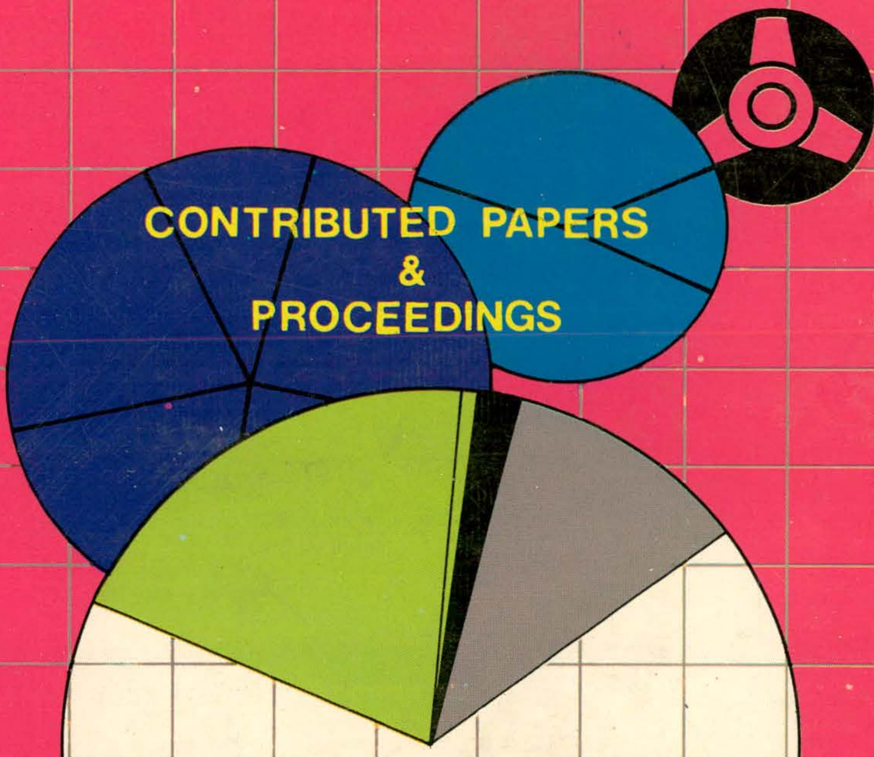
NINTH NATIONAL CONFERENCE OF AGRICULTURAL RESEARCH STATISTICIANS

July 19-21, 1989

CONTRIBUTED PAPERS & PROCEEDINGS



INDIAN AGRICULTURAL STATISTICS RESEARCH INSTITUTE
(I.C.A.R.)
LIBRARY AVENUE, NEW DELHI-110012

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PROCEEDINGS

INDIAN AGRICULTURAL STATISTICS RESEARCH INSTITUTE
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With Best Compliments From :

Prof. PREM NARAIN
Director,
I.A.S.R.I., New Delhi

Compiled and Edited by :

J.P. JAIN
T.B. JAIN
D.S. ANEJA

Cover Page Designed by :

A.R. PAUL
M.K. BHATT

PREFACE

It is, indeed, a great pleasure for me in presenting this compendium of contributed papers and proceedings of the Ninth National Conference of Agricultural Research Statisticians held at Tamil Nadu Agricultural University, Coimbatore from July 19-21, 1989. The main theme of the Conference was 'Research Challenges in Agricultural Statistics and Computer Applications in Agriculture' which was deliberated in four technical sessions. The deliberations, *inter alia*, has helped in identifying high priority areas of research requiring concerted efforts on the part of the scientists during the VIII Five Year Plan. I hope this compendium will be well received by the scientific fraternity and help in the formulation of appropriate research projects in different fields of statistics and computer applications in the VIII Plan.

We place on record our indebtedness to Dr. S. Jayaraj, Vice-Chancellor, Dr. Palaniappan, Dean (Agriculture) and Dr. M. Murugesan, Prof. of Agricultural Statistics, TNAU, Coimbatore for hosting the Conference at their campus and for making excellent arrangements. Our grateful thanks are due to Shri V.N. Amble, Ex-chief Executive Officer, National Sample Survey Organization, New Delhi and to Prof. N. Sundararaj, U.A.S., Bangalore for chairing the technical sessions. Special thanks are also due to various rapporteurs, speakers and the delegates who took keen interest in the deliberations of the Conference and helped in making it a grand success.

Efforts made by Dr. J.P. Jain, Shri T.B. Jain and Shri D.S. Aneja in coordinating the work of the Conference are indeed commendable. Thanks are also due to Sh O.P. Singh and Sh. P.P. Singh for their painstaking work related with the Conference and to Sh. Mahesh Kumar, Mrs. Anita Kohli, Mrs. Rajni Gupta and Sh. A.K. Bhalla for typing the proceedings of the Conference.

PREM NARAIN
Director, IASRI

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NINTH NATIONAL CONFERENCE
OF
AGRICULTURAL RESEARCH STATISTICIANS

JULY 19-21, 1989

Venue : Tamil Nadu Agricultural University
Coimbatore—641003

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10.30 A.M. to 1.00 P.M.	...	Inaugural Function
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Speakers :	...	1. Shri PN Bhargava, IASRI, New Delhi 2. Dr OP Kathuria, IASRI, N Delhi

3. Dr CKR Chetty, CRIDA, Hyderabad.
4. Prof N Sundararaj, UAS, Bangalore.
5. Dr PG Biswas, GBPUA & T, Pantnagar.
6. Dr NM Patel, GAU, Anand.

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Chairman : ... Sh VN Amble, Bangalore

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2. Dr R Venkatesan, MVC, Madras

Speakers : ...
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INAUGURATION

July 19, 1989 (Wednesday)

10.30 A.M to 1.00 P.M.

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Key-Note Address :	...	Prof. Prem Narain, Director, IASRI, New Delhi
Inaugural Address :	...	Dr. S. Jayaraj, Vice-Chancellor, TNAU, Coimbatore
Vote of Thanks :	...	Dr. M. Murugesan, Prof. of Agricultural Statistics, TNAU, Coimbatore

WELCOME ADDRESS

S.P. Palaniappan
Dean (Agri.), TNAU, Coimbatore

Respected Vice-Chancellor, Dr. Prem Narain, delegates from various Agricultural Universities and ICAR Institutions, Ladies and Gentlemen,

I am happy and thankful to the organisers of this conference who have given me this opportunity of presiding over the inaugural function.

Dr. Prem Narain, the Director of IASRI, needs no introduction to all of you who is the guiding force of the conference and also the activities of the Agricultural Research Statisticians in the country. First of all let me compliment you for your co-operation and involvement in agricultural research as a whole where we use almost all the statistical techniques, of course, with different methodologies in different disciplines.

I personally feel that no research problem in agriculture can be tackled scientifically without the applicatian of statistical tools but it may be different in its dimension.

The Agricultural College and Research Institute, Coimbatore had a small unit of Statistics as early as in 1950 with one Statistical Assistant. At present we have a Department in Agricultural Statistics with a Professor, two Associate Professors and two Assistant Professors who are in-charge of U.G. and P.G. teaching, analysing the experimental results of various projects including thesis projects. We also have a Computer Centre where we have developed almost all Computer Programmes covering all methodologies applied in Agricultural Research. We also offer periodical computer programming training to our staff members. Our statisticians have handled a number of research projects through which they have given many innovative methods covering fixation of optimum sample size, the effect of inter-plot competition in crop growth, clustering pattern of genotypes through genetic divergence techniques, yield loss assessment in sesamum, fixing idio-type of a sunflower plant through biometrical methods, prediction of rainfall through time series data, comparison of clustering pattern through Tocher's method and Canonical vector method, fixing optimum plot size using experimental data in sesamum, selection of plant characters in sesamum using genetic variations and path analysis, test of significance of intercept in multiple regression equation and a new method to assess efficiency of split-plot design.

We have the following future plan of work where we intend to have studies of (1) the yield loss assessment surveys on crops in collaboration with Entomologiests and Pathologists to forecast the loss, (2) the pre-harvest forecasting of the yield of different crops using biometrical and meteorological observations, (3) designing of indices for plant architecture involving statistical techniques (4) developing computer programme for storing the data on germplasm collections of all important crops and retrieval system will be developed for easy access to the Plant Breeders on the desired plant type for breeding programmes (5) developing suitable techniques based on sample survey results to assess the extent of spread of the high yielding varieties of different crops, (6) model building to simulate suitable systems in agriculture with the help of computers and developing a weather forecast model to predict the annual, seasonal and weekly rainfall for different agro-climatic regions of Tamil Nadu.

Friends, as you know today's agricultural development and its success definitely depends upon a system approach in agriculture which again I personally feel in the manifestation of developing different models in agriculture so as to utilise the resources in an effective and economic manner.

I hope that the conference will take up these issues and give some concrete solutions for the problems facing us.

Thank you very much for your invitation to preside over this inaugural function.

KEY-NOTE ADDRESS

Prem Narain,
Director IASRI, New Delhi

Realizing the importance of close cooperation and collaboration among research statisticians working in various ICAR Institutes and agricultural universities, the Achievement and Audit Committee constituted by the Council (ICAR) for assessing the research activities of the Indian Agricultural Statistics Research Institute (IASRI) for the period 1966-71 recommended *inter alia* holding of peridical meetings and conferences of Agricultural Research Statisticians. These forums would provide opportunities not only for exchange of ideas, discussion of current problems but would also foster fellow feelings among the scientists working in various agricultural research institutes in the country. For achieving these laudable objectives, the IASRI has been holding the conferences of agricultural research statisticians almost regularly since 1974, with, of course, change in the periodicity after 1983. So far we have had eight such conferences.

The first two conferences were held at IASRI in 1974 and 1976 respectively in which the emphasis was more on problems related to designs and analysis of experiments, sample surveys, use of computer in agriculture and animal sciences research, statistical techniques in plant and animal breeding, teaching of statistics in agricultural institutes and universities and research and training facilities. The third conference was also held at IASRI in 1978 with its theme as 'Role of Agricultural Statistics in VI Five Year Plan with special reference to integrated rural development with respect to agriculture, forestry, livestock and fisheries'. The fourth conference was held in 1979 at Himachal Pradesh Krishi Vishwavidyalaya, Palampur where there were five technical sessions besides the plenary session. The fifth conference of Agricultural Research Statisticians was organised jointly by the Directorate of Agriculture, Lucknow and the Indian Society of Agricultural Statistics in 1980. The technical sessions were related to current statistical research in agriculture, forestry, livestock and fisheries with respect to rural development. The sixth conference was again held at IASRI in 1982. The five technical sessions were mainly related to current statistical research problems in crop sciences, forestry, animal sciences and fisheries, teaching of agricultural statistics and computer application in agricultural statistics and development and exchange of software. Thus all the first six conferences were held in the Northern region of the country.

For the first time, in 1983, the seventh conference was held in the Southern Region at the University of Agricultural Sciences, Hebbal, Bangalore. The deliberations were held under four major heads : (i) Statistical research in crop sciences and forestry, (ii) Statistical research in animal sciences and fisheries, (iii) Teaching of agricultural statistics and (iv) Application of Computer in Agricultural Statistics. In addition Prof. P.K. Bose, Ex-Pro-Vice-Chancellor of Calcutta University delivered a special lecture on 'Imbalances in Relative Growth Rates in Agriculture—Causes and Remedies'. One major recommendation of this Conference was to elevate its status to National level and call this conference henceforth as the National Conference of Agricultural Research Statisticians. And as per the directive from the Council its periodicity was changed to once in three years. The next Conference i.e. the eighth in the series was held at the Central Arid Zone Research Institute, Jodhpur from July 29-31, 1986. The main theme of the Conference was "Priorities in research and Education in Agricultural Statistics and Computer Application". There were four technical sessions besides the plenary session, : (i) Coordination and linkages between different I.C.A.R. Institutes and research in agricultural statistics; (ii) Gaps and priorities of research in agricultural statistics pertaining to crop sciences; (iii) Gaps and priorities of research in agricultural statistics pertaining to animal sciences; and (iv) Gaps and priorities of research in agricultural statistics pertaining to social sciences/agricultural economics.

The ninth Conference i.e., present Conference is being held in Coimbatore, the Southern region of the country and that too at the prestigious Campus of the Tamil Nadu Agricultural University (TNAU). We are indeed grateful to Dr. S. Jayaraj, Vice-Chancellor of the University for having agreed to host the Conference here. The main theme of this Conference is "Research challenges in agricultural statistics and computer applications in agriculture". It is hoped that deliberations in the Conference, would inter-alia help in the formulation of appropriate research projects in different fields of statistics and computer applications during the VIII Five Year Plan. We have, therefore, planned as many as four technical sessions in addition to the plenary session viz., (i) Research challenges in agricultural statistics pertaining to crop sciences and agro-forestry; (ii) Research challenges in agricultural statistics pertaining to animal sciences and fisheries; (iii) Research challenges in computer application in agriculture; and (iv) Research and teaching coordination and linkage between ICAR Institutes and agricultural Universities.

Keeping in view the current needs of the Council as also of the Scientists of other disciplines in various ICAR Institutes we at our Institute have done some exercise in identifying research thrust areas for the next decade. Some six thrust areas have been identified, four in the discipline of agricultural statistics and two in the discipline of computer application in agriculture. These are :

Agricultural Statistics

1. Modelling for biological and economic phenomena
2. Use of Remote Sensing in forecasting and estimation
3. Improved techniques for analysis of survey and field experimental data
4. Development of designs in livestock, fisheries and agro-forestry research.

Computer Application in Agriculture

1. Development of computer software and data base management system
2. System modelling and simulation.

It would be more appropriate if we deliberate the theme of the conference according to these thrust areas.

I will now say a few words on the role of Computer Application and Information System in Agriculture. Initially the computer was looked upon merely as a computational aid for fast calculations but today computer has become a very effective and essential tool in almost every area and programme of work. The computer is of particular relevance for agricultural statistics which involves collection of large body of data requiring complex and indepth analysis. The power of computer has increased manifold with ability to store large mass of data in its memory which can be directly accessed and processed. With the development of mini computers and micro computers commonly known as personal computers this facility can be used in agricultural sector to a great advantage by setting up or creating computer units at district or block level all over the country. Data on various aspects of agricultural activities can be stored and maintained in these units in a readily available form. These computer units can be inter-linked with a central computer facility which would provide easy communication facility for transfer of data and their dissemination. Another important use of such computer network would be to prepare comparable data sets in different fields of agriculture so as to provide easy access to any organization or even individual research workers throughout the country.

Agriculture is the one enterprise which faces uncertainty at every stage. It, therefore, becomes essential to harness the power of the computer in such a way as to be able to respond to the needs and challenges of the modern society. The introduction of large and rapidly accessible memory system to store and retrieve massive data as well as the development of remote terminal system with display capabilities can enable us to work in man-machine conversational mode and evolve suitable analytical procedure in a sequential fashion. For this purpose, suitable models need to be developed so as to match not only the actual conditions underlying the problem but also those that are exhibited by the observed data.

Modern computer power and improved media such as T.V. have completely changed our outlook on the role of information in research and development activities. The generation of information as a production process has assumed the role of technology wherein commodity produced is information, which as a public good, is an essential input to the decision process and therefore has the implications for the design of Information and system. The value of this commodity increases as the uncertainty or risk in the decision process increases and can therefore act as a powerful tool in the hands of scientists. The development of information as a technology has progressed from electronic data processing through information system to knowledge engineering. From the mere manipulation of large amount of data we have come to the structuring of this data to give information to the user and in the future, actual deductive powers and reasoning. It is, therefore, obvious, that one of the emerging challenges in the field of agricultural research is to recognise the power and uses of information technology or informatics and to effectively use it for improved farm production.

Krishi Net

Although a number of information systems are coming up in different sectors, none so far has been contemplated in the agricultural sector. A rapid implementation of a cost-effective and efficient Agricultural Information System or KRISHINET, which will accelerate the pace, increase the productivity and efficiency of agricultural research, development and education in the country is therefore very much needed.

For implementation of the KRISHINET, an integrated plan should lay emphasis on the following.

—a systematic and comprehensive study of the information exchange (including information processing) requirements of the network.

—rapid and cost-effective development of the system.

—upward compatibility of the system to minimize obsolescence in the next quarter century.

—an efficient integration and effective synergy of the individual system components ; e.g.

—computer hardware, peripherals and user devices.

—research, development and educational software.

—large agricultural related data bases.

—multimedia local and nation-wide communications network and information exchange protocols.

—remote sensing and input-output devices.

It is imperative that from a functional and logistics point of view, the IASRI would be ideal nodal point for the KRISHINET. The large centralized computer to be used in KRISHINET could be conveniently located at the current computer facilities of the Institute, and can concurrently and cost-effectively serve the needs of KRISHINET as well as the Institute. While a larger state-of-the-art computer is urgently needed at the Institute, it will be advisable to assure that it can also effectively serve the needs and has the capability of being integrated with the KRISHINET.

Some of the immediate specific applications of the KRISHINET could be :

—creating a Library Information System for a nation-wide on-line access to books, journals, reprints and other materials related to agriculture.

—provide efficient information exchange and computer networking between large number of agricultural research and education institutes in the country.

—provide ready on-line access to the large computer system and its associated research and application software from diversely located research and educational institutes in the country.

—provide rapid electronic information access to international and foreign agricultural organizations.

INAUGURAL ADDRESS

S. Jayaraj
Vice-Chancellor, TNAU, Coimbatore

Dr. Prem Narain, Ladies and Gentlemen,

I am very happy to associate myself in the 9th National Conference of Agricultural Research Statisticians. At the outset, I extend a hearty welcome to all the delegates and visiting dignitaries to this campus of TNAU.

I would like to share with you my interest in Mathematics in my earlier days which gave me lot of confidence in the later days to undertake the statistical analysis of the experimental data by myself in which I derived maximum pleasure in furthering my research activities, Thanks to my teachers who gave me the basic statistical concepts and ideas in my formative stages.

All of us know that the statistical concepts are applied in all fields of research particularly in Agricultural Research activities. In agricultural research problems I can definitely say that a vast majority of statistical tools are applied which I feel are indispensible for such activities.

The present day Agriculture and its success mainly depend upon the adoption of systems approach in Agriculture which I feel is the management of the available resources in an effective and meaningful way. For such approaches developing sound systems in all the lines linked with Agricultural development as a whole is very important. This will become a reality when we contemplate modelling in Agriculture, the importance of which needs no special emphasis.

In this connection, I have to express my experiences from my recent visit to the United States and a few Land-grant Universities in that country. Modelling Agriculture and the Computer use in Agricultural Research have been developed to a tremendous scale supported with a sound software system in U.S.A. I feel it will take another two or three decades for such a situation to exist in our country.

I need not tell you about the super computer and its use in weather forecasting which will be a boon for dryland farming in addition to the effective forecasting of the pest and diseases. I mention particularly dryland farming here because 60% of our cultivable land are under rainfed conditions, In such a situation I feel

IX NATIONAL CONFERENCE OF AGRICULTURAL RESEARCH STATISTICIANS HELD AT TNAU, COIMBATORE FROM JULY 19-21, 1989

Dr S. Jayaraj, Vice-Chancellor, TNAU delivering the Inaugural Address at the Conference

Dr S.P. Palaniappan, Dean (Agri.), TNAU delivering the Welcome Address at the Conference personally that crop weather modelling will be useful to take up the sowing and other operations at the appropriate time since timely operations in Agriculture will pay high dividends. The above crop-weather modelling will also help farmers to take up pre-monsoon sowing and related Agricultural operations. These modelling techniques will be helpful in predicting weather parameters, incidence of pest and diseases so that the available resources will be made use in an effective manner.

We know that there are fifteen agro-climatic regions in the country, India is a country where we have a long stretch-coastal area. Modelling in Agriculture should be made use of to utilise the diversified agro-climinatic regions and lengthy coastal area effectively. I would like to suggest here that Departments of Agricultural Statistics attached to Agricultural Universities and other ICAR Institutions should have research projects in meteorology as a continuous one. I would even suggest tailoring the curriculum in Agriculture incorporating the programmes in modelling concepts even from the under-graduate level. When we talk about model, I feel such models should be most sophisticated but less cumbersome. Models should be easily adoptable and need-based. I look forward the conference to give for its suggestions and ideas in these lines since we are in the process of preparing 8th five year Plan and its perspectives, As a group of Agricultural Research Statisticians I feel that you are the competent body to suggest ways and means in the above areas with the particular reference to the faculty based specialisation and application of the subject.

Thank you very much for the opportunity given to me and with all happiness I inaugurate the Ninth Conference of Agricultural Research Statisticians.

VOTE OF THANKS

M. Murugesan

Professor of Agricultural Statistics, TNAU, Coimbatore

Respected Chairman, respected Vice-Chancellor, respected Prof. Prem Narain, Ladies and Gentlemen,

Now I stand before you to propose a hearty vote of thanks to all who involved in one way or other in the successful conduct of the 9th National Conference of Agricultural Research Statisticians.

