SOME STATISTICAL ANALYSES FOR A MAIZE AND BEANS INTERCROPPING EXPERIMENT

by

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ABSTRACT

Several univariate and multivariate analyses were applied to observations from an experiment involving sole crop and intercropped combinations of two maize and four bean cultivars. Some of the strengths and weaknesses of the analyses are indicated. For a joint analysis on maize and bean yields, analyses for crop value or income, land equivalent ratios, and a multivariate analysis with maize yields as one variable and bean yields as a second variable, were performed on the data. The last analysis necessarily ignores sole crop yields.

KEYWORDS – relay-cropping, mixed cropping, univariate and multivariate analyses, land equivalent ratio, general and specific mixing effects, function of combined yields of crops.

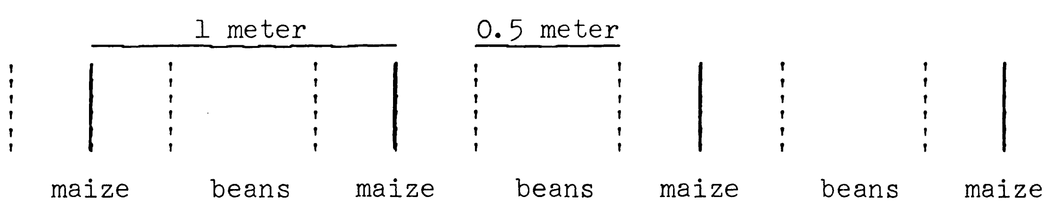
INTRODUCTION

Intercropping is a traditional form of agriculture in many developing countries with a tropical climate. However, it is relatively recent for researchers to set up intercropping experiments, to evaluate various intercropping procedures, and to do research on intercropping directly related to farmers' practices. Techniques and procedures in both agriculture and in statistics are well developed for sole cropped experiments but are in a very primitive state for intercropping, relay-cropping, and mixed cropping experiments. In these experiments, there are many items of interest in a single experiment, there are yields from more than one crop, and it is often difficult or impossible to identify a single criterion on which to base a statistical analysis, an evaluation, or an interpretation. For example, the different types of yield components for each of the crops involved in the intercropping system, total profit, total nutritive value in calories, total protein content, land equivalent ratios, and general and specific competitive or mixing effects are some criteria that come to mind. Univariate and multivariate analyses may both be used in the statistical analysis for a set of data from an intercropping experiment. Statistical analyses may be performed on the yields of individual crops, or on some function of the combined yields. To date, published literature focuses on the former.

For an experimental set of data, we shall give several statistical analyses and describe what is obtained from each of the analyses. Statistical analyses for single crop yields and for combined yields are presented.

THE EXPERIMENT AND THE DATA

The four varieties of beans used in the experiment are denoted as A, B, C, and D, where A = Riotibaji, B = California small white, C = Turinalba, and D = Costa Rica-1031. Varieties A and C were bush varieties and B and D were climbing varieties. Two varieties of maize, X and Y, where X = Piranao and Y = Agroceres, were used. Variety X was a dwarf maize variety and variety Y was a tall maize. The experiment was conducted at the National Research Center for Rice and Beans, Goiânia, Goiās, Brazil. The 14 treatments were X, Y, A, B, C, D, AX, AY, BX, BY, CX, CY, DX, and DY. That is, there were six monocultures and eight intercropped mixtures involving one bean variety and one maize variety. The density of bean plants was 140,000 plants/ hectare regardless of whether a sole crop or intercrop treatment was involved. The density of maize plants was 40,000 plants / hectare and was constant regardless of whether the treatment was sole or intercropped. The maize was planted in rows one meter apart, and the beans were planted in rows one-half meter apart. In the mixture, two rows of beans were interspersed between each pair of rows of maize as follows:



The experiment design was a randomized complete block with 14 treatments in four complete blocks.

The observations recorded for each crop are listed below:

Beans	Maize
1. number of pods/plant	1. number of ears/plant
2. number of grains/pod	2. grain weight — grams/square meter
3. 100 grain weight — grams/square meter	
4. grain weight — grams/square meter	

The maize plot size was six rows ten meters long, with the center four rows by six meters being harvested. The bean plots were twelve rows by ten meters long, with the center eight rows by six meters being harvested.

