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Statistical Assessment of Different Standardisation of Sole Crop Yields in Intercropping

M.K. Jagannath and M.V. Sholapurkar
University of Agricultural Sciences, Bangalore - 560065
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SUMMARY

The use of indices like land equivalent ratio (LER) and productivity equivalent ratio in analysis of intercrop experiments has come to stay despite its limitations both with respect to its interpretation and amenability of statistical analysis. Although the assumption of normality has been tested in various ways of computation of LER using different standardisation of sole crop yields, testing the vital assumption of suitability of additive model seems to have been overlooked. In a study of two different type of intercropping experiments, normality, and additivity of the model have been tested, in different ways of computation of LER. The study indicates that assumptions of additivity are more often not met in the case of PLER than in LER. Using different divisors for meaningful interpretation of PLER or LER will no way affect the suitability of additive model, although in few situation, it may affect the assumptions of normality. Combining of PLER's brings in a sort of harmony and the resulting LER is more amenable for statistical analysis. The appropriate transformation in case of PLER's not obeying the additive model, appears to be an inverse square-root transformation. As regards precision of different methods, standardisation of sole crop yields based on maximum yield gave relatively higher precision in all the experiments, compared to other methods of standardisation.

Key words : Non-additivity; Normality; LER; PLER

Introduction

Analysis of intercrop experiments are seldom complete without the computation of Land Equivalent Ratio (LER) and its analysis (Jagannath and Sunderaraj [1]). The sole crop yields in intercropping trials play a crucial role, as both biological and statistical interpretations would depend on it. Often in field experimentation because of soil heterogeneity, the sole crop yield in different block is subjected to lot of variation. This introduces a problem in the analysis of LER, besides the existing one being that it is a sum of two ratios of unstandardised normal deviates, which tends to follow the sum of two non-central Cauchy's distribution whose exact form is unknown, and not sum of two Cauchy's distributions as observed by Chetty and Reddy [5].

design variable X_3 is given a greater allocation. Under sample design (a), $V(\beta_{12})$ is very high in comparison to other sample designs.

Nathan and Holt [4] have shown that if Q = 1, in which case the bias of b_{12} becomes of $O(n^{-1})$, then $V(b_{12}) \geq (\hat{\beta}_{12})$. This is true under all the three different situations. In situation C, when the dependent variable itself is used as the design variable, $V(\hat{\beta}_{12})$ is less than MSE (b_{12}) in all the three sample designs considered. Since for simple random sampling, sampling inclusion probability $\pi_\alpha = n/N$, the weighted and the unweighted estimators coincide i.e. $b_{12} = b^*_{12}$ and $\hat{\beta}_{12} - \hat{\beta}^*_{12}$, so $V(b_{12})$ and $V(b^*_{12})$, and $V(\hat{\beta}_{12})$ and $V(\hat{\beta}^*_{12})$ under all the 3 situations don't differ much from each other. Under the sample design (b) and (e) in which only few values are selected from last stratum, the weighted estimator comes out to be better than unweighted estimators.

Further weighted estimators seem relatively insensitive to the sample design. But since the weighted estimators are model free, they may be more robust to departures from the model upon which the properties of b_{12} and $\hat{\beta}_{12}$ are based. The results which hold for situation A extend to the situation B also, where double sampling has been adopted as a method of design for estimating regression coefficients when the design variable X_3 is already available from the survey or can be measured cheaply. Under the situation C, when X_1 is measured at the first phase and so the dependent variable is used as the design dependent variable itself, the bias for b_{12} is more in comparison to the situation A and B. But in this case also, the results of situation A are applicable.

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Oyejola and Mead [3] made a statistical assessment of different ways of standardisations on LER. Here they considered residuals after accounting for block and treatment effects, and studied how the normality of these residuals are affected under different ways of standardisation.

In the present investigation, it is proposed to study the suitability of additive model and the effect on normality, under different standardisations. It is felt that additivity of the model employed in ANOVA is equally a stringent condition and in fact Snedecor remarks that anormality is relatively unimportant but is usually associated with non-additivity. Non-additivity may arise due to absence of homosedasticity or non-independence of errors and the effect of non-normality has little effect on inferences about means (Scheffe, [6]). But these residuals are obtained after assuming the additive model and after removing the effect of block and treatment. Hence the study of normality of such residuals, has meaning only if the basic additive model is appropriate. Further, in the computation of LER, if different estimates of sole crops yields are used in different blocks, this may affect the the basic additive model in analysis of LER (Oyejola and Mead).

