ABSTRACT OF PAPERS PRESENTED AT THE 17TH ANNUAL GENERAL MEETING HELD AT JAIPUR IN JANUARY 1964

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1. *Yield Trends in Rice and Wheat in First Two Five-Year Plans in India. V. G. Panse, I.A.R.S., New Delhi.*

In the present paper, we have extended our study on the trends of yield per acre of rice and wheat in India to the end of the Second Plan Period, *i.e.*, 1960–61. Results of crop-cutting surveys in important rice and wheat-growing States and covering over 70 per cent. of the area under rice and 65 per cent. of the area under wheat in the country have been analysed for a period of 15 years. This period covers a pre-plan period of five years from 1946–47 to 1950–51 and the First and the Second Five-Year Plan periods.

The main objective of the study is to find out whether and to what extent the two five-year plans have made their impact on the yield rate for rice and wheat in different States and in the country as a whole. The annual yield in any area is subject to the profound influence of climate. This influence may work in the direction of increasing or lowering yield, thereby either exaggerating the effect of planned effort and even misleading one to ascribe to planned effort an observed increase in yield which was really due to favourable climate, or if this influence was adverse, in lowering the effect of planned effort on yield or wiping it out entirely. A major precaution taken against this difficulty in the present study is to compare quinquennial averages of yield, rather than annual yields. This has the effect of reducing the influence of climate on yield, as positive and negative changes in annual yield due to climate would largely cancel out and the quinquennial average will be affected by only a fraction of the climatic influence to which annual yields are subject. Further even this residual influence is sought

to be assessed by means of the statistical technique known as the analysis of variance and allowed for by the calculation of standard errors in comparing the average quinquennial yields. We have used two tests for this purpose. One utilized the natural variation in annual yield among the different divisions of a State within each five-year period as a measure of the influence of climate, over the actual period of 15 years studied. The assumption here was that we were interested in ascertaining and estimating the effect of planned effort on yield against the background of overall climate, favourable, unfavourable or indifferent, actually experienced over the particular set of 15 years under study. We may also want to take a broader view of the influence of planned effort on raising yield by assessing whether the increase in yield is of a sufficient magnitude to withstand the annual climate variations in the State yield, such as are likely to be met with normally, rather than confining this assessment to a particular period of years. This more rigorous test can be made by testing the mean square between plan periods against the mean square for years within plan periods after removing any possible trend in the latter. Both tests have been made in the present study.

An interesting and important offshoot of the second test is to show that a certain minimum increase in the average yield over any plan period as compared to the average yield in the previous plan or any other quinquennial period is necessary to provide a reasonable assurance that it is the result of plan effort and not a fortuitous increase arising from annual variations in State yields due to climate and other associated factors. For rice this minimum increase is as high as 150 to 180 lb. per acre in States of Madhya Pradesh, Bombay and Bihar. In Madras, Assam and Andhra Pradesh, where rice yield are more stable, this figure ranges from 50 to 90 lb. In wheat the range is from 70 to 110 lb. per acre, the higher values being associated with Bihar and Madhya Pradesh.

In rice, plan effort has made a definite impact on yield, the average countrywide yield being raised by 40 lb. per acre during the First Plan and by 80 lb. per acre further during the Second Plan. The latter figure would be 86 lb. if all data for crop-cutting extended to additional areas including Mysore State are taken into account. The largest and most consistent increases were contributed by Madras and Andhra Pradesh States, these being 143 and 155 lb. per acre during the First Plan and 160 and 122 lb. per acre during the Second Plan. These increases retained their significance when tested against annual climatic variation in yields in these States, indicating that they were not brought

about because of any particularly favourable climatic conditions during those years. No other State showed such positive increase in yield during the First Plan, West Bengal did show an average increase of 89 lb. per acre, but it could not be considered significant when tested against annual variation in yield in the State. It should be noted that this State did not show any further increase in yield during the Second Plan, which supports the indication that the earlier increase was at least partly influenced by climatic conditions during the particular years. In the Second Plan several States contributed to increased yield of rice, these being Mysore (for which crop-cutting data for estimating increase in yield during the First Plan are not available), Bombay, Uttar Pradesh, Bihar and Madhya Pradesh. The increase was highest in Mysore, being 214 lb. per acre, Bombay with an increase of 127 lb. per acre came next while the other three States showed increases of less than 100 lb. per acre. The increases in Mysore, Bombay and Uttar Pradesh only were established more firmly in that they maintained their significance when tested against natural annual variations of yield in these States. The tempo of planned effort was thus distinctly greater during the Second Plan than in the First and raised the rice yield in the country by 16 per cent. when compared to the pre-plan yield level. Assam was one State which showed no improvement in yield, either in the First or the Second Plan, although a high rainfall and other relatively stable favourable environmental conditions should bring about a quick response to planned effort in this State.

