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Combination of Results of Groups of Similar Experiments

by

K. A. SESHU, B. Sc. (Ag.), Statistical Assistant,
Agricultural Research Institute, Coimbatore.

Introduction: The repetition of agricultural experiments in a number of places and/or over a number of seasons has become a common feature now. The varietal response to manuring experiment in paddy, the model agronomic experiments sponsored by the Indian Agricultural Research Institute on a number of crops and simple fertiliser experiments on cultivators' fields are instances. The object of such repetitions is to study the average response to treatments over a number of places or over a number of seasons and to make firm recommendations that hold good for a fairly wide tract or to a variety of seasonal conditions. It may also be desired to test the consistency of the responses from place to place or from season to season. A knowledge of the method of combining the results of the several repeated experiments, therefore becomes necessary. This article is intended to draw attention to a few of the salient statistical considerations involved in the procedure and to briefly indicate the steps to be adopted for a preliminary and overall apraisal of the results.

Material and Methods: The numerical data used here to illustrate the procedure relate to the yields of six bunch groundnut strains in a comparative trial to determine the best among them, carried out on the Central Farm, Coimbatore during the monsoon season of three years 1953, 1954 and 1955. The data are presented Table I.

The first step is to carry out an analysis of variance for the data of each season separately. The results of the three analyses are presented in Table II. A combined preliminary analysis is next computed after tabulating the data in a two way table as presented in Table III. The results of this analysis are furnished in Table IV.

The procedure outlined above is relatively simple and may be employed as a preliminary step to indicate the over all trend of results. But, it is open to the objection that the test of significance employed in the pooled analysis is not fully efficient and consequently the conclusions arising therefrom are not quite valid, owing to the heterogeneity of the error and the varieties x seasons interaction variances in the different experiment. This leads to the consideration of the steps involved in the procedure in four different situations arising from the combination of (i) the homogeneity of the error variances and (ii) the presence or absence of the varieties $\times$ seasons interaction.

Let us first consider the procedure for testing the homogeneity of error variances. This is done by what is called the Bartlett's 'M' test. This is a simple chi-square (X^2) test and is carried out as follows:

$X^2 = X'^2/C$, where C is a correction.

$$X'^2_{(n-1)} = \log_e 10 \left[\left(\sum_1^n K_i \right) \log_{10} \bar{S}^2 - \sum_1^n \left(K_i \log_{10} S_i^2 \right) \right]$$

Where n = no. of experiments; K_i and S_i^2 are the degrees of freedom and variance for error in the ith experiment: $\sum_1^n$ = summation over all experiments and $\bar{S}^2 = \sum_1^n K_i S_i^2 / \sum_1^n K_i$ = pooled error varince. If the error degrees of freedom are all equal, a simple average of the individual error variances would give the pooled error variance. The correction C for X'^2 is given by: $C = 1 + \frac{1}{3(n-1)} \left(\sum_1^n \frac{1}{K_i} - \frac{1}{\sum_1^n K_i} \right)$.

the symbols having the same meaning as above. Testing the homogeneity of the 3 error variances in Table II, we get,

$$\bar{S}^2 = \frac{565 + 4861 + 42340}{3} = 15922$$

$$X'^2_{(2)} = 2{\cdot}30259 \ \{ (75 \times 4{\cdot}20201) - 276{\cdot}63825 \}$$
$$= 88{\cdot}678$$

$$C = 1 + \frac{1}{3 \times 2}\left(\frac{3}{25} - \frac{1}{75}\right) = 229/225$$

$$X^2_{(2)} = 88{\cdot}678/C = 87{\cdot}130$$

This is a highly significant value of X^2 and shows that the error variances are not homogeneous. The next step in such a situation will be considered subsequently.

Assuming for the present that the error variances are homogeneous (indicated by a non-significant value of X^2), then the pooled analysis presented in Table IV is valid, The error variances of the three experiments are pooled together to get a pooled estimate of error for testing the significance of the varieties x seasons interaction. If the test is non-sigificant, we may assume that interaction is non-existent. In such a case, the interaction and error variance are pooled together to get a more precise estimate of the error for testing the varieties mean square. The appropriate conclusions regarding the overall performance of varieties may then be drawn depending on the significance or otherwise of this test.

