A REVIEW OF MAIZE-BEANS AND MAIZE-COWPEA INTERCROP SYSTEMS IN THE SEMIARID NORTHEAST BRAZIL[1]

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ABSTRACT - Fifty-one experiments on maize-beans and 34 on maize-cowpea intercropping systems conducted mostly in the semiarid Northeast Brazil were analysed to get an understanding of the performance of these intercrops in terms of their productivity as well as stability. Both the intercrop systems produced higher yields over their respective sole crops under a wide range of agroclimates; the average advantage with maize-beans was 32%, while that from maize-cowpea was 41%. The optimum row proportion for maize-beans was one maize: three beans, requiring 50% of sole crop maize population and 75% sole bean population. In maize-cowpea, alternate rows or one maize: two cowpea arrangement with about 50% of sole maize density and 100% of sole cowpea population seemed to be optimum. The intercrop yields showed the same degree of variability as those of the sole crops, but the intercrops being more productive were somewhat less risky than the sole crops. The intercrops failed less frequently compared to sole crops to meet specified incomes or yields. Sorghum seemed to be a good alternative to the traditional cereal because of its improved and consistent performance. Future research needs are discussed for further yield improvement in these two intercrop systems.

Index terms: sole cropping, land productivity, stability, sorghum, *Phaseolus vulgaris* L., *Vigna unguiculata* (L.) Walp.

UMA REVISÃO DOS SISTEMAS DE CONSÓRCIO COM MILHO-FEIJÃO E MILHO-CAUPI NO SEMI-ÁRIDO DO NORDESTE DO BRASIL

RESUMO - Foram analizados 51 experimentos com consórcio milho x feijão e 34 de milho x caupi, no semi-árido do Nordeste brasileiro, para análise do comportamento destas culturas quanto à produtividade e à estabilidade. Os dois consórcios apresentaram produções mais altas do que as culturas em plantios isolados sob diferentes condições agro-climáticas. A vantagem com milho x feijão foi de 32%; com milho x caupi foi de 41%. A proporção ótima de fileiras para milho x feijão foi uma fileira de milho para três fileiras de feijão com populações de 50% e 75% das culturas isoladas para milho e feijão, respectivamente. Para milho x caupi fileiras alternadas e uma fileira de milho para duas de caupi, com populações de 50% e 100% das culturas isoladas, para milho e caupi respectivamente, parecem melhores. As produções nos consórcios mostraram o mesmo grau de variação que nas culturas isoladas. Os consórcios, por serem mais produtivos, são menos sujeitos aos riscos do que as culturas isoladas. As perdas referentes à obtenção de específico retorno foram menos freqüentes nos consórcios que nas culturas isoladas. A cultura do sorgo parece boa alternativa para substituir o milho nos sistemas tradicionais, dado o seu comportamento consistente. Discute-se a necessidade de futuras pesquisas para um posterior aumento de produção nos dois consórcios.

Termos para indexação: culturas isoladas, produtividade da terra, estabilidade, sorgo, *Phaseolus vulgaris* L., *Vigna unguiculata* (L.) Walp.

INTRODUCTION

Intercropping is a traditional cropping system widely practised by small farmers in the semiarid Northeast of Brazil where crops are grown primarily under rainfed conditions and the risk is high. Of the several systems in this region, maize-cowpea in the drier region of the 'sertão' (350-600 mm annual rainfall) and maize-beans in the somewhat assured rainfall area of the 'agreste' and 'mata' (700-1500 mm annual rainfall) are particularly important, for the components are the basic food crops. Authentic figures on the extent of intercropping in Northeast are not available but at the country level it is estimated that nearly 56% of the total cultivated maize and 64% of beans is under intercropping (Fundação IBGE 1975). The area of these crops under intercropping would be much higher in the Northeast, as for example, more than 90% of the cowpea grown in the Northeast is seen in intercropping. Though intercropping in general has not received as much attention as cash crops, these two intercrop systems in recent years have been examined in the Northeast Brazil by a number of researchers. The farmer's objective in these systems is to have some of both the cereal and the legume; so the

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overall land productivity and the probability of satisfying the minimum subsistence needs are important criteria for evaluating them. There is a good deal of evidence throughout the semiarid tropics that intercropping of maize-beans and maize-cowpea gives higher yields compared to their respective sole crops (Willey & Osiru 1972, Karel et al. 1982, Francis & Sanders 1978, Ahmed & Rao 1982).

Apart from higher yields, intercrops are also considered to be less risky than the sole crops, but very little quantitative evidence is available on this aspect. Understanding the risk or stability of performance is not as straightforward as is the yield advantage, partly due to the lack of information covering a range of environments and appropriate methods of evaluation. Rao & Willey (1980) while examining the stability of sorghum-pigeonpea suggested that calculating the probability of failure of each system for any required income expressed the risk more clearly than the other methods they used, and by this method they found that sorghum-pigeonpea intercrop fails less frequently than the sole crops. This is understandable from the diverse growth habits of the components; sorghum uses the rainy season resources while pigeonpea uses the postrainy season resources which gives an excellent scope for compensation. Similar observations were reported by Francis & Sanders (1978) in maize-beans in Columbia, and Baker (1980) in sorghum-groundnut in Nigeria. Contrary to the above, Trenbath (1974) observed no appreciable improvement in stability of mixtures of genotypes or multilines where the components are not as widely different as in the above intercrops. There may be several means by which an intercrop system exhibits greater stability compared to sole crops but the chief mechanism is by compensation of one component when the other fails. Generally the scope for compensation would be higher when the failure of a component occurs in early stages than when it occurs late in the season.