STATISTICAL ANALYSES FOR OBSERVATIONS FROM EACH CROP

A simple form of statistical analysis is to consider individual crop yield components from a mixture. First let us consider the four components for bean yields. There are three cropping systems, sole, with X, and with Y, for each of the four bean varieties. The mean yields for these 12 treatments are given in Table 1. The grains/pod and 100 grain weight means for the mixtures are slightly higher than for the sole crops. However, the number of pods/plant is considerably reduced in the mixtures, resulting in decreased grain weight/square meter for all varieties except variety B with maize variety Y. Here the yield of beans for this low yielding variety was only about 10% less than for the sole crop. However, with the dwarf maize variety X the yield was approximately 50% of the sole crop yield. For the remaining varieties the yield of beans in the mixture was approximately 50 to 60% less than the sole crop grain weight/square meter.

Analyses of variance were performed and F-ratios of mean squares were computed. The probabilities of obtaining larger F-ratios under the null hypothesis were computed and are given in Table 2 for various sources of variation in the analyses of variance obtained. Here we note a very large F-ratio for cropping systems, which is due to sole versus intercropped responses for number of pods/plant. For the second component, number of grains/pod, the large F-ratio for varieties appears to be due to variety B versus variety D, which are climbing varieties. For the third yield component, 100 grain weight, the large difference among varieties is concentrated in the contrasts of the two bush and two climbing varieties. For the fourth yield component, grain weight/square meter, the large F-ratio for varieties is due to the large

Table 1. Means of Yields and Yield Components of Four Bean Varieties Under Three Different Cropping Systems

		Variable			
Bean variety	Cropping system	# of pods /plant	Grain /pod	100 grain wt.	Grain wt. pm^2
A	Sole crop	11.4	4.53	13.30	87.400
A	with X	4.95	4.525	13.95	43.300
A	with Y	4.45	4.775	14.075	39.225
B	Sole crop	9.63	3.3	13.6	52.900
B	with X	3.775	3.925	14.025	27.225
B	with Y	5.325	4.175	14.55	47.000
C	Sole crop	9.7	4.475	17.25	103.725
C	with X	4.425	4.2	17.325	40.575
C	with Y	4.2	4.275	18.275	45.550
D	Sole crop	12.075	4.675	17.525	116.025
D	with X	3.767	4.800	19.167	49.700
D	with Y	4.55	4.775	18.40	42.575

Table 2. F-Value Probabilities for Bean Yields and Yield Components

Source of variation	Degrees of freedom		Probability of a greater F-value: # of pods /plant	Grain /pod	100 grain wt.	Grain wt./m^2
Varieties	3		.7144	.0037*	.0001*	.0014*
Bush vs climbing		1	.9422	.3737	.2475	.4077
A vs C within bush		1	.3394	.2417	.0001*	.3276
B vs D within climbing		1	.5244	.0006*	.0001*	.0002*
Cropping systems	2		.0001*	.5505	.2828	.0001*
Sole vs intercropping		1	.0001*	.3536	.1245	.0001*
X vs Y within intercropping		1	.6087	.5835	.7384	.5935
Varieties X cropping systems	6		.6705	.7544	.9353	.0073*

* Significant at 5%.

difference in yields between the two climbing varieties B and D. Variety B yields only 61% as much as variety D averaged over the three cropping systems. The large F-ratio for cropping systems is due to the single degree of freedom contrast for sole-cropped versus intercropping systems. The difference in means for the cropping system with maize variety X did not differ much from that for maize variety Y. There is some indication of a variety-by-cropping-system interaction. This is due to the relatively low mean grain weight/square meter for variety B as a sole crop and its relatively high yield when intercropped with maize variety Y. This is depicted in Figure 1.

One might wish to study some function of the three yield components for beans, i.e., number of pods/plant, number of grains/pod, and 100 grain weight. Considering these as three multivariate variables X_1, X_2, and X_3, a multivariate analysis of variance was obtained [see, e.g., Morrison (1967), Rao (1973), etc.]. Using Wilk's criterion and a five percent level of significance, significant differences were found for cropping systems. Examination of the latent roots and the latent vector of $E^{-1}H_c$, where E represents the matrix of error sums of squares and cross products and where H_c is the sum of squares and cross products matrix for testing the null hypothesis for cropping systems, indicated that 99.5% of the variance was explained by the linear combination of X_1, X_2, and X_3 given by the first latent vector. Upon multiplying the coefficients by the corresponding standard deviations for X_1, X_2, and X_3 (see Table 3), it may be seen that most of the significant differences are attributable to differences in the variate X_1, number of pods per plant.

