# YIELD STABILITY OF SOLE AND INTERCROPPING SYSTEMS IN THE NORTHEAST OF BRAZIL[1]

EDUARDO ZAFFARONI[2], MAUTO DE SOUZA DINIZ and EDNA BASTOS DOS SANTOS[3]

ABSTRACT - Yield stability was analyzed by computing the coefficients of variation and using the regression technique (an adaptation of the procedure frequently used to examine the stability of individual genotypes over a range of conditions). These procedures were used to analyze the yield stability of cassava (*Manihot esculenta*), maize (*Zea mays*), cotton (*Gossypium hirsutum*) and dry beans (*Phaseolus vulgaris*) under sole and intercropping systems, in Paraíba State, in the Northeast of Brazil. The coeffients of variation were always higher in monocropping than in intercropping for the four crops. Maize and dry beans had the same slopes, while the coefficients of regression in cassava and cotton were higher than one for sole crops and statistically different from intercropping systems which had b values lower than 1 and hence were considered more stable. The advantage of intercropping in improving yield stability was more striking when the yields were negatively affected by the intercropping.

Index terms: cropping systems, maize, beans, cotton, cassava, intercropping stability, *Zea mays, Phaseolus vulgaris, Gossypium hirsutum, Manihot esculenta.*

## ESTABILIDADE DOS RENDIMENTOS EM SISTEMAS ISOLADOS E CONSORCIADOS NO NORDESTE DO BRASIL

RESUMO - A estabilidade dos rendimentos das culturas de milho (*Zea mays*), feijão (*Phaseolus vulgaris*), mandioca (*Manihot esculenta*) e algodão (*Gossypium hirsutum*) em cultivo isolado, consorciado e intercalado foi analisada através do cálculo dos coeficientes de variação e usando a técnica de regressão (uma adaptação do procedimento freqüentemente usado para examinar estabilidade de genótipos sob diferentes ambientes). Os coeficientes de variação foram sempre mais altos no cultivo isolado que no cultivo consorciado ou intercalado, nas quatro culturas. Milho e feijão são mais afetados pelo consórcio, mas têm a mesma pendente na análise de regressão. No entanto, os coeficientes de regressão foram maiores que no cultivo isolado, e estatisticamente diferentes dos de cultivo consorciado, que teve valores de b menores que 1 e, portanto, foram considerados mais estáveis. A vantagem do consórcio referente aos rendimentos mais estáveis é mais notável quando os rendimentos foram negativamente afetados pelos sistemas consorciados.

Termos para indexação: sistemas de cultivo, milho, feijão, algodão, mandioca, estabilidade do consórcio, *Zea mays, Phaseolus vulgaris, Gossypium hirsutum, Manihot esculenta.*

## INTRODUCTION

The predominance of intercropping in poorly developed agricultural countries in believed related to greater yield stability over different seasons. The basis for this reasoning is that if one crop fails or grows poorly, the other component crop or crops can compensate; such compensation is not possible if the crops are grown separately. But this is an additional and quite separate effect from that of spreading by growing several crops; this is achieved whether the crops are intercropped or not. There are many reports on the compensation effects of intercropping (Anderson & William 1954, Patil & Kosaddi 1960, Rao & Willey 1981).

The stability of intercropping systems might be improved by selecting for yield stability in each component itself under stress conditions. That should ensure lower yield fluctuations than sole cropping even under unfavorable conditions. This could be one reason why intercropping is more prevalent in low and erratic rainfall regions where agriculture is more risky (Aiyer 1949).

Rao & Willey (1980) analyzed the results of 51 experiments with sorghum/pigeon pea in India. The yield of sole pigeon pea had a coefficient of

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[2] Eng.-Agr., M.Sc., Ph.D., Associate Prof., Univ. Fed. da Paraíba, (UFPB), Centro de Ciências Agrárias, Dep. de Fitotecnia, CEP 58397 Areia, PB, Brazil.

[3] Eng. - Agr., M.Sc., EMBRAPA/Centro Nacional de Pesquisa do Algodão, (CNPA), Caixa Postal 174, CEP 58100 Campina Grande, PB.

variations of 44%, which was rather more stable than sole sorghum (49%), but intercropping yield was more stable than either (39%). When the regression technique was applied, it was observed that the slope of the pigeon pea regression line was much lower than that of the sorghum, and that intercropping had an intermediate value. Also in India, Rao et al. (1981) studied the stability of total yield of different intercropping systems. They found that sorghum-based systems were more productive and the stability of different intercropping systems was almost the same.