When I think of the three days deliberations, my mind goes to the Seventh National Conference held at UAS, Bangalore in 1983. It was decided to have the Eigth National Conference at Tamil Nadu Agricultural University, Coimbatore. But for some reasons or other the Eighth Conference could not be held here and the Ninth Conference has been inagurated just now. This is a reality only due to the encouragement and support given by our esteemed Vice-Chancellor Dr. S. Jayaraj. I take this opportunity to thank him most profusely and sincerely on behalf of everyone who has assembled here.

When anyone thinks of such conferences like the present one, it is not possible to think it without the name of Prof. Prem Narain who is the guiding force and embodiment of the wishes, aspirations and the activities of Statisticians as a whole. When I got the information from him fixing TNAU as the venue I was really happy and was in all appreciation and gratitude to Prof. Prem Narain for giving us this opportunity of hosting the conference. On my behalf and on behalf of TNAU and all the participants I extend my warm thanks to Prof. Prem Narain.

The Department of Agricultural Statistics is a very small unit with only a few staff members. When I ventured to host the conference I never thought the assignments will be so formidable and complex in nature involving, receiving of delegates, providing the accommodations, booking the return tickets, providing food and other amenities in addition to the scriptory work involved. I am sure that such a big affair became a pleasing and managable one only with the help, guidance and support given by our Dean (Agri), Dr. S.P. Palaniappan for whom all of us owe a lot. I thank him gratefully for his encouragement and support in conducting the conference.

I take this opportunity to thank ICAR and IASRI for their financial assistance for conducting the conference at Coimbatore. In this connection, I cannot miss mentioning the name of Dr. J.P. Jain for his timely help and co-ordination in making the conference a grand success. I thank him sincerely.

My thanks are due to the participants who have come from SAU's and other ICAR institutions whom I personally feel are important components of the conference.

I thank the Director of Extension Education and his staff for their help. I thank the Director, Sugarcane Breeding Institute, Coimbatore for allowing the delegates to stay in the Scientist Home of the Institute. I personally thank my colleagues in the Department for their unstained co-operation and hardwork for making all arrangements of the Conference. I also thank the members of the various committees who lent their support in conducting the conference.

I thank the Estate Officer of the University for making the auditorium available and other arrangements. I thank M/s Shiva PC, Raviraj Computers (P) Ltd and Koluthara Systems for hosting tea for the delegates during the Conference. I thank the press, Doordharshan and AIR for their news coverage of the conference.

I thank the students volunteers who helped us in receiving the delegates. I thank one and all who contributed their might to the extent possible to make the 9th National Conference of Agricultural Research Statisticians a grand success.

TECHNICAL SESSION I

RESEARCH CHALLENGES IN AGRICULTURAL STATISTICS PERTAINING TO CROP SCIENCES AND AGRO-FORESTRY

July 19, 1989 (Wednesday)

2.00 P.M. to 5.15 P.M.

Chairman :	Prof. N. Sundararaj, UAS, Bangalore.
Rapporteurs :	1. Shri S.C. Rai, IASRI, New Delhi 2. Sh. V. Gopalakrishnan, TNAU, Coimbatore
Speakers :	1. Sh. P.N. Bhargava, IASRI, New Delhi 2. Dr. O.P. Kathuria, IASRI, New Delhi 3. Dr: C.K.R. Chetty, CRIDA, Hyderabad 4. Prof. N. Sundararaj, UAS, Bangalore 5. Dr. P.G. Biswas, GBPUA & T, Pantnagar 6. Dr. N.M. Patel, GAU, Anand.

1.1 RESEARCH NEEDS IN DESIGN AND ANALYSIS OF EXPERIMENTS IN CROP SCIENCES

P.N. BHARGAVA, P.R. SREENATH AND P.N. SONI

Indian Agricultural Statistics Research Institute, New Delhi

The concept of design of experiments was introduced by R.A. Fisher during the period 1913-30 while planning agricultural field experiments at Rothamsted Experimental Station, England. Since then, various research workers like Yates, Bose, Kishen, Das and other eminent statisticians developed several new series of designs for factorial as well as non-factorial set of treatments. Designs developed by these statisticians are applicable to a wide range of situations and satisfy the various criteria for choosing the design for a particular situation. Some of the meaningful criteria for choosing the design are as follows : –

(a) total number of experimental units and observations,
(b) ability of the design to eliminate heterogeneity,
(c) balancedness,
(d) simplicity in analysis, and
(e) more information on contrasts of greater interest.

In addition to these, there are a number of other considerations like operational convenience and availability of material which play an important role in choosing the design. The other criterion like sensitivity/robustness also plays an important role in some of the situations. In the present paper, the present status of design and analysis of experiments and problems and studies which need to be taken up in future are discussed.

1. Nature of experimental programme

During the last two decades, agricultural experimental programme in the country has increased manifold. The type of experiments planned can broadly be classified as follows :—

(i) Varietal trials.
(ii) Testing of agronomic treatments on annual crops.
(iii) Identification of crop combinations in (a) mixed cropping, (b) intercropping, (c) crop sequences.

(iv) Input management practices in cropping systems.
(v) Long-term experiments (a) fertilizers, (b) crop rotations and involving both.
(vi) Experiments on cultivators' fields.
(vii) Water management studies.

In all these types of investigations, the programme differs on following aspects :—

(i) Number and nature of treatments,
(ii) Type of facilities and material availability,
(iii) Nature of contrast,
(iv) Method of analysis, and
(v) Utility of results—users.

2. Types of designs adopted

The type of designs adopted for the research continues to be simple and not so efficient. The designs generally adopted are randomised block, split-plot, strip-plot and confounded factorial. For varietal trials, simple lattice, Fedrer's augmented designs are used. The adoption of these designs are principally due to either familiarity of the agricultural scientist or ignorance of the statistician to provide suitable and better alternative designs. Other considerations for adoption of these designs are simplicity in lay-out and resolvability.

The studies carried out on the extent of adoption of different types of designs on the basis of the data collected under National Index of Agricultural Field Experiments at the Institute have shown that about 48% of these experiments are in simple RBD. nearly 19% complete factorial in RBD, 27% split-plot and the remaining 6% are generally confounded factorial design. Another investigation carried out in the Institute on the evaluation of the efficiency of the designs adopted in agricultural field experiments research revealed that for quite a large number of experiments, the design adopted did not commensurate with the expenditure incurred in terms of number of experimental units used in the design. In a number of situations, it was also observed that if an alternative design was adopted, the number of units could be effectively reduced and overall efficiency score improved (Nigam and Bajpai (1980), Bhargava *et al* (1979)). The other limitation was that the size and shape of the plot was not proper. As such, it appears that there is ample scope for introducing certain amount of economy with the help of the newly developed designs in the agricultural research.

3. Steps to introduce better designs

There is a need for advocating the use of efficient designs. For this purpose, it is essential to take following steps :—

(i) interact closely with the agricultural scientist,

(ii) convince them the merits of the alternative designs by actual illustration through the help of data from uniformity trials or other experiments,

(iii) prepare the reviews and catalogues of new series of designs along with their method of analysis for the ready use of the agricultural scientists as well as statisticians, and

(iv) evaluate the past experimental programme to identify the limitations of the designs adopted.

Some work has already been initiated at IASRI on the last two aspects. For the ready use of the scientists, the catalogue/reviews of the designs available for use for asymmetiical factorial, fractional factorial (orthogonal plans) and incomplete block designs have already been completed. The study on the evaluation of the past experiments on wheat and paddy for the experiments conducted in some of the states like U.P. during the period 1966-75 has already been completed. Similar type of studies on this aspect may also be undertaken by the statisticians utilising different sets of available data.

For motivating the scientists to the use of other efficient designs like BIB, PBIB, supplemented incomplete block design or nested designs, there is a need for close interaction with the agricultural scientist. As an illustration, while discussing with the agricultural scientist, it will be useful to identify the set of contrasts/comparisons which require higher precision and another set of contrasts which may need lower precision. Under such situations, group divisible and other PBIB can be suggested. Similarly, in the case of fractional factorial, a proper fraction of the design can be identified which is optimum and meet the properties of optimality developed by various statisticians. There are number of similar situations where the new series of designs can be adopted. While giving the designs, it is not only necessary to give the importance to balance and homogeneity but also look into the robustness of the designs. Under certain situations, there may be some mishaps during the course of experiment because of which we may lose the observations or there may be some unknown trends available in the material. On this aspect, a detailed study has already been initiated in the Institute to identify the designs which continue to be robust under various situations.

There are certain type of treatments like plant population and geometric pattern in the intercropping experiment, where there will be treatment associated heterosedasticity. This has an effect on the overall efficiency of the design and sometimes, the usual analysis, may lead to wrong conclusions. Under such situations, a proper design and analysis techniques need to be developed taking into account the variability associated with the treatment.

Before advocating any designs for adoption in an experimental programme, it will be useful if its sensitivity against disturbances like missing observations, systematic trend, outliers and adequacy of model be examined. Some studies on this aspect have already been initiated in the Institute to identify the designs which continue to be robust when some observations are missing.

4. Problems and studies on analysis of data

4.1. Problems

When experiments are repeated over space and time, following are some of the problems in the analysis of data in different situations :—

4.1.1. Varietal trials

(a) non-linearity in the relationship between environmental index and the variety yield,
(b) non-homogeneity in errors, and
(c) replacement of varieties from trial to trial.

4.1.2. Mixed and intercropping experiments

(a) variances-covariances are heterogeneous, standardised technique of analysis not available,
(b) limitations of method of analysis--(i) treating the data as multi-variate, (ii) converting into univariate, and
(c) plot size,

4.1.3. Cropping systems/long-term trials

(a) missing observations,
(b) standardising the technique of analysis,
(c) statistical technique for identification of crop sequences and their management practices, and
(d) determination of period when fertilizer application should be deferred or reduced in relation to soil health (in case of long-term fertilizer trials).

4.1.4. Soil-test crop-response models

4.1.5. Techniques for estimation of yardsticks for package of practices/cropping systems

4.1.6. Design and analysis of experiments in agro-forestry, silvi pastures and hilly areas.

Studies

1. Based on past data, the recommendations of crop sequences and their management practices in relation to soil parameters be formulated by undertaking the analysis of available long-term trials data at different research stations,

2. Yardstick estimates for different inputs at district level utilising the different sets of data available at the Institute and universities utilising the technique developed by the IASRI,
3. Simulation studies on water use efficiency by examining the data from water management studies collected over years,
4. Risk assessment and risk management studies be undertaken on the past data, and
5. Studies utilising the data on crop-weather be initiated for identification of suitable crop plans.

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1.2 AGRICULTURAL STATISTICS RESEARCH IN RETROSPECT AND TASKS AHEAD

O.P. KATHURIA

Indian Agricultural Statistics Research Institute, New Delhi

1. Introduction

Agricultural statistics include statistics of land utilisation, production of crops and their bye-products, costs and prices, rural employment, size and distribution of holdings and the details of their ownership and tenancy, agricultural machinery, livestock numbers, production of livestock products etc. Detailed and reliable information on various items connected directly or indirectly with the production, processing, distribution and utilisation of agricultural commodities including livestock and fishery would obviously form a strong and reliable basis for planning and policy formulation and implementation of development programmes in agriculture and allied fields.

The system of collection of agricultural statistics in some form or the other has been in existence in the country for several decades. Even during the Moghul period as part of the land revenue administration, records were maintained of the acreages sown under crops. Yet, it was in 1948 when ICAR decided to adopt crop cutting method in randomly selected fields for estimation of production of crops that the way was paved for development of agricultural statistics system in the country on sound statistical principles. Since then several methodological studies were conducted by IASRI and other organisations for estimation of various parameters relating to acreage, production and productivity of field, horticultural and perennial crops and their costs of production, estimation of production of livestock products and their costs, estimation of demographic parameters of different species of livestock etc. Based on the methodologies evolved from these studies, the Ministry of Agriculture, Govt. of India sponsored a number of surveys for generating statistics on various agricultural aspects on a regular and continuous basis while steps were taken to generate statistics on several other items as part of the normal activities of the concerned departments in the States as well as at the Centre.

1.1. Crop Yield Estimation

For over a decade since mid-thirties, considerable research had been going on for developing objective and reliable techniques for obtaining crop yield estimates for principal food crops. P.C. Mahalanobis at the Indian Statistical Institute, Calcutta, V.G. Panse, at the Institute of Plant Industry, Indore and P.V. Sukhatme at the ICAR experimented on different aspects like shape and size of crop cutting plots, number of crop cutting experiments required for determining the yield estimates with a desired precision, agency to be deployed for data collection etc. and appropriate methodology for estimation of yield of major crops was developed. The methodology was found highly useful in arriving at production estimates that the district, state and national levels and was extended to cover all important crops in the country.

2. Agricultural Development Programmes

With increased emphasis being laid on raising the production level of food crops in the country, different programmes like the Community Development Block, Grow More Food Campaign etc. were launched in the early 50's. The emphasis in these programmes was on making available to the farmers timely and adequate supply of inputs like seeds, irrigation, fertilizers and chemicals along with associated improved practices. However, the programme was not uniformly adopted in all parts of the country and there was wide disparity observed in the implementation of the programme as well as the production level achieved. The main lacuna observed in this programme was that a farmer found it difficult to obtain inputs supplied from different sources and places and was therefore, unable to adopt the recommended package of practices. This led to the formulation of Intensive Agricultural Development Programme under which all the needs of the farmers including input supplies, credit availability and other aspects were brought under one roof. A novel feature of this programme was that the assessment and evaluation of the impact of the intensive development programme was an integral component of the project and accordingly data on the performance of the project became available during the implementation period itself.

With the advent of high yielding varieties of major cereals in the mid 60's the agricultural production in the country showed a quantum jump. The main features of the high yielding varieties programme was that the new varieties apart from being of shorter duration were highly fertilizer responsive and it thus became possible to apply much larger doses of fertilizers than was the case with the conventional and indigenous varieties. However, the adoption of high yielding varieties was also found highly variable not only between states and over years but even between villages within a district. Surveys for assessment of high yielding varieties programme were undertaken in different parts of the country during the 4th and 5th Five Year Plans which provided a sound statistical data base for study of different aspects like adoption rates of new varieties and their replacement pattern, the yield vigour of the high yielding/hybrids, the fertilizer response ratios and on number of other related aspects.

3. Cost of Cultivation of Crops

An important aspect of crop production is the economics of raising of crops for which data on cost of cultivation is required to determine the extent of income to the farmers. Since the farmer in India has by and large meagre cash resources, crop cultivation is done mainly by use of family labour which introduces the concept of imputed cost in the overall cost of cultivation since no direct payment of wages is involved for the family labour. To examine these and other aspects, cost of cultivation studies were undertaken in different states in the mid 50's on crops like wheat, rice, sugarcane, cotton etc. which continued for over a decade. These surveys provided a wealth of valuable data on a number of important items like type and extent of labour employment, use of inputs including irrigation, agronomic and management practices adopted and finally the yield obtained. The relative efficiency of the commonly used methods of data collection namely, the survey method and the cost accounting method was also studied in these surveys. Subsequently, a comprehensive scheme of cost of cultivation of crops/has been launched by the Directorate of Economics and Statistics. With the implementation of this scheme the statistics of cost of production of crops has been placed on a sound footing for the purpose of fixation of prices by the government and the farmer is assured of a reasonable return for his investment in crop cultivation.

3.1. Fruits, Vegetables and Plantation Crops

The problems involved in estimating of acreage and yield rates of fruits, vegetables and plantation crops are different and more complicated than those of the field crops. Unlike cereal crops where fresh planting is done every year, fruits trees continue to remain standing for a number of years. Fruit trees are grown not only in orchards but also on any suitable land such as on the banks of rivers and canals, on the road sides, field bunds, backyards of houses etc. It is also a common practice to grow different types of fruit trees in the same orchard. Fruit trees take quite a few years to come to bearing stage. In case of vegetables, there is a common practice to grow two or more vegetables together in the same field. They are generally short duration in nature, involve several pickings and the same vegetable may be grown in different seasons throughout the year. A number of sampling investigations were carried out in the early 60's onwards to develop techniques for estimation of acreage and average yield of coconut, cashewnut, eracanut, cardamom and of several fruits and vegetable crops in different states of the country. Based on these studies the methodologies for estimation of acreage and average yields of these crops were standardized. The Directorate of Economics and Statistics has sponsored a survey on estimation of acreage and production of fruits, vegetables and minor crops while for other plantation crops, the concerned states are collecting statistics on acreage and production based on the methodologies developed earlier.

3.2. Statistics for Micro Level Planning

An important dimension in collection and compilation of agricultural statistics is the level of reporting for planning purposes. For majority of the crops, the estimates of acreage, production and productivity are reported at the district level. While the statistics of acreages under crops in the temporarily settled states are collected by the revenue agency such as the Patwari as part of the statistics on land utilisation, in the permanently settled states these are collected through sample surveys. Since the production of a crop at the district or state level is obtained as the product of area and yield rate, statistics of both area and yield have to be estimated with high degree of accuracy. As already mentioned the technique of crop cutting experiments using random sampling procedure for estimation of yield of crops is being used for the important crops in the country. However, for minor crops yield estimates are still being obtained through eye estimation. It may be pointed out that in some states the system of collection of agricultural statistics is being remodelled and a new agency for recording and reporting of agricultural statistics has been set up. This change needs to be considered carefully after taking into account the continuity and comparability of land records with the past data as also the cost of field operations involved. Moreover, non-uniformity in the concepts and coverage between states would also hamper comparison of land record statistics among states in the country.

It is a common knowledge that considerable heterogenity exists in soil and agroclimatic conditions in a district. Also the availability of irrigation facilities is not uniformly spread out in a district. There is, therefore, a growing demand from the agricultural planners that the statistics of acreages and yield estimates should be developed agroclimatic region wise as also separately for irrigated and unirrigated areas within each such region. Such a demand is also being justified on the ground that the benefits of crop insurance should be available to farmers in conditions of crop losses due to natural calamities. This calls for collection of reliable data at the micro level for small homogeneous areas e.g. yield estimates for blocks/panchayat. It may not be economically possible to increase the number of crop cutting experiments for building up estimates with reasonable degree of precision at such a lower level. Application of small area estimation technique may be required for building up estimates at block/panchayat level.

3.3. Methods and field agency employed for data collection

In most of the agricultural sample surveys data are either collected by enquiry or by physical observation or through combination of both. For instance, in surveys on cost of cultivation of crops the data on crucial inputs have to be collected on day to day basis and of output of crop by crop cutting experiments. The presence of enumerators in the field during these operations is essential for getting accurate data. Likewise for estimation of yield of crops, the enumerator is expected to be present at the time of harvesting of the sample plot. It is also expected that there should be a regular supervision by the supervisory staff to ensure that data collected are of reasonably good quality.

Considerable amount of research and experimentation had been gone through [Mahalanobis (1940), Panse (1948, 1951)] before deciding that the permanent primary agency of the state revenue administration, namely, the Patwaris be entrusted with the responsibility of collection of statistics of acreage and average yield of crops in the temporarily settled states. The simple reason advanced in favour of utilisation of Patwaris for this purpose was that they could watch the crop as it grows and collect sample cuts at the right time from the sample fields situated in the neighbourhood of their normal places of residence [Sukhatme (1968)]. Subsequently, bringing about uniformity in the system of collection of these statistics, it was decided that the Patwaris should collect and report the statistics of acreages only while an appropriate authority in the state government from among departments of agriculture, statistics or land records was designated as State Agricultural Statistics Authority (SASA) which along with NSSO was made resposible for conducting crop cutting experiments for the purpose of yield estimation. In the permanently settled states of Kerala, Orissa and West Bengal which had no such revenue agency, the acreage and yield statistics are now being collected on the basis of sample surveys by the staff specially recruited for this purpose and the methods of collection of data still being through physical observation.

Of late the system of collection of statistics on acreage and average yield of crops is being criticised on the ground that the agency responsible for collection of these statistics is saddled with multifarious duties as a result of which the data on acreage and crop cutting experiments are not being collected through physical observation in many cases. The States are also not reported to be excercising adequate supervision in collection of these data due to combination of several causes including constraints of resources. As a result, the statistics of acreage and average yield based on crop cutting experiments are not reported timely and the quality of data has suffered. Many changes have taken place in the country during the last 40 years in our group for modernisation. Agriculture is no exception. The changed scenario has brought in its woke many challenges in order to make the agricultural statistics system more purposeful and responsive to the needs of the time. There is perhaps need to have a relook at the existing system of collection of agricultural statistics.