If, however, the interaction is significant or if it cannot other wise be assumed to be absent even when the test is non-significant, the appropriate mean square will be that of the varieties x seasons interaction. The overall conclusions about the varieties are drawn based on the result of this test. The test for season may be similarly carried out but is generally of no importance.

A different situation has to be confronted when the errors in the different experiments are not homogeneous, as has happened in our example. Here the error variances cannot be pooled to obtain a joint estimate, as such pooling runs counter to the basic assumptions underlying the analysis. The presence or absence of varieties x seasons interaction, on which depends the test for the overall varietal differences, has to be tested by carrying out what is called a weighted analysis of variance.

For this analysis, the means of treatments (varieties) for each season are tabulated in a two-way table as in Table V. A weight W is then computed for each experiment from the formula.

$W_i = r_i/s_i^2$, where r_i and s_i^2 are the number of replications and the error variance respectively of the ith experiment. The sum of squares are next computed weighting them with the appropriate weights.

From the table, the sums of squares (S. S.) are calculated as follows :—

Correction factor (C. F.)	$= G^2/tW$, where t = number of treatments (venities)
	$= 51818{\cdot}16$
Total S. S.	$= E\ w_i S_i - C.\ F. = 5164{\cdot}71$
Treatments S. S. (varieties)	$= E\ T_i^2/W - C.\ F. = 1283{\cdot}73$
Seasons S. S.	$= E\ w_i\ Y_i^2/t - C.\ F. = 3779{\cdot}23$
Interaction S. S.	= Total S. S. — (Treatments S. S. + Seasons S. S.) = 101·75

For testing the presence of the interaction, the interaction has to be transformed into a X^2 by the formula :

$$X^2 = \frac{(K-4)\ (K-2)}{K\ (E+t-3)} \text{ x } I, \text{ with } \frac{(n-1)\ (t-1)\ (K-4)}{(K+t-3)}$$

degrees of freedom, where, K = degrees of freedom for error ; I = Interaction S. S., n = number of experiments ; and t = number of treatments.

Substituting values from our example, we get,

$$X^2 = \frac{(25-4)\ (25-2)}{25\ (25+6-3)} \text{ x } 101{\cdot}75, \text{ with } \frac{(3-1)\ (6-1)\ (25-4)}{(25+6-3)}$$

degrees of freedom.

$= 70{\cdot}207$ with 7·5 degrees of freedom.

This is a highly significant value of X^2 indicating the significance of the varieties X seasons interaction. Next, in the pooled analysis presented in Table IV, the varieties mean square is tested against the interaction mean square. The test is found to be significant in regard to the overall differences among the varieties. The results and conclusions are presented in Table VI.

If the value of X^2 is non-significant, indicating the absence of the varieties X seasons interaction, then no general test of significance appears to be available for testing the overall varietal differences. An approximate method would be to test the varieties mean square against the interaction mean square in the weighted analysis of variance, and the conclusions drawn based on this test.

There are many more situations likely to arise in the combination of results of a series of experiments, such as heterogeneity among different components of interaction corresponding to groups of treatments, the need for making comparisons of single degrees of freedom, the adoption of different designs for the experiments, the repetition of experiments in both space and time etc. These are much more complicated than what has been presented here and an elucidation of the appropriate procedures in such instances has, therefore, not been attempted. It may also be stated that satisfactory and fully efficient methods for meeting many of these situations are not, as yet, available.

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COLLEGE DAY AND CONFERENCE, 1960

The College Day & Conference will be celebrated from 19th to 22nd August, 1960.

The General Body Meeting of the M. A. S. U. will be held on 21—8—1960.

APPENDIX.

TABLE I.

Groundnut - Yield of dry picked pods in gm. per plot.