In an attempt to probe into the nature of the effect of climate on the yield of rice, the relationship between annual rainfall and yield was studied. Except in Andhra and Madras where most of the rice area is served with irrigation from canals and other large works, annual rainfall showed a significant influence on yield. This was so even in Mysore where practically the entire rice area is served by tanks; but these tanks which are mostly small are also at the mercy of the seasonal rainfall for their capacity to supply irrigation. The relationship between rainfall and yield is such that yield increases with increase in rainfall even beyond the normal rainfall for the region. Obviously under pressure of growing population rice cultivation has spread to areas where the normal rainfall is inadequate to meet the full requirement of the crop and extension of irrigation to rice area is an important measure for increasing rice yield. In fact, irrigation and use of fertilizers, while simultaneously spreading the use of strains developed from Indo-Japanica crosses which can respond to large doses of fertilizers, are the principal methods of raising rice yield substantially and these measures

need to be pressed forward with all possible speed, considering that over the two plans rice yield has increased by only one and half maund per acre and there is still a large scope for further increase.

In contrast to rice, the conclusion from the present study in regard to wheat is that there is no evidence of any impact of planned effort on increasing the yield of wheat per acre in any State either in the First or the Second Plan. Undoubtedly the average countrywide yield on the basis of our study for five States, Punjab, Uttar Pradesh, Bihar, Madhya Pradesh and Bombay, was nearly 12 per cent. higher in the First Plan period than in the pre-Plan quinquennium and all States individually contributed to this result with increases ranging from 5 per cent. in Punjab to as much as 27 per cent. in Bombay State. Increases in four States, with the exception of Bihar, were highly significant when tested against variation among annual yileds in different divisions of a State. This significance, however, completely disappeared when the test was made against annual variations in the State yield, indicating that the increase could be explained by seasonal differences. In fact, in 1946–47 there was a severe rust epidemic in the wheat belt of the country and in some areas the crop was all but wiped out. The effect of this epidemic on yield extended over the next two years in some areas. The epidemic was severest in Madhya Pradesh and Bombay and these were the two States that showed the largest proportional increase of 25 and 27 per cent. in the First Plan period. The conclusion is that the increase in yield observed in the First Plan was a measure of the recovery of the crop from the rust epidemic that it had suffered during the pre-Plan period. Further support to the conclusion that the increase observed in the First Plan period was due to extraneous factors and not due to any planned effort is given by the fact that the average Second Plan yield in the country stood at exactly the same level as in the First Plan. No change was observed in the individual States also, except for a disconcerting decrease of 37 and 36 lb. per acre in Bihar and Madhya Pradesh, which should be ascribed to climate. It is a serious matter that little or no planned effort has gone into raising the yield level of wheat in any State, when the importance of wheat among foodgrains is only next to rice. Causes for this lack of effort need to be investigated into and remedied urgently.

Like rice, the relationship between rainfall and yield was studied for wheat also in an attempt to find at least a partial explanation of the climatic influence. For this purpose the annual rainfall was split into two portions, monsoon and post-monsoon, and a joint relationship of these sub-totals of rainfall with yield was analysed. The result

was negative in that no evidence of any relationship could be found. The depression in yield during the Second Plan period in Bihar and Madhya Pradesh could also not be explained on this basis. This is a curious result when it is remembered that the wheat crop is much more at the mercy of rainfall than rice since a lower porportion of the wheat area is irrigated. Some other factors like humidity, temperature, distribution of rainfall, etc., would seem to play a more important role and deserve critical investigation.

