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PRELIMINARY STUDIES OF INTERCROPPING COMBINATIONS BASED ON PIGEONPEA OR SORGHUM†

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SUMMARY

Various intercrops were examined in an alternate row pattern with pigeonpea or sorghum on both Alfisol (red soil) and Vertisol (black soil). The slow-establishing and later-maturing pigeonpea combined well with earlier cereals and legumes to give very large yield advantages as measured by the Land Equivalent Ratio. In the pigeonpea/cereal combinations, the earlier the cereal the bigger the yield advantage tended to be, attributed to improved use of resources over time as the difference in maturity periods of the component crops increased. Sorghum was generally more competitive than pigeonpea and intercropping advantages tended to be less. But even where there was little difference in maturity periods of the component crops, both sorghum/legume and sorghum/cereal combinations gave substantial and statistically significant advantages, suggesting that improved 'spatial' use of resources was also important.

The importance of intercropping in India was emphasized as far back as 1949, when Aiyer (1949) gave a very detailed description of the cropping systems prevalent in different regions where it is typically associated with the high-risk, low-rainfall situations of the smaller and poorer farmers. The Deccan Plateau of the central and south central parts of India, on which ICRISAT is situated, is one such region, with an annual rainfall between 500–1000 mm in a slightly bi-modal distribution and a risk of mid-season drought. There are two predominant soil types, Alfisols (red soils) and Vertisols (black soils). Alfisols vary in depth, are light in texture, often with compacted layers at a depth of only 15 to 30 cm, and have high infiltration rates but low water holding capacity (about 140 mm of available water per metre). Vertisols are deeper and heavier, with a high proportion of expanding montmorillonite clay, and tend to have low infiltration rates but high water holding capacity (about 225 mm of available water per metre). Both soil types are poor in nitrogen and phosphate but are generally assumed to have adequate available potash.

Alfisols are cropped only during the rainy season, though the main crops such as sorghum are frequently intercropped with some long-season crop such as pigeonpea so that the latter can utilise any residual soil moisture after the main growing period. The deeper Vertisols are traditionally cropped only during the post-rainy period, using moisture stored in the soil profile, but it has been emphasized that with 700 mm or more of annual rainfall they should be able to produce a rainy season crop in addition to the traditional post-rainy season one (Krishnamurthy, 1974; Rao, 1975).

Jodha (1979) has identified a number of 'development' factors which tend

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to reduce the importance of intercropping in areas such as the Deccan Plateau, including the introduction, or further increase, of irrigated crops. These are often grown as sole crops, perhaps because their production systems tend to preclude intercropping (e.g. as with paddy rice), or perhaps because the farmer is reluctant to risk reducing the yield of a high value crop (e.g. as with sugar cane). It may even be that the greater yield stability which farmers are said to associate with intercropping is regarded as less important under the more assured situation of irrigation. A further factor identified by Jodha is the introduction of new high-yielding genotypes of cereals, which also tend to be grown as sole crops; again there may be considerations of higher crop value, or possibly lower risk; or the recommended practices associated with these new genotypes may simply not embrace intercropping situations.

However, despite these trends towards sole cropping, intercropping still remains the dominant practice in many areas and there is clearly a need for more research in this field. Indeed, because of increasing evidence in the literature that intercropping can provide substantial yield advantages, there is a case for questioning whether some of the above trends towards sole cropping are in fact acceptable. This paper describes some of the early ICRISAT experiments on intercropping, the objectives of which were simply to gain some preliminary information on different combinations of the crops commonly grown in low-rainfall, high-risk regions.