3.4. Data gaps and new areas of research

Agriculture statistics in India have come a long way and are available for a variety of parameters at different levels. However, there still remain gaps and shortcomings in respect of a number of important areas. Some of these are statistics relating to cropwise fertilizer consumption and cropped area fertilized, yield rates of irrigated and unirrigated crops, rural employment, social forestry etc. Considerable changes have taken place in the cropping system with new and better varieties of crops being evolved with high yield potential necessitating higher inputs and plant protection technology. The sampling methodologies for most of the field horticultural and plantation crops were evolved nearly two decades ago. Even the structure of the population which serves as the frame for sample selection must have undergone considerable changes over time. The sampling methodologies developed earlier may perhaps need to be revised in view of the changes that have taken place so far.

Fast changes have also taken place in the quality traits of crops like wheat, rice, tobacco, jute, cotton, oilseeds, pulses, sugarcane plantation crops, fruits and vegetable etc. Consequently new varieties of these crops are released for adoption by the farmers. It is not known how long the new varieties find adoption by the farmers in terms of their productivity, susceptibility/tolerance to pests and diseases and availability of seed material etc. Data needs to be collected periodically through sample surveys to find answers to these questions.

In rainfed agriculture water management is a major problem, statistical problems and the mathematical theory that will aid optimal use of water and the optimal management of crops in time of drought have not been investigated in the past. There is need for developing suitable statistical models for evolving optimal crop and water management systems.

Cropping in the hilly areas is primarily done in terraces which are generally long and narrow. Shifting cultivation still continues to be in vogue in the hilly areas of the states in eastern region. Practically no research has been done on the optimum shape and size of plots for crop cutting experiments for the crops grown in the hilly areas. It is high time that the statistical problems of agriculture in these areas are given due considerations and steps taken to plan a system for collection of agricultural statistics from these area on a regular basis.

In sample surveys, besides main parameters of interest data on number of ancillary characters are also collected. The effect of data on these ancillary characters is usually not adequately reflected in drawing inferences about the parameters of interest as it generally involves deeper analysis requiring sophisticated statistical tools and computer software. The techniques of complex survey analysis like Jack-knifing linearisation technique, use of regression models, bootstrep technique etc. are some of the ways of bias and variance reduction. With computer software increasingly becoming available it is high time that the data of agricultural sample surveys which are collected at high costs should be subjected to such deeper analysis.

Non-response bias and non-sampling errors are assumed negligible in agricultural sample surveys. In fact no attempt has ever been made to study the contribution of respondent/enumerator bias, the effect of call backs, the contribution of total item non response in the errors of an agricultural sample survey. Since the field data are collected at huge costs, it is desirable that studies in some of these areas are also taken up.

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1.3 RESEARCH CHALLENGES IN DRYLAND AGRICULTURAL STATISTICS PERTAINING TO CROP SCIENCES AND AGROFORESTRY

C.K. RAMANATHA CHETTY

Central Research Institute for Dryland Agriculture, Hyderabad

1. Introduction

In this paper, the following four important problems awaiting solution are discussed :

(i) Low precision in dryland agricultural experiments—improved analytical procedures as a solution;

(ii) Modelling for stability relevant to dryland crops/varieties/technology;

(iii) Statistical procedures for separation of two sources of variation—soil and genetic—in the case of plant breeders' trials for selection of plant material; and

(iv) Developing experimental designs for Agroforestry trials.

1.1. Statistical Tools for improving precision in dryland agricultural experiments

The precision attained in dryland experiments, in general; is less compared to those under irrigated conditions. This is clear from the perusal of high values of C.V. in experiments conducted by the 23 co-operating centres under All India Coordinated Research Project for Dryland Agriculture (AICRPDA) over the past two decades (Chetty, 1980). The problem can be tackled in three possible ways, viz., (a) Field-Plot Techniques, (b) Experimental Design and (c) Analytical Techniques. The work done in the area of Field-Plot Techniques in this Institute was explained by the author in the previous conference at C.A.Z.R.I., Jodhpur, in 1986. The problem of Experimental Design will be discussed in a subsequent section (Agroforestry) in this paper. Here, the usefulness of certain analytical techniques such as NNA is discussed.

Although Papadakis (1937) suggested the idea of adjusting yields of field experiments for local trend effects by analysis of covariance with respect to treatment-corrected yields of neighbour plots long ago, the idea was dormant until it was revived by Pearce and Moore (1976) and Bartlett (1978). The concept of NNA (Nearest Neighbour Analysis) of field experiments gained wide currency with the publication of the celebrated paper by Wilkinson *et al* (1983). There has been further rapid development in spatial statistics and their application to agricultural field experiments (Besag and Kempton, 1986). The author has applied some of the procedures dicussed in the aforesaid papers to yield data from dryland experiments and quite often were successful in improving the precision.

Three different methods of analysis were applied to several sets of yield data from different Co-operating Centres of All India Co-ordinated Research Project on Dryland Agriculture. The methods are—

(i) Analysis of covariance : In this method the auxiliary variable was the average of the residuals of the nearest neighbour plots;

(ii) Pearce's iterative procedure : For details please see Pearce (1976);

(iii) Moving Block Method : In this method, a new variate Y'_{ij} is defined as a linear function of Y_{ij}, is the yield due to ith treatment in jth block :

$$y'_{ij} = Y_{ij} - b\,(\bar{Y}_{nn} - \bar{Y}_t)$$

where $\bar{Y}_{nn}$ is the average of yields in neighbouring plots and $\bar{Y}_t$ is the corresponding treatment mean (averaged over blocks). The value of b is estimated iteratively such that Error Mean Square is minimised.

The values of the Coefficient of Variation (C.V.) before and after adjustment by Nearest Neighbour Analysis (NNA) and the Values of Efficiency percentage for 14 sets of data are presented in Table—1. The efficiency percentage ranged from 106 to 198.

Error mean squares before and after application of Pearce's iterative method for different blocksizes, along with efficiency (%) Values are presented in Table—2 and 9 different experiments conducted at Varanasi Centre of All India Coordinated Research Project for Dryland Agriculture (AICRPDA). These values ranged from 104 to 221.

For yet another 20 sets of data, the above two methods as also the Moving Block Method (Wilkinson *et al*, 1983) was applied and efficiencies arrived at. Table—3 presents the comparative efficiencies due to the three procedures for these 20 sets. By and large, Pearce's iterative procedure came out as the most efficient method of increasing precision.

Table—1. Values of C.V. (%) before and after adjustment by NNA and the efficiency (%) attained

S. No.	Centre	Year/ Season	Crop	Experiment	C.V Original	C.V After adjustment	Efficiency
1.	Udaipur	1980-81 Rabi	Linseed	Varietal trial	7.17	5.34	198
2.	Agra	1977 Kharif	Soyabean	Varietal trial	35.83	27.58	169
3.	Kovilpatti	1976-77 Rabi	Sorghum	Mulching	12.14	9.80	163
4.	Kovilpatti	1976-77 Rabi	Sorghum	Efficiency of weeding tools	12.14	9.80	163
5.	Agra	1977 Kharif	Guar	Fertiliser trials	25.41	20.38	158
6.	Udaipur	1981 Kharif	Sorghum	Incorporation of crop residues	9.17	8.31	145
7.	Anantapur	1973	Sorghum	Supplemental irrigation	64.47	57.16	135
8.	Udaipur	1981 Kharif	Blackgram	Varietal trial	28.86	26.90	116
9.	Anantapur	1973 Kharif	Groundnut	Varietal trial	15.38	13.83	130
10.	Agra	1976 Kharif	Pigeonpea	Fertiliser use	29.57	27.50	116
11.	Udaipur	1981 Kharif	Maize	Weeding tools	24.33	23.42	114
12.	Agra	1975 Kharif	Pigeonpea	Sub soiling	15.46	15.08	112
13.	Agra	1977 Kharif	Pearlmilet	Seeding dates	17.27	16.80	110
14.	Udaipur	1980-81 Rabi	Mustard	Varietal trial	26.33	25.73	106

Table—2. Error Mean Squares before and after the application of Pearce's iterative procedure, along with efficiencies for different experiments conducted at Varanasi Centre of AICRPDA

S. No.	Crop	Year	Title	Block Size	E.M.S. Before	E.M.S. After	Efficiency % due to iterative method
1.	Bajra	1973	Varietal trial	2	0.902	0.789	114
2.	Bajra	1975	Varietal trial	3	0.271	0.235	115
3.	Rice	1980	Production potential	4	12.216	5.025	241
4.	Rice	1981	Varietal trial	5	0.081	0.066	122
5.	Rice	1980	Varietal trial	2	0.154	0.148	104
6.	Rice	1980	Varietal trial	7	0.154	0.087	177
7.	Rice	1981	Varietal trial	5	0.102	0.051	200
8.	Rice	1981	Varietal trial	3	0.102	0.070	145
9.	Sesamum	1982	Varietal trial	2	0.018	0.010	175
10.	Rice	1975	Varietal trial	3	5.384	4.611	117
11.	Greengram	1981	Varietal trial	5	0.017	0.110	173
12.	Greengram	1981	Varietal trial	2	0.017	0.016	104

1.2. Modelling for stability of dryland agricultural technology

In literature stability has been dealt with in the context of the performance of crop cultivars only. Even in this limited arena, there is no unanimity among scientists about the definition of 'stability'. The problem gets more complicated when one has to measure stability due to improved dryland technology – a conglamoration of crops, varieties and various agronomic practices. Moreover, in the case of dryland agriculture, weather parameters and their relationship with productivity has also to be incorporated in developing a suitable statistical measure/model for stability. This

Table—3. Comparative Efficiency due to Nearest Neighbouring Plot Analytical Techniques

S. No.	AICRPDA Centre at	Test crop & Season	Efficiency (%) due to		
			Papadakis	Pearce	Wilkinson
1.	Udaipur	Barley, 1978-79	85	139	154
2.	Udaipur	Wheat, 1978-79	89	146	102
3.	Udaipur	Barley, 1980-81	91	154	102
4.	Udaipur	Eruca sativa, 1978-79	89	122	135
5.	Udaipur	Sorghum, 1981	145	279	103
6.	Udaipur	Blackgram, 1981	130	134	100
7.	Udaipur	Linseed, 1980-81	198	70	150
8.	Udaipur	Maize, 1981 K	114	176	125
9	Anantapur	Pearlmillet, 1973	93	146	104
10.	Anantapur	Groundnut, 1972 K	116	157	108
11.	Anantapur	Sorghum, 1973 K	135	205	121
12.	Anantapur	Greengram, 1973 K	96	157	104
13.	Agra	Pearlmillet, 1980	94	146	109
14.	Agra	Barley, 1980-81	91	154	116
15.	Agra	Barley, 1979-80	97	170	105
16.	Agra	Barley, 1977-78	90	155	103
17.	Agra	Clusterbeans, 1977	158	104	136
18.	Agra	Soyabean, 1977	169	325	122
19.	Kovilpatti	Sorghum, 1976-77	163	100	100
20.	Kovilpatti	Clusterbean, 1977 K	158	104	136

is an interesting problem on which the Institute's Statisticians are currently working.

1.3. Statistical Procedure for separation of sources of variation

Dryland plant breeders are facing a p roblem in the selection of the segregating material of F_2, the delineation of variability due to soil heterogeneity being essential for proper selection of plant material. Of course, homogeneity of soil can be artificially created (as was done at ICRISAT) but to do so over large stretches of land is both costly and time consuming. Hence, there is a need to develop a suitable statistical procedure for separation of the two sources of variation, viz., soil and genetic.

1.4. Design and Analysis of Agroforestry Experiments

Agroforestry (AF) investigations in India and some countries in Africa include following trials :

* Multipurpose tree (MPT) species/provenance introduction and testing trials,
* Hedge row—intercropping (alley cropping) investigations,
* Investigations with rotational plots,
* Agro-horticulture experiments.

It is the experience of all Agroforestry investigators that precision attained in such investigations (per unit cost) is quite low. Statisticians involved in Agroforestry research have been engaged in developing resource efficient designs. The basic philosophy of the science of Statistics in improving precision in any type of experiment is to somehow reduce the block size. Whenever the block size tends to become large as a result of too many treatments (e.g. varietial trials in which it is not uncommon to test 40 or even more varieties), a class of designs known as "Incomplete Block Designs" have been developed and are available in all standard text books on Experimental Designs. Yet another reason for increase in block size can be due to testing several factors, each having several levels. In this case the concept of 'confounding' came to the rescue of Statisticians. Agroforestry investigations are a class by themselves wherein block size becomes large even through the number of treatments/treatment combinations may be small ($\leqslant 8$). This is because the plot size is often large (sometimes of the order of 300 m^2) This is a new situation not encountered earlier by statisticians in any field and thus a challenge to those statisticians who are actively engaged in Agroforestry research work. A feasible solution for this problem is to use the concept of Nearest Neighbour Design. For instance, Cyclic order designs or Trend-free Block designs can be used. However, the number of replications required to balance the precision attained for comparison of treatment pairs would be large. Thus, tbe problem of finding a 'resource-efficient' design comes back to square one. Only alternative, in the option of the author is therefore, to use improved analytical techniques such as NNA (Nearest Neighbour Analysis) is conjunction with the best possible design, for improving precision i.e., to minimise experimental error.

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1.4 SOME STATISTICAL CONCEPTS AND CONSTRUCTS IN INTERCROP EXPERIMENTS

N. SUNDARARAJ AND M.K. JAGANNATH

University of Agricultural Sciences, Bangalore

1. Introduction

Intercrop experiments have engaged attention of agronomists and statisticians alike in recent times. During the last decade a good number of papers have been published highlighting inherent difficulties in analysing such data and pleading for a more statisfactory method of analysis. As a common ground, majority of such methods make land equivalent ratio (LER) and its varied forms as their focus. An excellant status review of this area of research is available in Mead and Riley (1981). A few of the most recent ones in the last ten years are Willey (1979). Mead and Willey (1980), Willey and Rao (1981), Willey and Reddy (1981), Reddy and Chetty (1984), Pearce and Edmundson (1984), Jagannath and Sundararaj (1987).

In this paper major focus is on developing some new concepts and constructs related to intercrop experiments, which have received little or no attention in earlier publications. The assumptions of normality and ANOVA which are fundamental to many statistical methods of analysis are always in question in respect of methods involving LER. In the present conceptualization many of these difficulties are tide over by defining new concepts of intercrop environment and indexing its intensity in a scheme like p:q by a grading method. Also such grading and cataloguing of schemes hopefully usher in new concepts in designing of intercrop experiments to admit the usual conventional methods of analysis. Hopefully some of these concepts are expected to receive more critical attention towards further improvement and adaptations.

2. Two Basic Parameters

In an intercrop scheme involving two component crops we may recognise two basic sources of influences viz., proportion of physical areas occupied by the two component crops in a scheme, which we may call Land Factor, and the other Biological Factor which influences crop response in a complex way. This biological factor comes into operation as a result of nature and degree of intercrop environment to which the two component crops in the scheme get 'exposed' and which itself is a result of many factors like relative densities of the two component crops, their spatial arrangements, their 'affinity' etc.,—all generated by geometry of arrangement of the component crops in that scheme.

Contribution of land factor is directly proportional to areas under two crops, that is; as the land area for a crop increases the yield of that crop increases. While this is always true of land factor, effect of biological factor is not so simple since it dopends upon nature of biological affinity between the two crops. By way of illustration consider, for instance, an intercrop scheme 1:1 a 1 with two component crops A & B, with proportion of area a for A and (1-a) for B (a 1) depending upon their row spacings. Then all the schemes in the series (1:1), (2:2), (3;3). . allot the same proportion of area a for A and (1-a) for B, but differ from one another in their geometry of arrangements of the two component crops and hence differ in respect of nature and degree of intercrop environment to which the two component crops get exposed. And thus any difference in the yield of crop A (or B) between the two schemes say, (1:1) and (2:2) is purely due to this biological factor and not due to the land factor. On the other hand a scheme like (2:1) which allots greater area to crop A than the scheme (1:1), higher yield for crop A in (2:1) could be entirely due to land factor only, even in absence of any biological factor due to intercropping being operative. While this is always true of land factor it cannot be said so in respect of biological factor which influences crop yield in a more complex manner depending upon nature of relationship between the two component crops as, for example, whether they are 'mutually co-operative', 'mutually compensatory' or 'mutually inhibitive' to use Willey's terminologies (1979).

Thus difficulties in estimation and apportionment of effects on yield due to these two factors—land and biological—are immediately obvious as the geometry of arrangement of the two component crops and the crop areas are both intimately interwined in a scheme and looks at first thought a formidable task for a solution for separate estimates. But all the same there is indeed a necessity for devising some ingeneous but pragmatic way of isolating them, if one wants to seek feed back indicators to exploit benefits of the more important one of the two factors—biological factor—since benefit due to increased land factor could be realized even in a sole crop environment by merely increasing land factor to that specific component crop.

Towards this end we need to define an 'intercrop environment' embedded in a scheme and to devise a scientific basis for grading the intensity of this intercrop environment; and to examine ways of incorporating the same in designing intercrop experiments to isolate and estimate contributions from the two factors—land and biological. This will be the focus of the subsequent sections.

3. Defining intercrop Environment

Concept of intercrop environment which is a constituent part of biological factor is not easily amenable for a unique definition, acceptable from all view points

—agronomical, physiological or other biological view points. All the same a definition needs to be devised with its foundation rooted in its inherently intuitive nature of crop environment generated in an intercrop scheme.

For evolving one such definition we first note that in a sequence (AAA...AA) or (BBB...BB), when grown as a sole crop, intercrop envirornment is totally absent and hence intensity of intercrop environment is zero or same as sole crop environment is 100%. In contradistinction with this, at the other end the sequence (ABAB...ABAB) of the 1:1 scheme, intercrop environment is complete for both the crops and hence its intensity is 100%, while sole crop environment is zero. The two sequences (AAA...AA) and (ABAC...ABAB) could thus serve as two end points for grading on intercrop environment and a basis for devising a scale for measuring intensity of other intermediary schemes like 3:2 viz.,...B/AAABB/A. etc.

Also in an intercrop environment one may identify three fundamental types of segments which we may call Primary (P), Secondary (S) and Tertiary (T) types of environment. These three types would determine nature and degree of intercrop environment embedded in a scheme. In a segment like BAB in a scheme intercrop environment for crop A is complete since it is flanked by the intercrop B on either side. Likewise for B in ABA. We may define such an envionmental segment as of primary degree since it provides maximum intensity of intercrop environment. On the other hand in a segment like BAAB, the intercrop environment for crop A could be defined as of Secondary degree since each A is flanked by the intercrop B only on one side and monocrop of its own species A on the otherside. The intensity of intercrop environment in respect of each A is thus only 50% of the primary type, Likewise for B in ABBA. A third type of segment—the tertiary type—is experienced by the central row of A in BAAB since the central row A is flanked by its own species A on its either side and only obliquely by the intercrop B. Obviously this tertiary segment may be of varied length as, for instance, segments like BAAAB and AAAAAB have two and four central rows of A respectively under tertiary influence of B, each successive row possibly experiencing different degree of such influence depending upon how far away that row is from the flanking rows of B. Likewise for B in ABBBBA or ABBBBBBA etc.

A simple device for enumeration of primary (P), Secondary (S) and tertiary (T) numbers in a scheme is to consider a run of three consequitive letters in succession and identify each type in them. For instance, for scheme 3:9, adding the last letter B of the previous row as a prefix and the first letter A of the succeeding row as a suffix resulting in...B/AAABB/A...runs of three successive letters are BAA, AAA, AAB, ABB, BBA which readily facilitate identifying primary, secondary and tertiary of segments in this scheme. Thus 3:2 scheme contains, for crop A, zero segment of primary type, two secondary types one each in BAA and AAB, one tertiary type in AAA; and for crop B, zero primary type, two secondary types one each in ABB and

BBA zero tertiary type. Thus this simple devise may be used for enumerating different types of segments in a given scheme.

For grading the three types of segments for intensity of intercrop ervironment, it may be desirable to base it on simplicity and intuitively operational Since a primary segment provides maximum intensity we may assign a score of one. By borrowing analogy from crop competition we may grade a secondary type equivalent to half the intensity of a primary type and assign a scope of half or equivalently two secondary types may be considered equivalent to one primary type. For grading a tertiary type of segment, one needs to be a bit careful sincc there is no simple way for grading it. For instance, if one could assume, as it is sometime done in crop competition, that an intercrop environment would not percolate beyond one neighbouring row to an appreciable degree, then every tertiary row, for example as in...B/AAAAAABBB/A...could be assigned a score of zero as such rows are treated like monocrop rows; in which case, under this simplistic assumption, the total intensity of intercrop environment comes solely from primary and secondary segments only. If this assumption is in doubt, this could be tested by comparing average yields of such testiary segments in different schemes with monocrop rows.

Other grading devises for tertiary types may also be examined. For instance, extending the analogy that a secondary type is half of a primary type and numbering the positions of tertiary rows as in . .B/A A A A A A A B B/A . . of 6:2 symmetrically from their ends, the weights could be $(\frac{1}{2})^2$, $(\frac{1}{2})^3$ etc., for positions 1,2 etc., in that scheme. Or a score equivalent to e^{-r} where r is the position of the tertiary row under consideration could also be examined if one could assume the intensity to decrease exponentially as the tertiary row moves away from the intercrop row. There could be other considerations too like a linear decline in a regression fashion.