Year	Repli-cations	Varieties					
		TMV. 2	A. H. 4111	A. H. 4218	A. H. 4515	A. H. 6279	A. H. 6481
	I	550	745	875	720	900	570
	II	905	935	950	825	960	675
1953	III	940	875	1125	900	1020	630
	IV	875	945	1175	985	1255	745
	V	905	900	1245	885	1000	695
	VI	825	930	1070	825	1245	620
Total		5000	5330	6440	5140	6380	3935
	I	420	400	300	350	180	120
	II	340	350	225	260	340	100
1954	III	370	250	240	210	400	60
	IV	440	290	440	280	410	200
	V	395	300	420	380	430	220
	VI	375	300	450	190	240	150
Total		2340	1890	2075	1670	2000	850
	I	2344	2697	2571	2179	2219	1730
	II	2458	2731	2537	2139	2424	1821
1955	III	1718	2083	2003	2127	2093	1730
	IV	2151	2202	1821	2480	2105	1514
	V	2503	2663	2242	2242	1923	1707
	VI	2299	2424	1991	1764	1945	1878
Total		13473	14800	13165	12931	12709	10380

TABLE II.

Analyses of Variance.

Year	Source of Variation	Degrees of freedom	Sum of squares	Mean Squares	'F'
	Replications	5	251604	50321	
	Varieties	5	735938	147188	260·50**
1953	Error	25	14133	555	
	Total	35	...	...	

TABLE II. *(Contd.)*

Year	Source of Variation	Degrees of freedom	Sum of squares	Mean Squares	'F'
	Replications	5	50596	10119	
1954	Varieties	5	222437	44487	9·15**
	Error	25	121525	4861	
	Total	35	...	...	
	Replications	5	729798	145960	
1955	Varieties	5	2732640	336528	8·18**
	Error	25	1058503	42340	
	Total	35	...	...	

TABLE III.

Varieties X Seasons.

Varieties	Seasons		
	1953	1954	1955
TMV. 2	5000	2340	13473
A. H. 4111	5330	1890	14800
A. H. 4218	6440	2075	13165
A. H. 4515	5140	1670	12931
A. H. 6279	6380	2000	12709
A. H. 6481	3935	850	10380

TABLE IV.

Pooled Analysis of Variance.

Source of Variation	Degrees of freedom	Sum of Squares	Men Square	'F'
Seasons	2	64295749·8	32147874·9	
Varieties	5	1786165·9	357233·2	3·948*
Interaction: Varieties x seasons	10.	904846·9	90484·7	

TABLE V.

Weighted analysis - Mean yield per plot.

Varieties	Seasons			$T_j = \sum_i w_i x_{ij}$
	1953	1954	1955	
TMV.	833	390	2246	9·6406
A. H. 4111	888	315	2467	10·1634
A. H. 4218	1073	346	2194	12·1280
A. H. 4515	857	278	2155	9·7450
A. H. 6279	1063	333	2118	11·9952
A. H. 6481	656	142	1730	7·3836
$Y_i = \sum_j x_{ij}$	5370	1804	12910	$W = \sum_i w_i$ = 0·01199
$w_i = r/s_i^2$	0·01062	0·00123	0·00014	
$\sum_i w_i Y_i =$	———————>		$= G = \sum_j T_j$	= 61·0557
$S_i = \sum_j x^2_{ij}$	4926516	579378	28067090	
$w_i S_i$	52340·84	712·63	$\sum_i w_i S_i$	= 56982·87

TABLE VI.

Summary of results from the Pooled analysis at Table IV.

Variety	Mean acre yield in lb.	Standard Error	Critical Difference (P = 0·05)
TMV. 2	672·8		
A. H. 4111	711·8		
A. H. 4218	700·8	41·27	130·02
A. H. 4515	638·5		
A. H. 6279	682·1		
A. H. 6481	490·6		

Conclusion :

A. H. 4111, A. H. 4218, A. H. 6279, TMV. 2, A. H. 4515, A. H. 6481.