MATERIALS AND METHODS

The experiments were conducted in 1975 and 1976 on an Alfisol and a Vertisol at the ICRISAT Center, about 25 km north-west of Hyderabad, India (17.5° N, 78.5° E at 545 m altitude). Physical and chemical characters of the soils on the experimental sites are given in Table 1. The mean annual rainfall at ICRISAT Center is 760 mm, with an average of 86% falling during June–October. Annual rainfall during 1975 and 1976 was 1104 mm and 822 mm, respectively: 1975 was characterized by rainfall well above average during the later growing season in September and October; 1976 had above average rainfall during the early

Table 1. *Characteristics of Vertisols and Alfisols on the experimental sites*

Depth (cm)	Composition: Sand (%)	Silt (%)	Clay (%)	Bulk density (g/cc)	Field capacity (Dry-wt basis) (%)	Wilting point (Dry-wt basis) (%)	Available nutrients: N (kg/ha)	P (kg/ha)	K (kg/ha)
				Vertisols					
0–25	20.5	15.9	63.7	1.3	36.5	19.0	137	9.2	739
25–60	30.6	18.7	50.8	1.4	42.0	18.5	164	13.2	624
				Alfisols					
0–18	64.5	6.0	29.6	1.5	14.5	5.0	181	10.4	256
18–35	45.8	7.2	47.2	1.6	17.0	8.0	216	7.6	232

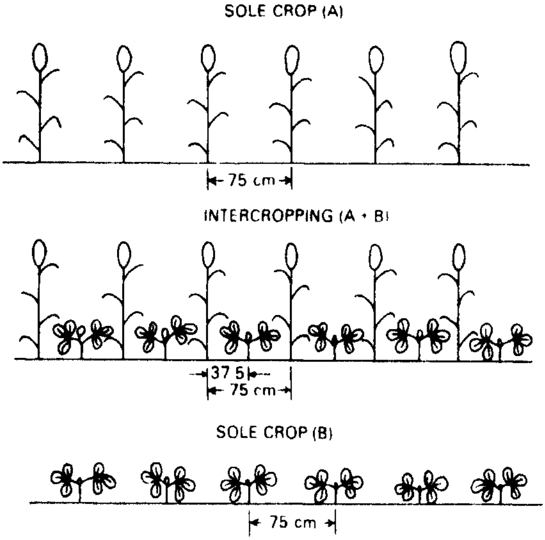

Fig 1 Planting patterns of sole crops and intercrops (Setaria and groundnut sole crops were in 37 5 cm rows in 1976)

part of the season in July and August but was particularly dry during the late growing period

In 1975, a range of 'intercrops' were grown in three 'cropping systems', namely (i) intercropped with sorghum, (ii) intercropped with pigeonpea, and (iii) as sole crops Intercrops and cropping systems were factorially combined in a 'strip plot' layout with four replications (Cochran and Cox, 1964) Sorghum and pigeonpea were also included as 'intercrops' to provide sole sorghum, sole pigeonpea and sorghum/pigeonpea intercropping treatments Sole crops were grown in rows 75 cm apart and the intercrop combinations were 'additive' in 37 5 cm rows (Fig 1) Details of crops, genotypes and populations are given in Table 2

Some changes were made in 1976 in the genotypes and intercrops (Table 2), but the same three cropping system treatments were continued Sorghum and pigeonpea were not included as intercrops in this second year but the inclusion of a 'no-intercrop' treatment provided for sole sorghum and pigeonpea plots Cropping systems were arranged as main plots and the 'intercrop' and 'no intercrop' treatments as sub plots, again with four replicates Some of the sole crop populations were low in 1975 so the row widths of sole crop groundnut and setaria were decreased to 37 5 cm in this second season (at the same within row spacing) and the populations of sorghum, pearl millet and pigeonpea were increased (Table 2).

Table 2. *Genotypes, maturity periods and plant populations as sole crops*

	1975			1976		
Crop	Genotype	Maturity (days)	Population (plants/ha)	Genotype	Maturity (days)	Population (plants/ha)
Setaria	H-1	80	Unthinned	H-1	80	Unthinned
Pearl millet	HB-3	85	100,000	HB-3	85	133,000
Sorghum	2077A	110	100,000	CSH-6	95	133,000
Maize	–	-	–	SB-23	95	50,000
Cowpea	57	80	Unthinned	1152	80	Unthinned
Soyabean	UPSS 38	115	Unthinned	–		
Groundnut	–		–	TMV-2	115	267,000
Pigeonpea	ST-1	185	30,000	ICP-1	170	40,000
Castor	–	–	–	157-B	150	40,000