This paper reviews and summarises the available experimental results on maize-beans and maize-cowpea intercropping systems in Northeast Brazil. It further examines (i) whether there is any evidence for greater stability in both these intercrop systems compared to their respective sole crops and (ii) how maize compares with an alternative cereal such as sorghum particularly in the dry areas. Based on the available information promising areas for future research are suggested.

MATERIAL AND METHODS

Results of 51 experiments on maize-beans and 34 on maize-cowpea conducted mostly in the semiarid northeast Brazil during 1974/1982 were collected from different sources (Aidar et al. 1979, Araujo et al. 1976, Bezerra et al. 1979, Cardoso et al. 1981, Relatório Técnico Anual do CPATSA 1979, Empresa Pernambucana de Pesquisa Agropecuária 1981, Fontes et al. 1976, Oliveira Filho & Lordelo 1982, Pereira Filho 1981, Santa-Cecília & Vieira 1978, Serpa & Barreto 1981, Serpa & Barreto 1982a, 1982b, Siqueira & Sobral 1979, Souza Filho & Andrade 1982 and Vieira 1980). These represented 59 different situations for maize-beans and 42 for maize-cowpea either because the experiments were conducted at more than one location or examined at different fertility levels and row proportions. Only the results from Northeast Brazil were used for stability analysis (Fig. 1). The results of maize-beans from three other sites (Viçosa, Paulo Cândido and Rio de Janeiro) were considered only in the respect of agronomic factors. The trials were entirely rainfed and used optimum populations for sole crops which were 40,000 to 50,000 plants/ha for maize and cowpea and 200,000 to 300,000 plants/ha for beans. Only those intercrop treatments which conformed to the following widely used populations were considered in the present analysis; 20,000 to 25,000 plants/ha of maize in both the systems and about 150,000 plants/ha of beans in row arrangements of 1 maize : 2 beans or 1 maize : 3 beans in maize-beans combination and 100% sole crop density of cowpea in 1 maize : 1 cowpea or 1 maize : 2 cowpea in maize-cowpea combination. Most of the studies used improved genotypes such as maize: Centralmex, Piranão and Azteca, beans: IPA - 74 - 19, IPA 1 and P 589, and cowpea: Pitiuba and Serido. In addition to mean yields of each system, information on fertilization and rainfall was also gathered wherever possible.

Yield advantages and effect of different agronomic factors

Yield advantage of intercropping was assessed by the Land Equivalent Ratio (LER) which expresses yields as sum of the land areas required for the two sole crops to produce the same yields as from one hectare of intercropping. LERs were computed for each experiment separately using the sole crop yields and finally the average advantage of each combination was calculated. The average effects of different populations, row arrangements or fertility levels were similarly calculated across trials that examined these factors. Two or more row arrangements were

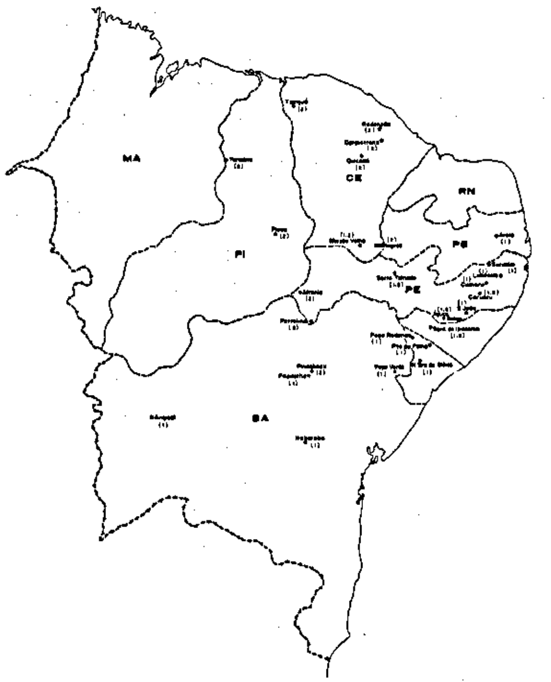

FIG. 1. Locations in Northeast Brazil where the maize-beans (1) and maize-cowpea (2) experiments reviewed in the present study were conducted.

evaluated only in maize-bean combination in seventeen trials, and studies with different populations of both components at comparable levels were available only in maize-cowpea. Fewer trials examined different genotypes and fertility levels in both the combinations. To observe how the intercrop advantage was related to fertility and water, LERs in each combination were plotted against the applied nitrogen and the rainfall received during the growing season. These were possible with 37 and 29 observations in maize-beans and 36 and 30 observations in maize-cowpea for the above two relationships respectively. Though the applied phosphorus across the trials was not constant, its effect was not considered here because the levels varied within a narrow range compared to nitrogen and the effect of nitrogen was generally much greater than that of phosphorus.

Evaluation of stability

Stability was evaluated by the following methods:

1. Comparing coefficients of variation of different systems.

2. By regressing yields of each system against an environmental index. The index was based on yields of different systems on the assumption that yield, as a product of the integrated effect of various environmental factors, describes well any given environment. It was calculated for each location (or experiment) by subtracting the mean yields of all locations (an average environment) from the mean yield of that particular location; positive values indicated favourable environments and negative values indicated poorer environment as compared to the average. The index was a combined one taking all the systems being compared into account, viz, sole maize, sole legume, 'shared sole crop' (see later) and the intercrop. Since maize and legumes have different yield potentials and different values their yields under different systems at each location were expressed on a relative scale taking their respective mean sole crop yields as 1.0. The relative yields of the component crops in intercropping were combined later. The performance of the systems was compared by mean (x), slope of the regression (b) and goodness of fit of the regression (r^2) (Rao & Willey 1980). The stability of sorghum vs maize was compared by the same technique using the data of fourteen trials conducted mostly in the state of Pernambuco.