Significant differences also occurred between bean varieties.

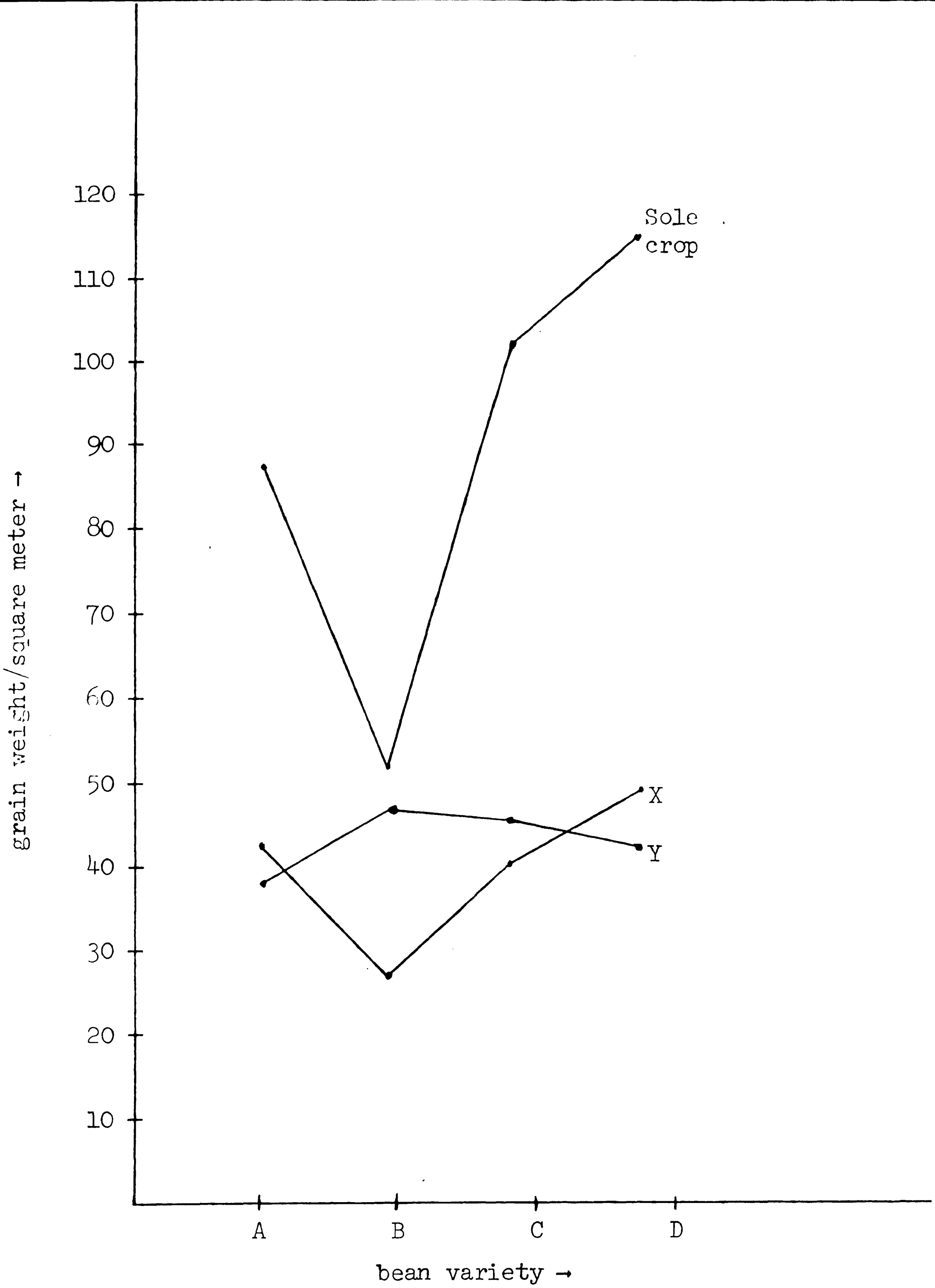


Figure 1. Mean yields of beans for varieties A, B, C, and D in the various cropping systems.