The present series of crop cutting surveys on foodgrains and other crops as we mentioned at the beginning of this paper form the most vital and reliable means for a critical evaluation of successive Five-Year Plans in relation to the level of crop yields. The importance of continuing this series and strengthening it further cannot be overemphasised. Today there is a considerable degree of non-response in several States in the conduct of crop-cutting and supervision of the field-work is also not on an adequate scale. The district estimates of yield do not have sufficient precision and we have for this reason compiled divisional estimates for our analysis. Analysis with district-wise data would be much more penetrating, will help in spotting out weak areas in relation to planned effort and would be more rewarding in any attempt to discriminate between the influence of planned effort and other factors like those of climate on yield level. For this purpose the aim of crop-cutting surveys should be to provide district-wise estimates of important food and non-food crops with a reasonable level of accuracy, that is, with a standard error within 5 per cent. This requires concentration of all available financial and technical resources on strengthening the primary reporting agency and supervision of field-work in the States, in imparting proper training to the field staff in improving the technical competence of State organizations directing this work, instead of dissipating these resources in all kinds of experimentation with plot sizes and field agencies, which has no relevance to our needs.

2. *Controlled Selection--A Technique in Random Sampling. B. V. Sukhatme and M. S. Avadhani, I.A.R.S., New Delhi.*

Selection of a sample at random from a population may sometimes result in 'non-preferred' combination of units in the sense that collection of information from such a sample is likely to be seriously affected by non-sampling errors, specially non-response and investigator bias. It would, therefore, be of utmost utility, especially in large-scale surveys, to examine the feasibility of developing a sampling

methodology so as to reduce the chance of getting a non-preferred sample from the population to the minimum possible extent and yet conforming to the well-known principles of random sampling.

Goodman and Kish (1950) had suggested a solution for this problem but it does not appear to be entirely satisfactory in the sense that it involves certain amount of subjective element and does not enable one to obtain the precision of the estimate of the character under study.

The authors have given here a method of constructing a Random Sampling Design corresponding to a given population and a given sample size n (Godambe, 1955), by means of which the probability of getting a non-preferred sample from the population can be reduced up to a certain level. Appropriate methods of analysing the data obtained from samples selected by this procedure are also given.

3. *Some Estimation Procedures in Fruit Surveys. B. V. Sukhatme and Ravindra Singh, I.A.R.S., New Delhi.*

In fruit surveys conducted by I. A. R. S., the sampling design used is a stratified multi-stage design where primary units are selected with unequal probabilities and with replacement while at subsequent stages, units are selected with equal probabilities and without replacement. Depending upon the auxiliary information available such as reported area under all fruits, total number of fruit trees, etc., several biased and unbiased estimates of the population total can be constructed. The authors have investigated various such estimates as regards their bias and relative efficiency. All these estimates have been shown to be particular cases of a single multi-stage ratio estimate. With reference to this estimate, the results have been extended to the case of double sampling and several auxiliary variables. The data collected in the survey carried out in Uttar Pradesh in 1961–62 to study yield and cultivation practices on mango crop have been used for the purpose of illustration.

4. *Leaf Area in Coffee. N. A. Awatramani and H. K. Gopalakrishna, Central Coffee Research Institute, Chickmagalur.*

Recent physiological studies on nutrition and growth have shown that leaf area is a reliable index of growth factors determining dry matter accumulation, carbohydrate metabolism, yield and quality of crops. Field measurement of areas of large number of leaves is, however, laborious and time-consuming. The method, therefore, should be quick, simple and not tiring for the operator.

Various authors working on cereals have suggested formulæ for working out the leaf area. While working with coffee it was found that neither Goff's equation (1895) $A = L \times W \times \frac{2}{3}$, nor that devised by Montgomery (1911) and used by Kiesselbach (1950) $A = L \times W \times \frac{3}{4}$ —will hold good for coffee. This study was therefore undertaken with a view to obtain an empirical relationship between actual leaf area (A) and length (L) × Max. Breadth (B). The other objective of the study was to find out whether the quantum of field-work could be reduced to determine the total area of leaves on a branch.

The study was conducted on 5 varieties of *Coffea arabica*, *viz.*, Kents, Coorgs and Selections S. 288, S. 947 and S. 795 on a total of 180 leaves. The leaf dimensions were measured and actual area determined with graph paper.

Constant K to determine leaf area from leaf dimensions ($Y = K \times L \times B$) was found to be 0·63 since test of significance (Tippett, 1952) revealed that 'b's were not different pooled 'b' was obtained.

Logarithmic relationship with leaf length gave the following regression equation:

$$\text{Log } Y = -0{\cdot}5660 + 2{\cdot}0003 \text{ Log } X.$$

Different methods were compared and significant differences were found between actual leaf area and area estimated by Logarithmic method. Therefore, though this method will be less time-consuming in the field due to measurement of single leaf dimension, it is less reliable.

Among regression equations and simple relationship utilising value of constant K, the latter will be easy of computation once both the dimensions of leaf are measured. This method is therefore recommended for adoption.