Thus for grading a scheme for intensity of intercrop environment, it is crucial to take decision in respect of tertiary rows in a scheme. However it is also possible to devise schemes involving only primary and secondary types thus eliminating the problem of tertiary segments. In section 5 grading total intensity in respect of conventional intercrop schemes is discussed, while in section 6 we discuss nonconventional new schemes involving only primary and secondary types of segments.

4. Grading a Conventional Intercrop Schemes (p:q) for Total Intensity of Intercrop Environment

Total intensity of intercrop environment in a unit plot depends upon two parameters; numbers of P.S.T. segments embedded in a basic scheme S (p:q) and number of such schemes that could be accommodated in a unit plot of given size. For simplicity and to fix ideas with clarity we shall, at first instance, assume equal spacings for the two component crops and a unit plot of 100 rows to facilitate expressing intensity on a percent scale. In practice this figure could be adjusted for any plot size. And later comments will be offered for suitable modifications when row spacings are different for different component crops. Also by 'convention schemes' we mean here that layout of scheme S (p:q) requires p rows of A followed by q rows of B, this sequence being repeated to cover the entire plot of 100 rows.

Table 1 gives the computational steps for determining the total intensity in the entire plot. The information about numbers P,S,T segments embedded in a basic scheme as computed from the enumeration method described in the previous section is shown in Col. 5; the number of basic sets in a unit plot of 100 rows at the rate of (p+q) rows per set in Col. 6; total number of P,S,T segments in this unit plot in Col. 7; intercrop intensity as measured by $(P+\frac{1}{2}S)$ for each crop in Col. 8; total intensity in the plot along with total tertiary number of rows in Col. 9. Since there are multiple possibilities for scoring tertiary rows they are shown as such with freedom to employ any grading method and add the resulting score to $(P+\frac{1}{2}S)$ to obtain the final score for the total intensity in the plot as a whole.

In the Table 1 only a few schemes to serve as illustration of the new concepts proposed are presented. The method could be employed for any arbitrary scheme too. It may be noted as a passing remark on such conventional intercrop design S (p:q) that, except in 1:1 scheme, there is no primary intercrop segment at all in such a scheme which will result only in increased tertiary lengths as p & q increase and thus such rows are likely to behave more like sole crop rows. One could see from Table 1 that the percentage of tertiary rows increases from zero for S (1:1) scheme to 66 2/3% for the Scheme S (8:4) *at the expense of intensity of intercrop environment.*

It is thus strikingly obvious that such conventional schemes in general do not seem to incorporate the very vital sinews of intercrop environment to isolate and exploit the crucial beneficial effects in full measure for component crops; and p:q seems to be determined mostly to achieve desirable densities for the two component crops to meet needs of farmers from economic view point for an assured area for main crop.

Thus some alternative approaches are desirable to ensure not only realizing densities p:q for the two component crops but at the same time to achieve desirable intensity of intercrop environment with a view to exploit benefits from biological factors. This has been attempted in the next section.

5. Designing Schemes for higher Degree of Intensity of Intercrop Environments

In any intercrop scheme we have already identified that primary and secondary types of segments offer high degree of inter crop environment. By selective integration of these segments in a scheme it is not only possible to achieve higher degree

Table 1. Procedure for Grading total intensity of Intercrop Envirenment in a unit plot of 100 rows with equal spacings for the two component crops A & B in conventional schemes B (p:q).

Sl. No.	Scheme S (p:q)	Scheme (p:q) Lay out	Crop	No. of P.S.T. in Basic set P	S	T	Number of sets per 100 rows 100/(p:p)	Total No. of P.S.T. in unit plot P	S	T	Crop intensity in unit plot crop-wise $P+\frac{1}{2}S$	Total $P+\frac{1}{2}S$	T
1.	S (1:1)	. .B/AB/A. .	A	1	0	0	50	50	0	0	50	100	0
			B	1	0	0		50	0	0	50		
2.	S (3:2)	. .B/AAABB/A. .	A	0	2	1	20	0	40	20	20	40	20
			B	0	2	0		0	40	0	20		
3.	S (3:3)	. .B/AAABBB/A. .	A	0	2	1	$\frac{100}{6}$	0	$33\frac{1}{3}$	$16\frac{2}{3}$	$16\frac{2}{3}$	$33\frac{1}{3}$	$33\frac{1}{3}$
			B	0	2	1		0	$33\frac{1}{3}$	$16\frac{2}{3}$	$16\frac{2}{3}$		
4.	S (8:4)	. .B/AAAAAAAA BBBB/A. .	A	0	2	6	$\frac{100}{12}$	0	$16\frac{2}{3}$	50	$11\frac{1}{3}$	$22\frac{2}{3}$	$66\frac{2}{3}$
			B	0	2	2		0	$16\frac{2}{3}$	$16\frac{2}{3}$	$11\frac{1}{3}$		

of intensity but also achieve any preselected density for the ratio p:q for the two component crops. Only a few illustrative examples are presented in Table 2. The guiding principle for this is to integrate proper ratios of primary and secondary segments in the required scheme p:q if necessary to add monocrop rows for marginal adjustments as is sometimes suggested to achieve Staple Land Equivalent Ratio suggested by Reddy & Chetty (1984).

Table 2 attempts to do this for p:q schemes by integrating segments P and S in different permutations and combinations as displayed in Col. 3 resulting in non-conventional types designated as S′ (p:q) to distinguish it from the conventional type S (p:q) of Table 1. For this purpose the first four schemes of Table 2 are designated as *fundamental* schemes. They are termed so because S′ (1:1) provides primaay type of environment with mrximum intensity for both the component crops A & B, S′ (1:2) providing primary for crop A only but secondary type for crop B. S′ (2 : 1) its vice versa and lastly S′ (2:2) providing only secondary types for both the crops. A derived scheme, for instance, S′ (3:3) may then be generated in more than one way viz. S' (1:1)+S′ (2:2) or S′ (1:2)+S′ (2:1), in which the symbol+stands for the operation of integration of S′ (1:1) and S′ (2:2) to yield the pattern...B/ABAABB/A...with an intensity of 66 2/3% and S′ (1:2) and S′ (2:1) to yield the pattern...B/A B B A A B/A...with an intensity of 66 2/3% (Table 2).

The computation of intensity of intercrop environment embedded in a scheme in Table 2 could follow the same procedure as laid out for Table 1. However one could also compute this from the knowledge of the intensities of the two fundamental schemes which enter this derived scheme. For instance, if the scheme S′ (3:3) requiring six rows is achieved by integrating the two schemes S′ (1:1) with two rows and S′ (2:2) with four rows, it is readily seen that the intensity of the resulting scheme is weighted average of the two intensities viz., (2/6) (Intensity of S′ (1:1) plus (4/6). (Intensity of S′ (2:1)) which is equal to (2/6). (100)+(4/6). (50)=66 2/3. In general if two schemes S′ (p:q) & S′ (p′:q′) with intensities I_1 & I_2 are integrated to result in a new scheme S′ (p+p′ : q+q′), then the intensity of I of this scheme is given by

$$I = \frac{p+q}{(p+q)+(p'+q')}(I_1) + \frac{p'+q'}{(p+q)+(p'+q')}(I_2)$$

From this Table it may be noted that the degree of intensity of intercrop environment gets increased to varying degrees in a p:q scheme although such resulting nonconventional schemes may apparently appear to offer layout difficulties in field conditions and likely, at first instance, to be less attractive at farmer's level. Nevertheless one cannot fail to admit the merit of such schemes at least at experimental stage and the potentialities they carry with them in incorporating the very vital concept of intercrop environment to understand the underlying

Table—2. Procedure for grading total intensity of intercrop environment in a unit plot of 100 rows with equal spacings for the two component crops A and B in *non-conventional* scheme S' (p:q)

Sl. No.	Scheme S' (p:q)	Scheme S' (p:q) layout	Crop	No. of P.S.T. in Basic set P	S	T	Number of sets per 100 rows 100 (p:q)	Total No. of P.S.T. in unit plot P	S	T	Crop intensity in unit plot $P+\frac{1}{2}S$	Total $P+\frac{1}{2}S$	T
1	2	3	4	5			6	7			8	9	
1.	S' (1:1)	.,B/AB/A..	A	1		0	50	50	0	0	50	100	0
			B	1	0	0		50	0	0	50		
2.	S' (1:2)	. .B/ABB/A	A	1	0	0	$\frac{100}{3}$	$33\frac{1}{3}$	0	0	$33\frac{1}{3}$	$66\frac{2}{3}$	0
			B	0	2	0		0	$66\frac{2}{3}$	0	$33\frac{1}{3}$		
3.	S' (2:1)	. .B/AAB/A	A	0	2	0	$\frac{100}{3}$	0	$66\frac{2}{3}$	0	$33\frac{1}{3}$	$66\frac{2}{3}$	0
			B	1	0	0		$33\frac{1}{3}$	0	0	$33\frac{1}{3}$		
4.	S' (2:2)	. .B/AABB/A..	A	0	2	0	$\frac{100}{4}$	0	50	0	25	50	0
			B	0	2	0		0	50	0	25		
5.	S' (3:2)	. .B/ABAAB/A..	A	1	2	0	$\frac{100}{5}$	20	40	0	40	80	0
		S' (1:1)+S' (2:1)	B	2	0	0		40	0	0	40		
6.	S' (3:3)	. .B/ABBAAB/A. .	A	1	2	0	$\frac{100}{6}$	$16\frac{2}{3}$	$33\frac{1}{3}$	0	$33\frac{1}{3}$	$66\frac{2}{3}$	0
		S' (1:2) + S' (2:1)	B	1	2	0		$16\frac{2}{3}$	$33\frac{1}{3}$	0	$33\frac{1}{3}$		
7.	S' (2:3)	. .B/ABABB/A. .	A	2	0	0	$\frac{100}{5}$	40	0	0	40	80	0
		S' (1;1) + S' (1:2)	B	1	2	0		20	40	0	40		
8.	S' (4:6)	. .B/ABBABBAABB/A..	A	2	2	0	$\frac{100}{10}$	20	20	0	30	60	0
		S' (1:2) + S' (1:2) + S' (2:2)	B	0	6	0		0	60	0	30		
9.	S' (5:5)	. .B/ABAABBAABB/A..	A	1	4	0	$\frac{100}{10}$	10	40	0	30	60	0
		S' (1:1) + S' (2:2) + S' (2:2)	B	1	4	0		10	40	0	30		
10.	S'' (5:5)	. .B/ABABABAABB/A..	A	3	2	0	$\frac{100}{10}$	30	20	0	40	80	0
		S' (1:1) + S' (1:1) + S' (1:1) + S' (2:2)	B	2	2	0		30	30	0	40		

phenomenon of biological factor in intercrop expeiiments. Such schemes will be helpful in identifying compatible crops for selection to serve as companion crops; also to design experiments with specific objectives. Some of these are considered in the next section.

As a point of merit, it may be noted that none of the schemes has the problem of tertiary rows, although if need be, one could incorporate such rows in a measured way by ensuring their number to be constant in every scheme to study their behaviour in different schemes:

New schemes could also be generated by integrating, say, m sets of scheme S′ (p:q) and n sets of another seheme S (p′:q′) subject to the constraint m (p+q)+ n (p′+q′) = 100 rows to yield a new scheme S′ (mp+np′): (mq+nq′). The resulting intensity I of this new scheme is easily computed by noting down the numbers of P & S segments for S′ (p:q) and P′ & S′ for the scheme S′ (p′:q′) and combining them in the form $I = m\ (P+\frac{1}{2}S) + n\ (P'+\frac{1}{2}S)$. Then in a plot of 100 rows I will yield the percent intensity in the resulting new scheme. In a similar way one may extend this principle for integrating, say, of m sets of S′ (p;q), n sets of S′ (p′:q′) and t sets S′ (p″:q″) to yield a new scheme S′. (mp+np′+tp″): (mq+nq′+tq″) with a lot of flexibility to realize any density level l:m in the new scheme.

Other variations could also be introduced in generating new schemes. For instance, in a plot of 100 rows a scheme S′ (p:q) could be sown in only r rows (r 100) and filling the remaining (100—r) rows with monocrop rows of either component crop A or B or both. This will not only ensure a plot with preselected intensity but will also provide flexibility to achieve Staple Land Equivalent Ratio (SLER) for the component crops.

Before quitting this section a word about the case when the two component crops do not have the same row spacings and the unit plot provided is of area, say M. Since the row spacings are not the same as assumed for all the previous discussions, there is now need to take this into account while determining the intensity of intercrop environment in the basic scheme S’ (p:q) and in the unit plot of area M. While information in Table 1 from Col. 1 to Col. 5 remains same, whether row spacings for the two component crops are same or not, the number of basic sets of Col. 6 which needs to be determined, should take into consideration area occupied by a basic set. For instance if α and β are the row spacings for A & B respectively in S’ (p:q) with p rows of A and q rows of P, the area per set will then be $(\alpha p+\beta q)$ so that the number of sets that could be accommodated in unit plot of area M is $M/(\alpha p+\beta q)$. This will be the multiplying factor in Col. 6 to compute P, S,T segments in Col. 7 from Col. 5. With this necessary modification further computations in Table 1 or Table 2 remain unaltered.

In summary, we have so far introduced a new concept of defining an intercrop environment, a scientific basis—intuitively appealing too———operationally defined to measure its intensity embedded in a scheme so as to facilitate indexing such schemes for further statistical use In the next section we may examine the ways of utilizing this information on designing intercrop experiments with optimum properties satisfying the usual assumptions about ANOVA etc.

6. Some Design considerations for Intercrop Experiments

From the foregoing formulations we now recognize that an operationally viable scientific basis has been evolved to index every scheme of the type S (p:q) on twin parameters of land and biological—the latter being defined operationally by the Index of intensity of intercrop environment provided by the gaemetry of arrangement of crop sequence in a scheme. Although the above concepts are mostly developed in Table 1 and Table 2 for the special case of equal spacings for the two component crops A & B it offers no difficulty whatsoever when row spaces are different; indeed this situation might throw open wider choices of designing schemes to unravel any hidden advantages of intercrop experiments; into which we shall not proceed further. However by way of illustration in the case of equal row spacings for the two component crops as in Table 2, we note that the scheme S′ (2:2) allots half the area to crop A and the other half to crop B and the intensity of intercrop environment in it is 50%. On the otherhand the scheme S′ (2:3) allots just 40% area to crop A and 60% to B and the intensity of intercrop environment is 60%. Thus every scheme of the kind S (p:q) or S′ (p:q) may be indexed by these loadings in respect of land factor and the factor of index of intensity of intercrop environment.

With this indexing facility made available for each scheme, it is possible to devise intercrop evperiments to isolate and estimate contributions to yield responses in the two component crops A & B from land and biological factors as promised in the Section 2 of this paper. Although one could think of many illustrative and novel ways of demonstrating some of these, we shall content ourselves with three major types of common interest. These are :

I. Factorial set up to isolate and estimate contributions from land and biological factors in an intercrop experiments.

II. Nested classification designs' nesting intensity factors into land factors and vice-versa.

III. Response curve designs to study responses of component crops A & B with a view to asses their biological affinity or disaffinity for screening a suitable companion crop.

I. Factorial Set Up : In this set up levels of land factor and levels of intensity factor are combined in a factorial fashion to facilitate separation of their effects due to each of them and their interaction effect from observed responses like yield from the component crops. Table 2, for instance, we note that the two schemes S′ (5:5) and S″ (5:5) allot the same proportion of area viz., 50% to component crop A (hence 50% for B too) but contain different levels of intensity viz., 60% and 80% respectively. Likewise the two schemes S′ (4:6) and S′ (2:3) allot the same but slightly lower percent area viz., 40% to component crop A (Hence 50% to B) but contain, as before, intensity levels of 60% and 80%. In otherwords if we denote the area a_e=40% and qa_1=50% and the intensity levels I_0=60% and I_1=80%, we readily recognize that the treatment combination a_0I_0 is embedded in the scheme S′ (4:6), a_0I_1 in S′ (2:3) a_1I_0 in S′ (5:5) and a_1I_1 in S″ (5:5) resulting in a factorial set up of treatment combinations as in Table 3.

Table—3. A$^2 \times 2$ factorial combination of treatments for the two factors Land and Intensity

		FACTOR : INTENSITY I_0 (60%)	I_1 (80%)
FACTOR : LAND (Area to Crop A)	a_0 (40%)	S′ (4:6) (a_0I_0)	S′ (2:3) (a_0I_1)
	a_1 (50%)	S′ (5:5) (a_1I_0)	S″ (5:5) (a_1I_1)

If these treatment combinations (schemes) are tried in an RCBD with r replications, the resulting data for yield or some other response variable for each crop may be subjected to customary ANOVA under the usual linear model response (yield) appropriate to Randomized Complete Block Design. The final ANOVA table would then show contributions to total variability in response variate from different sourees viz., Land, Intensity (Biological) and their interaction effect. In the ANOVA table if the Intensity source turns out to be nonsignificant, it would only support the hypothesis that there would be no special advantage in growing the two crops in an intercrop environment due to lack of biological effects and such rows would behave just like monocrop rows with yields proportionate to the areas sown under each crop. On the other hand if this F-test turns out to be significant, it may have an interesting story to say about the advantages of growing the two crops as intercrops; and comparison of cell means would then directly reflect such advantages. If the interaction component turns out to be non-significant, the two factors viz., land and biological are contributing independently and in this case schemes with higher load of intercrop intensity but with same proportions of areas for component crops in the two schemes would prove advantageous. If the interaction component turns out to be significant then a detail study of cell means is desirable to effect judicious choice of a particular scheme.

In summary. the present approach to intercrop analysis is more advantageous than LER approach, since the proposed method facilitates a means for apportionment of contributions accruing separately from the land and the biological factors and facilitates judgement about the relative importance of these two factors in increasing the yield of a crop. In the absence of biological factor contribution from land factor should be of the same level as in monocrops.

Another striking advantage to be expected is about the assumptions of normality etc., so much essential for meaningful statisical analysis; it is more likely to be satisfied in the present analysis as only linear combinations of observations are involved rather than ratios as in the case of LER. Lastly, any scheme picked up this analysis should be expected to yield higher LER score to reflect the same.

II. A Nested Set Up : In this set up levels of intensities of different schemes may be nested within selected levels of land factor or vice versa, For instance, schemes S (1:1), S (2:2), S (3:3), S (4:4) . . . all share a common proportion of land for each component crop, say, a_0 for crop A with different levels of intensities. Likewise the series S (2:1), S(4:2), S(6:3) . . . allot the same but higher proportion say, a_1 of area to crop A, ($a_1 > a_0$) but vary in respect of their intercrop intensities. These schemes may then be nested under a_0 & a_1 respectively. The resulting treatment combinations may be replicated in RCBD. The data on yield realized from such an experiment may then be subjected to appropriate analysis of variance suitable to the hisrarchal classification.

If one desires such data, obtained either from factorial set up or from nested set up, may also be subjected to a Bivariate ANOVA with necessary assumptions for MANOVA. Other comments in respect of normality already made earlier hold good here also.

III. Response curve analysis : In any intercrop experiment it is always desirable to select a companion crop to the main crop which provides mutual benefit to each other. In such studies response curve analysis seems to be particularly appropriate. For a meaningful response curve analysis, yield responses for component crops are to be generated for different degrent degrees of intensities varied in a measured way; which means schemes are to be designed specially to meet this objective in view. Although it has been conceptualized that two secondary segments are equivalent to one primary segment, it may be instructive to vary intensities using one pattern only.

For instance if one likes to study crop responses under primary type of intensity for both the crops A and B, plots may be constructed with required number of AB types of intercrop segments, to achieve desired intensity level and filling the balance part of the plot with mono crop rows of A and B since they contribute zero score to the intercrop intensity in the plot. Then a plot of 100 rows may look like this:

Intercrop	Monocrop A	Monocrop B
. .AB . . type	. .AA. .type	. .BB11 type
r_i sets	r_2 rows	r_3 rows
$=2$ r rows		

with $2\,r_1+r_2+r_3=100$ rows contributing to a total intercrop intensity of $2\,r_1\%$ since r_2 monocrop rows of crop A r_3 monocrop rows of crop B totally contributing zero to intensity.

Then setting $(r_1, r_2, r_3)=(50, 0, 0)$, $(40, 10, 10)$, $(30, 20, 20)$, $(20, 30, 30)$, $(10, 40, 40)$, $(0, 50, 50)$ will successively lead to plots of 100, 80, 60, 40, 20 and 0 percent intensity. The data may then look like:

Plot Intensity (%)	0	20	40	60	80	100
Crop A	x_1	x_2	x_3	x_4	x_5	x_6
Yield :						
Crop B	y_1	y_2	y_3	y_4	y_5	y_6

And the same may be analysed graphically as well analytically by fitting appropriate response curves for A and B.