3. Calculating the probability of failure (or risk) of each system at specified incomes or yield. Assuming that the data follow normal curve, the probabilities were calculated by computing the standard normal deviate $(\frac{x - \bar{x}}{s})$ where x - specified income or yield, $\bar{x}$ mean and s - standard deviation) and referring to the normal curve tables (Snedecor & Cochran 1974).

In all the comparisons of intercropping vs sole cropping systems, in addition to sole maize and the sole legume another system of sole cropping 'shared sole crop' was also included. This latter represented a system where both the maize and the legume were grown as sole crops in the same proportion as represented by the average yield proportion harvested in intercropping. On this basis the proportion of crops in shared systems corresponding to the maize-beans and maize-cowpea intercrop systems were 0.53 ha maize and 0.47 ha beans and 0.56 ha maize and 0.44 ha cowpea respectively. The intercrop vs shared crop comparison not only avoids bias due to changes in yield proportion of crops but also is particularly desirable considering that the shared system represents an alternative to meet both the components.

The data used in the present analysis, although covered many locations, represented only a few years at any particular location. In the absence of sufficient time-series data we could not measure stability in the strict sense of variability over time which is very important, for a farmer at any particular location experiences risks over years. Also, in the absence of replicate data, within site variation could not be considered.

RESULTS AND DISCUSSION

Yield advantages

The average yield advantage of intercropping expressed by Land Equivalent Ratio (LER) was

32% in maize-beans and 41% in maize-cowpea over their respective sole crops (Table 1). In other words these two intercrops require respectively 24% and 29% less area to match the yields of the corresponding sole crops. Thus, these intercrops would be particularly advantageous where labour and/or land is limiting, for the farmer is required to cultivate less area and he can use some portion of his land after meeting his food needs to other cash crops. Both maize-beans and maize-cowpea intercrop systems gave an advantage of 20% or more (that is of pratical value) in about 70% occasions. The yield advantage observed here follows closely those reported for these systems elsewhere (Willey & Osiru 1972, Francis & Sanders 1978, Karel et al. 1982) as well as of other similar cereal-legume combinations (Ahmed & Rao 1982, Reddy & Willey 1981).

Effect of agronomic factors

The effect of different row proportions in maize-beans is presented in Fig. 2. There was no significant difference between row arrangements of 1 maize : 1 beans, 1 maize : 2 beans and 1 maize : 3 beans with regard to their overall yield advantage, although the proportional yields of the components changed markedly. The alternate row arrangement produced almost 'full' yield of maize but gave very poor yield of beans due to severe competition of maize. Therefore, this arrangement would be acceptable only in regions where maize is the principal crop as in Southeastern Brazil. There, it compared well with the current recommended practice of mixed planting of both crops in the same row (Ramalho et al. 1982). The bean performance improved with a higher sown proportion in 1 maize : 2 beans and 1 maize : 3 beans. In the latter system beans maintained its yield per plant while maize more than double its yield per plant. Less variability in the total advantage and a higher proportion of bean yields make this arrangement more preferred over the 1 maize : 2 beans, particularly for small farmers of Northeastern Brasil. However, increasing the sown proportion of beans higher than in 1 : 3 (eg. 1 maize : 4 beans) was not advantageous as bean yields did not increase proportionately and compensation from maize remained low.

Few studies examined different row proportions in maize-cowpea, and a majority of them used either 1 maize : 2 cowpea or alternate rows making the comparison difficult. Considering that cowpea canopy is bigger than that of beans, either of these arrangements appears to give the potential advantage of this combination provided the spacing between maize rows does not increase beyond 2 m. However, specific studies may be required to see whether yield proportions change unfavourably at the extreme situations of moisture and/or fertility.

We did not come across many experiments that evaluated factorial combinations of different populations of maize and beans, but most studies included a few population treatments, often confounded with spatial arrangement. Maize being the dominant crop its population is critical for an optimum balance of the components. The effect of maize population on relative yields meaned over thirteen trials (that examined these against a constant bean population) is shown in Fig. 3. Maize yield increased with increase in its population but it caused a simultaneous decrease in bean yields. Considering the total advantage, around 20,000 plants/ha seemed to be optimum for intercrop maize. Studies with bean populations against a constant maize population were few, but most studies suggest that the requirement of bean population for intercrop would be proportional to the area it occupies in relation to the sole crop. At a sole crop optimum density of 250,000 plants/ha, the optimum for 1 maize : 3 beans at a constant 50 cm row spacing works out 150,000 plants/ha.

The relative yields of maize-cowpea intercrop as affected by different populations are shown in Fig. 4. The relative yield of each component increased with increase in its population but that resulted in a decrease in the yield of the other component. Only the highest cowpea population (50,000 plants/ha) gave a reasonable cowpea yield and even this density produced only 50% of the sole crop yields in combination with high maize populations. To achieve a high proportion of cowpea yields combined with a high total advantage one should, therefore, have a 'full' population of cowpea and a low population of maize (17,500 to

TABLE 1. Yields of maize-beans and maize-cowpea intercropping systems along with their respective sole crops.

System	Fertilized[1]			Unfertilized[1]			Mean over all experiments	
	Yield (kg/ha)	Standard deviation	CV (%)	Yield (kg/ha)	Standard deviation	CV (%)	Yield (kg/ha)	LER
				Maize-Beans				
Sole maize	3229	1691	52	810	402	50	2614	
Sole beans	1201	561	47	569	265	47	1040	
Shared sole								
Maize	1711	906	53	429	220	51	1385	
Beans	564	267	47	267	129	48	488	
Total	2275	1024	45	696	303	43	1873	
Intercrop								
Maize	2441	1575	64	482	328	68	1943	0.70
Beans	647	319	49	447	248	55	596	0.62
Total	3088	1609	52	929	435	47	2539	1.32
				Maize-Cowpea				
Sole maize	2699	1341	50	1081	611	56	2160	
Sole cowpea	885	460	52	544	302	55	771	
Shared sole								
Maize	1511	751	50	605	342	56	1210	
Cowpea	389	202	52	239	133	55	339	
Total	1890	848	45	844	426	50	1548	
Intercrop								
Maize	2055	1149	56	858	489	57	1655	0.79
Cowpea	531	350	66	318	211	66	460	0.62
Total	2586	1282	50	1176	597	51	2115	1.41

[1] Number of observations in fertilized and unfertilized trials were 44 and 15 in maize-beans and 28 and 14 in maize-cowpea respectively.