Intercropping is the main farming system in the Northeast of Brazil. For instance, cotton is intercropped in 74% of the area planted to cotton, beans and maize 96%, and the cassava in 67% (Fundação IBGE 1979).

The objective of this research was to study the yield stability of the main crops in the Paraíba State, Northeast of Brazil, under sole and intercropping systems.

## MATERIAL AND METHOD

The study was carried out for the Paraíba State, in the Northeast of Brazil, and the data were collected from the agricultural census for 1975 (Fundação IBGE 1979). Four crops were selected: beans, cassava, cotton and maize which are the most important with regard to intercropping. The selected counties produced more than 100 t and there was, at least, a difference of 2 t between them.

The weighted average was computed for the month of planting and harvest. Maize and beans were planted in February, cassava in March, and cotton in April. Cotton and cassava were harvested in September, maize in August and beans in June.

The yields of the following cropping systems were analyzed: 1. sole crop: one crop grown alone in pure stands at normal density, 2. intercropping: growing two or more crops simultaneously on the same field, and 3. intercalated cropping: growing a crop between the rows of a perennial crop.

Yield stability was examined by: 1. computing coefficients of variation (CV), and 2. adapting the regression technique, which has been frequently used to examine the stability of individual genotypes over a range of environments (Eberhart & Russell 1966, Finlay & Wilkinson 1963). The Statistical Analysis System (SAS) computer package was used to analyze the data. The coefficients of regression were compared using the t teste.

The environmental index (which is the mean yield of county minus the general mean) was ploted against the yields of the different cropping systems. The partial land equivalent ratio - LER - (intercropped yield/sole yield) was ploted against precipitation. The precipitation was taken from the data bank of SUDENE (Recife, PE, Brazil).

## RESULTS AND DISCUSSION

### Maize

The yields of the different cropping systems as well as the coefficient of variations for the corresponding yields are presented in Table 1. The yields of the sole, intercropping and intercalated cropping systems were not statistically different at the 5% level of significance. The yield of intercropping and intercalated cropping systems had much lower relative variabilities around the mean (which is weighed by the coefficient of variation) than sole cropping.

The lowest CV was observed with intercropping (24.8%), the highest with sole cropping (39.6%) and an intermediate value (29.1%) for intercalated but much lower than maize alone.

Rao & Willey (1980) reported similar results in intercropping sorghum/pigeon pea, but the difference was less striking. They reported CVs of 48.9% and 47% for sole and intercropping sorghum and 43.6% and 42.7% for sole and intercropping yield pigeon pea. They also compared the CV of total yield of intercropping crops and they found this value lower than for the sole crop.

The lower CVs of intercropping may be due to change in the ecological conditions in which the crop is growing. Under sole crop situation the plants could be more affected by drought, diseases or pests. The buffer effect, the ability of one crop to compensate for the poor growth of its companion crop, has been used by some researchers to explain the higher stability of intercropping systems. However, it cannot be applied here because we are comparing the same crop and individual yields. The buffer effect is more applicable when it is compared the total yield of the intercropped and the sole crops.

In the analysis of stability through the regression technique (Fig. 1) it was observed that the slopes for the different cropping systems were close to one; 0.86 for sole cropping, 0.81 for intercalated and 0.97 for intercropping. As a matter of fact, the coefficients of regression of the three equations were neither statistically different among themselves nor different from 1, and all were significantly different from zero (Table 2). Thus, the stability of the yield of the three croping systems was similar for maize. The standard errors of the b's for intercropping and intercalated were lower than for sole cropping. If the CV *per si* is considered as an estimation of the stability, the intercropping and the intercalated yields were more stable.

In order to determine if there were advantages in the yield of intercropping in the poorest environments, the partial LER (ratio of yield of intercropping to yield of sole crop) was plotted against the rainfall. Also the partial LER for intercalated was regressed on rainfall. In the first case the coefficient of regression was very low ($-7.37 \times 10^{-5}$), but in the second case (partial LER using intercalated yield), which is presented in the Fig. 2, was a little bit higher b = -0.0003. In both cases the regression coefficients were not different from zero, but they both showed the same trend. Since a negative regression coefficient was obtained, intercropping may have some advantages in the poorest environments. The relationship between intercalated and sole crop yield is higher in the poorest and lower in the best environments. Hence, the advantages of intercalated cropping systems seem to be more striking under places with low precipitation.