Analysis of variance for leaf area of 100 leaves of S. 795, consisting of 5 branches, 10 positions and 2 sides on which leaves are located at the same node, indicated that leaf area of the two leaves at the same node of the branch (sides) was not significantly different. It is, therefore, suggested that to arrive at total leaf area of leaves on the branch, leaves on the side of the branch only need be measured.

5. *Rotation Designs for Sampling on Repeated Occasions.* *J. N. K. Rao, National Council of Applied Economic Research, New Delhi.*

There are many studies, notably in sociological and economic research, which are concerned with estimating characteristics of a

population on repeated occasions in order to measure time trends as well as the current values of characteristics as a time series. It is well known that, in such situations, the use of rotation sampling may increase the precision of the estimators on the current occasion and of the change.

Hansen *et al.* (*J. Amer. Stat. Ass.*, 1955) have developed composite estimators of the population total on the current occasion and of the change in connection with the Current Population Survey conducted by the U.S. Bureau of the Census. However, the variance of the composite estimators was not investigated in detail and, moreover, the population size, N, on each occasion was assumed infinite. In this paper we develop a unified finite population theory for the composite estimators under a general rotation pattern. The variance is obtained explicitly and the optimum values of the weight factor in the composite estimators are obtained under certain simplifying assumptions regarding the correlation pattern from occasion to occasion. The variance for the particular rotation pattern used by Hansen *et al.* can be obtained as a special case from our general results.

In monthly surveys, these composite estimators take advantage only of ρ_1, the correlation between consecutive months. However, with characteristics strongly influenced by seasonal variations, the correlation, ρ_2, between occasions 12 months apart may be about the same magnitude (or even higher) as compared to ρ_1. We develop here generalized composite estimators which take advantage of both ρ_1 and ρ_2. The generalized composite estimators lead to considerable gains in efficiency over the simple composite estimators.

6. *Bias in Estimating Heritability by the Method of Intra-Sire Regression Non-random Mating Populations.* *M. Rajagopalan and J. N. Garg, I.A.R.S., New Delhi.*

While discussing the ways of estimating heritability Lush commends the method of intra-sire regression of offspring on dam as it dodges questions about departures from random mating "because it expresses heritability as a fraction of variance which existed among the females mated to the same sire".

It is shown in this paper that this method in the presence of dominance leads to a biased estimate of heritability when (i) the parents are from different non-random mating populations and (ii) inbreeding is practised.

Expressions for the magnitude and direction of bias are obtained for different types of populations.

7. *Cost of Production of Mutton and Wool. K. C. Raut, I.A.R.S., New Delhi.*

Estimation of the costs of production of meat and wool in areas where wool-bearing sheep are maintained presents an interesting problem. Alternative methods for proper apportionment of cost of production of mutton and wool have been discussed in the present paper with examples worked out from the pilot enquiries for estimating the cost of production of sheep sponsored by the Indian Council of Agricultural Research.

8. *Studies on Gene-Environment Interactions. Prem Narain, I.A.R.S., New Delhi and T.C.S. Sarma, C.S.R.I., Mysore.*

Selection is the basic tool for plant and animal breeders to improve upon the characters of economic importance. It has, however, been noticed by several workers that estimates of genetic advance under selection are often overestimates in the absence of appropriate corrections for gene-environment interactions. It is, therefore, desirable to study the variations caused by these interactions and the effects they produce on the other components of variation. In the present paper, following Mather (1949) and Jones and Mather (1958), appropriate components of variations, in the presence of gene-environment interactions, have been described in its most general form, *i.e.*, when allelic and non-allelic, both types of interactions are taken into account. An attempt has also been made to indicate the methods of biometrical analysis for the separation of various components of variation in the two cases, *viz.*, random and non-random distribution of individuals over environments.

9. *A Study of the Effect of Some Weather Factors on the Yield of Wheat in Ludhiana District, Punjab. B. M. Rao, Ford Foundation, New Delhi.*

A linear multiple regression study has been done on some weather factors as independent variables and wheat yield obtained from irrigated and unirrigated fields as dependent variable. The weather factors are rainfall, humidity, temperature (maximum and minimum) and Rain × Wind velocity. Four different combinations of these factors have been tried and the results have been discussed from agronomical point of view.

From this study, rainfall of December, February and March and humidity of January and February have emerged as the most important

weather factors and irrigation alone cannot offset the profound effect of weather.