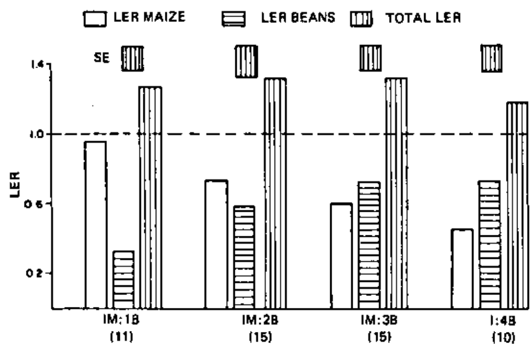

FIG. 2. Effect of different row arrangements on LERs in maize (M) - beans (B) intercropping (Numbers in perentheses are experiments over which results were averaged.).

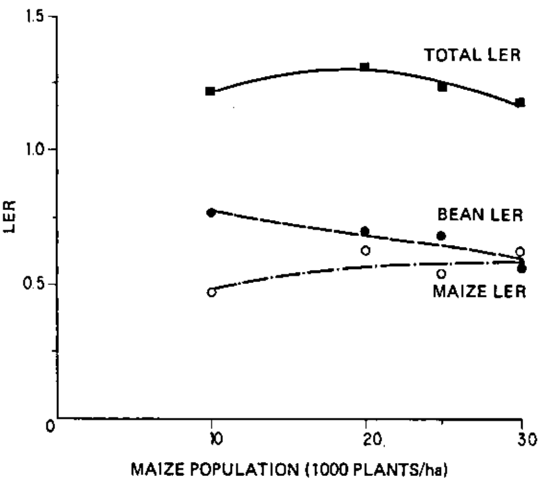

FIG. 3. Effect of maize populations on LERs in maize-bean intercropping (mean of thirteen trials).

25,000 plants/ha). Interestingly, the requirement of maize population works out similar in both systems which is about half of the sole crop optimum.

Very few studies in Northeast Brazil compared a reasonable number of genotypes in both sole and intercropping simultaneously. One study that examined 10 to 11 maize genotypes in seven different environments indicated significant correlations between sole and intercrop yields in four situations, while in the remaining three there was no significant correlation. Similarly, in three out of five trials that evaluated different bean genotypes, the intercrop yields were significantly correlated with those under sole cropping, while there was no such relationship in the remaining two. These results do not give any definite clues as to whether there is scope for genotype selection and whether selection under sole cropping is valid for intercropping also. In dominant species such as maize there may be less scope for selecting genotypes specifically for intercropping but in the dominated species (eg. cowpea or beans) considerable scope might exist. However, conflicting reports are seen in the literature, while Francis et al. (1978) reported a significant relationship between sole vs intercrop bean yields and hence recommended screening of beans under sole cropping. Wein & Smithson (1981) observed significant genotype x system interaction for cowpeas and advocated genotype evaluation in intercropping. Genotype evaluation has so far been a much neglected area in the Northeast, and we strongly recommend more studies in the future involving a large number of genotypes with varied plant characters so that characters associated with better intercropping performance are identified and that they can be employed as selection criteria in breeding programs.

The relationships of LER vs applied nitrogen and LER vs rainfall during cropping period are plotted in Fig. 5 and 6 respectively. LER advantage did not show any discernible relationship with nitrogen or rainfall in both maize-bean and maize--cowpea intercrop systems. There was considerable variability in the data which could be due to marked differences in the growing conditions across the experiments including native fertility, proportion of rainfall actually available to crop growth, and management, so these results have to be viewed cautiously. Nevertheless, they do point out that the benefits of intercropping do not disappear with fertilization or better moisture conditions. In the experiments that studied fertilization vs no fertilization simultaneously (Fig. 7), LERs were high where no fertilizer was applied, which indicates that under nutrient stress the intercrop yields were less variable than those of the sole crops. The diverse crops in intercrop systems might have exploited the limited nutrients under unfertilized situation more

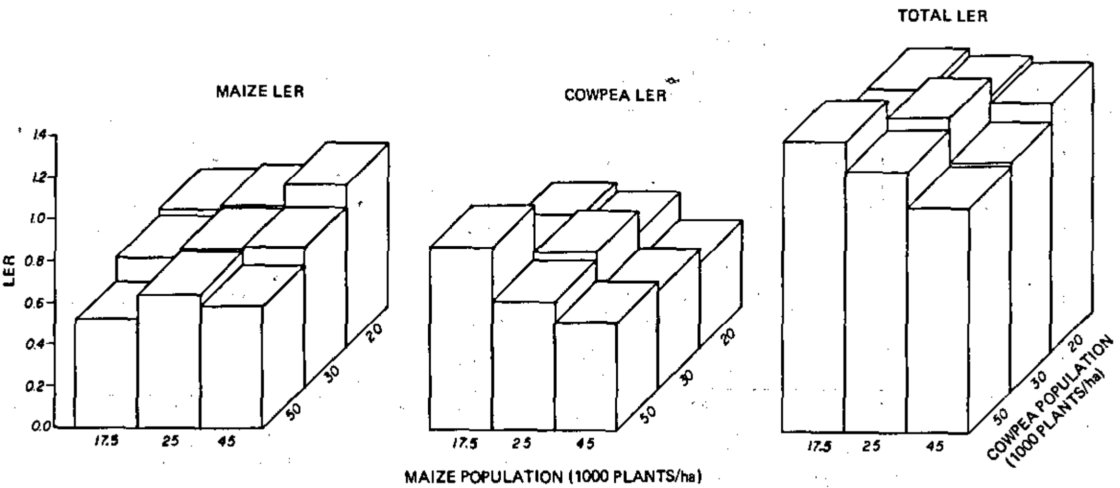

FIG. 4. Effect of different populations of maize and cowpea on LERs in maize-cowpea intercropping (mean of five trials).