A similar experiment may be planned with secondary types of segments only like (AABB) for both the crops; or mix-up AB AABB types too. Such experiments may bring out qualitative as well as quantitative differences, not otherwise obvious, to identify whether crops are mutually co-operative, mutually compensatory or mutually inhibitive.

In brief : This paper proposes a few new concepts and constructs in inter-crop experiments which hopefully overcome many difficulties encountered in LER analysis; at the same time usher in new grounds for intercrop experiments with reference to design, analysis and interpretation of such experimental data.

Acknowledgement

This research was carried out under Project No. DR/UAS/ST/21/1986 in the University of Agricultural Sciences, Bangalore, The authors would like to express their grateful thanks to Dr. K. Krishna Murthy, the then Director of Research and our present Vice-Chancellor, UAS, Bangalore for his keen interest in this project.

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1.5 PREMIUM RATES FOR COMPREHENSIVE CROP INSURANCE SCHEME

P.G. Biswas, V.P. Manglik, V.K. Pandey, B. Prasad
G. B. Pant University of Agriculture & Technology, Pantnagar (Nainital)

1. Introduction

The high rate of premium is the main problem with the insurance scheme and economists have tried to bring it down by lowering the indemnifiable limit [3]. Government subsidised the premium rates to make Crop Insurance popular. It is felt that alternative method of premium calculation should be developed so that more realistic premium rates can be offered by the insurance agencies and the project be pulled on without government's help in the long run.

Keeping the above problem in mind in this paper an attempt has been made to study the distribution of yields of majore crops in different regions of the U.P. State, the extent of risk therein and to develop a suitable criteria for determining premium rates.

2. Methodology

One district has been selected from each of the ten administrative divisions of U.P., except the two Hill divisions. Selection of districts has been done based on highest rainfall variation. The crops selected were rice, wheat, pulses (kharif), pulses (rabi), total pulses, oilseed (kharif), and total oilseed. Data from 1950-51 to 1984-85 were collected for all the above crops.

It was felt that a time series of 35 observation is not sufficient to examine the distribution, hence possibility of the combining data of the same crop over the districts was first investigated. For this purpose : Kolmogorov—Smirnov Two sample Test, Mann—Whitney U Test and Two Sample Run Test have been used ([6] and [7]).

Normal and Exponential distributions have first been fitted [8] and their fit tested through Kolmogorov-Smirinov one sample test. [6]

As doubted, those distributions did not fit. Pearson system of distributions [9] was then tried.

3. Premium Determination

3.1 Normal curve Technique

If the insurance program has no profit motive then premium received over a long period of years would, on an average, be equal to the indemnities paid during same period. The premium rates would depend upon (i) average crop production per hectare (ii) the year to year variability in the average yield and (iii) the level of coverage. The expected indemnity expressed as a percentage of the threshold yield gives the premium rate.

If the threshold yield is designated by c, the area yield by y, then the indemnity (I) paid to the farmers in the insured area is given by.

$$I = c - y \text{ if } y \leqslant c$$
$$= 0 \text{ if } y \geqslant c$$

(a) In case of Normal curve the average indemnity [5] can be obtained as

$E(I) = A\,(c - m) + d \times \text{s.d.}$, Where

A = area under the normal curve to the left of the ordinate at $y = c$

d = ordinate of the normal distribution at $y = c$

(1) When $c = m$, $E(I) = d \times \text{s.d.}$

$$\text{Premium} = \frac{d \times \text{s.d}}{m} \times 100$$

$= d \times \text{c. v}$; c. v. = coefficient of variation

(2) When $c = pm$; $0 < p < 1$

$$E(I) = A\,(c - m) + d \times \text{s.d.}$$
$$= -mq\,A + d \times \text{s.d.} \quad (q = 1 - p)$$
$$\text{Premium} = \frac{(-mq\,A + d \times \text{s.d.})}{pm} \times 100$$
$$= 1/p \times (-100q\,A + d \times \text{c.v})$$

(b) In general

$$E(I) = E\,(E\,(I : y))$$
$$= E\,((c - y) : y \leqslant c)\,\Pr\,(y \leqslant c) + 0.\,\text{pr}\,(y \geqslant c)$$
$$= E\,((c - y) : y \leqslant c)\,\text{pr}\,(y \leqslant c)$$

$$\text{But } E\,((c - y) : y \leqslant c) = \frac{\int_{-\infty}^{c} f(y)\,dy}{\Pr\,(y \leqslant c)}$$

$$\text{Hence } E\,(I) = \int_{-\infty}^{c} (c - y)\,f(y)\,dy$$

$$= c\int_{-\infty}^{c} f(y)\,dy - \int_{-\infty}^{c} y\,f(y)\,dy$$

$$\text{Where } f(y) = y0 \left(1 + \frac{y}{a_1}\right)^{m_1} \left(1 - \frac{y}{a_2}\right)^{m_2}$$

for Type I curve.

$$\text{Therefore, } E(I) = c \int_{-\infty}^{c} y0 \left(1 + \frac{y}{a_1}\right)^{m_1} \left(1 - \frac{y}{a_2}\right)^{m_2} dy - y0$$

$$\int_{-\infty}^{c} y \left(1 + \frac{y}{a_1}\right)^{m_1} \left(1 - \frac{y}{a_2}\right)^{m_2} dy$$

Solving the above integrals with the help of Simpson method the expected indemnity payable to the farmers in the insured area can be worked out. The premium as percentage of threshold yield is given by :

$$\text{Premium} = \frac{E(I)}{m} \times 100$$

In case of other type of Pearson curve the f (y) expression will change and other procedure remains the same.

3.2 Dandekar's method

Dandekar's procedurs [3] and the normal curve technique for working out the premium rates are similar except that Dandekar uses MD instead of S.D; where $MD = 0.7979 \times s.d.$ for normal distribution.

Result

Based on the largest rainfall variation one district was selected from each administrative division of Uttar Pradesh. The districts selected were Saharanpur, Allahabad, Aligarh, Bareilly, Rampur, Jalaun, Gazipur, Deoria, Lucknow and Faizabad.

1. Nature of Distribution

Time series data on yield of each of the selected crops were collected from 1950-51 to 1984-85. The results of Kolmogorov—Smirinov two sample test, Mann Whitney U test and Two sample Run test for all the selected crops show that the yield data of a particular crop of all the districts belong to the same population.

Based on these results, yield series of same crop for all the ten districts have been combined and thus the total number of observations have become 350 for a series. This series of 350 observations has been tested for different distributions.

Results of Kolmogorov—Smirinov one sample test are shown above in table no. 1.

Table—1. Kolmogorov—Smirinov one sample test for Normal and Exponential Distribution

Crops	Normal		Exponential	
	Dn=Fn(×)—F(×)	Prob.	Dn=Fn(×)—F(×)	Prob.
Rice	5.804	0.00000	8.240	0.00000
Wheat	2.094	0.00031	2.405	0.00002
Pulses (kh)	1.633	0.00897	3.848	0.00000
Pulses (ra)	1.477	0.02534	2.832	0.00000
Pulses (tot)	1.983	0.00076	2.458	0.00001
Oilseed (kh)	1.541	0·01729	2.619	0.00002
Oilseed (tot)	1.621	0.01037	2.726	0.00000

Both for Normal and Exponential type of distributions all the probabilities are less than .05 which indecates that the crop yield series were neither normally distributed nor exponentially distributed. Pearson Type distributions were then tried. The bas'c test statistics of Pearson distribution were calculated and presented in table no. 2.

Table—2. Statistics for selection Pearson Distribution

Crops	Statistics	Type
Rice	b0= —19.3282 b1= —2.5210 b2= 0.0900 k = —0.9136	i
Wheat	b0= —32.2965 b1= —3.2059 b2= 0.2148 k = — 0.3704	i
Pulses (kh)	b0= —20.5656 b1= —1.0155 b2= 0.3676 k = — 0.0341	i
Pulses (ra)	b0= — 2.0825 b1= —0.6198 b2= 0.0137 k = — 3.3558	i
Pulses (tot)	b0= —13.1708 b1= —2.4595 b2= 0.3526 k = — 0.3256	i
Oilseed (kh)	b0= — 6.0381 b1= —0.9756 b2= 0.0084 k = — 4.7033	i
Oilseed (tot)	b0= — 5.1349 b1= —0.9480 b2= 0.0010 k = —45.0805	i

The negetive k values in table 2 indicates that all the crops series are distributed as Pearson type I.

2. Premium Rates

Premium rates have been calculated by all the three method i.e. by normal curve method, by Danderkar's method and by the technique developed for Pearson type I distribution. Assuming a 100 percent indemnifiable insurance scheme, expected indemnity and premium rates were calculated and given in table 3.

Table—3. Expected Indemnity and Premium Rates for 100 percent Indemnifiable Insurance Scheme

Model	Rice	Wheat	Pulses (kh)	Pulses (rabi)	Pulses (tot)	Oilseed (kh)	Oilseed (tot)
Pearson—I							
E (I)	0.3498	0.4732	0.0577	0.0993	0.1386	0.0142	0.0601
Premium	4.22	4.08	0.96	2.70	2.73	0.19	0.8200
Normal							
E (I)	46.20	38.87	52.86	38.21	49.35	32.05	30.6700
Premium	16.94	15.50	21.08	15.04	19.68	12.78	12.2300
Dandekar							
E (I)	36.86	31.01	42.18	30.49	39.38	25.57	24.4700
Premium	14.70	12.37	16.82	12.16	15.70	10.20	9.7600

The coefficient of variation of the crop series rice, wheat, pulses (kharif), pulses (rabi) pulses (total), oilseed (kharif) and oilseed (total) were 46.20, 38.87, 52.86, 38.21, 49.35, 32.05 and 30.67 respectively and coefficient of mean deviation were 36.86, 31.01, 42.18, 30.49, 39.38, 25.57 and 24.47 respectively.

Premium assuming normal distribution comes to be 16.94 percent for rice, 15.50 percent for wheat, 21.08 percent for pulses (kharif), 15.04 percent for pulses (rabi), 19.68 percent for pulses (total), 12.78 percent for oilseed (kh) and 12.23 percent for oilseed (total).

Premium by Dandekar's method has been worked out as 14.70 percent for rice, 12.37 percent for wheat, 16.82 percent for pulses (kharif), 12.16 percent for pulses (rabi), 15.7 percent for pulses (tot), 10.2 percent for oilseed (kh) and 9.76 percent for total oilseed. Whereas the premium calculated as per Pearson distribution has come out to be 4.22 percent for rice, 4.08 percent for wheat, 0.96 percent for pulses (kharif). 2.70 percent for pulses (rabi) and 0.82 percent for total oilseed.

These premium rates do not include any administrative cost. It can thus be concluded that if we determine the distribution of the yield series and then calculate the premium rates according to the appropriate distribution, the premium rates may be more realistic for the Comprehensive Crop Insurance Scheme.

Summary

For determining a realistic premium rate for a 100% indemnifiable scheme an attempt has been made in this paper (i) to study the distribution of yields of major crops in different divisions of the U.P. state and the extent of risk therein and (ii) to develop a suitable criteria for determining premium rates.

It was tested wheather the yield data of a crop of all the divisions belong to the same population. Three type of tests were used.

It was found that all the series of a particular crop belong to the same population and hence all the series were combined and distributions were tested. It was observed that the yield has a Pearson Type—I distribution.

Premium has been calculated considering Pearson Type—I distribution and it appeared to be a realistic premium rate.

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1.6 RESEARCH CHALLENGES IN AGRICULTURAL STATISTICS PERTAINING TO CROP SCIENCE

N.M. PATEL
Gujarat Agricultural University, Anand

The profession of a statistician is, generally of advisory nature. He helps in planning, designing, collecting observations and analysing and interpreting the results of research projects. Statistical methods have proved helpful in planning of field experiments and analysing available data. Due to location specificity, several problems are being faced at planning stage of the experiments as well as in analysis and interpretation of the collected data. I would like to illustrate few of them which are related to crop science having praetical utility (majority of us working in SAUs are facing these difficulties/problems as a statistician).

1. Experimental design : There is tremendous literature available on the construction of designs, mostly contributed by Indian Statisticians. But the application picture of complicated designs developed during last three decades is hazy. These designs are claimed theoretically efficient than traditionally used simple designs like RBD, Split plot etc. Everyone knows that simple designs are predominantly used not only in India but world over in agricultural experimentation. Non-acceptance of newly formulated designs in day to day use by biological workers makes me to believe that we are confined to mere theoretical aspects of designs from academic angle only forgetting the inbuilt difficulties in their use by field workers. If development of theory has a inbuilt component of workable field utility and ease there should not be much difficulty in its acceptance by the field workers. Therefore there is an urgent need for collaborative research by IASRI and SAUs scientists so that the new designs developed have an inbuilt component of field testing before they are recommended for use.

The efficient experimental designs for agricultural experimentation on irrgation methods, multiple cropping, inter-cropping, plant protection, seed technology, nursery experiments, etc. are yet to be developed to help control errors in the conduct of experiments and generate maximum information from the experimental data. These areas are vital and have direct application to agricultural production in the country.

2. Experimental Plot Size : The literature on plot size relating our conditions indicates the need for generating more information on agro-climatic zone basis for irrigation, varietal, cultutral, plant protection etc. research. This will not only help in economy but will also help in improving efficiency of field experimentation at micro level. For this purpose it would be desirable to inter-wouve this philosophy in AICRP net work of ICAR as it will not only help in utilizing existing infrastructure but will also help generate information for diversified crops/disciplines over a variety of agro-climatic conditions over space and time which will be very useful for improving experimental efficiency and optimization of expenses.

3. *Sample size to evaluate treatment effect, crop losses etc* : During growth phase as well as maturity stage of experimental crop, the observations on yield attributes, pest intensity, quality traits etc. are recorded by selecting few plants or leaves per plant per plot of each replication. This involves the theory of subsampling. At present, the number of plants or leaves sampled are generally divided arbitarily affecting the precision of the estimates. Like plot technique, this is also an important area of applied research having direct influence on estimate and interpretation of treatment effect (s). This information needs to be generated for each crop variety in cultivation as well as new varieties to come. It is needless to mention that plant breeding material is a separate group to be thought of from this angle.

The pests and diseases attacking aerial parts viz., stem, leaves, flowers, fruits etc. of plant are visible and it is easier to work upon them. But some sampling methodology may not be applicable for soil borne pests, diseases, parasites etc. Therefore, it is necessary to evolve sampling method including size for estimating incidence of soil borne pests, diseases etc. and losses caused by them.

4. *Problems related to variety release progromme* : As a statistician we expect that the new variety to be considered for release for commercial use should differ statistically for yield and/or other attributes from the existing variety in cultivation. Unfortunately, this common yardstick is getting diluted in most of the cases. Even consistency is not observed for number of seasons (including locations) the new variety to be tested under state trials, national trials and adoptive trials. In the interest of farming community it is necessary to evolve common yardstick for this purpose with statistical reasoning palatable to crop breeders. This will help to have better predictability of the variety.

5. *Number of research stations/centres* : This point I shall discuss keeping Gujarat State in focus. There are 55 research stations (main as well as testing) in the state spread over well defined eight agro-climatic zones. Often question arises whether so many research centres are really needed? When resource constraints is a limiting factor can these centre be minimized without sacrificing efficiency? Similar situation exists in many states. Though this is a delicate matter yet more attention need to be paid to it to save valuable resources.

These problems are directly related to planning phase of experiments as well as resource utilization, therefore they merit attention of agricultural statisticians. I have not touched to the statistical problems related to risks and uncertainties, reliability of data, fertilizer recommendations, post harvest technology, seed technology, cost of production of agricultural commodities, price fixation, sample surveys, crop cutting experiments etc. I do hope that we would devote some time to solve above mentioned practical problems for efficient utilization of resources.

TECHNICAL SESSION—II

RESEARCH CHALLENGES IN AGRICULTURAL STATISTICS PERTAINING TO ANIMAL SCIENCES AND FISHERIES

July 20, 1989 (Thursday)

9.00 A.M. to 11.15 A.M.

Chairman : 1. Sh. V.N. Amble, Bangalore

Rapporteurs : 1. Sh. T.B. Jain, IASRI, New Delhi
2. Dr. R. Venkatesan, MVC, Madras

Speakers : 1. Dr. J.P. Jain, IASRI, New Delhi
(paper presented by Dr. H.P. Singh)
2. Dr. Prajneshu, IASRI, New Delhi
3. Dr. R. Venkatesan, MVC, Madras
4. Dr. Bhupal Singh, NDRI, Karnal
5. Dr. L. Siddappa, UAS, Dharwad.

2.1 PLANNING STATISTICAL RESEARCH IN ANIMAL SCIENCES IN THE NINETIES

J.P. JAIN AND H.P. SINGH

Indian Agricultural Statistics Research Institute, New Delhi

1. Introduction

Quite a significant headway has been made over years in developing statistical methodologies for indigenous problems related with animal breeding, nutrition, animal productivity, disease control, assessment and evaluation, population projection and planning. It is now opportune that we critically examine the achievements made in adopting various methods in agricultural statistics and identify research areas that should receive due attention in the nineties. Our purpose here is limited to elaboration of some such problems in the field of animal sciences under two broad disciplines :

(i) Statistical Genetics & Bio-statistics, and (ii) Survey Sampling.

2. Statistical Genetics and Biostatistics

2.1 Mixed Model Theory in the Estimation of Parameters

Animal breeding data analysis frequently involve mixed linear models, that is, linear models including fixed and random effects. Whereas estimation of parameters of mixed models with balanced data is straightforward, estimating parameters, particularly variance parameters, in mixed models with unbalanced data is usually a complicated undertaking. We here delineate areas for future development of the mixed model theory.

2.4 Variance and Covariance Estimation

There is a variety of methods now available for estimating variance parameters of mixed models with unbalanced data. Some of these methods are : Henderson's (1953) analysis of variance Methods II & III, MIVQUE (Minimum variance quadratic unbiased estimation), MINQUE (minimum norm quadratic unbiased estimation) and REML (restricted maximum likelihood). The choice among these depend upon the use of the estimates e.g. construction of selection indexes, BLUP, estimation of heritability and of genetic correlations, etc. and the ease of computation. All these methods start with initial estimates of variance components and the number of rounds of interaction required for convergence varies with the initial estimates and the data.

A model which encompasses most, if not all, mixed linear models that has been used in animal breeding is the following :

$$\underline{Y} = \underset{\frown}{X}\ \underline{\beta} + \underset{\frown}{Z}\ \underline{u} + \underline{e}$$

where $\underline{Y}$ denotes the nxl vector of observations, $\underline{\beta}$ is a vector of fixed effects, $\underline{u}$ is a random vector of sire effects, $\underline{e}$ is a vector of random errors and $\underset{\frown}{X}$ and $\underset{\frown}{Z}$ are design matrices. It is usually assumed that

$$E\ (\underline{u}) = \underline{o},\ E\ (\underline{e}) = \underline{O}.\ Var\ (\underline{u}) = I\sigma^2,$$

$$V\bar{a}r\ (\underline{e}) = I\ \sigma_e^2,\ Cov\ (\underline{u}, \underline{e}') = \underline{O}$$

$$Var\ (\underline{y}) = \underset{\frown}{Z}\underset{\frown}{Z}'\ \sigma_s^2 + I\ \sigma_e^2$$

where σ_s^2 is the variance component between half-sib progeny groups, σ_e^2 is the error variance and I is the identity matrix.

For multiple traits $\underset{\frown}{Z}\ \underline{u}$ in the model can be reckoned as

$$\underset{\frown}{Z}\ \underline{u} = \Sigma\ \underset{\frown}{Z_i}\ \underline{u_i}$$

where $\underline{u}_i$ are sub-vectors of $\underline{u}$. For example, $\underline{u}_1$ could be additive genetic value of trait 1, $\underline{u}_2$ additive genetic values of trait 2, etc.

The foregoing mixed model is too simplistic. The assumptions Var $(\underline{u}_i) = I\sigma_s^2$ (i), and Cov $(\underline{u}_i, \underline{u}'_i) = O$ mean that the model will not handle important situations such as :

(1) the use of certain animal relationships (if $\underline{u}_i$ is a vector of sire effects, the use of relationships amongst sires) leads to Var $(\underline{u}_i)$ being non-diagonal; and

(2) the observation vector $\underline{y}$ containing, in the multiple-trait case, several measurements on a single animal.

Very of en the data set to be used in estimation is a random sample from a selection experiment. None of the available techniques take care of the possibility of selection having occurred previously. Estimating parameters free of the effects of selection is therefore another major concern for animal breeders.

Another high priority research area is the development of techniques for estimating variance parameters when in the multi-trait mixed model with continous and categorical variables are involved.