Table 3. MANOVA and Associated Statistics for Three Bean Varieties

X_1, X_2, X_3

Source	Degrees of Freedom for F-distribution	Wilks' λ	Probability of a Greater F-Value
Cropping Systems	6,56	.2221	.0001*
Bean Varieties	9,68	.1655	.0001*
Interaction	18,79	.72844	.9383

* Significant at 5% level

Latent Roots and Vectors Associated with Significant Effects

Effect: Cropping Systems:

Latent Root	% Variance	Coefficient		Standard Deviation	Relative Importance
3.4238	99.49	X_1	.0943	1.99	1.00
		X_2	.0687	.58	.22
		X_3	-.0281	1.51	.23
.0176	.51	X_1	.0149	1.99	1.00
		X_2	.2680	.58	5.31
		X_3	.0622	1.51	3.19

Effect: Bean Varieties:

Latent Root	% Variance	Coefficient		Standard Deviation	Relative Importance
2.7731	82.25	X_1	-.0024	1.99	1.00
		X_2	.0473	.58	5.77
		X_3	.1184	1.51	37.58
.5928	17.58	X_1	.0509	1.99	1.00
		X_2	.3158	.58	1.80
		X_3	-.0278	1.51	.41

Again, examination of the latent roots and the latent vectors of the relevant matrix indicated that 82% of the variance was explained by a linear combination of X_1, X_2, and X_3 obtained from the first latent vector; the remaining 18% of the variance was explained by a linear combination of X_1, X_2, and X_3, given by the second latent vector. The former linear combination was dominated by X_3, 100 grain weight, while the second one was dominated by X_2, number of grains per pod, and to a lesser extent by X_1 (see Table 3). These results agreed with those obtained from univariate analyses. The interaction of variety by cropping systems was not significant, agreeing with the univariate results.

Since significant differences in each of the two main effects, varieties and cropping systems, could be attributed mainly to individual variates X_1, X_2, or X_3, a multivariate analysis added little to what was obtained for the univariate analyses on the individual variables X_1, X_2, and X_3 as given in Tables 1 and 2. Also, the variable grain weight per square meter is a nonlinear function of X_1, X_2, X_3, and number of plants per square hectare. If density is almost constant, then this variable is a nonlinear function of X_1, X_2, and X_3 and significant effects due to this function will not be indicated by a linear function. However, the univariate analysis on grain weight per square meter indicated that this nonlinear function of X_1, X_2, and X_3 discriminated clearly between varieties, cropping systems, and their interaction.

The only new item obtained from a multivariate analysis of variance on the three variables X_1, X_2, and X_3 over that obtained from three univariate analyses of variance was the fact that all information about effects of interest can often be obtained from a single linear function of X_1, X_2, and X_3. We also see the relative importance of these variates in differentiating between varieties and cropping systems and their interaction.

Note: In this instance, it was seen that the univariate analyses agreed with the multivariate analyses for significant effects. However, this need not necessarily be the case, as a multivariate analysis on the variates may yield linear combinations of the variates responsible for significant differences between effects which would not be at all obvious from examination of univariate analyses on each of the variates considered separately.

The same type of univariate analyses may be obtained from the maize yields on the ten treatments X, Y, XA, XB, XC, XD, YA, YB, YC, and YD. The means for maize yields for the two variables, number of ears per plant and grain weight per square meter, are presented in Table 4. With regard to number of ears per plant, there was a 14% reduction in number for maize variety X in a mixture over the sole crop. Likewise, there was a 12% reduction for the tall variety of maize, Y, over the sole crop. As can be seen from Figure 2, the maize yields for the dwarf variety were nearly the same whether in a mixture or in a sole crop. Thus, any bean yields obtained would be a benefit since the yield of maize was the same whether a bean variety was present or not. However, with the tall variety Y, the yields of maize when each of the four bean varieties was present, was considerably lower than the sole crop yield.

Performing an analysis of variance on the number of ears per plant, large F-values with low probabilities for larger values, were obtained for differences in the two varieties and for sole crop yields versus intercropped yields. There was little or no evidence of interaction between varieties X and Y and cropping systems (see Table 5).