efficiently than the sole crops. But under fertilized situations other factors such as moisture might have restricted the response to the applied nutrients. To our knowledge no studies have been made in the Northeast on the performance of these intercrops in relation to different levels of water application to understand clearly whether they have any stability mechanism against moisture stress.

Evaluation of yield stability

For homogenity the experiments were grouped into "with and without fertilization", and within each coefficient of variation (CV%) was calculated for different systems (Table 1). The variability in general was high for all systems because of large differences in yields across the experiments, but for a given system it was similar for fertilized and unfertilized experiments. Cowpea yields, in whatever form it was grown, showed greater variability than those of beans, and as a result maize-cowpea systems presented higher CVs compared to maize-beans systems. This points out the diverse conditions under which the cowpea based systems were grown. In the maize-beans trials, the CV of sole maize was higher than for sole beans. The variability of these components increased in intercropping presumably due to competition, but the CV of the total intercrop yields was of the same order as that of the sole crop. Interestingly, the shared sole crop showed the minimum CV. In maize-cowpea combination, both the sole maize and the sole cowpea showed similar coefficients of variation. The intercrop CV compared with either that of the sole crops in fertilized experiments but in unfertilized experiments it was lower than those of both the sole crops. The shared system again showed the lowest CV.

The coefficient of variation merely describes the variation around the mean and as such did not bring out clearly the risk associated with different systems. Particularly the shared vs intercrop comparison can be misleading as the combined yields of these systems represented yields of different species with different values. Moreover, the intercrop yields even after accounting for the variability were still higher than those of both the sole crops. So the results of coefficient of variation have to be considered in the light of other methods discussed below.

The regressions of relative yields of sole crops and intercrops against an environmental index are shown in Fig. 8 and 9 for maize-beans and maize-cowpea respectively. The data of all experiments were considered as each one represented a different environment. The regression of the sole legumes in both combinations had a slope less than one indicating that bean and cowpea yields were stable.

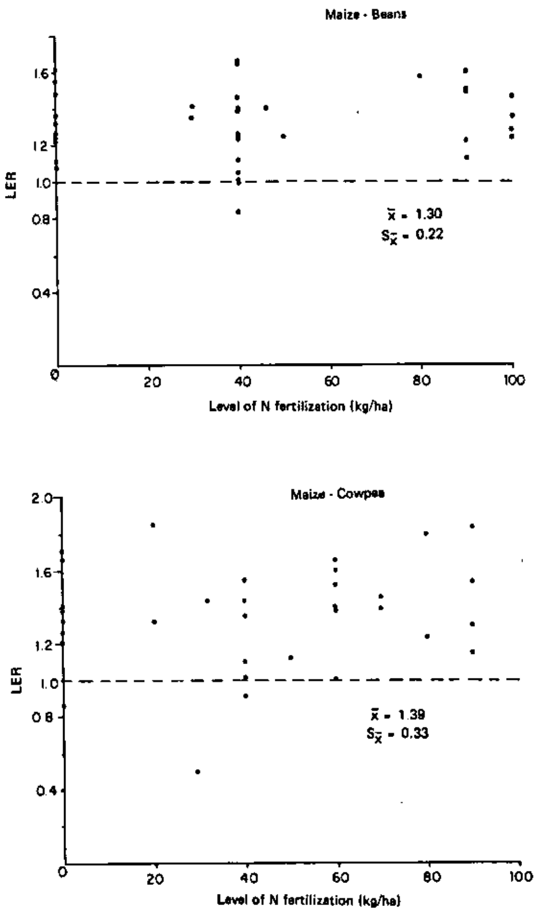

FIG. 5. Relationship of LER advantage with applied nitrogen in maize-beans and maize-cowpea intercropping systems. (Based on 37 observations in maize-beans and 36 in maize-cowpea).

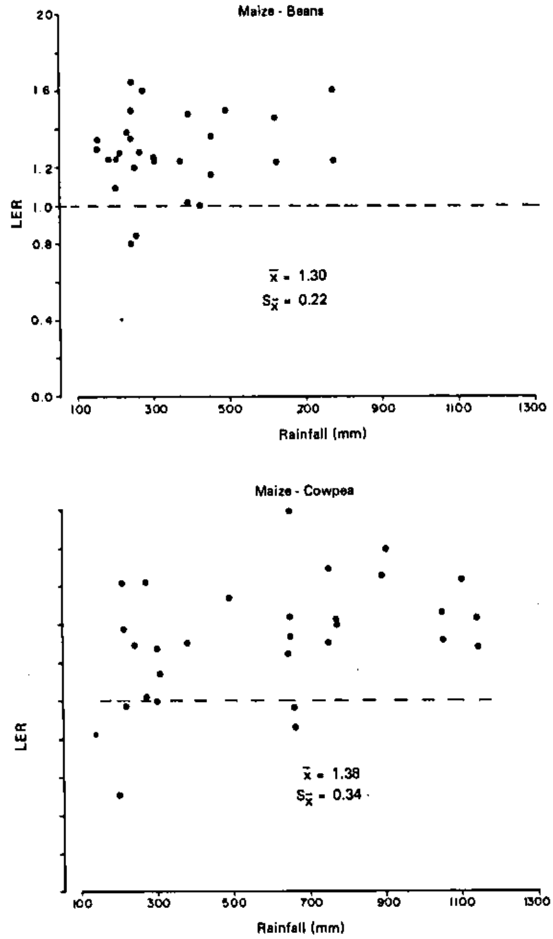

FIG. 6. Relationship of LER advantage with seasonal rainfall in maize-beans and maize-cowpea intercropping systems. (Based on 29 observations in maize-beans and 30 in maize-cowpea).

