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METHODS OF DATA ANALYSIS FOR INTERCROPPING SYSTEMS UNDER RUBBER

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ABSTRACT

Analysis and interpretation of intercropping experiments are complex due to inclusion of two or more crops. Moreover, various types of experiments are involved in intercropping systems. Therefore, it is not to be expected that a single statistical approach suits all kinds of problems. The basic objective in all intercrop experiments is to assess biological or agronomic advantage in any intercrop system. This paper suggests possible ways of analyses for combined benefit of rubber based intercropping systems during the immature stages of rubber by employing the proxy variables girth and girth increment to substitute for rubber yield. Moreover, several other indices viz. *Income Equivalent Ratio (IER) and Monetary Advantage (MA) have been modified to suit intercropping systems under rubber. For the Rubber-Tea intercropping system, Bivariate analysis and diagrams were made using rubber girth and tea yield. The proposed analyses can be employed to assess the beneficial/deleterious effect of intercropping in rubber based farming systems.*

Key words: bivariate analysis, IER, intercropping systems, LER, MA, PER, rubber

INTRODUCTION

There are many items of interest in a single intercropping experiment, which consist of yields from more than one crop, making it often difficult or impossible to identify a single approach for statistical analysis, evaluation or interpretation. For instance, different types of yield components for each crop in the intercropping system, beneficial effects of intercrops on the growth of the main crop, total profit,

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ratios such as; land equivalent ratio [LER] (Wiley & Osiru, 1972), productivity equivalent ratio [PER] (Jagannath & Sunderaraj, 1987), monetary advantage [MA] and income equivalent ratio [IER] (Wiley, 1979) are some criteria which are of interest to a researcher. However, many experimenters are content in using the same statistical methods with intercrops as they apply to sole crops, giving little thought to the additional complications (Mead & Riley, 1981). This will lead to incomplete interpretations, masking some of the important findings from an intercropping system.

Recently, a number of intercropping trials have been established by the Rubber Research Institute (RRI) at various locations. Short term crops such as; banana, pineapple, passion fruit, vegetables and long term crops such as; coffee and cocoa are recommended as intercrops by RRI. Interplanting rubber with tea has become a very popular practice among small holders (Yogaratnam & Iqbal, 1998). The intercrops provide a buffer against price fluctuations and yield drops which are beyond the control of farmers and an additional income during the immature phase of rubber. Intercropping studies need comprehensive analysis which probably require a sound knowledge of statistics accompanied with basic understanding of agronomy. Therefore, the objective of this paper is to provide some basic guidelines for a researcher to come up with a complete interpretation from intercropping experiments under rubber.

METHODOLOGY

The different methods of analyses are illustrated using the data from an experiment where tea was used as an intercrop in rubber plantations.

EXPERIMENT

The experiment consisted of 4 intercrop schemes involving rubber and tea and the two sole crops in a randomized complete block layout with 4 replications. This experiment was started in June, 1990 by the Adaptive Research Unit of the Rubber Research Institute (RRISL, 1991). The treatments and their descriptions are given in Table 1.

Rubber was grown at 2 different spacings while the spacings were same within and between rows (2' and 4' respectively) for tea as well as in the sole crop situation. The spacing, 12' × 18' was considered as the recommended spacing for rubber under normal conditions and was established in sole plots. The observations recorded for each crop are; girth (cm) and yield (g/tree/tapping) for rubber and green tea yield in kg/bush/year. The yields were adjusted to kg/ha/year for both crops. For rubber, 140 tapping days were assumed for a year in the calculation of annual yields.

Data

The 4 intercrop schemes (Table 1) cannot be evaluated compositely as there was a lag of 2 years for tea under rehabilitated condition (Treatments 2 and 4). The analyses were carried out on data obtained in the year 1994 (Table 2) and 1996 (Table 3) for the rehabilitated condition of tea.