Table 4. Means of Yields and Number of Ears/Plant for Maize

Variety	Cropping System	Variable: No. of Ears/Plant	Variable: Grain Wt./m^2
X	Sole crop	1.15	469.275
X	with A	1.025	453.525
X	with B	.95	492.75
X	with C	1.025	470.35
X	with D	.95	469.275
Y	Sole crop	1.25	603.000
Y	with A	1.0	373.25
Y	with B	1.15	513.95
Y	with C	1.075	489.825
Y	with D	1.20	406.525

Table 5. Analysis of Variance on Maize

Source of Variation	Degrees of Freedom		Probability of a Greater F-Value: # of Ears/Plant	Probability of a Greater F-Value: Grain Wt./m^2
Varieties (X vs Y)	1		.0074**	.9635
Cropping systems	4		.0562*	.0387**
Sole vs Intercropping		1	.0047**	.0231**
Bush vs climbing		1	.4875	.2814
A vs C within bush		1	.5553	.0986*
B vs D within climbing		1	.6936	.1884
Varieties x cropping systems	4		.2109	.0511*

* Significant at 10% level.

** Significant at 5% level.

With regard to grain weight per square meter, there is evidence of differences in sole crop yields and intercropped yields with the difference being attributable to the increased sole crop yield for maize variety Y (see Figure 2). There was a difference in maize yields when grown with bush beans A and C. The differences of maize variety yields when maize was intercropped with bean varieties A and D as compared to B and C and of sole crop yield differences accounted for a significant interaction of cropping systems and maize varieties (see Figure 2).

The above analyses considered each crop separately. Their weaknesses lie in the fact that a farmer uses a combination of both yields for obtaining food or profit. He does not consider the yields separately but rather the total yield of beans and corn from his farm. Therefore, some analyses making use of both crop yields simultaneously, instead of individually, are considered in the next section.