**Beans**

The same trend observed for maize was also obtained with this crop. Yields of the cropping systems (Table 1) were not significant different. The CV was higher for sole crop and lower for intercropping and intercalated systems.

**TABLE 1. Yield means, number of observations, standard deviations, coefficients of variation, and range of the different cropping systems in Paraíba State, Brazil, in 1975.**

| Crop and cropping systems | Mean yield (kg/ha) | n | S.D. | Range Mn. Val-Max. Val. | C.V. |
|---|---|---|---|---|---|
| **Maize** | | | | | |
| Sole | 611 a | 72 | 243 | 250-1500 | 39.6 |
| Intercropping | 535 a | 72 | 132 | 311-877 | 24.8 |
| Intercalated | 555 a | 72 | 161 | 175-1000 | 29.1 |
| **Beans** | | | | | |
| Sole | 379 a | 61 | 115 | 200-677 | 30.4 |
| Intercropping | 328 a | 61 | 70 | 218-584 | 21.2 |
| Intercalated | 341 a | 53 | 89 | 167-667 | 26.3 |
| **Cassava** | | | | | |
| Sole | 6790 a | 76 | 1705 | 4479-14059 | 25.1 |
| Intercropping | 6096 b | 76 | 1105 | 2000-9695 | 18.1 |
| **Cotton** | | | | | |
| Sole | 506 a | 38 | 183 | 180-1063 | 36.1 |
| Intercropping | 365 b | 38 | 73 | 227-557 | 19.9 |

Means, with crops, followed by the same letter are not statistically different according to the t teste ($P < 0.05$).

The regression analysis for beans also indicated a response similar to maize, but the highest b was obtained in the intercalated yield (Fig. 3). Again, the regression coefficients were not statistically different among them.

The regression analysis for partial LERs on precipitation was also similar to that for maize but the slope was less steep (b = 0.0001 and b = -0.0002, for intercropping and intercalated, respectively) than for corn.

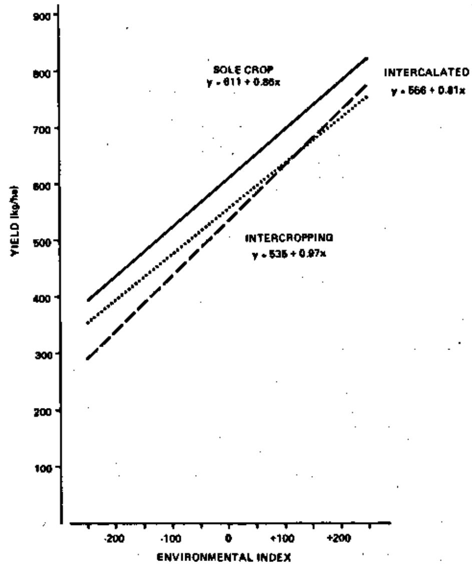


FIG. 1. Regression of absolute yield of corn on environmental index in different cropping systems in Paraiba State.

ference between sole and intercropping of cassava yields. This crop is not intercalated because cassava is not usually intercropped with perennial crops. But again, the coefficient of variation was lower for intercropping than for monocropping.

From the stability analysis, using the regression technique, it can be seen that the intercropping yields were more stable among the different environments (Fig. 4); the coefficent of regression was 0.53 for intercropping against a b = 1.24 for sole cropping. The regression coefficients of the two cropping systems were statistically different from 1, the sole cropping had a b higher than 1, and the intercropping lower than 1. Based on Finlay & Wilkinson (1963) method, yields from the intercropping of cassava appeared more stable than sole cropping, the intercropping system was better adapted to low yield environments, with a stability above the average (b = 1). This means that the yields were less affected by changes in the environments; these yields were less sensitive. On the