2. *Material and Methods*

Data of three intercrop experiments, two conducted under AICARP and the remaining one by a PG research worker are considered. The first and third belong to additional series, while the second one is a replacement series. The first experiment conducted at GKVK farm, had pigeonpea as the main crop and the intercrops were ragi, cowpea, soybean and sunflower with different agronomic practices, along with sole crops.

The second experiment was a replacement series of intercrop experiment conducted at MRS, Hebbal, with groundnut as main crop and sunflower as an intercrop, with eight different agronomic treatment combinations.

In the other experiment conducted at Honnaville Research Station sole crop of pigeonpea was raised under normal, paired row system and skip-row system. Groundnut both as sole crop and intercrop was tried in all these 3 systems with three fertilizer levels.

In interpretation of LER as an index of yield advantage for comparing different crop treatments (Mead and Wiley [2]) three different methods of standardisation as followed by Oyejola and Mead[3] viz. (a) The average sole crop yield based on all replications (b) the best sole crop yield in any block (c) the respective sole crop yields in each replication or block, were followed for the results of first and third experiments. For the second experiment having additional sole crop treatments at different agronomic practices, the following additional three methods for proper agronomic interpretation were also tried.

(1) Treatmentwise within the blocks

(2) Average of all the treatments blockwise

(3) Treatmentwise-each block

Here it was felt that effect of the change of divisors both within and between blocks on the assumptions of additivity, would be worth investigating.

3. *Assessment of Standardisations*

The effect of different methods of standardisation are assessed based on the following three aspects.

(1) *Additivity :* Tukey's test was adopted by apportioning portion of variance due to non-additivity and testing the same against the remaining error variance (Snedecor and Cochran), for each analysis of the two individual PLER's, in addition to the combined LER, under different standardisation of estimation of sole crop yields. The suitable transformation as suggested by he test was used whenever the non-additivity portion was significant. Thus transformed data were tested again for additivity.

(2) *Normality :* The residuals of each observation after accounting for block and treatment effects were calculated and coefficient of skewness and kurtosis were worked out. Although these two coefficients may not fully reflect the features of normal distribution (Kendall and Katti [4]) these provide about non-symmetric and peaked or plateau like features of normal distribution.

(3) *Precision :* The quantum of error mean sum of squares were compared in the analysis of variance under each standardisation. Although in a strict sense such a simple comparison may not be valid, in the present case since basically values involved are the same, the error variance itself would truly reflect the precision.

4. *Results and Discussions*

(a) *Additivity :* Departure from additivity in the ANOVA of PLER's and LER computed by following different methods of standardisations are furnished in terms of proportion of non- additivity to the total residual variances (Table-1). Results indicate that for experiment-1 the PLER in respect of pigeonpea crop showed significant proportion of non-additivity thereby indicating the non-suitability of additive model, while for the other PLER and combined LER, this proportion was quite less, indicating the suitability of additive model.

The second experiment of replacement series indicated higher proportion of non-additivity for ANOVA of PLER of main crop and intercrop as compared to combined LER. But these departures from additivity were not significant, thereby indicating suitability of additivity model.

Result of experiments conducted at Honnaville is of more interest, as there are six types of different standardisations adopted for working out PLER and LER. Here the ANOVA of main crop indicated in general the suitability of additive model. The analysis of PLER in respect of intercrop showed higher variation in the proportion of non-additivity. It varied from 5.45% to 28.16%. The lowest proportion was under treatmentwise standardisation. While it was the highest under the standardisation based on general mean. For LER, the proportion of non-additivity was only to 7.9%, even under treatmentwise and blockwise standardisation, wherein divisors varied both within and between blocks.

In cases where the additive model was not appropriate, suitable transformation as suggested in Tukey's test was performed, analysed, and then again tested. An illustration is furnished below.

ANOVA of PLER for pigeonpea in Experiment-1 using Replicationwise standardisation.