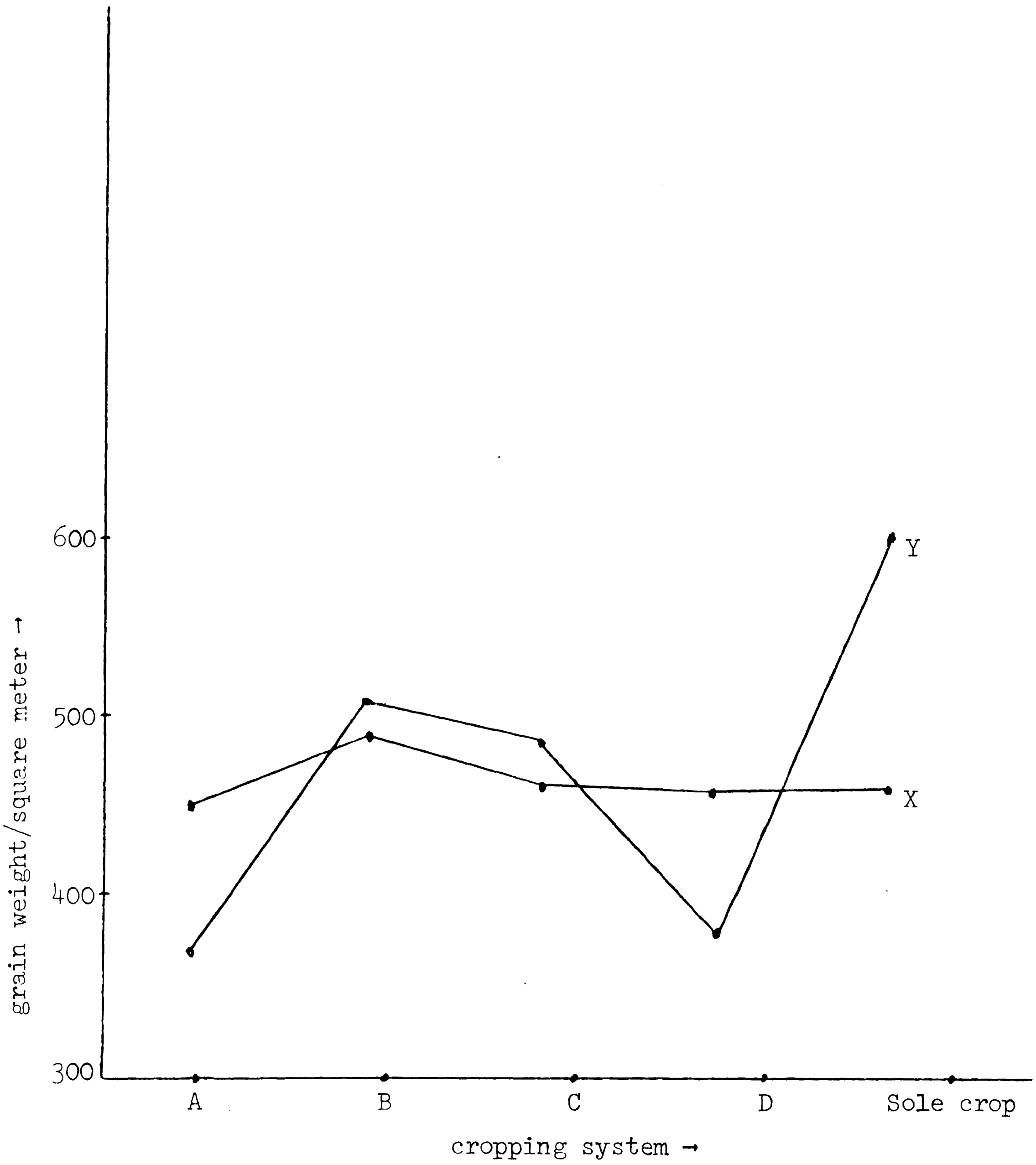


Figure 2. Mean yields of maize for varieties X and Y in the various cropping systems.

STATISTICAL ANALYSES USING YIELDS OF BOTH CROPS

Many analyses on univariate combinations and functions of the yields from both crops are possible. Some of these are total yield, total value (income, profit), total calories, land equivalent ratios, etc. When all crops are present in a mixture and when different lines or variates of a crop are used, it is possible to perform a multivariate analysis on the intercropping systems and to consider similar observations, e.g., yield, on each of the crops as the variables in the observation vector. In the following sections we present two univariate analyses for total value of the crop and for land equivalency ratios and a multivariate analysis with maize yields as one variable and bean yields as the second variable.

1. Univariate analysis on monetary value of the crop

It should be noted that in general the monetary value of interest to a farmer would be profit. However, since the available data did not include information on input costs (seed, fertilizer, labor, harvesting, etc.) for the different monocultures and intercropping systems, we shall consider value of the crop under the assumption that the prices of beans per kilogram is three times that of corn. That is, value is equal to $c_b Y_b + c_m Y_m$, where c_b is the sale price of beans per kilogram, Y_b is the yield of beans per hectare, c_m is the sale price of maize per kilogram, and Y_m is the yield of maize per hectare. In addition, we assumed that c_b was the same for all four bean varieties A, B, C and D, and that c_m was the same for both maize varieties X and Y. Then, relative value per plot was taken as $3Y_b + Y_m$. The mean values for the 14 cropping systems are given in the top part of Table 6. For the variable total value, there are large significant differences among the

14 treatments. One could have used one or more of the several multiple range tests that are available [see, e.g., Federer (1974), Chapter II]. We, however, decided to concentrate on possible goals of a farmer and to compute a number of related single degree of freedom contrasts (bottom part of Table 6).

All contrasts had relatively large F-values with low probabilities of occurrence except for the contrast maize variety Y in sole crop versus intercropping, where Y was involved. We note that value for bean varieties B and C with Y exceeded the value of Y as a sole crop. The considerably reduced value for the intercrop of bean variety A and Y, and to some extent bean variety D and Y, contributed greatly to the nonsignificance of the contrast. This means that individual bean varieties perhaps can be found which will not greatly affect the yield of maize variety Y nor its own yield in an intercrop relative to sole crop yields. Also, if the price for beans is relatively higher than computed here, then value from intercropping systems would be increased.

If a farmer grows maize variety X and his goal is to maximize value and yield of maize, then he is always better off if he uses an intercrop of a bean variety and maize X. If he grows Y, then he is better off with the mixture of the low yielding bean variety B and Y. If, on the other hand, he wishes to maximize his bean yields and crop value, then he is in a considerably better position growing bean variety D with maize variety X. A second choice would be to intercrop B with Y. In both cases the bean yields are considerably reduced over sole crop yields, but the value is considerably increased over that from growing beans alone.