**TABLE 2. Regression coefficients (b) of yield on environmental index, standard errors of b, and statistical significance for the hypotheses $\beta = 0$ and $\beta = 1$.**

| Crop and cropping systems | Regression coefficient (b) | Standard error of b | Significance Tests $H_0:\beta = 0$ | $H_0:\beta = 1$ |
|---|---|---|---|---|
| **Maize** | | | | |
| Sole | 0.8595 | 0.2010 | ** | n.s. |
| Intercropping | 0.9670 | 0.9670 | ** | n.s. |
| Intercalated | 0,8078 | 0.1158 | ** | n.s. |
| **Beans** | | | | |
| Sole | 0.6856 | 0.2006 | ** | n.s. |
| Intercropping | 0,8554 | 0.0719 | ** | n.s. |
| Intercalated | 0,9155 | 0.1283 | ** | n.s. |
| **Cassava** | | | | |
| Sole | 1.2387 | 0.0727 | ** | ** |
| Intercropping | 0.5342 | 0.0840 | ** | ** |
| **Cotton** | | | | |
| Sole | 1.4051 | 0.2571 | ** | n.s. |
| Intercropping | 0.5985 | 0.0970 | ** | ** |

* Signicances at ($P < 0.01$).
n.s. = nonsignificant.

## Cassava

The response of cassava was, in some aspects, different than that obtained for maize and beans. It was noticed that there was a significant difference between sole and intercropping of cassava yields. This crop is not intercalated because cassava is not usually intercropped with perennial crops. But again, the coefficient of variation was lower for intercropping than for monocropping.

other hand, the sole yield of cassava was more sensitive to environment improvement and the stability would be considered below the average stability which is considered equal to 1. Another important fact to point out is that the regression coefficients were significantly different while in the case of corn and beans they were not. The standard errors of b was slightly higher in the case of intercropping.

There is an advantage of intercropping, concerning the yield stability, when the yields are low. The reasons for these different responses to cropping systems could be that maize and beans respond to improvement in the environment in the

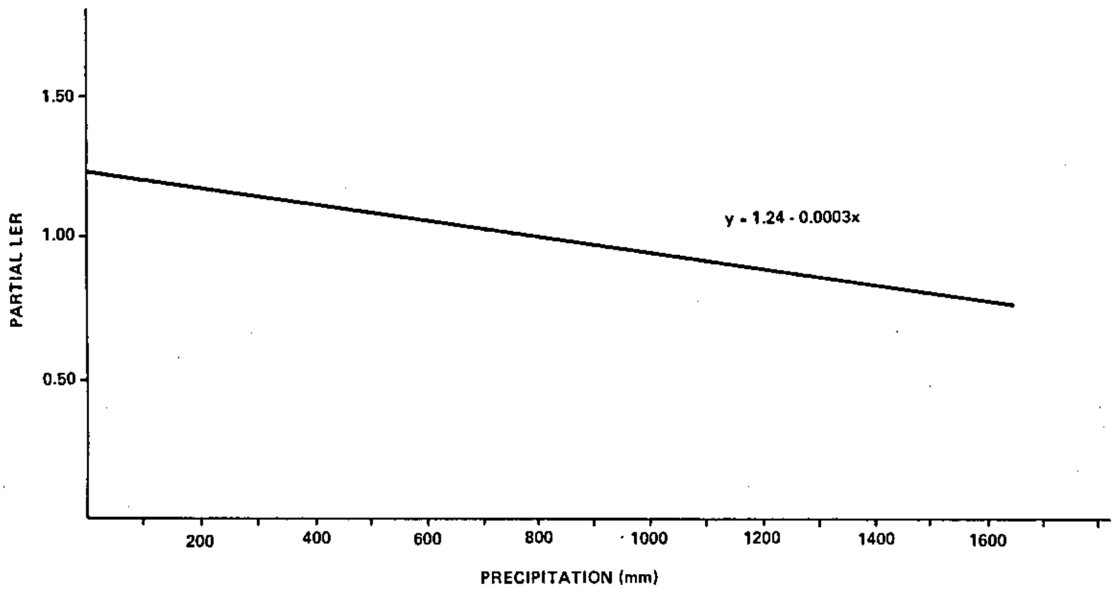


FIG. 2. Regression of partial LER (yield of intercalated/yield of sole cropping) of corn against precipitation in Paraiba State.

## Cotton

For cotton the same trends found for cassava were observed. The coefficient of variation was significantly higher for sole cropping and the yield of sole cropping was statistically different from that of intercropping (Table 1).

The coefficient of regression for the sole yield was significantly higher than for intercropping yield when testing using the t test (Fig. 5). These results agree with those found for cassava; intercropping was more stable according to regression technique.

The b of sole cropping was not statistically different than one; meanwhile the b of intercropping was different than one (Table 2). The standard erros of regression coefficients were, as in all cases but cassava, higher than sole crop cotton.

