was tested in Kundasale (1) and (2) trials only. Similar to that reported above, intercropped maize yields were higher than monocropped maize, being 42% and 16% in Kundasale (1) and (2) respectively. Legume yield decreased in both experiments due to intercropping, the reduction being 78%. The total system yield was higher than under the monocrop system.

3.5.4 Maize-Groundnut Intercrop System

Intercropped maize increased yield by 68% over monocropped maize in Kundasale(3), while monocropped groundnut outyielded intercropped groundnut by 71%. The total yield of the system was higher than those of the monocropped system.

Human Nutrition Value

The effect of the cropping systems and N level on crude protein content of maize and soyabean in three trials at Kundasale are indicated in Table 3.

TABLE 3. Effect of cropping system and N level on crude protein content of maize and soyabean crude protein %

	N, kg/ha	Monocrop System			Intercrop System		LSD P=0.05	CV (%)	
		50.00	25.00	0	25.00	0			
Kundasale (1)	Maize	10.56	10.00	9.75	—	9.94	9.00	0.22	10.6
	Soyabean	—	—	—	33.63	33.11	32.95	0.08	1.8
	Total kg/ha	38.42	33.79	30.24	11.90	49.44	35.31	0.30	4.6
Kundasale (2)	Maize	9.94	9.63	8.69	—	10.06	8.75	0.18	9.7
	Soyabean	—	—	—	35.5	35.06	34.40	0.25	5.2
	Total kg/ha	33.11	31.52	23.94	7.50	42.54	30.41	0.26	4.1
Kundasale (3)	Maize	8.38	7.75	7.68	—	7.56	6.63	0.17	5.7
	Soyabean	—	—	—	31.74	32.43	33.00	0.50	5.1
	Total kg/ha	40.94	27.82	19.24	27.42	44.64	33.13	0.26	4.5

N increased the crude protein content of maize under both systems of cropping. In monocropped maize, the differences were significant in Kundasale (1) and (2) at both 25 kg N and 50 kg N and in Kundasale (3) at 50 kg N only.

Similarly, under intercropping, the crude protein content of maize increased in the 25 kg N level in all trials, the differences being significant in Kundasale (1) and (3). At 25 kg N, intercropping depressed crude protein content of maize in two out of three trials, the difference being significant in Kundasale (1) and (3). A similar effect was noted at the zero N level. The crude protein content of intercropped soyabean increased in the 25 kg N level in two trials, the effect being significant in Kundasale (1) and (2). Monocropped soyabean significantly increased crude protein content in Kundasale (1) and (2). The results indicate the possibility of enhancing the crude protein content of intercropped soyabean with N application.

In general, applied N tended to increase the crude protein content of both maize and soyabean. Although intercropping tended to depress the crude protein content in some cases, the crude protein harvest of combined maize-soyabean was significantly higher than that of the monocropped system. Since soyabean contains a higher content of amino acids, including those deficient in maize, intercropping could substantially contribute to the protein intake, which is below the required minimum in most Asian regions. From a human nutrition point of view, therefore, intercropping will be of great importance.

Economics

A method commonly used to assess intercropping advantages is the Land Equivalent Ratio (LER), defined as the relative land area required for monocrops to produce yields obtained in intercropping.¹³ The yield increase shown by the LER could then be used to calculate the monetary advantage.

LER computed at various levels of N are given in Table 4. For convenience of comparison, data collected in the same season in different locations were grouped together, e.g.—Kundasale (1) and (2) and Peradeniya (4) and (5).

TABLE 4. Land Equivalent Ratio (LER) for intercropped maize-soyabean

	25 kg N/ha	0 kg N/ha
Kundasale (1) and (2)	1.40	0.95
Kundasale (3)	1.21	1.03
Peradeniya (4) and (5)	1.55	1.41
Peradeniya (6)	1.16	1.68

At 25 kg N, LER increased in all experiments. The highest LER was recorded for Peradeniya (4) and (5) 1.55 followed by Kundasale (1) and (2) 1.40. At zero N, the highest LER was for Peradeniya (6) and the lowest values of LER could be attributed to the lower yields obtained from intercrops compared to the monocrops. Comparison of the values of LER indicates better land utilization due to intercropping.

The total economic value of the produce obtained (Rs/ha) from both systems of cropping is shown in Table 5. The data was computed on the basis of market prices prevailing during the period of experimentation. In all experiments, regardless of N level, the intercrop system provided higher economic returns than the corresponding monocrop system.

TABLE 5. Economic returns (Rs/ha) of mono and intercropping at varying N levels

Expt. No.	Crop	Monocrop system				Intercrop system	
		N kg/ha	50	(Rs/ha) 25	0	(Rs/ha) 25	0
Kundasale (1 and 2)	Maize	5894.40	5618.10	4942.78	—	5664.15	4144.50
	Soyabean	—	—	—	1396.85	1427.55	1320.10
	Total	5894.40	5618.10	4942.78	1396.85	7091.70	5464.60
Kundasale (3)	Maize	8273.65	6078.60	4236.60	—	6385.15	3361.65
	Soyabean	—	—	—	3407.70	1857.35	2379.25
	Total	8273.65	6078.60	4236.60	3407.70	8442.50	5740.90
Peradeniya (4 and 5)	Maize	7183.80	4543.60	1274.05	—	4835.25	2041.55
	Soyabean	—	—	—	10345.90	5188.30	5449.25
	Total	7183.80	4543.60	1274.05	10345.90	10023.55	7490.80
Peradeniya (6)	Maize	4067.75	2901.15	1381.50	—	2916.50	1995.50
	Soyabean	—	—	—	3284.90	1089.85	752.15
	Total	4067.75	2901.15	1381.50	3284.90	4006.35	2747.65

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