2.1 Use of Blup for estimation of Genetic Merit

Availability of powerful computers has enabled animal breeders to use more complex statistical procedures to aid selection. Of particular significance in the last decade is the use of BLUP, first proposed by Henderson (1975). The mixed-model equations enable data to be used more effectively and the application of BLUP technology, though complex, is now widespread use in major breeding programmes. However, there are areas where further development of the BLUP theory is called for. One such area is the analysis of categorical (all or none) data. Although quite a few techniques are in use at present but problems remain. There is a need to decide which of the methods is best suited to each problem, which mathematical model is more appropriate to the biology of the situation. Also, there is the problem of how to include fixed effects in the model; the variance structure between categories will vary within level of these fixed effects.

Another problem which require further research is the development of theory for estimation of genetic merits using multitrait BLUP model with inequality constraints imposed on some traits. Also, there is need to develop theory to allow BLUP equivalent of restricted selection indices to be calculated. For traits having intermediate optima, a quadratic term could be included in the multiple regression used to define total economic merit. Furthermore, how can BLUP theory be extended to cater for non-linearly related traits such as milk yield and calving interval, when included in multi-trait mixed linear models.

Yet another unresolved problem is connected with the estimation of genetic correlations. Their estimation is generally imprecise. Reliable genetic correlations are required for selection indices and multi-trait BLUPs. At present, they are often the least accurate part of computations.

The inadequacies of the mixed model theory in the foregoing areas are keenly felt and the development of appropriate solutions is expected to further the statistical component of animal breeding technology.

2.2 Possible use of Moet to Increase Response to Selection

The value of recently developed technology of multiple ovulation and embryo transfer (MOET) for genetic improvement of cattle has been described by many workers (Land and Hill, 1975; Siedel, 1981, Nicholas and Smith. 1983). Although prima facie this technology seems to offer great advantage in providing replacement heifers but on closer examination it has been seen to show not much promise if additional milk yield is the only source of added income. Also MOET clearly is contra-indicated for progeny testing of potential bull (or female) dams, as the negative effect of increased generation interval does not make up for the increased accuracy of selection. Furthermore MOET has very little to contribute to the rate of genetic improvement of dairy cattle in traditional progeny-testing schemes, because increase in the selection differential of cows to breed bulls would be small in an efficiently operated improvement scheme (e.g. McDaniel and Cassell, 1981). Potential benefits from MOET are most important under today's technology when applied to production of young sires from elite dams. Nicholas and Smith (1983) considered two schemes of MOET to increase the rate of genetic response. One scheme, their pedigree scheme, involves selection among transferred sons and daughthers based on available records of their dams. In the other scheme, called the sib scheme, selection of transferred males is delayed until their female sibs have completed their first lactation, so that males can be selected on an index using sib and dam performance. Many other selection strategies involving MOET can be thought of which can result in enhanced rate of genetic response. It is, therefore, imperative that all the contending selection strategies involving MOET technology are evaluated to find one yielding optimum return. Some selection strategies that could be considered are :

(i) Selection of bull mothers from the entire population in the breeding tract on the basis of their own available records;
(ii) Elite cows selected as in (i) are mated to progeny tested bulls from the nucleus herd to secure sons through MOET for breeding;
(iii) Pedigree selection scheme for both sons and daughters
(iv) Sib selection scheme for both sons and daughters
(v) Pedigree selection scheme for sons and sib selection scheme for daughters
(vi) Sib selection scheme for sons and pedigree selection scheme for daughters
(vii) Two-stage selection scheme in males : preliminary selection on the basis of pedigree index and final selection on the basis of female sib's first lactation performance.

2.3 Madels for Non-Linear Response among cross-Bred Cows with Increasing level of Exotic Inheritance

Most of the investigations on production traits in crossbred dairy cattle have established a curvilinearity in response to the level of exotic inheritance (Amble and Jain, 1966, 67; Narain and Garg, 1978). For instance, milk yield increases upto 50% of exotic inheritance beyond which there is little improvement or there is a decline. More recently Narain and Sharma (1985) who studied the effect of the level of heterozygosity on the economic traits have reported superior performance of half-breds (with 100% heterozygosity) as compared to other grades. The culvilinear relationship could possibly be due to (i) the reversal of the effect (on production) of genes controlling fitness in the tropical environment leading to a negative correlation between production and fitness traits; (ii) GE interaction—the gene complexes which confer fitness in exotics in temperate regions may become 'load' on the population in the native environment; (iii) the disintegration of coadapted polygenic block determining the balanced genotype (Lerner, 1954); or (iv) higher survivability of gametes carrying higher complements of chromosomes from the indigenous parent (Acharya and Bhat, 1984). These causes are not mutally exclusivc. In fact. they overlap each other and sometimes represent different aspects of a single phenomenon. No attempt has been made so far in testing these hypotheses as possible explanation for culvilinearity. This therefore calls for developing suitable models which can explain curvilinear responses.

2.4 Statistics in Surveillance

Another area where statisticians need to direct their prowers is 'Surveillance of important animal diseases'—an area that is rapidly gaining in stature among other scientific endeavours. A few of the important issues requiring immediate attention are : adjustment for reporting lag; imputation methods for completeness of data; detection of changes in patterns of the occurrence of disease; detection of aberrations in the patterns of disease surveillance data; detection of trends overtime; the estimation of the impact on a population of health problem and the evaluation of intervention programmes. Specifically, then, these call for the following :

(i) Development of suitable models for adjustment for time lag in case reporting;
(ii) Development of model-based imputation methods for completeness of data;
(iii) Adaptation of methodology from other areas such as clustering method from quality control in industry for detection of changes in patterns of occurrence in the incidence of disease;
(iv) Exploring the potential of time series forecasting techniques like ARIMA model (Auto Regressive Integrated Moving Average), Box-Jenkin transfer function model for describing trend of disease adequately; and
(v) Development of analytic methods or adaptation of known techniques like that of bootstrap for identifying aberrations in the occurrence of disease;
(vi) Development of time series intervention models for assessing the impact of a given health programme.

For details of these problems a reference could be made to Statistics in Medicine Vol. VIII No. 3, March, 1989.

2.5 Genotype-environment Interaction

One of the most important advances in biometrical techniques during the last 25 years has been in the investigation, elucidation and measurement of the genotype-environment (GE) interactions. GE interaction is related to both dominance and correlated response and their relationships effect selection response. It is related to degree of dominancc to the extent that more heterozygous individuals excel in average performance over varying environments and to correlated response in that the genetic correlation between performance of the same genotype in different environments measures (inveresely) the degree of such interaction. Much remains to be explored concerned both the importance and implications of GE interaction for animal breeding, particularly for combined measures of net productivity. The data fiom military dairy farms could be used for the prupose. Some stray attempts have been made by different research workers but with loose statistical techniques. The computer facilities available at IASRI could be used to undertake sophisticated analysis.

2.6 *Simulation Studies in Population Genetics*

In the mathematical theory of population genetics the main problem is to investigate the changes in the genetic composition of a Mendelian population through time under both systematic and dispersive forces. Such fundamental studies help in the formulation of appropriate genetic models for use in animal improvement programmes.

2.6.1 *Response to Selection in Finite Populations*

The size of the population of animals under improvement in a given place and time is usually small. It does not, therefore, satisfy the conditions for the laws of population genetics to hold. The application of population genetics to animal breeding in such cases, is therefore, not strictly valid. This is because most of the theory assumes an infinitely large population with negligible sampling fluctuations in gene frequencies. It is, therefore, necessary for the prediction of the genetic improvement due to selection in small populations that necessary theory is developed. The rate of response to selection and their ultimate limits in finite populations can be algebraically dealt with in simple genetic models but in more complicated cases it is not possible to do so. With the help of Monte Carlo method, however, genetic systems can be simulated on a computer and the effect of introducting selection can be numerically studied. So it is worth while that we direct our efforts to simulate various model genetic selection experiments to have a better understanding of the factors affecting the response to selection in small populations.

2.7 *Effect of Linkage on Homozygosity of a Population under various Inbreeding Systems*

A problem of considerable importance in the application of population genetics to animal breeding is the level of homozygosity achieved under regular systems of inbreeding. Well known results are used by the breeders assuming either a single locus or several independently segregating loci. Linkage between loci is expected to effect these results considerably. However, very little is known about the effect of linkage on the homozygosity of the population. Thus a study is called for to fill this gap.

3. Survey Sampling

Basic problems in planning and implementation of livestock surveys are similar to those for agricultural crops. However, some of the special features which are specific to animal husbandry practices differentiate these surveys from other agricultural surveys. The commonness of both the types of surveys stem from the common rural base. Therefore, hierachical structure at different levels are similar For example, the districts, tehsils, villages and even the households are the different levels of sampling units in both type of surveys. In livestock surveys, the spatial distribution of different types of animals are rather uneven. Invariably, some specific areas scattered rather unevenly. This makes the problems in livestock surveys somewhat similar to problems of surveys for minor crops. Another distinguishing feature of livestock surveys is the longitudinal nature of studies. Whether it is milk yield or poultry or wool production, the observations are spread over time. Besides, there are various other features such as integrated nature of livestock studies, varying animal husbandry practices for bovines, ovines and poultry etc. which require somewhat different treatment in the planning and execution of livestock surveys.

Quite extensive studies have been carried out in developing sampling methodologies for indigenous problems pertaining to animal sciences. In these studies efforts have been made to take into account specific features of animal husbandry practices and relevant problems. Based on methodologies developed so far, different types of livestock surveys are being carried out regularly in the entire country. Surveys on livestock products particularly milk, meat, wool and eggs are specific examples. Problems in livestock surveys may be considered as of two types. The first type consists of problems related with already existing methodologies. In this type the main concern is to improve the techniques already in practice. The second type covers problems emerging as a result of enhanced aspirations and data needs of the users. Various new techniques of data acquisition as well as data analysis have got an important role to play in the solution of these types of problems.

Some problems of the first type in the data acquisition and analysis of already existing techniques are due to multi-subject surveys, problems related to deficiencies in the quality of data due to imperfect frames, incompleteness of data etc. One of the basic limitations in planning and implementation of livestock surveys is the lack of timely and adequate auxiliary information. Although, various types of information is collected through livestock census and also from various surveys, the timely availability of such information at desired level is still lacking. Improvement in this will go a long way in improving the present status of livestock statistics. In the following an attempt has been made to identify some areas of research in the field of survey sampling as applied to livestock sector.

3.1 Small area Estimation

"Small Area" does not necessarily mean small geographical areas only. A part of the population is normally termed as domain. There are ways and means to estimate population parameters of domains in the sample survey literature. However, when domains are reduced in size, the problems of smaller sample sizes from such domains become more and more severe. Sometimes, domains are small enough such that they are not adequately represented in the sample. For such domains, estimates developed from any of the available sampling techniques, loose their relevance and utility. It is in this context that several small area estimation techniques have been developed.

There is a growing awareness towards micro level planning. This necessitated development of valid estimates at smaller geographical area levels. In most of the livestock studies, so far emphasis has been towards developing state estimates. In the context of lower level planning, data requirements at district or block levels become extremely important. In livestock studies, the breed of animal and specific age groups are extremely important for getting an idea about production. Quite often the interest lies in a specific breed or even in a specific age group within the particular breed. Combination of small geographical area, breed and age-group makes the domain of interest as very small. This is a typical example of small area situation in livestock surveys. Even a carefully planned sample survey may not be able to provide good estimates at such small area levels. Therefore, the importance of small area estimates in livestock surveys is evident.

Various methods of small area estimates are available in literature. Most of the methods were developed in the context of demographic studies. A review of small area estimation was made by Purcell and Kish (1979-80). One of the most important commonly used method is synthetic method of estimation. A commonly accepted definition of synthetic estimator is as follows : 'An unbiased estimate is obtained from a sample survey for a larger area. When this estimate is used to derive estimates for sub-areas having the same characteristics as the larger area, these estimates are identified as synthetic estimates'.

In this method the estimates developed for the larger areas are scaled down to the smaller area on the basis of certain model assumptions. (These assumptions normally involve certain auxiliary characters). Normally it is assumed that the relations for study characteristics as well as for the auxiliary character between the larger area and the small area remain the same. If this model assumption is true, synthetic estimator has its strength in "borrowing" information from larger groups for use in small domains. On the other hand if model assumption is not true, the technique of synthetic estimation gives biased estimators. This method was initially considered by NCHS (1968) and further improved by Ghangunde and Singh (1977) and Purcell and Kish (1979). The method is essentially model based in the sense that the strength of the estimator depends on the validity of the model.

For applying this method to a particular situation one has to conceptulise realistic relationship amongst the various characteristics at small area and the larger area of the survey. The first step in this direction is to identify the factors responsible for locating the group which has got similar characteristics in the small area as well as the entire population. The next step would be to ensure the availability of auxiliary variable to develop the estimate at the small area level. At this stage the information from livestock census will be of immense use. As an example let us consider that milk production at Block level is needed. Estimates of milk production are obtained as product of number of milch animals and average yield of milk per animal. It may be realistic to assume that average milk yield of animals of same breed under same age group and same environmental levels should be same in the Block as in the entire population. Thus breed, age, environmental factors are the factors identified for locating the group. The survey estimate of the milk yield for the entire population is then used for this group. If number of animals in this group is known from some sources, it becomes simple to estimate the milk production in the individual groups which may be aggregated to obtain the estimates for small areas.

Another small area estimation technique is Structure Preservation (SPREE) method. This method is suitable for developing inter-censal estimates at small area level. This method was developed by Purcell and Kish (1980). The rationale behind this method is that the population at the time of census has got an association structure which does not change very fast. However, the survey estimates do not reflect that structure due to small sample sizes from the respective small areas. The method is an attempt to preserve the association structure, through the census information which establishes relationship between study variables and associated variables. The preservation is done through the approach of raking ratio method of estimation.

A good account of various methods on small area estimation is available in the proceedings of a symposium on this topic edited by Platek *et al* (1978).

Besides, examining the applicability of various small area estimation methods in livestock studies it is worthwhile to explore the possibility of improving some of the techniques in view of the availability of data structure and also to investigate freshtechniques for small area situations.

3.2 Regression Analysis in Sample Surveys

Regression analysis is considered as an important aspect of data analysis particularly when one is interested in studying the causal behaviour of a number of variables. In livestock studies also, regression analysis is considered as an important tool. In the usual analysis, the available data is analysed through standard regression analysis techniques without much regard to the way in which data has been collected. When data is collected through sample surveys, the complexity of survey design effects some of the underlying assumptions of regression models. It becomes, therefore, important to investigate the effect of survey design on regression analysis. A good amount of discussion on this aspect is available in research papers by Brewer and Mellor (1973), Fuller (1975), Holt and Scott (1981), Klonijn (1962), Nathan and Holt (1980) etc. It may be mentioned that in the context of regression analysis, any deviation from simple radom sampling with replacement is considered as complex survey design. This is mainly because of the fact that the independence of observations are effected due to deviations from equal probability with replacement sample procedures. Simple concepts like stratification, clustering, etc. make the sampling design complex. There is a growing awareness that the sampling design should have a role to play in the estimation of regression parameters. In this context a mention of two view points regarding model-based estimation and design-based estimation may not be out of place. In regression analysis the regression parameters are estimated on the basis of underlying models while the survey design utilises the sample design for estimation. Recently considerable amount of theoretical developments have taken place. Some references on this aspect are Hansen, Madow and Tepping (1983), Hartley and Sielkon (1975), Kalton (1983), Kish and Frankel (1974) etc. Subsequently a number of software packages have been developed for estimating the regression parameters which account for underlying survey design. SUPERCARP developed at Iowa State University is one such package. References on this aspect are Hidiroglou (1982) and Hidiriglou, Fuller and Hickman (1980). It would, therefore, be in the fitness of things that we make use of latest techniques for regression analysis with survey data generalised using complex designs.

3.3 Model Based Inference

In the classical approach for estimating population parameters like population mean and total, estimators were developed for a given sampling design. Due consideration was given to the properties like unbiasedness, consistency, efficiency, etc. in the choice of estimators. In some situations, models were indirectly used either for comparison purposes as in unequal probabilities and systematic sampling or in the choice of sampling strategies (such as in systematic sampling with different type of trends in the population). However, models were not used for making the inference from the sample data. Recently, some model based procedures have been developed for estimating the population parameters. Royall's prediction approach of estimation is considered as alternative to the classical design based approach. An important feature of this approach is its dependence on the model. Therefore, validity of the model plays a crucial role in the success of this approach. It is true that models seldom hold good perfectly. Therefore, in any model based approach two aspects are important.

1. Suggesting robust procedures which are reasonably good in case of model failures and

2. Testing and validity of models.

The first aspect requires theoretical investigations while the second one needs empirical studies.

Vast amount of data already collected in various livestock surveys may be useful in testing specific models needed for different situations.

The small area estimation as well as regression analysis from survey data are also model based approaches. In small area estimation procedures, models are used in the form of underlying assumptions while in regression analysis the regression models are used for developing the estimates.

This area is somewhat new and it requires lot of empirical investigations. In the context of livestock surveys the specific situations where different types of models are required needs to be identified. This calls for carrying out empirical studies for testing the models, and studying robustness of estimation procedures.

3.4 Categorical Data Analysis

Survey data is often available in qualitative forms. Sometimes, even quantitative data is summarised in the form of categorised data. Analysis of such qualitative data is normally termed as categorical data analysis. Results of surveys are often represented in the form of two way or sometimes multiple classifications tables. In livestock surveys also there are various situations when data is presented in such tables. Frequency data for breed X age classifications is a simple example of two-way table. Normally simple χ^2 test is applied for testing the independence of two classificatory variables. Due to complexities of survey design, the basic assumptions of χ^2 test are sometimes violated. Recently, emphasis has been on studying the effect of sample survey design on χ^2 test. Investigation on this type of categorical data analysis on livestock survey data needs to be carried out for various types of classifications, taking into account the complex survey designs. The application of log-linear models in the context of categorical data is another area in which investigations are needed.

3.5 Application of Methods of Imputation

Adjustment for missing data has been a matter of concern in most of the sample survey data. In livestock surveys, instances of non-availability of data are more due to longitudinal nature of study, movement and frequent transactions of animals, etc. Therefore, data needs to be adjusted quite often at analysis stage. Normally there are two methods of adjustment of data : (i) adjustment through weighting, and (ii) adjustment through imputations. In case of unit non-response i.e. when there is complete non-response from a unit, the method of weighting is normally used. In case of item non-respose when required information on some of the items is not available, the method of imputation is normally used. One of the primary objectives of imputation is to make the data set complete. This is done for convenience of analysis of large scale data on computer. Various methods of imputation are available in literature. Some of these like Hot Deck and Cold Deck procedures are entirely computer based. In developed countries where non-response rates are quite significant, considerable research work has been done on methods of imputations. Some references on this aspect are Chapman (1976), Fellegi and Hold (1976), Kalton and Kasprzyk (1982) Platek and Gray (1979), Platek, Singh and Trembley (1978) and Sande (1982). In the case of livestock studies, there is distinct advantage is imputing the data due to longitudinal nature of such studies. Invariably, there are regular trends in the observations over time. For example, milk yield of an animal has got a trend over entire lactation period. Similarly, the egg production has also got its own trend. In such cases imputation of missing data for some of the observations can easily be done with the help of knowledge about the trend and location of the missing observations in terms of time. These imputation methods may be developed for specific studies keeping in view the nature of data in the study. Investigations are therefore needed on methods of imputation particularly suitable for livestock studies.

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2.2 SOME STATISTICAL PROBLEMS IN FISHERIES MODELLING

PRAJNESHU
Indian Agricultural Statistics Research Institute, New Delhi

1. Introduction

In any fishery it is of paramount importance to have an idea of sustainable yield that can be harvested in perpetuity from available biological resources. In spite of several drawbacks, the concept of maximum sustainable yield (MSY) is generally utilised to achieve this task. MSY assumes that too much or too little fishing would reduce the amount obtained in the long run. Too much would reduce the population excessively while too little would result in a small harvest. Thus the equilibrium yield is assumed to be a convex function of the effort with a maximum attained at some intermediate value between small and large effort.

Two models widely employed for the management of fish population are respectively the Schaefer and Fox models. The former is given by the differential equation.

$$dN/dt = rN\,(1 - N/K) - qEN. \tag{1}$$

Here N (t) denotes the population size or biomass at time t, r is the growth rate, K is the carrying capacity, q is the catahability coefficient and E is the fishing effort. This model has been extensively applied, e.g. in the management of pacific balibut, North Atlantic redfish, baleen whales, Pacific tuna (May *et al.*, 1978). It also provided an argument which ultimately led the International Whaling Commission (IWC) to ban the harvesting of blue whales in 1965.