The improper selection and combination of variables would vitiate the results and undue emphasis on the statistical significance of the coefficients is undesirable. In the selection of variables any *a priori* knowledge of such variables, if available, should be taken into consideration.

10. *Efficiency of Varying Probability Selection in Surveys of Fertilizer Practices.* *K. B. L. Rastogi, I.A.R.S., New Delhi.*

The Institute of Agricultural Research Statistics is carrying out sample surveys of fertilizer and other manuring practices in selected districts of various States. The main objectives of these surveys are to estimate the cropwise area benefited by various fertilizers and manures, their rates of application, etc. In these surveys, the sampling plan adopted is one of stratified two-stage random sampling with a tehsil as a stratum, a village as the first stage sampling unit and a cultivator as the second stage unit. The villages are selected with probability proportional to the cultivated area.

The relative efficiencies of probability proportional selection (with the cultivated area of the village as size for determining the selection probability) as compared to the simple random sampling, for estimating the area benefited by various fertilizers and manures under different crops have been investigated. The results indicate that selection with probability proportional to the cultivated area of the village would be more efficient for estimating area benefited by manures under crops having large or even moderate area under them; further, for a given crop, larger the extent of application of a manure, larger woud be the gain in efficiency due to probability proportional selection.

11. *Some Aspects of the Statistical Analysis of Data on Nitrogen Content of Bidi Tobacco Samples.* *S. Balakrishna.*

With a view to examining the possibility of grading bidi tobacco on the basis of its nitrogen content the Directorate of Marketing and Inspection carried out a sample survey on bidi tobacco in 1958. Following a sort of quota sampling method about 400 samples—of bidi tobacco as well as manufactured bidis—were collected in all from important producing areas as well as manufacturing centres. In the three producing areas selected, namely Gujarat, Nipani and Mysore, samples were collected from growers as well as merchants. Collection

of samples of bidi tobacco ready for manufacture and of manufactured bidis were confined to 10 important manufacturing centres in the country. In each area the samples collected covered the important varieties and types—the latter being based on the position of leaf in the case of growers and on the stage of processing in the case of merchants and manufacturers. Samples collected related to main and ratoon crops of 1958 and earlier years. In this paper only 250 samples of bidi tobacco—not manufactured bidis—relating to main crop of 1958 are considered for purposes of statistical analysis.

Statistical analysis presented in this paper relates to the following aspects:—

(*a*) Significance or otherwise of differences between average nitrogen content of samples collected from the three agencies, *viz.*, growers, merchants and manufacturers.

(*b*) Significance or otherwise of differences between average nitrogen content of samples collected from growers in three areas, *viz.*, Gujarat, Mysore and Nipani.

(*c*) Significance or otherwise of differences between average nitrogen content of samples collected from growers and relating to different positions of leaves (whole plant, top, middle or bottom leaf).

(*d*) Significance or otherwise of differences between average nitrogen content of samples collected from merchants in three areas, *viz.*, Gujarat, Mysore and Nipani.

(*e*) Specification of 5% lower limit of nitrogen content on the basis of 250 samples considered in this paper.

The results in respect of these aspects are summarised below:—

(*a*) The variances were tested for homogeneity and found to be 'homogeneous'. No significant differences were revealed by the analysis of variance between the average nitrogen content of samples collected from the three agencies.

(*b*) The test for homogeneity of variances indicated the presence of heterogeneity. In view of this, the method involving the calculation of a pair of weighted mean squares and testing their ratio against the F-distribution was adopted to test the equality of means. But no significant differences were discernible in the means.

(*c*) On testing for homogeneity the variances were found to be 'homogeneous' and no significant differences between the means were revealed by the subsequent analysis of variance.

(*d*) The variances were tested for homogeneity and found to be 'homogeneous'. The means for Nipani and Gujarat samples differed significantly while the other two differences did not.

(*e*) The test for normality showed that the distribution of nitrogen content did not follow the normal pattern. 5% lower limit was, however, calculated on the assumption of normality and found to be 1·22.