All the crops in a given experiment were sown at the same time. Seeds were sown on the Vertisol in dry soil in mid-June, before the onset of the rains, and during the last week of June on the Alfisol, after the onset of rains. The experiments were kept weed-free by periodic hand weeding. Pests of pigeonpea and cowpea, especially Heliothis borer, were controlled by two sprays of 0.35% Endosulphan. All experimental sites received a basal dressing of 18 kg/ha N and 46 kg/ha P_2O_5 as diammonium phosphate and the non-legumes received an additional top dressing of urea to make the total N up to 80 kg/ha.

RESULTS AND DISCUSSION

As has been emphasized elsewhere (Willey, 1979), to assess accurately the possible yield advantages from a given intercrop combination, the maximum intercropping productivity should be compared with the maximum sole crop productivity. Experimentally, this means examining a sufficient range of sole crop and intercrop treatments, especially in terms of plant population and spatial arrangement, to identify these maximum productivity situations. But the experiments reported here were at an early stage in the development of the ICRISAT intercropping work, and the objective was simply to obtain initial indications of the relative merits of a range of different intercropping combinations. Yield advantages and competitive effects are presented, but it must be emphasized that for any given combination these were calculated from a single intercropping treatment which was standardized for experimental convenience.

Results are examined by means of the Land Equivalent Ratio (LER), which can be defined as the relative land area required for sole crop(s) to produce the yield(s) achieved in intercropping. This parameter is now the most widely used to examine intercropping effects; in effect it indicates relative yields and is particularly useful in providing a means of combining, and comparing, the yields from different crops. In this paper, an LER is presented for each individual crop to indicate competitive effects, e.g. an LER of 0.5 for a given crop indicates that it has produced in intercropping the equivalent of 50% of its sole crop yield. For examining overall yield advantages of intercropping, the total LER (sum of individual LERs) is used; in this case a total LER of, say, 1.20 indicates an overall yield advantage of 20%.

A statistical problem raised by the use of LERs is that they are probably not normally distributed, and subjecting them to an analysis of variance may thus be questionable. It has been pointed out, however, (S. C. Pearce, 1978 – Personal Communication) that this lack of normality probably has the effect of increasing the calculated standard errors, which will tend to increase the stringency of tests of significance based on these standard errors. Because of this reasoning, LSDs are presented with the LER values.

Sole crops

In 1975 a male-sterile line of sorghum was inadvertently sown instead of the intended hybrid, so no grain yield was obtained. However, vegetative growth was good and quite uniform, so total dry matter was measured to indicate yield levels and competitive effects. Yields of other crops were generally good over both soil types in this first season (Table 3), setaria and pearl millet yielding over 3000 kg/ha, soyabean and pigeonpea over 2000 kg/ha, with cowpea the only poor yielder at 820 kg/ha on the Alfisol and 720 kg/ha on the Vertisol. There was very little effect of soil type in this first season, presumably because the major difference between these soils is the better moisture holding capacity of the Vertisol, which was minimized by the prolonged wet season. Only pigeonpea, which was much the latest maturing crop, appeared able to respond to any possible moisture difference, producing the exceptionally high yields of 2148 kg/ha on the Alfisol and 2522 kg/ha on the Vertisol.

In 1976 yields were generally lower, though sorghum and maize produced over 3000 kg/ha on the Alfisol (Table 3). The low yields were no doubt partly due to the excessive rains during the peak growing period in August, which were presumably also responsible for the lower yields on the poorer-drained Vertisol compared with the Alfisol. A further factor was probably the early cessation of the rains. As in 1975, however, pigeonpea was still able to benefit

Table 3. *Sole crop grain yields (kg/ha)*

Crop	1975 Alfisol	1975 Vertisol	1976 Alfisol	1976 Vertisol
Setaria	3290	3520	1780	1670
Pearl millet	3310	3080	2110	1360
Sorghum	19400*	21690*	3500	2290
Maize			3180	2280
Cowpea	820	720	1310	750
Soyabean	2180	2140		
Groundnut (pods)			1230	480
Pigeonpea	2148	2522	800	1250
Castor			730	

* Total dry matter (see text)

to some extent from the better end-of-season moisture retention of the Vertisol, producing 800 and 1250 kg/ha on the Alfisol and the Vertisol, respectively.