Table 1. *The experimental details of the rubber-tea intercropping trial used in the illustration*

Treatment	Description			
	Density		Cropping Intensity	
	Tea (bushes/ha)	Rubber (trees/ha)	Tea	Rubber
1. Rubber (sole) [12'×18']		500		
2. Rubber (8'x27') + Tea (2'×4') [Rehabilitated]	7950	500	0.39	0.61
3. Rubber (8'×27') + Tea (2'×4')	7950	500	0.39	0.61
4. Rubber (8'×40') + Tea (2'×4') [Rehabilitated]	9340	335	0.53**	0.47**
5. Rubber (8'×40') + Tea (2'×4')	9340	335	0.53	0.47
6. Tea (sole) [2'×4']	12500			

** Calculated as: Tea - (9340/12500) = 0.75 Rubber - (335/500) = 0.67, 0.75 + 0.67 =1.42
Then by standardization, *i.e.* for tea (0.75/1.42) = 0.53.
Similarly, for rubber - (0.67/1.42) = 0.47

Note:- Clones : Rubber - RRIC 121, Tea - TRI 2026
The spacings 12'×18' = 3.63m × 5.45m, 8' × 27' =2.42m × 8.18m,
8' × 40' = 2.42m × 12.1 m and 2' × 4' = 0.6m × 1.21 m.

Table 2. *Yield of tea under rehabilitated condition and girth of rubber in 1994 (4th year)*

Treatment	Replicate				
	1	2	3	4	Mean
Girth of rubber (cm)					
1. Rubber (12'×18')	37.40	38.41	40.59	40.67	39.27
2. Rubber (8'×27') + Tea	38.12	41.39	39.26	39.91	39.67
4. Rubber (8'×40') + Tea	39.06	38.43	42.45	42.25	40.55
Adjusted yields of tea (kg/ha)					
2. Rubber (8'×27') + Tea	1192.7	1202.0	855.5	1095.5	1086.4
4. Rubber (8'×40') + Tea	1407.9	1493.7	1438.6	1187.1	1381.8
6. Tea (2'×4')	2791.8	2258.4	2038.8	2961.6	2512.6

Table 3. *Yields of rubber and tea under rehabilitated condition in 1996*

Treatment	Replicate				Mean
	1	2	3	4	
Adjusted yields of rubber (kg/ha)	1734.60	1856.40	2542.40	1311.10	1861.13
1. Rubber (sole) [12'×18']					
2. Rubber (8'×27') + Tea (2'×4')	1856.40	2276.40	2480.10	2404.50	2254.35
4. Rubber (8'×40') + Tea (2'×4')	1187.04	1593.66	909.39	1518.62	1302.18
Adjusted yields of tea (kg/ha)					
2. Rubber (8'×27') + Tea (2'×4')	2302.02	1863.48	1500.96	1523.22	1965.82
4. Rubber (8'×40') + Tea (2'×4')	2237.86	2170.62	2178.09	1961.40	2428.40
6. Tea (sole) [2'×4']	6770.00	4945.00	4265.00	5040.00	5245.00

Data analysis

Statistical analysis for observations from each crop

The simplest form of statistical analysis is to consider individual crop growth or yield components of the two crops (tea and rubber). The analysis can be carried out for different yield components of researcher's interest if data are available.

Analysis for rubber and tea yields

Preliminary statistical analysis consisted in performing an analysis of variance for the individual yields of both crops. The plot yields of sole crops are usually greater than the yields of combined plots and exhibit significant treatment effects in many instances. Therefore, it would be preferable to determine single degree of freedom contrasts compared to multiple comparison procedures in mean separation. In this example, single degree of freedom contrasts were computed to set apart the effects sole *vs.* intercropped situations and the two spatial arrangements of rubber. The means of different treatments and contrasts are given in Table 4, for yields of rubber and tea.

Univariate analysis based on a single year's data cannot be used to identify a suitable cropping system. For this, the series of experiments carried out for a sufficiently large period of time in various locations should be analyzed. Moreover, it is usually advisable to generate single degree of freedom contrasts as it may provide more information in intercropping trials. This idea is more important in the case of several combinations of varieties for both component crops being tested in an experiment.

The weakness of univariate analyses is that, even a series of analyses on individual yields, will not reflect the combined benefit of the cropping system. In this illustration, an increase in rubber yield was observed in situation 2 over 4, while yield of tea showed an increase in the reverse order. Hence, further analyses based on combined benefit is needed to identify a suitable intercropping system.