12. *Multiple Regression Method of Estimation.* *P. Krishnan, University of Rajasthan, Jaipur.*

For increased precision, very often the regression method of estimation is employed in sample surveys. In this procedure generally only one auxiliary variate is considered and the regression set-up is linear. But possibility of securing more than one auxiliary variate is often there and as such a multiple linear regression can be considered. Formulae for the multiple regression estimates are derived for the finite population case for large samples. Variance of the multiple linear regression estimator is obtained as

$$V(\bar{x}_{1(mr)}) = \frac{N-n}{Nn} S_{x_1}^2 (1 - R^2)$$

where R is the multiple correlation coefficient between x_1, and $x_2, x_3, \cdots, x_p$. Setting $p = 2$, R reduces to the simple correlation coefficient between x_1 and x_2 and we get the usual result

$$V(\bar{x}_{1(\rho r)}) = \frac{N-n}{Nn} S^2_{x_1} (1 - \rho^2).$$

13. *A Note on Enlarging the Size of First-Stage Units.* *G. L. Narasimha Rao, University of Rajasthan.*

It is shown (Hansen, M. H. and Hurwitz, M. N., *Ann. Math. Statist.*, 1943) that there is gain in precision by enlarging the size of first-stage units provided ρ_1 and ρ_2 the intra-class correlations within the first stage units, before and after consolidation of the first-stage units, are positive and $\rho_1 \geqslant \rho_2$. It is assumed that the same number n of first-stage units and the same number m of second-stage units from each selected first-stage unit in the sample before consolidation are taken in the sample after consolidation. If there are N/C first-stage units of MC second-stage units each after consolidation, it may be desirable to select n/c first-stage units and mc. second-stage units from each selected first-stage unit, in the sample. It is shown that the latter scheme of sampling is more efficient than one given by

Hansen and Hurwitz irrespective of the cost consideration if ρ_2 is negative. When ρ_2 is positive, the latter scheme of sampling may be more efficient when cost is taken into consideration.

14. *On Some Allocation Procedures in Two-Way Stratification.* *B. D. Tikkiwal, University of Rajasthan and U. N. Bhat, University of Western Australia.*

There are situations where the N elements of a population are classified in a two-way table with N_{ij} in the i-th row and j-th column of the table. If each cell of the table is treated as a stratum for purposes of sampling, there are strata, referred here as Type I, where $N_{ij} \geqslant R_i C_j/N$, R_i and C_j being the respective totals of the units in the i-th row and j-th column. The remaining strata not satisfying this relation are termed as Type II strata. Several allocation procedures have been considered in this paper which are bettter than the existing Neyman and proportional allocation procedures under certain conditions met under practical situations. One such allocation procedure allots $nN_{ij}/N(1+\rho_2)$ units to an (i,j)-th stratum of Type I and $nR_iC_j/N^2(1+k)$ units to an (i,j)-th stratum of type II; where $k = \Sigma(\delta_{ij})/N$, $\delta_{ij} = (R_iC_j/N - N_{ij})$, the summation is over strata of Type II.

5th *January* 1964

Chairman:

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1. *An Alternative Method for the Construction of Confounded Symmetrical Factorial Designs.* *M. N. Das, I.A.R.S., New Delhi.*

An alternative method of construction of confounded symmetrical factorial designs has been described. Through this method most of the known results can be obtained in a straight-forward and very simple way. The method consists of first writing the independent treatment combinations in the key block and next the other requirements of the design including the interactions confounded are simply written down therefrom. Through this method the maximum number of factors that can be accommodated in a block of a given size such that no interaction up to a given order is confounded, can be investigated in a simple manner.

2. *On the Removal of a Treatment from Some Non-Symmetric BIBD.* *K. Seshagiri Rao, Kathmandu.*

Of the many techniques of deriving a PBIBD from a BIBD, the removal of a treatment from the BIBD is one. This technique if successful gives simultaneously two derived PBIBD. The author had already done some work in this line and this paper is an extension of the work already done. The technique is extended to some non-symmetric cases not discussed so far to derive a number. PBIBD in two associate classes and some PBIBD in three associate classes. Wherever it is necessary solutions for the BIBD are worked out so that from them the PBIBD can readily be derived.

3. *On Asymmetrical Rotatable Designs.* *J. S. Mehta and M. N. Das, I.A.R.S., New Delhi.*

Rotatable designs evolved so far are symmetrical, that is each factor has the same number of levels. As against this type of designs, there is some need for asymmetrical rotatable designs. With this object we took up the problem of obtaining asymmetrical rotatable designs.