Source of variation	df	Sum of squares		M.S.S.	
		Original data	Transformed data*	Original data	Transformed data*
Treatement	19	1.3559	20.2559	0.0714	1.0661
Replication	2	0.2530	1.2925	0.1265	0.6462
Residue	38	1.0588	17.1911	0.0279	0.4523
Non-additivity	1	0.1950	0.0380	0.1950 (8.5227)	0.0380 (0.0522)
Remainder	37	0.8638	17.1531	0.0233	0.4638

* transformed using transformation x^p, where estimated value of 'p' is –0.4066, as suggested by the test. Values in parantheses are observed 'F' values.

(b) *Normality* : Results of skewness and kurtosis obtained for the residuals are furnished in Tables 1(a), 1(b) & 1(c) for experiment 1, 2 and 3 respectively. For partial LER main crop in experiment-1, skewness and kurtosis were small, suggesting that the values are fairly normally distributed. The corresponding values for intercrop indicated that it was negatively skewed and leptokurtic. The composite LER were slightly skewed negatively and leptokurtic, when the standardisation was based on general mean and maximum sole crop yields. But the LER values using replicationwise standardisation were fairly normally distributed.

In the replacement series of intercropping, the values of PLER in respect of main crop, were slightly skewed negatively and platykurtic, while for intercrop slight positive skewness and platykurtosis was observed. The composite LER's were slightly skewed negatively and platykurtic, when standardisations were based on general mean and maximum yield, but for replicationwise standardisation when different divisors were used the distribution was negatively skewed and were leptokurtic.

Analysis of Honnaville data using 6 different types of standardisations, revealed that PLER values for main crop exhibited positive skewness in all types of standardisations. This was more when average of the best treatment was used for standardisation. This also led to leptokurtic distribution. It was interesting to note that even in cases where different divisors were used, the values of co-efficient of skewness and kurtosis were fairly close to the values of normal distribution. For intercrop the value of residuals were positively skewed and highly leptokurtic for cases of standardisation using respective treatments in each block. In other cases of standardisation the skewness varied from –0.2269 to 0.7142, but the values of kurtosis were nearly mesokurtic. The composite LER values exhibited lower variation both in skewness and kurtosis. The treatmentwise and blockwise standardisation lead to slightly leptokurtic distribution.

However, effect of such violations of normality assumption is slight on inferences about mean, whenever the equality of means is tested (Scheffe [6]). Departures of β_2 by about 1 brings in a slight change in the level of significance (α), from a specified level of 0.050 to 0.052 to 0.053. Further Scheffe reports that for inferences about means, the power calculated under normal theory should not be affected much by non-normality of the errors.

(c) *Precision* : The mean residual variance under different methods of standardisations are presented in Tables 1(a) to 1(c) for experiments 1, 2 and 3 respectively. The variances were more for the standardisation using general mean and replication values, in experiment-1 & 3, while for standardisation using maximum values the variances were lower indicating better precision.

In the experiment-2, among the six methods of standardisation using maximum value recorded the minimum variance and the next best was the standardisation based on average of all treatments- blockwise.

To summarise, the analysis of PLER values often exhibits lack of suitability of additive model, while LER values in general conform to additive model. Using different divisors will in no way affect the suitability of basic additive model. Regarding normality assumptions, often the kurtosis was found to be more and did not meet the specification of the normal distribution as compared to skewness. The composite LER values exhibited variation in kurtosis depending upon the method of standardisation. Using standardisation of different treatments within each block, wherein different divisors were used, did not affect either skewness or kurtosis.

Table 1. *Results of additivity and normality for various standardisations*

Standardisation procedure	Proportion of non-additivity variance (in %)			Co-efficient of skewness (β_1) and kurtosis (β_2)					
	Main crop ($PLER_1$)	Inter crop ($PLER_2$)	LER	Main Crop		Inter Crop		LER	
				β_1	β_2	β_1	β_2	β_1	β_2
(a) Additional series intercropping experiment on pigeonpea and other crops conducted at GKVK									
(1) Replication-wise	18.41* (0.027)	1.11 (0.088)	0.56 (0.147)	0.2731	3.5283	–0.2156	3.732	0.3054	2.9356
(2) G.M.	17.51* (0.028)	0.23 (0.130)	0.22 (0.139)	0.2677	3.5361	–0.7542	4.135	–0.1401	4.5792
(3) Maximum	17.50* (0.023)	0.46 (0.074)	0.24 (0.111)	0.2572	3.5174	0.7745	4.2661	–0.3185	5.5595
(b) Replacement series of intercropping on Groundnut and Sunflower and Hebbal									
(1) G.M.	14.04 (14.77)	8.95 (9.48)	5.54 (24.72)	–0.2029	2.4495	0.0600	2.0741	–0.2655	1.9717
(2) Replication-wise	11.00 (14.96)	6.46 (9.23)	4.17 (38.66)	–0.1885	2.4745	0.0785	2.1321	–1.6865	4.9093
(3) Maximum	14.10 (14.35)	8.94 (9.25)	5.49 (23.98)	–0.2116	2.4597	0.0694	2.0826	–0.2622	1.9707