If the fishery is assumed to be in equilibrium the parameters q,r,k occuring in eq. (1) can be estimated by using the catch and effort data which is readily available for most fish populations. Thus, if U denotes the catch per unit effort, a straight line of the form

$$U = a - bE \tag{2}$$

can be fitted to the data. Then the optimum value of effort and MSY are respectively

$$E_{opt} = \frac{r}{Zq} \simeq \frac{a}{2zb}, \quad MSY = \frac{rK}{4} \simeq \frac{a^2}{4b} \tag{3}$$

For model differs from Schaefer model in that the regulation term is proportional to N log N instead of N^2. For a pair of interacting species having prey-predator relationship, the well-known model is the Lotka-Volterra model. Vito Volterro was motivated to investigate competing species by discussions with this friend D' Ancona who made a statistical analysis of fish catches in the Adriatic. If N_i, $i=1,2$ denote respectively the prey and predetor populations, this model is given by the pair of differential equations :

$$dN_1/dt=r_1N_1-s_1N_1N_2 \qquad (4)$$
$$dN_2/dt=-r_2N_2+s_2N_1N_2$$

Unfortunately, the exact solution of even such a simple nonlinear model is not yet known.

2. Statistical Problems in Fisheries Models

We now present some important research problems in fisheries models.

2.1 Non-Equilibrium Situation

The fish population is generally assumed to be in equilibrium. This has rarely been the case in recent years since most fisheries have experienced a rapid increase in effort accompanied by a decline in biomass. Even if all of the data fell on a straight line, this would not be the line of equilibrium; in a declining fishery it would lie above it. The method of averaging is generally used to correct for disequilibrium. In this method, the values of yield that correspond to the same value of effort are averaged out. However, this method is valid if the stock is in a state of periodic equilibrium and is not valid if the same level of effort is maintained for a number of successive years. In this latter situation, the most recent value of yield will correspond most closely to the equilibrium. Walter and Hoagman (1971) used a multiple regression procedure in which $(\bar{U}_{n+1}-\bar{U}_n)/\bar{U}_n$ was regressed on $\bar{U}_n$ and $\bar{E}_n$, where the bar denotes the average over the year. Walter (1975) used a graphical method in which the catch per unit effort was corrected to bring it into equilibrium. Schnute (1977) employed an integral form of equation and then averaged it over two years before using multiple regression. However, none of the methods is satisfactory. The estimates of the parameters often do not make sense biologically, e.g. the estimate of K coming out to be negative. Hence it is highly desirable to develop sound statistical methods to correct for disequilibrium.

2.2 Incorporation of time Lag, Age-Structure Spatial Variability

In most models, it is assumed that the rate of change of biomass depends only on its current value. However, in the real world, the growth rate of a popu'ation often does not respond immediately to changes in its own population or that of an interacting population but rather will do so after some time lag. Mac Donald (1978) has given a good account of time delays in various models. Some work has recently been done by Prajneshu (1989) to incorporate this aspect into the various fisheries models. However, it will be a challenging task to apply the results obtained to a real-life situation. Furthermore, the aspects of age-structure, spatial variability etc. are generally not included in various models. Therefore, attempts should be made to incorporate some of these in order to develop more realistic models.

2.3 Stochastic Approach

With the growing realization that one of the crucial problems in fisheries is the enormous variability in the population sizes, it becomes essential to abandon deterministic models in favour of stochastic ones. This implies that the differential equations occuring in the models should be replaced by stochastic differential equations. To this end, Beddington and May (1977) have shown that for Schaefer model in random environment, the stationary distribution does not exist if harvesting is taken at the MSY level. However, as demonstrated by Kirkwood (1981), a first-passage time analysis can be carried out to evaluate the risk of extinction of the species. Such an analysis serves to emphasize the possible danger of extinction that may result due to over-estimation of the MSY level. This fact has been recognized by the IWC in setting allowable catch limits at not more than 90% of the estimated MSY. Thus such stochastic models have great applicability and there is a need to investigate stochastic versions of other deterministic fisheries models.

During the last decade or so several articles on stochastic fish models have appeared in the periodical press (see e.g. May *et al*, 1978; Prajneshu, 1980, 83, 89). However, very few efforts have been made to fit these models to data. The main reason for this is that estimation procedures are not available when observations are made at discrete time instants on a single realization of the stochastic process. This is certainly a challenging research problem for statisticians.

2.4 Bioeconomic Modelling

A fishery is an economic enterprise and should be analysed as such. Evidently, future catches are worth less now than present catches and accordingly should be discounted. The quantity to be maximized is the present value (PV) of the net revenue derived from fishing. This net revenue is the price of the catch less the cost of harvesting. This type of bioeconomic approach employs the concepts of 'control theory' and 'dynamic optimization' and has been pioneered by Clark (1976, 1985). However, there are still a number of unsolved research problems in this area.

2.5 Multispecies Approach

The above discussion pertains to modelling the dynamics of a single-species fish population which is merely one component of any complex fishery system which includes, among other things, predators, preys, and competitors. Thus the desirability of employing a multispecies approach is quite clear. Walter and Hogman

(1971) used such an approach to model an eight-species fishery on Lake Michigan. Pope and Harris (1976) studied stocks of South African Pilchard and anchovy by combining knowledge of biological interactions together with data fitting. The above are only some isolated examples where multispecies approach is attempted.

One fundamental problem in fishery management is that the multispecies analogue of MSY is ambiguous, self-contradictory, or economically absurd. Consider two ecologically interdependent species X_1, X_2. The objective of MSY for each of X_1, X_2 separately is obviously logically inconsistent. If "yield" is defined as a weighted sum

$$Y = \Sigma p_i H_i ,$$

where H_i denotes the yield of X_i and p_i is the "weight", then a value judgement pertaining to the weights p_i is unavoidable. In exceptional cases it may be reasonable to consider yield Y in terms of total biomass, but usually this will be economically unacceptable.

2.6 Optimal Harvesting Policies

The main types of harvesting policies are :

(a) Constant quota

(b) Constant effort

(c) Protection scheme.

In (a), a total allowable catch (TAC) is agreed upon in advance and fishing is continued until that catch is realized whereas in (b), the number of boats harvesting fish is fixed in advance. In spite of a number of disadvantages, TAC is widely used as it provides second best solution to the problem of limiting effort. Protection policies protect harvesting if stocks drop below a certain level and these are already a reality. An important kind of protection scheme is the constant harvesting if stock levels are lower than the specified escapement. However, one undesirable sire-effect of such policies is that these produce yields with great fluctuations. Ludung (1980) has compared for single-species fish models in random environment some harvesting strategies according to their effect upon the expected discounted yield, the coefficient of variation of the yield, and the expected time to reach 10% of the carrying capacity. This work employs an extensive use of computers and concepts of stochastic control theory. Although some progress has been made in obtaining optimal harvesting policies, yet further substantial research efforts in this direction are called for.

3. Concluding Remarks

In recent years there has been over-exploitation of many fish populations, e g. yellowfin tuna, catfish, silverbelly (at Kakinda), threadfin-bream (CMFRI, 1986). Furthermore, spotted searfish stock in Palk Bay collapsed due to uncontrolled fishing.

As pointed out by Devaraj (1983), questions are being raised whether the increasing mechanisations of our two prime fisheries viz. Indian Oil sardine and Indian mackerel would lead to ultimate collapse of these stocks. Thus there is on urgent need to manage efficiently our fishery resources. Fishery management is a multidisciplinary area involving fishery biologists, statisticians, and resource managers. Statisticians can play their role in this endeavour by developing more refined models and at the same time also applying these in practical situations.

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2.3 RESEARCH CHALLENGES IN AGRICULTURAL STATISTICS PERTAINING TO ANIMAL SCIENCES & FISHERIES

R. VENKATESAN
Madras Veterinary College, Madras

This paper is presented to focus the attention of Agricultural Research Statisticians with regard to the gaps and priorities of Research in Agricultural Statistics to Animal Sciences.

First and foremost amongst the gaps and priorities is a sort of communication gap and the priority to bridge this gap. Dialogues between Statisticians and Animal Scientists about this topic, understanding the problem and giving the appropriate solution to this are to be considered. This gap can be bridged by having (i) remedial courses or training in Animal Sciences including Fisheries to Agricultural Research Statisticians, (ii) Veterinarians and Fishery Scientists can be exposed to in-service training in Ag. & A.H. Statistics at the Agricultural Universities under the faculty of Animal Sciences offered by the Deptt. of A.H. Statistics.

Next to be considered is the standardisation of all livestock Farm records. Uniform formats for the maintenance of records for various kinds of livestock including poultry are to be formulated first by forming high level committees at ICAR level with leading Animal Science Scientists having farm experience and then following scrupulously the recommendations suggested by them. This item of work has already been there as recommendations of earlier conferences but not implemented fully.

Development of new experimental designs specific for experiments for Animal Sciences & Fisheries with their constructions and step-wise procedure for analysis and inference. This may be considered as one of the priorities.

Sampling techniques specific to investigations in the field of Animal Sciences and Fisheries and newer concepts in the estimation procedure can be considered amongst gaps and priorities.

Development of certain making designs with greater efficiency regarding Diallel, Triallel and multi-way crosses along with procedure for analysis may also be considered.

Development of research data bases maintenance and documentation : immediate necessity to be considered for implementation at 5 or 6 I.C.A.R. Institutes/ Agricultural Universities identified for this purpose.

2.4. A CRITICAL REVIEW OF STATISTICAL METHODOLOGIES ADOPTED IN THE FIELD OF DAIRY RESEARCH AT N.D.R.I., KARNAL

BHUPAL SINGH
National Dairy Research Institute. Karnal

A large number of experiments are carried out in the country in the disciplines of dairying and animal husbandry by central and state research Institutes and Agricultural Universities. There is an imperative need to make an appraisal of statistical methodologies adopted in all such experiments as statistical evaluation must form an integral part of all experimental programmes. The present investigation is a review of various statistical methodologies adopted and their extent of adoption in various disciplines. The same have been outlined briefly as under :

Processing

In this category of research, mostly there are laboratory experiments in the branches of Chemistry, biochemistry microbiology, bacteriology and technology and as such in about 33% of the experiments so far done in this Institute, no statistical analysis has been done. Out of the remaining, in about 64% no statistical design of experiments has been adopted. In the rest, however, the most commonly used design in these laboratory experiments is RBD (16%) followed by CRD (14%).

Generally the statistical analysis is confined to finding out the averages with respective S.E., C.D., C.V. etc. Percentages and Range are commonly found out in chemistry and bacteriology experiments. Wherever a design has been adopted, the data is generally analysed with the usual analysis of variance technique to test the significance of the treatment effects. In some cases, correlation and regression studies are carried out.

Production

This includes the most important disciplines of research namely Animal Nutrition, Physiology, Forage Production, Animal Breeding & Livestock Production. Each is described in brief here.

Animal Nutrition

The nutritional experiments are carried out on animals to study the effects of various feeds, their extent of digestibility, their effect on growth rate and ultimately productivity. The designs of experiments normally should be C.O.D./S.O.D. or L.S.D. But because of its convenience and feasibility RBD (in 30% cases) is used while in about 20% cases the C.O.D./S.O.D. or L.S.D. has been used. The statistical techniques used in analysing the data of these experiments are that of finding ANOVA corresponding to the design adopted and correlation/Regression for fitting of certain models besides averages, respective S.E. or C.D.S.

Animal Physiology

The experiments are conducted on animals to study their Physiological variations, behaviour etc. by applying various treatments generally managemental or feed or medicinal. The designs of experiments are mostly RBD (32%) followed by C.R.D. (28%). The analysis as usual being correspoding Analysis of variance, Correlation and Regression in addition of averages, S.E. etc.

Forage Production

As the name suggests, the research is mainly on the growing of fodder crops, the testing of suitable varieties in relation to their yield, utility with regard to their nutritive value to the animals. The crops are grown in N.D.R.I. research farm. The experiments are laid out in Randomised Block Design (60% cases) or factorial RBD (25%). In about 11% the lay out was in split Plot.

In addition to the analysis of data as per the design adopted, studies are extended to estimate the genetic characters of the plants from 1977 onwards. The various genetic parameters tested include heritability (Broad Sense), Genotypic Phenotypic and environmental correlations, Genotype, Phenotype Coeff. of variation. Genetic advance expected genetic gains, selection indices by the method of variance-co-variance matrix. These are also estimated by the usual methods available in the literature. Path coefficients are being determined in some cases.

Animal Breeding & Genetics & Livestock Production

The experiments are conducted to improve the breed of animals in relation to their productivity and performance characteristics. The statistical studies include the assessment and evaluation of such experiments done in the past as also in recent years. As such in 75% cases the investigations have been undertaken utilizing the secondary data of cattle maintained at various organised dairy farms in the country. The data of the herd at NDRI farm has been systematically kept since 1965 when the crossbreeding programme was initiated and the same has been utilised by the scientists and students of the Institute for making following types of studies.

These constitute the estimation of genetic parameters like heritability, repeatability, sire evaluation, progency testing heterosis, genetic gains or advances, correction factor etc. The available methods in literature are employed to estimate the above mentioned parameters.

Studies on performance characteristics like lactation curve, persistency, breeding efficiency have occasionally been undertaken.

The data being non-orthogonal, in more than 60% cases the Harvey Technique of Least Square Analysis is used to analyse the same.

Wherever some specific experiments are conducted the animals are grouped as per the requirements of the experiments so as either to form an RBD or CRD and then the analysis is done accordingly.

Management

This comprises of the research being carried out in the field of Dairy Economics and Dairy Extension. In this discipline units are generally selected by various sampling techniques. The general practice is that of adopting stratified random sampling (21%) followed by simple random sampling (15%), complete enumeration (10%) and purposive selection (7%). Case studies are also undertaken. But still in about 25% no sampling design has been adopted.

The statistical analysis mainly consists of fitting suitable mathematical models/ Production function through the usual regression analysis (28%) followed by the calculation of averages with S.E., C.D. or C.V. alongwith correlation and regression studies (20%). The application of χ^2 test of significance is generally adopted in the data of Extension Projects and research thesis.

Recently the most sophisticated technique of factor/Path analysis has been initiated to analyse the data of Extension Research.

Conclusion

It may be concluded that inspite of the best efforts and interactions of the limited staff located at NDRI Karnal, adoption of statistical methods in the experimentation in the field of animal sciences is not so satisfactory. There may be two main reasons for that viz.; i) the statistical methods to suit the research problems are not available and ii) funds and time to meet the requirement of the statistical methods are limited. Whatever may be the reasons, there is a research challenge before the agricultural statisticians to develop new methods and modify the old ones, to meet the requirement of the workers engaged in the research and teaching in the field of animal sciences and related fields.

25 A STUDY ON COST OF REARING FEMALE SURTI BUFFALO CALVES FROM BIRTH TO THEIR AGE AT FIRST CALVING

L. SIDDAPPA

UAS, Dharwad

272 farmbern Surti Heifers were selected for the study at AICRP on Buffalo Dharwad and categorised into three groups namely early, normal and prolonged calvers. The average age of these heifers from birth to age at first calving was estimated to be 1303 ± 115 days, 1544 ± 65 days and 1933 ± 203 days for early, normal and prolonged calvers respectively. The total net cost incurred maintain a Surti Heifers from birth to its age at first calving was Rs. 5824.56, Rs. 6908.21 and Rs. 8626.03 for early, normal and prolonged calvers respectively. A highly significant correlation between age at first calving and total net cost was observed. The regression equation was worked out for predicting the total net cost for each day of shortening the age at first calving, indicated that a saving of Rs. 4.77 in case of early, calvers, Rs. 901 in case of normal calvers and Rs. 5.48 in case of prolonged calvers.

TECHNICAL SESSION—III

RESEARCH CHALLENGES IN COMPUTER APPLICATIONS IN AGRICULTURE

July 20, 1989 (Thursday)

11.15 A.M. to 1.00 P.M.

Chairman : Prof. Prem Narain, Director, IASRI, New Delhi

Rapporteurs :

1. Dr. Prajneshu, IASRI, New Delhi
2. Sh. I. Sankaranarayanan TNAU, Coimbatore

Speakers :

1. Dr. S.S. Pillai, IASRI, New Delhi (paper presented by Shri S.P. Doshi)
2. Dr. S. Bhagavan, NDRI, Bangalore
3. Dr. P.R. Ramachander, IIHR, Bangalore
4. Sh. S. Shanmuga Sundaram, SBI, Coimbatore
5. Sh. P.N. Bhargava, IASRI, New Delhi

3.1 RESEARCH CHALLENGES IN COMPUTER APPLICATIONS IN AGRICULTURE

S.S. PILLAI
Indian Agricultural Statistics Research Institute, New Delhi

Introduction

Computers have made in-roads into almost all fields of science. Agriculture is not an exception to this. However the use of computers both for research and extension in the country has not been to the extent desired due to the high cost of computers and the non-availability of computer systems with the research and other workers at large.

Computers have been mainly used in Agriculture in our country so far only for statistical analysis of data collected during research work and implementation of sample surveys or for analysis of data collected during routine administrative work of the Governments. There are a number of personal, mini and main-frame computers installed in various research Institutes and Government organisations where such work is done. There are a number of problems which require larger computers if proper analysis of the data collected by various organisations is to be done. In addition, very large data-bases are required to be maintained properly if computers are to be successfully used in applications in agriculture.

Data Loggers

Many equipments used for analytical observations are capable of outputing digital readings for recording on magnetic media. There is a need for developing programs to directly read such outputs and process the data. Suitable statistical methods will have to be evolved to take care of this. As research methodologies become more and more sophisticated, use of computers will become inevitable in investigations in various disciplines of agricultural science. It is essential that up-to date computers are made available to research workers if India is to continue to have a lead in agricultural research and education at least in the third world.

Crop Forecasting

One of the areas in which much progress has not been made in the country in real terms is in forecasting of production of various crops based on scientific methods. Such forecasts are very valuable for preparation of adequate plans as well as for evaluating the effects of implemented programmes. Suitable statistical methodologies are also required to be developed using computers so that timely and adequate forecasts can be made.

Remote-Sensing

Since a number of changes have taken place in the administrative set up at the district, panchayat and village levels the existing method of collection of data on area under different crops leaves much to be desired. Collection of basic data for estimation of area through the revenue agencies will become more and more difficult in view of the multi-farious activities which are entrusted to them. In recent times new methods for using remote sensing techniques have been tried out. A number of remote sensing satellites have been put into orbit by a few countries including India. Very large amount of information is being collected by these satellites and are avaiable for exploitation. Suitable statistical methods for interpretation of the data collected through remote sensing are to be developed. The research work in this area will involve development of algorithms or of adaptation of existing algorithms for processing of images, as well as for identifying areas under different types of land utilization in conjuction with ground truth surveys. In the decade to come the statisticians working in the field of agriculture will have the responsibility of working in close collaboration with National Remote Sensing Agency, Space Application Centre and other organisations to develop suitable techniques for interpretation of remote sensed data with a view to developing techniques for estimation of area under different crops with a fairly good degree of precision. The possibility of estimating production of selected crops can also be explored even though the techniques available at present may not be satisfactory.

Simulation

There are many activities in research which cannot be simply based on observational data. The cause and effect relationship between number of variables can only be studied by use of appropriate simulation techniques.

There is considerabie area in the country which does not get adequate amount of irrigation even in areas which are covered by assured irrigation. Availability of water differs from year to year depending upon the amount of rain-fall, groundwater exploitation and also climatic conditions. Research work in close collaboration with meteorological department is required to be done using computer simulation techniques for studying the availability of irrigation water for crop growth. Simulation studies are also required to be conducted in unirrigated areas. Again, with close collaboration with meteorological department crop production in these areas can be maximised by proper choice of crops and varities depending upon the long term and short-term forecasts whieh are likely to be available with the installation of the super computer for the purpose. Information collected by agromet stations all over the country will be required to be collected for making such studies.

Data Bases

In order to develop suitable plans for optimising agricultural research in the country a large number of data bases will have to be developed. Information collected from national demonstration trials, Krishi Vigyan Melas and other extension work done by the Indian Council of Agricultural Research as well as the State Governments will have to be suitably stored in data bases. While such data bases can be used for monitoring the extension activities they will also provide information for development of appropriate plans for efficient management of agriculture.

Agricultural development and progress is measured in terms of parameters like area, production, yield, irrigated area, area under high yielding varieties, farm harvest prices, fertiliser used etc. The data on these need to be compiled on a comparable basis over all the districts and crops for the past three to four decades. The data bases which are prepared crop-wise and district-wise on these parameters along with meteorological data will form material for research work, Information on related aspects will also be available through agricultural and livestock censuses which are conducted from time to time.

A number of surveys have been conducted in the past on different aspects of agriculture and animal husbandry and the large body of data collected in these surveys have not been analysed to study the changes in agricultural practices. There is need to collect information from different sources and store them in a data base so that information contained in them can be extracted.