The method of construction of such designs consists in the choice of suitable transformations of the dose variables which when applied to a known symmetrical Rotatable Design render the number of levels of the various factors unequal in the transformed design and at the same time the transformed design satisfies all the conditions of rotatability. The transformations which have been chosen are linear functions of the dose variables and they are such as to leave the estimate of the variance of the estimated response unaltered. Again, it has been possible to choose certain transformations which have the property of reducing the number of levels of all the factors in the transformed design keeping it symmetrical still. Secondly they have in some cases the property of reducing the number of levels of some of the factors and keeping the number of levels of the other factors the same as in the original design or increasing the number of levels of some of the factors.

4. *On the Exploitation of a New Series of Pairwise Balanced Designs of Index Unity for the Construction of Mutually Orthogonal Latin Squares.* *J. S. N. Murthy, I.A.R.S., New Delhi.*

The following two series of Pairwise Balanced Designs of index unity and type (v, k_1, k_2) have been obtained:

(i) $v = s(s-p)$; $b = s^2 + s - p$; $k_1 = s - p$; $k_2 = s$.

(ii) $v = s(s-p) + s + 1$; $b = s^2 + s - p + 1$;

$$k_1 = s - p + 1; \quad k_2 = s + 1.$$

where s is a prime or prime power.

Using the first series of designs $(s-p-1)$ m.o.l.s. of order $s(s-p)$, that is, the product of any two prime powers can be obtained. This is actually the number conjuctured by MacNeish. Though such m.o.l.s. have been obtained through other methods this single series of pairwise balanced designs enable us to obtain all of them through the method of Bose and Shrikhande (1960).

Further, following the methods given by Bose, Shrikhande and Parker (1960), the above two series have been utilised to improve upon the lower bound of the number of m.o.l.s. of order v (v 154) as shown in the following table:—

Maximum Number of m.o.l.s.

v	Obtained by Bose	Obtained through the present series
90	2	4
94	2	5
106	2	5
110	2	5
114	2	5
124	4	5
134	5	6
138	4	6
142	5	6
146	5	6
154	2	4
116	3	5
148	3	4

5. *Construction of Second-Order Rotatable Designs in Blocks of Equal Size. M. N. Das and B. S. Gill, I.A.R.S., New Delhi.*

In this paper two methods describing how the central composite rotatable designs can be split into blocks of equal size, have been evolved,

The methods consists in obtaining design points in a block of the rotatable design from the treatment combination in each of the blocks of 2^n factors such that no main effect and two-factor interaction is confounded and then either augmenting it by the design points obtainable from the set $(b\,000\cdots 0)$ or in some cases putting these points in a separate block and repeating it a required number of times. A further method for blocking second-order rotatable designs obtainable through B.I.B. designs has also been evolved. Through these methods designs with any number of factors can be obtained split into blocks of equal size.

6. *Mixed Model Analysis of Covariance in Agricultural Experiments. A. K. P. C. Swain and M. N. Ghosh.*

....An attempt has been made to use auxiliary information in Scheffe's mixed model for the analysis of groups of experiments. It has been seen that the usual 'F' test for the test of the component due to interaction of places with treatments holds good. The property of unbiasedness of the test has also been justified for the same.

7. *A Note on the Bartlett's Statistics for Testing Homogeneity of Variances. Vinod Behari, I.A.R.S., New Delhi.*

This criterion is the one most commonly used for testing the homogeneity of a number of estimated variances. However, only large sample approximations to the distribution of this criterion, and in fact of all others used for the purpose, are available. The expression of the characteristic function of the exact distribution of Bartlett's criterion is available but the integrand involved in the use of the inversion theorem is so formidable that this approach has not been pursued to obtain the density or distribution function of the criterion. Various authors modified the cumulants generating function of the criterion into that of a weighted sum of a series of chi-square variates with different numbers of degrees of freedom. The distribution of the weighted sum has been used to obtain the approximate percentage points of the criterion.

In this note the author has given some expressions of the cumulants of the Bartlett's criterion in terms of Polygamma functions. Making use of the tables of selected percentage points of the Pearsonian system of curves, it is possible to obtain the percentage points without specifying the form of the curve. The advantage of this approach is that the percentage points of the distribution of the criterion can be evaluated even for the case of small and unequal number of degrees of freedom.

8. *Second-Order Rotatable Designs in Three Levels. A. K. Nigam and M. N. Das, I.A.R.S., New Delhi.*

For construction of second-order rotatable designs through B.I.B. designs it has been found that if $r = 3\lambda$, a design is always available in three levels. But, if the relation $r = 3\lambda$ does not hold we have to introduce sets of the type $(b\ 0 \cdots 0)$ or $(b\ b \cdots b)$ according as $r < 3\lambda$ or $r > 3\lambda$ and this requires five levels for such designs. A new technique has been developed as given below to obtain three-levelled designs from B.I.B. designs where $r \neq 3\lambda$. The number of points in such designs are also reasonably small.