It should be noted that the particular contrasts selected will

Table 6. Mean Crop Values and an Analysis of Variance on This Variable

	A	B	C	D	Sole Crop
X	583.425	574.425	592.075	618.667	469.275
Y	490.925	654.950	626.475	534.250	603.00
Sole Crop	262.200	158.700	311.175	348.075	

Analysis of Variance

Source of Variation	Degrees of Freedom	Probability of a Greater F-Value
Blocks	3	.0153
Cropping systems	13	.0001

Non-Independent F-Tests for Some Single Degree of Freedom Contrasts

Source of Variation	Degrees of Freedom	Probability of a Greater F-Value
Sole cropping vs intercropping	1	.0001
X as a sole crop vs intercropping systems including X	1	.0068
Y as a sole crop vs intercropping systems including Y	1	.5454
A as a sole crop vs intercropping systems including A	1	.0001
B as a sole crop vs intercropping systems including B	1	.0001
C as a sole crop vs intercropping systems including C	1	.0001
D as a sole crop vs intercropping systems including D	1	.0001

vary, depending upon the nature of the experiment and the goals of the experimenter. If maize was of prime importance in the staple diet or farming system and crop value was of secondary importance, then the yields of maize in an intercrop would have to be high enough to satisfy dietary requirements. This could mean, say, growing maize variety Y with bean variety B. If, on the other hand, bean yields were of prime importance, a farmer might need to change the density per hectare of maize, say 1.5 or 2.0 meters between rows, and retain the density of beans, rows 0.5 meters apart. This should increase the bean yield in the intercrop relative to sole crop yields. Experiments would need to be constructed with these goals in mind. Also, it should be noted that a variety of other contrasts could have been made with these data.

2. Land equivalent ratios

As with income, we combine yields of all crops in an intercropping system into one univariate response, i.e., a land equivalent ratio. This ratio gives the relative amount of land in sole crops required to obtain the yields produced in the intercrop [see, e.g., Mead and Willey (1980)]. For the experiment reported here, land equivalent ratios (LER) were calculated for each intercrop within each block as follows:

$$LER_{hij} = \frac{B_{hij}}{B_{hhj}} + \frac{M_{hij}}{M_{iij}} ,$$

where h = A, B, C, or D to denote bean variety, i = X or Y to denote maize variety, j = 1, 2, 3, or 4 to denote block number B_{hij} and M_{hij} equal yields of beans and of maize, respectively, when grown as an intercrop consisting of the h^{th} bean variety and the i^{th} maize variety, B_{hhj} and M_{iij} equal yields of h^{th} bean variety and i^{th} maize variety, respectively, when grown as sole crops, and $0 \leq LER_{hij} < \infty$ are the bounds on LER_{hij}.

The LER_{hij} are correlated in that one of the denominators is the same for a number of the LER_{hij}. One could take account of this correlation as Geisser and Greenhouse (1958) did, but for a first analysis one may ignore this fact and proceed as for uncorrelated LER_{hij}'s. The mean values of the LER_{hij} for the eight intercrops are given in Table 7. For maize variety X, 39% to 56% more land would be required to produce the same yields when grown as sole crops. For maize variety Y, 5% to 74% more land would be required for sole crops than for intercrops. Using the LER_{hij}, the most favorable land use combination is bean variety B and maize variety Y, which is also the combination yielding the highest crop value. This, however, points up one of the weaknesses of LER's in that the 75% increase is due mainly to the fact that B is a low yielding variety as a sole crop and its mean yield is about the same with maize as without; also, the yield of maize is not affected as much with B as with other bean varieties. The total yield of maize plus beans is given at the bottom of Table 7. Here we may note the $LER_{BY.}$ is relatively exaggerated as compared to total yield or crop value.

The LER describes land use giving equal weight to the crops in an intercropping system. This need not be the case as one could use differential weights for the various components of LER. Mead and Willey (1980) discuss other modifications of LER's to satisfy various criticisms.