Table 4. *Estimates of rubber and green tea yield*

Cropping system	Estimated yields of crops (kg/ha/year)	
	Rubber	Tea
1. Rubber (sole) [12'×18']	1861.16	
2. Rubber (8'×27') + Tea*(2'×4')	2298.80	432.48
4. Rubber (8'×40') + Tea*(2'×4')	1302.14	534.24
6. Tea (sole) [2'×4']		1313.75
Rubber (sole) *vs.* Rubber as an intercrop	60.69* (p=0.0283)	
Tea (sole) *vs.* Tea as an intercrop		830.39 (p=0.0012)
Intercrop situation 2 *vs.* 4	996.66 (p=0.1)	-101.76 (p=0.0002)

* Contrasts with positive values indicate higher value for the first entry listed.

Statistical analysis using yields of both crops

The analyses in the previous section indicated certain weaknesses which lie in the fact that a farmer uses a combination of both yields for obtaining food or profit. This section focuses on simultaneous analyses based on yields of both crops. The combined benefit can be assessed by a number of univariate combinations and functions of the yields of both crops. Some of them are, total income, profit and ratios like LER, PER and IER.

a) *Analysis on monetary value of crops*

This illustration presents some results on an analysis of variance based on total income from the four cropping systems for prevailing market prices (as at July 2001) of the two component crops. The prices used were Rs.64 for a kilogram of rubber (assuming manufacture of rubber grade - RSS) and rupees 24 for a kilogram of green tea. The analysis of variance was carried out in the usual way and the contrasts of interest were considered as; sole rubber *vs.* sole tea, intercropping situation 1 *vs.* situation 2. Other possible treatment contrasts of interest are income through sole rubber *vs.* intercropped rubber, sole tea *vs.* intercropped tea. Further, it should be noted that a variety of other contrasts could have been made from these data.

The differences in total income for the prevailing prices are given against the contrasts in Table 5. The same kind of analysis for profits would be more desirable from an economic point of view, since the ultimate aim of any venture is to maximize profit.

Table 5. *Estimates of income from different cropping systems under prevailing prices[+] of rubber and green tea*

Cropping system	Estimated income (Rs./ha)
1. Rubber (sole) [12'×18']	119112
2. Rubber (8'×27') + Tea*(2'×4')	104834
4. Rubber (8'×40') + Tea*(2'×4')	66352
6. Tea (sole) [2'×4']	126120
Rubber (sole) *vs.* Rubber × Tea	33519 (p=0.0487)
Tea (sole) *vs.* Rubber × Tea	40527 (p=0.0223)
Rubber (sole) *vs.* Tea (sole)	-7008 (p=0.6896)
Intercrop situation 2 *vs.* 4	38482 (p=0.0497)

* Contrasts with positive values indicate higher value for the first entry listed.
[+] Prevailing prices of rubber (RSS-1) and green tea are Rs.64 and Rs.24, respectively.

b) *Indices for the assessment of combined benefit*

The Land Equivalent Ratio (LER), originally suggested by Wiley and Osiru (1972) is one of the most common indices used in analysis of intercropping experiments. This has been extensively used in recent studies by Mahakular *et al.*, 1995; Singh & Arya, 1995; Maheshwari *et al.*, 1995; Mishra & Ali, 1995; Pajkaray *et al.*, 1995 and Badiyala *et al.*, 1995, although various other indices were suggested for assessment of benefits from intercrop schemes.

Some of the limitations of LER and further suggestions on improvement are illustrated by Jagannath & Sunderaraj (1987). It is a known fact that the basic objective in all intercrop experiments is to assess biological or agronomic advantage accruing in association of two or more crops. As stated by the previous authors, the inherent limitation of LER is not bringing out such an aspect of the intercropping scheme and consequently the Productivity Equivalent Ratio (PER) was suggested as an improvement to the LER. The formulae for the computation of these indices are given below;

$PPER_1 = (I_1/S_1)$ -------- *(1)* $PPER_2 = (I_2/S_2)$ --------- *(2)*, and
$PER = PPER_1 + PPER_2$ ---------- *(3)*

where, I_1 and I_2 are the yields respectively, for the two component crops; 1 and 2 occupying respective areas in the ratio of $a : (1-a), (a<1)$. Similarly S_1 and S_2 are the sole crop yields grown side by side in areas corresponding to the same ratio of the component crop.