This also means that these legumes were less responsive to favourable environments, and the response was less predictable because of low r^2 value. The slope of sole maize regression was close to 1.0 indicating an average stability for maize and its average response to inputs. The shared crop regression parameters closely followed those of sole maize partly because it had a greater proportion of maize. The response of shared crop, however, was predictable better than that for sole maize. The intercrop regression, in both combinations, was above all other regressions in most environments ($\bar{x}$ = 1.31 or 1.36) and showed extremely good fit. A slope of >1.0 suggests that intercropping was advantageous particularly under favourable conditions and was inferior to sole legumes in unfavourable environments. Poor growing conditions may be the result of low fertility, poor management and low and irregular rainfall, the latter being the most common limiting factor in the semiarid Northeast. There is no evidence in the present as well as past results that intercropping advantage is limited by nutrient stress (Fig. 5 and 7, Ahmed & Rao 1982). But where moisture is limiting the intercrops, having a higher population density, perhaps may experience

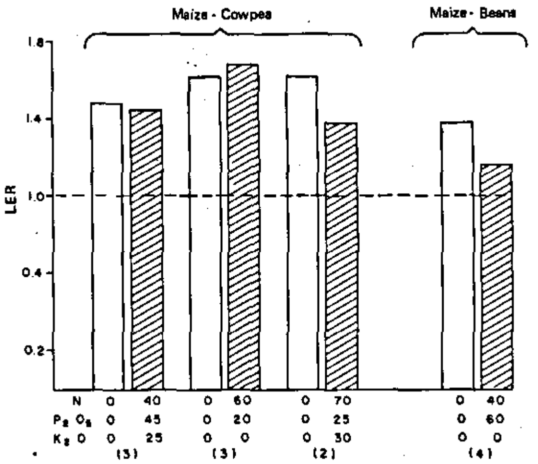

FIG. 7. Effect of fertilization on LER advantage in maize-cowpea and maize-bean intercropping systems. (Numbers in parentheses are experiments over which results were averaged).

greater stress and consequently suffer more than the sole crops. There is no direct experimental evidence in the Northeast but Fisher (1977) and Stewart (1982) reported that advantage of maize--beans intercropping was confined to only nonstress conditions. Obviously more studies are required to understand whether or not intercropping offers any stability mechanism against moisture stress.

Often the farmer is concerned with crop failures to meet his requirements, hence the probabilities of different systems satisfying specified incomes or yields were calculated. Probabilities of returns were estimated on the data of fertilized trials on the premise that for resourceful farmers (who could apply fertilizer) total returns may be more important than the contribution of individual components. The returns were the gross returns based on the minimum guaranteed prices during October-November 1982 (maize - Cr$ 33.54/kg, beans - Cr$ 78.37/kg and cowpea - Cr$ 54.86/kg). The probabilities of failures calculated at the above fixed prices for different levels of income are shown in Fig. 10. For any given targetted income, sole crops failed more frequently than the intercrops, and the advantage of intercropping was particular-

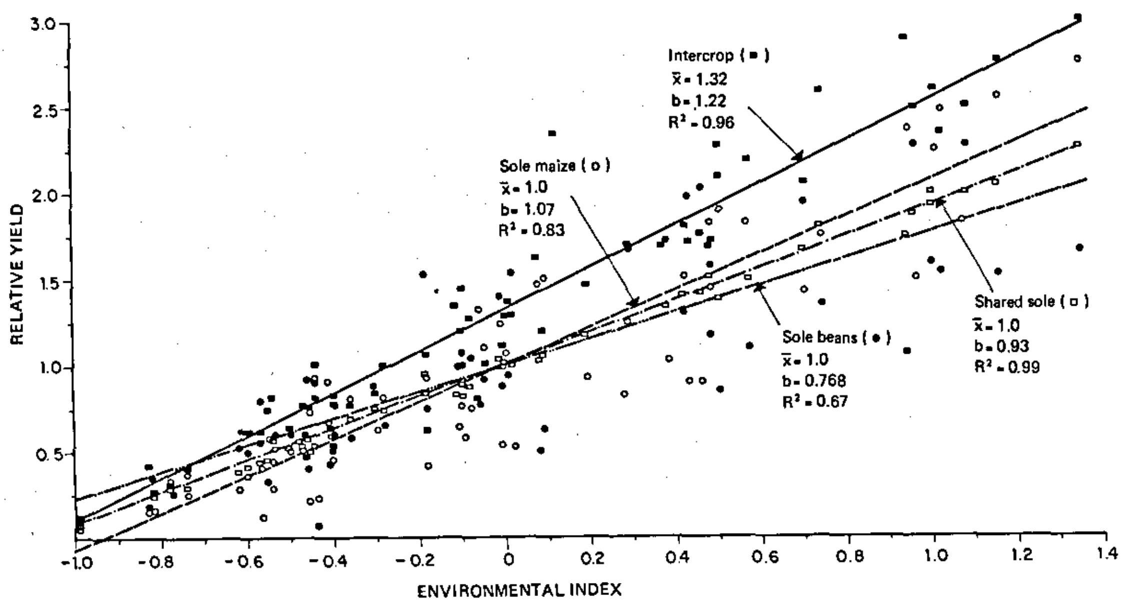

FIG. 8. Regression of relative yields of sole crops of maize and beans and their intercrop on an environmental index.