* Denotes signifince at 5% level

Values in parentheses are error mean squares (in units of 10^{-4} for expt. 1 (b)

Standardisation procedure	Proportion of non-additivity variance (in %)			Co-efficient of skewness (β_1) and kurtosis (β_2)					
	Main crop ($PLER_1$)	Inter crop ($PLER_2$)	LER	Main Crop		Inter Crop		LER	
				β_1	β_2	β_1	β_2	β_1	β_2
(c) Additional series of intercropping experiement at Honnaville with Groundnut and Pigeonpea									
(1) General mean	0.69 (0.0437)	28.16** (0.0398)	0.58 (0.0630)	0.409	3.812	0.534	3.527	–0.151	2.499
(2) Maximum	0.69 (0.0253)	28.18** (0.0150))	0.1 (0.0304)	0.407	3.812	0.532	3.524	–0.110	2.770
(3) Treatment wise over all blocks	1.72 (0.0538)	13.48** (0.0578)	0.9 (0.0671)	0.517	4.720	0.529	3.327	–0.059	2.905
(4) Average of best treatment over all blocks	– (0.0519)	28.14** (0.0322)	0.18 (0.0661)	1.139	5.879	0.533	3.520	0.457	4.425
(5) Average of all treatment blcokwise	1.74 (0.0430)	7.43 (0.0407)	4.0 (0.0521)	0.409	3.784	0.714	3.266	0.186	3.014
(6) Treatment wise each blcok	0.62 (0.637)	5.45 (0.0445)	7.9 (0.0783)	0.403	3.326	1.156	6.547	0.571	4.692

** Denotes 1% level of significance.
Values in parantheses are error mean squares

5. Conclusions

In general the LER can be analysed using any of the standardisation without much loss in the precision of comparisons. The fear that different divisors used for computation of PLER and LER would violate the basic structure of additive model and usher in fresh problems about the assumptions of the non-normality appears to be little unfounded. And agronomists may use different sole crop treatments in their experiment, for meaningful interpretation. Considering all the three aspects of additivity, normality and precision, the standardisation treatmentwise over all the blocks appears to be the best.

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On Systematic Sampling Allowing Estimation of Variance of Mean

S. Ray and M.N. Das*
Central Statistical Organisation, New Delhi
(Received, August, 1994)

SUMMARY

A slightly modified circular systematic sampling scheme is presented. It is equally simple and provides estimate of variance of mean. As joint probabilities of inclusion of pairs of units, are unequal, Horvitz-Thompson method of estimation has been adopted. These probabilities can be obtained quite easily.

Key words : Circular Systematic Sampling, Horvitz-Thompson Method of estimation, Estimation of Variance.

Introduction

Systematic sampling provides a very convenient scheme of sampling as compared to other sampling schemes. It is used widely in different situations. It is being used extensively in different surveys conducted by the National Sample Survey Organisation, Government of India. This technique has, however, the drawback that though it provides unbiased estimate of population mean, it cannot provide an estimate of the variance of the estimate of mean. As much the user cannot get any idea of precision of the estimate. The usual systematic sampling scheme requires that population size N is an exact multiple of sample size. Lahiri (1954) suggested a modification of systematic sampling which does not have the above drawback and called it circular systematic sampling. This scheme also has the drawback that it cannot provide estimate of variance. In this paper a modified technique of circular systematic sampling is provided. This technique ensures unbiased estimates of variance of mean and at the same time does not affect the simplicity of the existing scheme. Though the scheme works for both linear and circular systematic technique, we are emphasising on circular systematic sampling as this scheme works for any population and sample sizes. The linear systematic sampling is also covered by the present method.

2. *A Modified Circular Systematic Sampling Technique.*

Let N denote the size of population and n, the sample size. The units are provided serial numbers in any order.

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* Formerly at, IASRI, New Delhi.