All the indices that quantify the beneficial effects of intercropping systems take into account yields of both component crops. However, the beneficial or deleterious effect of intercrops on the growth of rubber has to be assessed in many instances. The main criterion of growth during the initial stages of rubber is girth or the girth increment. All the agronomic practices are therefore aimed at attaining the tappable girth (50 cm) early as possible. Therefore, the following indices are suggested to quantify the effect of intercropping during the immature stage in a rubber based intercropping system.

$$INDEX\ 1 = \frac{\text{Avg. girth of rubber in mixture}}{\text{Avg. girth of rubber in pure-stand}} + \frac{\text{Yield of intercrop in mixture}}{\text{Yield. of intercrop in pure-stand}} \quad \text{........ (4)}$$

Similarly, another index can be suggested by replacing the average girth in the above equation by annual girth increment. For mature stages of rubber, when both component crops produce yields, the first part of the equation can be replaced by the following.

$$\frac{\text{Yield of rubber in mixture}}{\text{Yield of rubber in pure-stand}} \quad \text{........... (5)}$$

The yields have to be recorded in equal units of weight per unit area. The above indices are all based on the LER.

Income Equivalent Ratio (IER);

$$IER = \frac{\text{Income from both crops in intercropping}}{\text{Income from the main sole base crop}} \quad \text{............. (6)}$$

and Monetary Advantage (MA);

$$MA = \text{Value of combined yield} \times \frac{LER - 1}{LER} \quad \text{........... (7)}$$

suggested by Wiley (1979) can also be employed directly for the mature stage of rubber. This can be modified for the immature stage of rubber in the following manner.

$$MA = \text{Value of the yield of intercrop} \times \frac{INDEX1 - 1}{INDEX1} \quad .... (8)$$

MA of this form is compared with zero, since immature rubber will not give any monetary benefit.

Index values calculated according to the proposed Index-1 are presented in Table 6. I^*_{TEA} (column 9, Table 6) was calculated in the following manner;

$I^*_{TEA} = I_{TEA} \div$ estimated area under tea

I^*_{TEA} is similar to PPER given in equations 1 and 2.

For instance, $I^*_{TEA} = 0.43 \div 0.39 = 1.10$ (Table 6, column 9, row 1). These indices can be employed to assess the overall benefit and partial performance of each crop.

The index, I_{RUBBER} exceeds 1 ($I_{RUBBER} > 1$) in both intercrop schemes, indicating the beneficial effects of intercropping with regard to growth of rubber (Table 6). No apparent advantage was evident in any system for tea ($I_{TEA} < 1$). This is obvious since the cropping intensities for tea were 0.39 and 0.53 for the two intercrop treatments considered. However, the partial index (I'_{TEA}) for both situations indicated the presence of biological efficiency ($I'_{TEA} > 1$), *viz.* There were beneficial effects on yield of tea when equal areas were considered for pure-stand and intercrop conditions. There was aggregate benefit *via* intercropping in both systems with Index 1 > 1 (Table 6). It is advisable to use non parametric procedures for comparisons between these calculated ratios, as further checks need to be carried out for validity of assumptions for parametric analyses. However, these ratios can be used for appropriate descriptive analyses to assess the overall benefit from different intercrop situations.

Table 6. *Calculated Indices for intercrop schemes - Rubber x Tea (rehabilitated)*

Intercrop Scheme	Area under Rubber	Area under Tea	Girth (cm) Rubber	Yield/-ha Tea	I_{Rubber} (6)	I_{Tea} (7)	Index 1 6 + 7 (8)	I'_{Tea} (9)
2	0.61	0.39	39.67	1086.4	1.01	0.43	1.44	1.10
4	0.47	0.53	40.55	1381.8	1.03	0.55	1.58	1.04
Pure stand			39.27	2512.6				

2. Rubber (8'×27') + Tea (2'×4') [Rehabilitated]

4. Rubber (8'×40') + Tea (2'×4') [---- do -------]

Bivariate analysis

Bivariate analysis applies to situations when two quantities need to be studied together. Bivariate diagrams are constructed from bivariate analysis and are considered very useful in the study of intercrops.