Pigeonpea intercropping

LER values for the individual crops and total LERs for both crops combined for the intercrop combinations with pigeonpea in 1975 are shown (Fig. 2), grouping cereals and legume intercrops separately and in order of increasing maturity period. The earliest cereal, setaria, produced an individual LER of approximately unity for each soil type, indicating that it was virtually unaffected by pigeonpea competition, whereas the pigeonpea showed slight effects of setaria competition on the Alfisol but none on the Vertisol. The combined intercrop yields were thus roughly equivalent to the additive sole crop yields, and total LERs showed yield advantages for intercropping of 83 and 104% for the Alfisol and Vertisol respectively. The slightly later maturing (85 days) and very vigorous pearl millet also showed little evidence of suffering competition from pigeonpea, but this crop did reduce yield of the latter especially on the Alfisol. Thus overall advantages were lower than with setaria, being 33 and 86% for the Alfisol and Vertisol respectively. Sorghum, the latest maturing cereal (110 days), suffered competition from the pigeonpea but the latter suffered less competition than with pearl millet, with yield advantages of 20 and 57% for the Alfisol and Vertisol respectively.

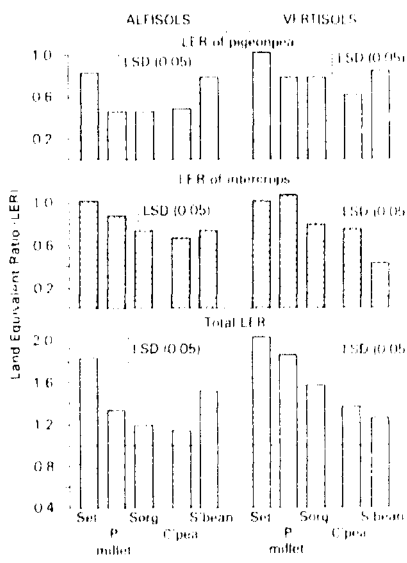

Fig. 2. Land Equivalent Ratio (LER) of pigeonpea intercropping systems at ICRISAT Center in 1975.

Considering the legume intercrops, cowpea and soyabean both suffered an appreciable, and roughly similar, degree of competition from pigeonpea on the Alfisol, but on the Vertisol the cowpea suffered less competition and the soyabean much more. The effect of these legumes on the pigeonpea is of particular interest because the earlier maturing cowpea (80 days) was clearly much more competitive than the later soyabean (115 days). This effect differed from the cereals, where the earliest maturing setaria had least effect on the pigeonpea. Presumably the different growth habits of the legume intercrops must have contributed to their different competitive effects, the upright soyabean being less competitive than the spreading cowpea. Below-ground competition could also have been a factor, because cowpea is noted for being a very strong competitor for below-ground resources, particularly in conditions of poor fertility. The overall yield advantages of these legume/pigeonpea combinations was not consistent; soyabean/pigeonpea was better on the Alfisol (51% advantage) but cowpea/pigeonpea better on the Vertisol (37% advantage). With the exception of the soyabean/pigeonpea on the Alfisol, yield advantages tended to be lower than with the cereal/pigeonpea combinations.

In 1976, sorghum was replaced as an intercrop by a rather earlier maturing maize (95 days compared to 110 days) and the soyabean was replaced by groundnut of similar maturity (115 days). The cowpea genotype was also changed and castor was added as an intercrop on the Alfisol. The cereal/pigeonpea advantages again decreased with increase in growing period on the Alfisol, though there was little difference between the combinations on the Vertisol (Fig. 3). Setaria/pigeonpea, although still the best combination, produced rather lower advantages than in 1975 because the setaria showed more effect of pigeonpea competition. Maize/pigeonpea proved roughly comparable with the previous sorghum/pigeonpea, though the maize, despite its earlier maturity, appeared to be more competitive than the sorghum.