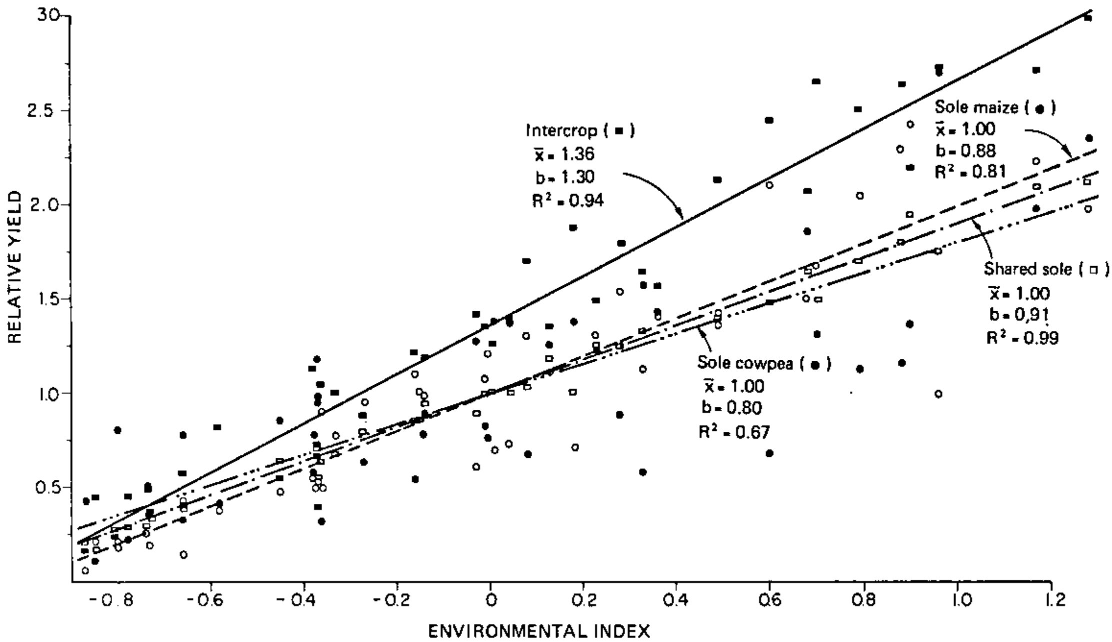

FIG. 9. Regressions of relative yields of sole crops of maize and cowpea and their intercrop on an environmental index.

ly highlighted as the required income increased. To quote for an example income of Cr$ 60,000/ha, sole beans failed once in every four years, sole maize failed once in five years, the shared system once in six but the intercrop failed only once in nine years. For a required income of Cr$ 40,000/ha, sole cowpea failed once in three years, sole maize once in seven years, the shared crop once in every six years whereas the intercrop was unsuccessful only once in nine years.

Not only prices of individual crops vary from time to time and across places, but the relative values of crops also change affecting the profitability of different systems. So the probability of failure of each system was calculated at different price ratios of the legume to maize experienced during the last five years in Northeast Brazil (bean prices varied from 2.3 to 6 times those of maize, whereas cowpea prices varied from 1.6 to 4 times). These were calculated for a fixed return of Cr$ 60,000/ha in maize-beans, Cr$ 40,000/ha in maize-cowpea (Fig. 11). Risk with sole beans or sole cowpea was greater than that with sole maize as long as the prices of these legumes remained lower than approximately 3 times that of maize, but at higher prices the sole legumes were better than the sole maize. On the other hand, the risk with shared crops was lower than that with sole maize even at the legume prices that were just twice that of maize. The shared crop of maize--cowpea was better than sole cowpea at all the price ratios and similarly that of maize-beans maintained its advantage over sole beans as long as the bean prices were lower than four times that of maize. In both combinations, the intercrops were less risky than all other systems. However, an exception was at the equal prices of the components where the intercrops, in spite of their superiority over sole legumes, did not show much advantage over sole maize.

The primary objective of small farmers is to produce their subsistence needs, and they generally do not fertilize their crops. So the probability of the shared vs intercrop systems satisfying the minimum food needs of a family, consisting of a husband and a wife, was calculated using the data of unfertilized trials. Suppose the family requires

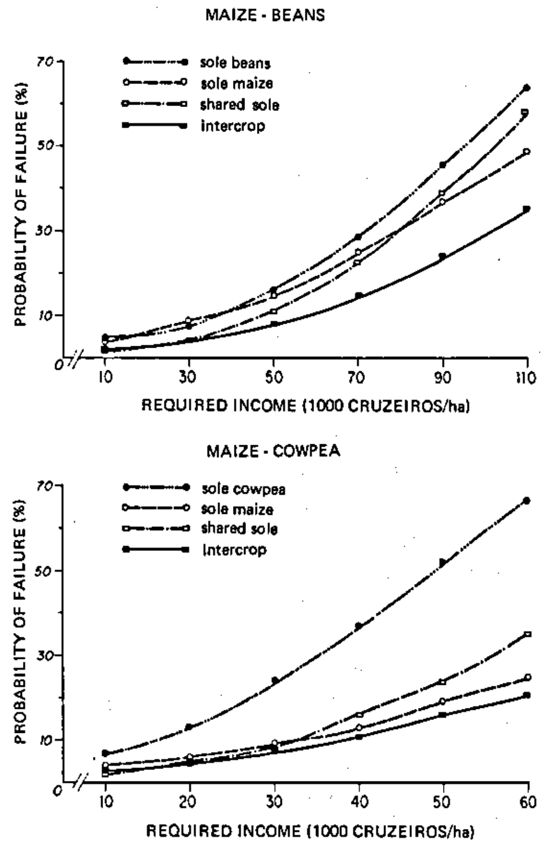

FIG. 10. Probability of failure of sole vs intercrop systems for obtaining different levels of income.