Case 1.—*When* $r < 3\lambda$: Instead of taking the set $(b\ 0 \cdots 0)$ we take the set $(a\ 0 \cdots 0)$ and repeat it p times. Then the equation

$$\Sigma x_i^4 = 3 \Sigma x_i^2 x_j^2 \text{ gives the value of } p.$$

Case 2.—*When* $r > 3\lambda$: We take the set $(a\ a \cdots a)$ and repeat the original B.I.B. design p times. The value of p is to be obtained by solving the equation

$$\Sigma x_i^4 = 3 \Sigma x_i^2 x_j^2.$$

For $v = 4$, 7, 10 and 16 the B.I.B. designs are available satisfying the relation $r = 3\lambda$. It has been found that if we omit one of the treatments in such designs the relation $r = 3\lambda$ still holds. Thus, we can get three-levelled second order rotatable designs for 3, 6, 9 and 15 variates also without adding any more set.

For example, from the design $v = 7$, $k = 3$, $b = 7$, $r = 3$, $\lambda = 1$, $r = 3\lambda$ when we omit treatment 7 we can get a rotatable design in 6 factors of three levels each with 56 non-central points.

9. *Construction and Analysis of Truncated and Irregular Fractional Designs. B. S. Gill and M. P. Jha, I.A.R.S., New Delhi.*

Even though fractionally replicated designs are in vogue long since, the problem of choosing the fraction property, so as to suit diverse situations, still remains. Recently attempts have been made to choose fractions which are irregular and hence different from what was suggested by Finney. Rotatable designs is also an example of such an incomplete factorial design. In some fields research workers prefer to include for experimentation only those treatment combinations each of which involve not more than three factors at a time, at their non-

zero levels (when the factors are each at two levels) even though the number of factors is more than three.

An attempt has, therefore, been made in the present paper to obtain such a truncated design by omitting from a regular symmetrical 2^n factorial those combinations which contain more than a specified number of factors at its non-zero levels. A study of the effect of such truncation on the estimation of treatment effects along with the problem of analysis has also been investigated. The fractional designs with $2^{n-p}+p$ treatment combinations of a 2^n fractorial and irregular fractions with $2^n - k2^{n-r}$ treatment combinations have been studied.

10. *Incomplete 2^n Factorial Designs.* *W. B. Hall, Division of Mathematical Statistics, C.S.I.R.O., Australia.*

A class of designs will be discussed in which the normal euqations associated with the estimation of effects are of a particular form. The method of constructing the information matrix and of obtaining its inverse will be given for this class of designs. An illustration will show the use of these methods in the design and analysis of a fractional factorial with replication of some treatment combinations.

11. *Study of Estimates in Univeriate Pareto and Multivariate Pareto Type 1 Populations.* *K. V. Mardia, University of Rajasthan, Jaipur.*

If a random sample is drawn from a Pareto population with frequency function

$$f(x) = pa^p \; x^{-(p+1)} \; x > a > 0, p > 0.$$
$$= 0, \text{ otherwise.}$$

It is shown that the maximum likelihood estimates of a and p are distributed independently. Also the efficient estimates of a and p exist. Further for a random sample from a k-variate Pareto Type 1 population (Mardia, *Ann. Math. Statist.*, 1962, **33** 1008–15) with frequency function

$$\frac{(ak)^n \, p\,(p+1), \cdots, (p+k-1)}{(x_1 + \cdots + x_k)\, p+k}, \; x_i > a > 0, \; i = 1, \cdots k, \; p > 0.$$

It is shown that the same property holds for the maximum likelihood estimates in this case and their distributions are obtained. The efficient estimates of a and p in this case are also provided.

12. *Agricultural Productivity in Bihar. B. N. Sahu, Bihar State Electricity Board, Patna.*

The present-day need of the country in the sector of agriculture is to increase agricultural production through increase in agricultural productivity per unit area, per worker and so on. In this paper an investigation has been made to exhibit how agricultural productivity per worker in Bihar has changed since 1948–49. This has been done on crude basis by dividing the money value of total outturn from agriculture by the number of agricultural workers. For finding the value of the outturn both current and constant prices have been used. It has been found that on the basis of constant price, labour productivity has increased in the State to some extent though no trend could be found over the years.

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