The cowpea genotype proved to be better than the one used in the previous season. It was less competitive, being about equal with the pigeonpea, and yield advantages were 55% and 63% on the Alfisol and Vertisol respectively. The pigeonpea was more competitive than the groundnut on the Alfisol and the overall advantage was quite high at 53%. On the Vertisol, the groundnut was badly suppressed and the advantage was only a (non-significant) 22%, probably because (as stated earlier) groundnut is not well adapted to the Vertisol, especially under the heavy rainfall conditions that occurred during the early part of this season.

Castor and pigeonpea did not perform well together. The castor was slightly more competitive but the overall advantage was only 12%, which was not significant, presumably because these two crops have very similar growth patterns, growing slowly at first and then having a relatively long season of indeterminate growth. Both crops are also noted for their deep root systems and ability to yield well under low moisture conditions on the Alfisol; there is thus probably little basis for complementarity in terms of the use of below-ground resources.

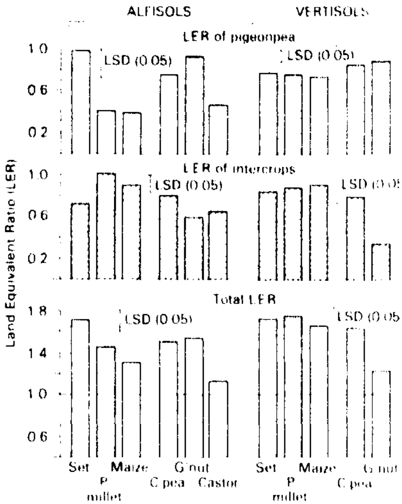

Fig. 3. Land Equivalent Ratio (LER) of pigeonpea intercropping systems at ICRISAT in 1976.

Sorghum intercropping

The sorghum intercropping systems (Figs 4 and 5) are shown in a similar pattern to that of pigeonpea. Sorghum was generally much more competitive than pigeonpea and the intercrops tended to make a smaller contribution to final combined yield. Overall yield advantages were small in 1975 and most did not reach significance (Fig. 4). The early setaria suffered more competition from the sorghum than the slightly later, but taller and more vigorous, pearl millet, but the sorghum itself produced more yield with setaria, so overall yield advantages with these two cereal intercrops were little different. This pattern of results was very similar for both soil types, though no yield advantage reached significance.

On the Alfisol, soyabean seemed a rather better intercrop than the cowpea because it not only made a slightly greater contribution itself but also had less effect on sorghum yield. This pattern was very similar to, though less marked than, the one which occurred when these were intercropped with pigeonpea. On the Vertisol, both soyabean and cowpea were drastically suppressed by the sorghum, and there was no evidence of yield advantages, probably because the wet year made the Vertisol inherently unsuitable for these two legume crops, further aggravated by the severe competition from sorghum. The pigeonpea/sorghum, repeated in Fig. 4 for comparison, was little different from the soyabean and cowpea combinations on the Alfisol but much better on the Vertisol by virtue of a much better pigeonpea yield.

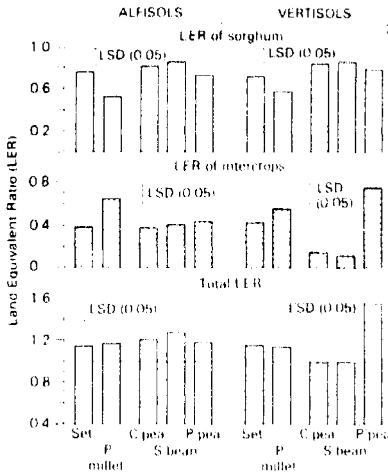

Fig. 4. Land Equivalent Ratio (LER) of sorghum intercropping systems at ICRISAT in 1975.