An analysis of variance was performed on the LER's (Table 8) and F statistics were computed. It should be noted that the LER's are correlated and computing F statistics in the usual manner is not correct [see Geisser and Greenhouse (1958)]. This then is only an approximate procedure for a first appraisal of LER's. This is one of the difficulties in using LER's. Another difficulty of the LER is in the

Table 7. Mean Values of LER's and Total Yields

Maize \ Bean	LER A	LER B	LER C	LER D
X	1.39	1.56	1.41	1.47
Y	1.16	1.74	1.27	1.05

Maize \ Bean	Total Yield (Beans plus Maize in Grams/Square Meter) A	B	C	D
X	497	520	511	545
Y	412	561	535	449

Table 8. Analysis on Land Equivalent Ratios

Source of Variation	Degrees of Freedom	Probability of a Greater F-Value
Maize varieties (X vs Y)	1	.0875*
Bean varieties	3	.0185**
Bush vs climbing	7	.1141
Within bush (A vs C)	1	.6681
Within climbing (B vs D)	1	.0066**
Maize variety x bean variety	3	.1075

* Significant at 10% level.

** Significant at 5% level.

comparison of two such ratios; the two ratios could be identical, but the crop yields for one of them could be only a fraction of the second. Their main use would be in considering a specified pair of crops. A comparison of LER's, as is done in the above analysis of variance, is frought with many difficulties. Also, it would be desirable to be able to compute a confidence interval for an LER. This would involve obtaining a variance of the ratio [see, e.g., Bliss (1967), section 9.3c].

3. Multivariate analysis on yield vector for eight intercropping systems

A multivariate (bivariate) analysis of variance was conducted on the vector (Y_{bi}, Y_{mi}) for all eight treatment combinations of intercropping systems with two varieties of maize and four varieties of beans. Y_{bi} denoted bean yield and Y_{mi} the maize yield for cropping system i $(1 \leq i \leq 8)$.

It should be noted that since the multivariate analysis of variance could only be conducted on the intercropping systems, no hypotheses related to comparisons with sole cropping could be tested or investigated. This analysis could only obtain information on differences within the set of eight intercropping systems.

Hypotheses on the effects of bean and maize varieties as intercrops, and their interaction, were tested. It was found that no significant differences occurred between the four bean varieties or the two maize varieties (Table 9). However, the mean yield vectors from intercropping systems involving maize variety X differed significantly from those with maize variety Y $(P < .1)$.

A study of the linear function of the two yields (Table 10) responsible for 97% of the variation indicated that these differences were more predominant for bean yields. This result was also obtained in the

Table 9. Multivariate Analysis of Variance on Yield Vector (Y_b, Y_m)

Source of Variation	Degrees of Freedom of F-Distribution	Wilks' λ	Probability of a Greater F-Value
Bean varieties	6,38	.65058	0.20
Maize varieties	2,19	.92596	0.48
Interaction	6,38	.5466	0.06*

* Significant at 10% level.

Table 10. Latent Roots and Vectors for Significant Effect of Interaction

Latent Root	% Variance Explained	Variate	Coefficient	Standard Deviation	Relative Importance
.7825	96.75	Y_b	.0254	8.32	.21
		Y_m	.0011	88.19	.10
.0263	3.25	Y_b	-.0092	8.32	.076
		Y_m	.0023	88.19	.203

univariate analyses on maize yields and bean yields, as bean yields showed a significant interaction effect and maize yields did not.

One could partition out single degrees of freedom contrasts, as was done for univariate analyses. This was not done for this example.

DISCUSSION AND SUMMARY

The data from the experiment contained three missing plot values. Hence, the analyses were for disproportionate subclasses [see, e.g., Searle (1971)], using a computer package routine. Thus, it can be seen that the methods hold for balanced as well as unbalanced (disproportionate) situations.

This paper attempts to describe the numerous possibilities for analyzing data from intercropping experiments by using an example. It considers both univariate and multivariate analyses and, within each of these contexts, the possibility for analyzing both observed variables and functions of the observed variables which are of vital interest. In this experiment the effects of varying plant density on intercropping systems was not considered, and a constant density was maintained for each type of crop in both monocultures and mixtures.

The purpose for conducting these experiments may vary greatly in the type of information required, which would be related to conditions under which such intercropping systems are utilized in different climatic and socio-economic situations. Thus, the types of analyses ideal for each situation would vary. Often a number of different analyses would yield different types of information and much care and thought is required so that only relevant analyses, pertaining to the questions being asked, are performed on the data.

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TABLES

FIGURES

Figure 1. Mean yields of beans for varieties A, B, C, and D in the various cropping systems.

Figure 2. Mean yields of maize for varieties X and Y in the various cropping systems