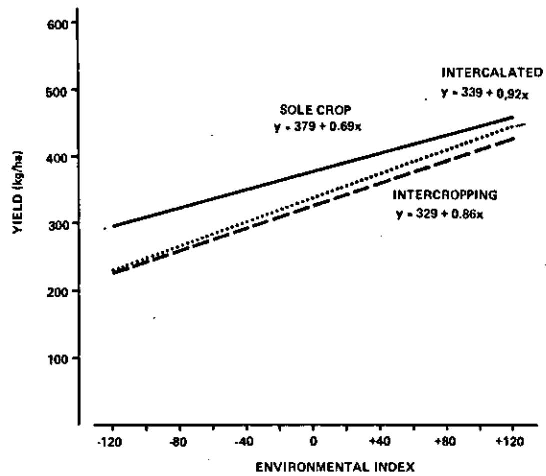


FIG. 3. Regression of absolute yield of beans on environmental index in different cropping systems in Paraiba State.

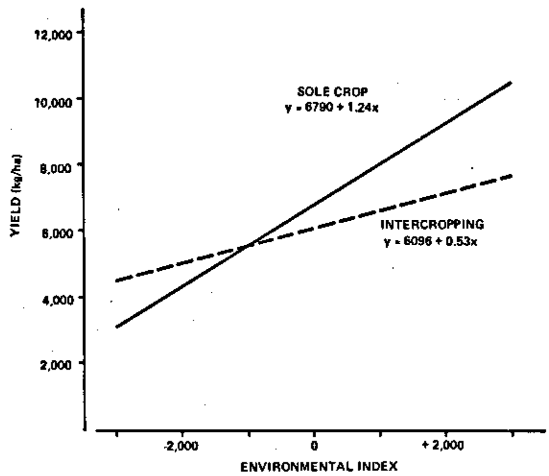


FIG. 4. Regression of absolute yield of cassava on environmental index in different cropping systems in Paraiba State.

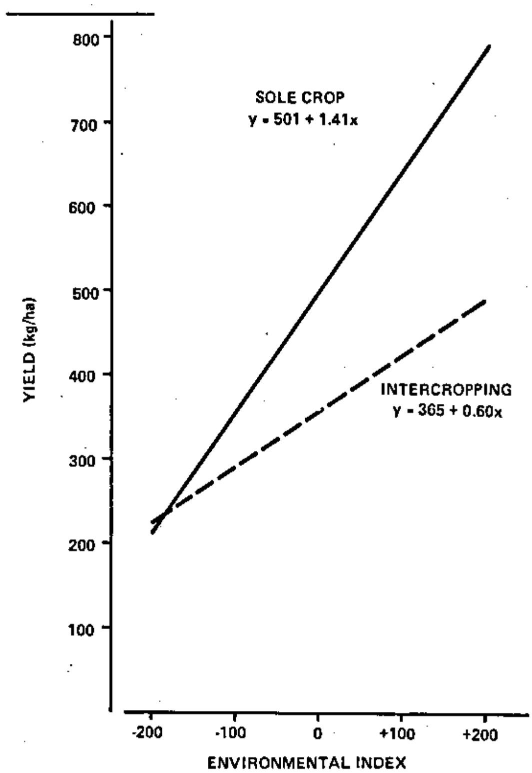


FIG. 5. Regression of absolute yield of cotton on environmental index in different cropping systems in Paraiba State.

same form whether they are intercropped or not. On the other hand, cassava and cotton respond more to the improvement in environment in sole cropping systems. Furthermore, it is well known that cassava and cotton are two crops recognized as having a good level of tolerance to poor environmental conditions and perhaps this could be one of the reasons why these two crops are less variable under intercropping systems.

## CONCLUSIONS

1. The yield of maize and beans were not significantly affected by intercropping systems while the yield of cassava and cotton were significantly affected by intercropping.

2. The coefficients of variation were always lower for the intercropping systems.

3. The yield stability of intercropping, when analyzed using the regression procedure, seems to depend on the kind of crop and how it is affected by intercropping. The crops that showed the grater reduction in yield when intercropped (cotton and cassava) had significantly lower coefficients of regression (more stable) under intercropping than under sole cropping. Whereas, the regression coefficients of the crops that were not affected by intercropping (maize and beans) were statistically the same under the different cropping systems.

4. More research is needed, studying different environments and years to obtain more definitive conclusions in long term situations.

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