In 1976 (Fig. 5) the contribution of the sorghum base crop was considerably higher than with comparable crops in 1975, presumably due to the higher sorghum population in the second season. This effect may also have contributed to the rather higher total LER values which were achieved, all of which reached significance. On the Alfisol, the addition of the maize crop made the pattern of cereal intercrop effects even clearer. As the maturity and height of the intercrop increased (in the order setaria, pearl millet, maize) the greater the contribution from the intercrop but the lower the sorghum yield. Thus there was relatively little difference in overall advantages, though the pearl millet/sorghum combination was best with an advantage of 42%. On the Vertisol, both the sorghum and cereal intercrops gave individual LER values of well over 0.50 and overall advantages were extremely high. Pearl millet/sorghum was again the best combination, giving a yield advantage of 86%.

The cowpea/sorghum combination on the Alfisol was very similar to 1975, with a yield advantage of 33%. Groundnut was markedly suppressed on the Alfisol but a very high sorghum contribution (recorded as 10% more than the sole crop) made the groundnut/sorghum combination appear quite good, with an overall advantage of 38%. On the Vertisol, cowpea and especially groundnut gave a poor contribution, but very high sorghum yields again made the overall advantages quite good at 35% and 22% respectively. As might be expected from the differences in maturity periods, castor proved more compatible with

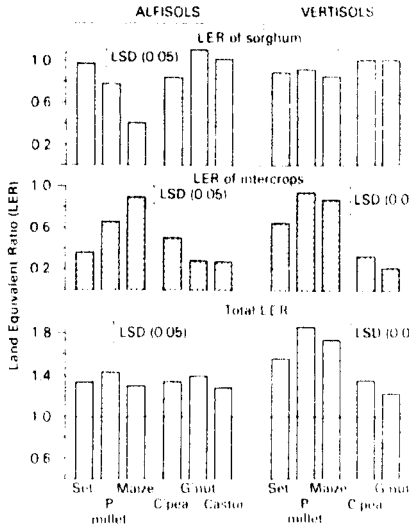

Fig. 5. Land Equivalent Ratio (LER) of sorghum intercropping systems at ICRISAT in 1976.

sorghum than with pigeonpea. It was very suppressed by the sorghum, achieving an individual LER of only 0.27, but the sorghum yield was not reduced so the average yield advantage was 27%.

CONCLUDING COMMENTS

It was emphasized earlier that one of the problems of examining intercropping effects on the basis of single treatments of sole crops and intercrops is that comparisons may be biassed if any treatment is not at optimum population and spacing. The most likely bias is that intercropping advantages are underestimated, because little is yet known of the optimum population and spatial arrangement requirements for intercropping, though there can be an overestimate of intercropping advantages if either sole crop is not at its optimum. For example, this may have occurred to some extent with the sorghum in 1976 because sorghum yield in several of the combinations was as high in intercropping as in sole cropping. Nevertheless, despite the problems with this type of experiment, some interesting patterns obviously emerged.

The most obvious effect was that distinct differences in the maturity periods of the component crops usually resulted in quite large yield advantages. This type of combination clearly allows for better use of resources over time, as has been observed by a number of workers (Andrews, 1972; Freyman and

Venkateswarlu, 1977; IRRI, 1974, 1975; Osiru and Willey, 1972; Willey and Osiru, 1972). The present experiments emphasized the possible importance of this effect, particularly in the cereal/pigeonpea combinations, where the intercropping advantage generally increased with differences in maturity period.

However, the experiments also emphasized that factors other than temporal differences can also be important. Thus the sorghum/low-growing legume combinations, which often had little difference in maturity period, also gave quite substantial advantages. With these combinations it is relatively easy to envisage ways in which differences between the crops might result in better 'spatial' use of resources, e.g. canopy differences, possible differences in rooting pattern, or legume/non-legume nitrogen interactions. But substantial advantages also occurred with the sorghum/cereal combinations, where there appeared to be little difference in either maturity periods or characters likely to give better use of the spatial resource. Thus the results emphasize that there is a great deal yet to be learned about the compatability of different crops in intercropping and the kind of combinations which may confer yield advantages.

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