The major steps towards construction of bivariate diagrams are as follows;

Suppose there are two variates; a and b [a= yield of tea (kg/ha), b = girth of rubber (cm)]

These two variates; a and b are transformed to two other variates; x and y, such that,

(A) variances of x and y = 1 and

(B) covariance of x and y = 0 or x and y are independent.

Let $x = a / \sigma_a$ .... (9)

A regression of b on a gives a regression coefficient β. Now subtract from b the component that could have been predicted from a (i.e. βa). This leaves ($b - \beta a$). The variance of this adjusted variate; $b - \beta a = \sigma^2_b (1 - \rho^2)$. Therefore, the standard error is $\sigma_b \sqrt{(1 - \rho^2)}$, where ρ is the estimated correlation coefficient between a and b.

Dividing by the standard error gives;

$$y = \frac{(b - \beta a)}{\sigma_b \sqrt{(1 - \rho^2)}} \quad \text{.............} \ (10)$$

Once the plot means are known for a and b, the transformed variates can be calculated using the expressions given in equations 9 and 10, respectively. These y's can be plotted against x's to depict the relative position of each intercrop treatment. Since the original values are transformed to have variances = 1 and covariance = 0; the standard error of treatment difference = $1/\sqrt{r}$, where r is the number of replications. Circles of radius, $2/\sqrt{r}$ around each point indicate 95% confidence regions.

The bivariate diagrams for the rehabilitated condition of tea is given in Figure 1 based on the results presented in Table 7. This bivariate diagrams clearly depict the relative position of each intercrop treatment. In this illustration, the standard error of treatment difference was 0.5 and $2/\sqrt{r} = 1.0$. Therefore, in the rehabilitated condition, the two intercrop treatments were statistically different at the probability level 0.05 with respect to the yield of tea. No apparent differences were observed with respect to girth of rubber [Fig. 1].

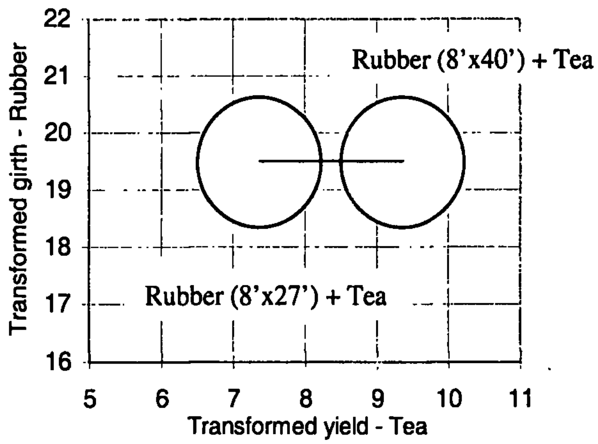

Fig.1. Bivariate diagram for rubber × tea intercropping systems

Table 7. *Transformed values of girth of rubber and yield of tea under rehabilitated condition*

Treatment	Yield of tea (*a*)	Girth of rubber (*b*)	Transformed values	
			x	*y*
Rubber (8'x27') + Tea	1086.4	39.67	7.36	19.48
Rubber (8'x40') + Tea	1381.8	40.55	9.36	19.49

CONCLUSIONS

This study suggests possible ways of analyses for combined benefit of rubber based intercropping systems during the immature stages of rubber by employing the proxy variables such as girth and girth increment to substitute for rubber yield. Moreover, several other indices *viz.* Income Equivalent Ratio (IER) and Monetary Advantage (MA) have been modified to suit intercropping systems under rubber. The proposed indices can therefore be employed to assess the beneficial/deleterious effect of intercropping on rubber during the immature stages of rubber in rubber based farming systems.

The bivariate diagrams are generally prepared using yields of both crops. However, under immature situation in rubber, several intercropping systems can be compared using bivariate diagrams using the girth of rubber and yield of the intercrop as suggested in this study.

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