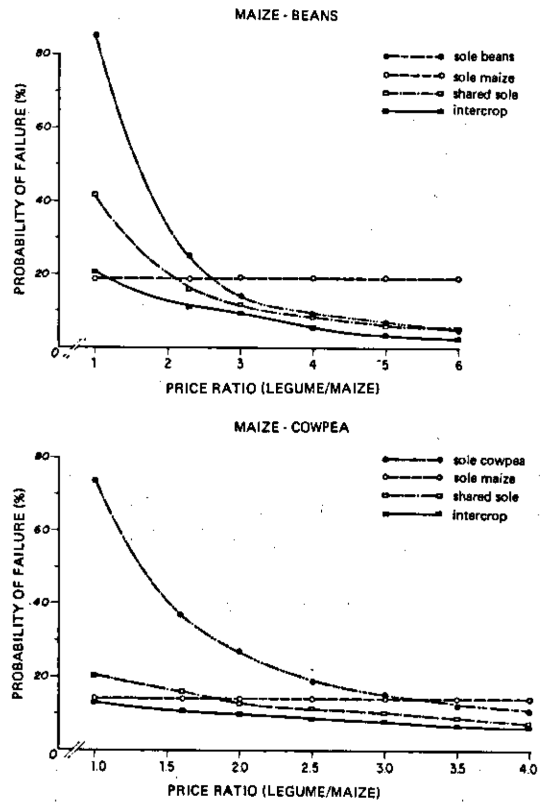

FIG. 11. Probability of failure of sole vs intercrop systems for a particular income at different price rations of legume/maize.

450 kg of maize and 160 kg of bean per year[4] the probability of obtaining the required quantity of maize or beans alone from the maize-bean shared system was 46% and 80% respectively. But the probability of the system being successful in respect of both the components simultaneously was approximately 37% (Pearce & Edmondson 1982). On the other hand, the probability of success for individual components with maize-bean intercrop was 54% for maize and 88% for beans which gives 47% success for both the crops together. Similar calculations with maize-cowpea combination showed that the shared sole system would probably meet the requirements of both the cereal and the legume on 49% occasions whereas the probability of success with the intercropping was 62%. Thus, by practising intercropping small farmers can reduce their risks.

[4] These are approximate limits calculated on the basis that a normal man would require daily 450 g of carbohydrate and 50 g of pulse protein, and a woman's requirement is 83% of that of a man. Average composition of maize, cowpea and beans with 75% utilization was used in the calculation.

Stability of maize vs sorghum

Results of maize vs sorghum comparisons in sole and intercropping with cowpea are given in Table 2. Sorghum outyielded maize in sole as well as intercropping, and expectedly sorghum yields were less variable than maize yields. The regression parameters also suggested that maize was particularly suitable to favourable environments but was inferior to sorghum in the majority of the locations.

TABLE 2. Yields and regression parameters of sole crops vs intercrops pf maize-cowpea and sorghum-cowpea combinations.

Parameter	Sole-maize	Sole-sorghum	Sole-cowpea	Maize-cowpea intercrop	Sorghum-cowpea intercrop
Yield (kg/ha)[1]	1569	2326	623	1613	1988
CV (%)	75	51	51	76	56
Regression parameters					
Mean relative yield	1.0	1.0	1.0	1.31	1.24
Slope (b)	1.19	0.72	0.52	1.48	1.10
r^2	0.85	0.67	0.27	0.92	0.98

[1] Mean of 14 observations.

Cowpea performed similarly in association with maize and sorghum, and there was little difference in the overall yield advantage of the two intercropping systems. Therefore, maize in the traditional intercrop systems can be replaced by sorghum without sacrificing any yield advantage, particularly in the drier areas where risk with maize is high.

CONCLUSIONS

1. Maize-beans and maize-cowpea intercropping systems outyielded their respective sole crops by 32% and 41% respectively, probably by making efficient utilization of the growth resources. The arrangements of 1 maize : 2 beans and 1 maize : 3 beans were equally good in terms of total advantage, and therefore the choice between them depends on which of the components is more important. The optimum population for maize--beans seemed to be around 20,000 plants/ha of maize and 150,000 plants/ha of beans. In the case of maize-cowpea, 1 maize : 1 cowpea or 1 maize : 2 cowpea, depending on whether the row spacing was wider or narrower, seemed to provide the potential advantage of this combination. The optimum population for maize was similar as with maize-beans, but cowpea required 100% of the sole crop density at 40,000 to 50,000 plants/ha.

2. The intercrop yields were as variable as those of the sole crop systems but because of higher yields the overall risk, measured in terms of returns as well as fulfilling the subsistence needs, was less with intercropping. The reduced risk with intercrops was observed at a wide range of price ratios between the two components. Sharing the land for two sole crops in a suitable proportion was better than growing either of the components alone, but a limitation with the shared system is that when one component fails, the other can not compensate as efficiently as in intercropping.

3. Sorghum gave consistently higher yields than maize in sole as well as intercropping. The relative advantage of sorghum-cowpea was not much different from that of maize-cowpea. Therefore, sorghum can be recommended to substitute maize in the traditional systems of the Northeast, particularly in the dry areas.

4. Because of the limited data, it was not possible to distinguish stability from that of productivity. In this respect planned long term multilocation experiments are suggested. Studies are also needed to understand the mechanisms underlying the stability, particularly on intercrop responses to water in conjunction with nutrients and plant population. Among others, genotype evaluation should receive priority.

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