Expert Systems

Considerable development is taking place in developed countries in preparation of knowledge based systems dealing with specific areas in which human expertise is required for taking decisions. Agriculture is an area in which development of such expert systems will benefit thc farmers to a large extent provided the facilities of the computers can be extended to them. Under the Computerised Rural Information System Project (CRISP) computers have been installed in almost all districts of the country. The National Informatics Centre of the Planning Commission has also in all the districts which are net-worked together using a communication satellite. These computers can perhaps be utilised ultimately for provididg expert advice to the farmers using expert systems, provided they can be developed by our Institutes. Computer software for development of expert systems are available and are being used by a number of organisations in the country, particularly by the Space Applications Centre. If adequate software and computer facilities are provided to various institutes under the Council, there is no reason why suitable systems be not developed in these Institutes on similar lines. The areas under which knowledge based system can be developed are in animal husbandry and crop production, agricultural management, identification of pests and diseases, adoption of suitable prophilatic measures and also in the area of fertiliser applications for different varieties of crops depending upon moisture availability in almost all cases where agricultural experts are required for giving advice to the farmers. It should be possible to develop suitable expert systems and make them available atleast at the district level for use by farmers. One can even consider making mobile vans fitted with such computers which can move from village to village on per-determined dates for giving advice to the farmers on various problems relating to agriculture. With the availability of very cheap computers this is a practical feasibility. Considerable amount of research has to be done before setting up expert systems which can provide actual service to the farmers.

Management Information Systems

A number of information systems will have to be developed for proper management of research projects, personal management, financial management as well as inventory control. The ICAR has got vast amount of resources in a number of research institutes located over the country which include a variety of equipments implements and other assets. Computer systems should be effectively used for building up inventory control systems to facilitate management of such assets.

The research workers in the Council produce considerable amount of research documents every year. Most of these documents are not being properly used by other scientists because of non-availability of proper library services. There is a need for providing bibliographic information storage and retrieval services on a nation wide basis. Computer systems in all the research institutes in the country which are networked using satellite communication channels will go a long way in providing these facilities. Again there is a need for developing expertise in development of bibliographic information services and this is a challenge which the computer scientists working in agriculture will have to face. The number of research projects implemented in the country is quite large. India is perhaps the only country where we have got a well co-ordinated programme of research and education with a number of Institutes and Universities specialising in agriculture and animal husbandry research. There is a need to establish a research project information system based on on-going research projects in the field of agriculture and animal husbandry and allied sciences, being implemented by the Council as well as by State Governments autonomous bodies and private organisation. A proper data base will have to be developed and implemented so that the research conducted in various organisations can be properly monitored and the results disseminated in time for the benefit of the farmers.

Networking

The need for net-working all computers in various research Institutes has been mentioned in the previous paragraphs. When computers are net-worked it will be possible to have continuous dialogue between research workers in various Institutes. Programmes developed in Institutes can be exchanged and expert advice can be sought by research workers from Institutes whenever required by using the electronic mail services and facsimile services available at cheaper cost in networked systems. In order to develop such facilities considerable work will have to be done by computer scientists in all the Institutes so that such systems can be implemented.

Fourth Generation Languages

In the area of computer manufacture there has been considerable progress in the country. A number of manufacturers have come out with computer syftems of various sizes and capacities. On the software side also a number of software houses have come up in the country to develop complicated software systems and sell them abroad. A few companies are also engaged in developing software for indigenous use. Much progress has not been made in the development of software for local supply mainly because of the large scale software piracy which is going on and the developers find in uneconomical to produce software for the local market. One of the latest developments in the softwaie front is the development of fourth generation languages. These are nothing but programming tools which help the programmers to develop application programmes in specific disciplines without using a conventional programming language. Fourth generation languages for statistical applications need to be developed so that persons who do not have much experience in writing computer programmes can use these for development of statistical software. There is considerable scope for developing fouth generation languages for statistical analysis in the country particularly in the area of agriculture because considerable expertise in statistical methods is available in all the Institutes. One of the challenges statistians should face in the next decade is to develop fourth generation software for statistical analysis of data.

Computer Aided Design & Manufacture

Agricultural engineers are engaged in development of tools and implements for improvements of agriculture. This is an area where computer aided design and computer aided manufacture can play predominant role. There is a need for equipping the agricultural engineering units of the Institutes and Agricultural Universities with the CAD/CAM systems to facilitate research in this direction. Statisticians who are quite familiar with computer programming can assist in the development of suitable software for their use.

Training

With the proliferation of computer systems in different Institutes and the Universities there is need for research in development of software in a number of areas which have been discussed in the earlier paragraphs. The development of the software can be achieved by creating a core of experienced programmers in all the Institutes for which adequate training programmes at a central place will have to be planned. The central place should be equiped with powerful computer systems and teaching aids so that the statisticians in various Institutes can get adequate training and hands-on experience to facilitate development of such programmes. Periodical conferences of the statisticians will be required to be organised for monitor ing progress of the development of software by various organisations, reduction of duplication of work and for exchange of ideas.

Acknowledgement

The author is grateful to Dr. Prem Narain, Director. IASRI for the encouragement in the preparation of the paper.

3.2 COMPUTER AIDED RESEARCH CHALLENGES THROUGH FLEXIBLE ACCESS TO MODELS AND DATA

S. BHAGAVAN

Southern Regional Station, National Dairy Research Institute, Bangalore

An overview

In these days of information revolution, computer is now common place in industry, government, medicine and even politics. The computing technology abounds, we use it in many ways, from visible to invisible; spectacular to routine; video games to automation of scientific equipments. Although the common man still stands in awe of it, he has realised the efficacy of computerisation for they make possible the smooth and efficient operation of airline/railway/bus reservation offices, accounting and payroll functions, electronic banking and countless other applications, both large and small. These applications used to require painstaking hours of human labour, if they were possible at all.

Computer technology both with respect to hardware and software has developed at a soaring rate, but the most important aspect is the capacity of those selected band of people who have had ideas and skill to harness these computers so tnat it performs the various tasks that we observe today. The emergence of 4th generation of computers has made a definite impact in India too. Hands-on users have increased with the introduction of computers even in smallest of small organsations/business houses all over the country, thereby enlarging the scope of computer applications.

Although computers have entered Indian scene in a big way their applications are mostly concentrated for increasing the efficacy of the day-to-day operations such as those in the payroll, invoicing and inventory accounting systems. Some applications do address research application systems, but they are mostly rigid on assumptions, objectives and input requirements simultaneously demanding high level computer proficiency from the user. Examples of such systems are various tailor made data management and analytical routines developed by established software companies and individual users.

Computer specialists are of the opinion that these shortcomings can be remedied by developing systems that combine user-friendliness, flexibility in processing models and data and adoptability to the changing needs of users. Design of such systems was not feasible untill recently because of the limitations of hardware and software. With the advent of powerful processors, graphic devices and easy-to-use interactive software, it is now possible to develop flexible systems for research application.

Research oriented application packages in the past

There have been several attempts in the past to develop both tailormade and general application softwares of research interest which can process the data on the various models/design-analysis. But since they are developed mostly by the researchers themselves and/or the computer professionals attached to researchers, the packages developed will be specific to suit their research objectives or very much broad-based providing little amount of flexibility. These packages in addition to the rigidity and mundaneness, will have setbacks for altogether a new set of research data, if the assumptions, limitations and input requirements are not met. There is no difference of opinion that attempts were made to develop research oriented softwares way back in early 70's even when the computers could be accessed only by selected few people, with the computer technology still at medicare level. Agricultural researchers, specially the plant breeders had felt the need of computerising their taxonomical/ germplasm data for a flexible access: Krauss (1973) has highlighted the use of Generalized information processing systems in the biological sciences. Hudson et al (1971) designed a TAXIR—A biologically oriented information retrieval system as an aid to plant introduction; Hall (1972) developed a computer based-data banking for taxonomic collections; and Andrews *et al* (1978) developed a computer-based retrieval system for plant breeding material.

During the same time several statistical packages and interactive systems were developed for research result analysis. Of which the SAS (Statistical Analysis System) developed during 1972 by A.J. Barr and J.H. Goodnight of North Carolina State University was considered as one of the best packages. It included flexible procedures for data input, transformations, multivariate and other statistics, graphics, time series analysis, clustering and calling up procedure from outside SAS. The only limitation was that it was designed for IBM installations alone. Another package which was most widely used is the Statistical Package for the Social Sciences (SPSS). Unlike SAS, the number of procedures (multivariate) were limited.

Apart from this Biomedical Computer Programs (BMD and BMDP), CLUSTAN, NT/SYS (a system for multivariate statistical programs), EAP (Ecological Analysis package written in PL1 language) Cornell Ecology programs, GRAPHPAC (a graphic package for depicting spanning trees, scatter plots, response surfaces etc., and two scientific subroutine packages for matrix and vector manipulation namely SSP and EISPACK were developed during late 60's and mid 70's.

In short an agricultural scientist with the ability to use SAS or SPSS, or CLUSTAN or NT/SYS was finding that most of his/her computing needs are met though at times he/she may need to look elsewhere for certain clustering and ordination procedures. But all these packages could be accessed by selected few who had expertise in hands-on usage of computer.

Current status of research oriented application packages

Presently the scene is totally changed with the large influx of microcomputers with almost every researcher having hands-on access to these computers. Some of the software developers cited above especially SAS and SPSS have even revised their packages keeping in line with the current advancement both in hardware and software. Likewise new software developers have emerged namely MSTAT developed by Dr. O. Nissen, Deptt. of Crop & Soil Sciences, Michigan State University, SYSTAT Inc. of Evanston, and STATGRAF of Statistical Graphics Corporation, USA. MSTAT offers 60 and odd functions organised in 6 major modules namely MANAGER, DESIGN, STATS, CORREG, AOV and ECON. The MANAGER module takes care of file and data management, DESIGN possessing experimental documentation features and the remaining 4 modules takes care of some of the widely used statistical and economical analysis. This package is not very user-friendly and has few setbacks because of its rigidity.

SYSTAT which is rated above SPSS/PC+and PC—SAS offers a full-screen spreadsheet data entry; flexible input of ASCII files; File handling match, merge, append; Subgroup processing with SELECT and BY; Unlimited transformations; Basic statistics; Exploratory and Analytical graphics; Correlations; Multiple regression; Polynomial regression; Residual analysis; Stepwise regression; Regression diagnostics; Cannonial correlation; Multivariate general linear model; Discriminant analysis and Classification; Mutiway MANOVA, MANCOVA; Principal components with rotations and scores; Cluster analysis and various other statistical analysis.

STATGRAF is an integrated system of statistical and graphic utilities for exploring and modelling data. It offers more than 250 functions organised into 22 major sections namely Data management; System environment; Report writer and graphies replay; Plotter interface; Plotting functions; Descriptive Methods; Estimation and testing; Distribution functions; Exploratory data analysis; Analysis of Variance; Regression analysis; Forecasting; Quality control; Smoothing; Time series analysis; Categorical data analysis; Multivariate methods; Non-parametric methods; Sampling; Experimental design, Numerical analysis and Mathematical functions. The package written completely in a structured fashion with the graphic utilities being very flexible, it is quite useful and appealing for the researcher in many ways.

Research Application System (RAS)

A Research Application System is a computer application that supports the researcher to have a user-friendly flexible access to models and data

The key features of RAS are :

* user—friendly
* ability to browse edit and append the information selectively
* graphical depiction of required data
* flexible access to models and data
* focus on research implications
* scope for incorporating human judgement in dealing with research.

An RAS need not necessarily use a new model or a new device for analysis or management of information. It can use the available techniques and still be called a RAS provided it combines the techniques such that the user gets a flexible, adaptive computing aid that enhances the researcher to focus on the problem effectively.

Although the latest softwares such as PC—SAS, SPSS/PC+, MSTAT, SYSTAT, STATGRAF etc., incorporates most of the features of RAS there is still, little amount of rigidity with regard to data manipulation, modelling techniques and statistical analysis and management of Information, mainly because these software developers have attempted broad based package incorporating every aspect of analysis and data handling in one package, There is ample scope for developing simple RAS softwares which are widely applicable for a pre-defined task and a provision for linking various RAS softwares aiming at different tasks so that the researcher has a detailed access to each of the RAS package to have a better overview of the research results and incorporate his/her judgement before tackling another RAS package for further analysis.

RAS for research information

Bhagavan and Rao (1988) for the National Research Centre for cashew developed a simple RAS which aims at management of available research information to help the researchers in quick scanning of research abstracts either authorwise or subjectwise. Given a single key word on any desired subject or a contributors name, one can go to any depth in the review of literature with just a hands-on computer time little while rather than spending months together inhaling dust and insecticides of the back volume journals in the library.

RAS in Dairy Plant

The Southeren Regional Station of NDRI and IIM Bangalore (1988) jointly developed a menu-driven package called MILK (Milk Industry Linear programming Kit) for working out optimal product mix for a typical Dairy Plant. This package which incorporates LINDO subroutine (a linear programming analysis) has flexible access to each day's dairy plant's data (such as milk received, number o f various equipments in working condition, demand for various products etc.) to arrive at how much to produce each of the milk products considering various constraints so that the industry is profited. It further gives scope for research on financial aspects of the Milk Industry.

RAS for cattle herd management

An RAS package to monitor cattle herd performance in response to production and reproduction traits was developed by National Dairy Research Institute (1988). Maintaining an exhaustive database on the cattle herd with the facility to update data on insemination, calvings, pregnancy, milk yield, lactation length and similar such parameters, it is possible to estimate the Expected Producing Ability (EPA) of each animal at periodical intervals and interact with health and other disorders for taking decision on culling of animals. The package can effectively be used for identifying research implications through an in-depth study of treated and untreated animals on various experimentation aspects.

Guidelines for developing RAS

Choosing the problem area is the first step. The Software engineer in consultation with the researcher, should identify the area that is important for the wide applicability in general and immediately research needs in particular.

Most of the research rssults analysis may be tackled under the following four major heads

* Management of information system
* Data handling and manipulation
* Visual display of results
* Modelling aspects and statistical analysis

Every researcher will have a better perspective of the research implication if he/she has the complete grasp of the research results. Management of information system through utilities such as dbase, sympthony etc., aids the researcher to have a broad overview of the research results. Next comes data handling and manipulation. A full screen spreadsheets data entry, with the ability to browse, edit, append, delete information selectively and also generate new variables/factors using the utilities LOTUS 123, Supercalc, Frame work, spreadsheet etc , helps the researcher to have flexible access to data screening/Spread handling before analysis. There must also be provision to import/export the data to suit the various utility packages. Visual display of results through interactive graphics is yet another important aspect. The crucial question is what to display, how much and when. Displaying too much information distracts the user, whereas displaying too little causes inconvenience because he/she has to change screen frequently in search of relevant information. The content of display should provoke the user to enter into an active interaction with the system in focussing research implications. Visual display of the results can be made using the graphic utilities such as Graphic Kernel System (GKS), Geographical Information System (GIS). THE matic MAP ping Systems (THEMAPS).

Research result analysis is the most primitive factor in these RAS softwares. There should be flexible access to modelling and statistical analysis in a completely structured fashion, so that at each stage of the analysis, the user will have access to intermediatory results for studying the research implication of the factors/variables considered. If necessary, enter into an active interaction with the data handling routine for screening/generating/manipulating variables and incorporate human judgement before attempting further analysis. Some of the standard subroutine decks such as Calculation of p-by-p covariance matrix from n-by-p data set with transformation and standardisation options; Matrix multiplication and inversion; Roots and vectors of symmetric and non-symmetric matrix might become handy for most of the multivariate analysis.

To sum up, RAS should have maximum flexibility. Since it is a research aid and a thinking tool, the sequence of steps in its operation should be as loose as possible. Ideally, a processing step should be immediately accessible from every other processing step. More importantly, a RAS should be able to adopt to the needs of the user. It should be so designed so, that the focus on research takes on a new dimension for the researcher. One must realise that RAS is no way reduces the thinking and planning responsibilities of the researcher. Infact with a RAS, he/she may end up spending more effort in planning. However, the ultimate result is expected to be more informative.

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3.3 COMPUTER REVOLUTION AND IT'S IMPLICATION TO AGRICULTURAL RESEARCH – PAST, PRESENT AND FUTURE

P.R. RAMACHANDER
Indian Institute of Horticultural Research, Bangalore

1. Past

It was during the 60's that the use of computers in agricultural research was initiated in IASRI (Then IARS). Initially few unit record machines were purchased and an IBM-1620 Machine was added to the Institute. Very useful work was done and large amount of software was developed for use of various Agricultural Scientists. The sample surveys conducted by IASRI were also analysed using this machine.

Due to the prohibitive cost, need for sophisticated site and meagre funds available for purchase of equipments the different ICAR Institutes were doing all their calculations with Facit hand operated calculators during this period. Few of the fortunate institutes owned electrically operated Facit machines which rarely worked continuously for more than one month.

It was with the microcomputer revolution which started trickling into India around 1975 that all this changed. The first to reach the ICAR Institutes were the electronic calculators followed by programmable calculators. The Indian Institute of Horticultural Research was one of the first institutions in the country which went in for a bigger model of programmable calculators. Unlike the main frame computers, which Scientists had acquired some knowledge, these program programmable calculators were entirely different. The programmes had to be written using the machine language with the only advantage of having some user defined keys. Programming was cumbersome and difficult. It was for the first time the scientists were exposed to a machine which was not available for computing when the data was being fed. There were no training programmes and no guidance to be received from IASRI, who did not purchase various models of these calculators Within another five years the first micro computers were being marketed in India. These machines supplied BASIC compilers (usually an outdated version) which helped the user in preparing user-interactive-programmes. In 1980 one such machine was installed at IIHR. Two major problems were faced. (1) There were no institutions in the country who gave training in BASIC language and (2) The firms which marketed these microcomputers were supplying very poor quality software, mainly meant for the use of business houses. Statistical packages given by them were more mathematical packages. Most of those institutes and Universities who purchased these machines did not tap the full potential of these micro computers due to this sorry state of affairs. However IIHR developed expertise in using the version of BASIC language supplied by the firm and developed all necessary software for statistical analysis as well as packages for preparation of paybill, storage of biodata of personnel etc. Programmes for some special statistical techniques in Horticultural research were also prepared. At this stage it is again worth mentioning that IASRI continued to develop programmes in FORTRAN and also offered courses in FORTRAN. For users who had installed microcomputers these courses were not at all useful mainly because the data entry for the version of FORTRAN supplied with the micro computers were very cumbersome and difficult.

And now we have reached the third stage of computer activity in India. This is the arrival of very powerfull microcomputers, which are faster and are capable of admitting software like Database, Word-processor, spread-sheet, Graphics etc. They also are capable of having many terminals and doing several jobs simultaneously. But the fact remains that the software support by the firms towards agricultural statistical research applications was almost nil. Only two software firms in India came out with software packages for analysis of agricultural experiments. These were very primitive and did not meet the requirements of even a small agricultural statistics unit. A few of the ICAR Institutes have been mainly using FORTRAN compilers and have adapted the FORTRAN programmes developed by IASRI. The other institutes continue to use BASIC language and are engaged in develping the needed software for their use. It is important to mention here that a few institutes have been able to import software packages directly and are using them. An exchange of such programmes to other ICAR institutes would ease the work very much.

2. Present

Computerisation of the research work in ICAR institutes was accompanied by host of problems. Since there was no direction and no guidance some of these problems had to be solved by experimenting only. This process of experimentation was tedious and sometimes counterproductive. Some of these are highlighted below.

2.1 Almost no ICAR institute till the end of sixth plan had any staff component to man the computer as also to develop software. This lead to the diversion of time of the scientists engaged in applied statistical work to pursuits which are not productive from their individual point of view since the work done did in development of software was mostly considered non-statistical and there were no avenues available for each scientist to claim the credit of developing of good software. This was because unlike research, software development became commercial, and these were marketed rather than published. This peculiar situation lead to the phenomena of non-exchange of software between Institute to Institute and even between scientist to scientist in the same Institute. In the IIHR scientists engaged in software development were encouraged to give details of work done in software development by them in their assessment report in an elobarate manner so that due credit could be given to this activity. To a large extent software was given to other sister institutes. But unfortunately the problem has not been solved and would assume mega proportions soon. The publication of the list of software with each ICAR Institute is a step in the right direction.

2.2 Due to the non-recognition of programming activity as statistical work there is lot of reluctance from individual scientists for dedicating themselves to this type of work. So the progress in software development is rather slow. The only alternative to solve this situation is to create a separate discipline of computer-programming in the ARS system. If there is some objection to this the alternative would be to create posts in the technical cadre. If this is done it is likely that the software staff would not know any statistics and statisticians would have to spend lot of time in describing the algorithams for each analysis to these programmers. Which method would be more efficient is for the future to decide ?

2.3 Unlike the mainframe computers the microcomputers were not available for use when data was being fed and this naturally slowed down the statistical analysis procedure. Since number of statisticians were working at IIHR and each of them had to analyse data from large number of scientists, the computer time was shared equally among the statisticians though this approach solved the problem to a certain extent, it was obvious that the optimum use of the computer was not being made. With the purchase of a much bigger model of computer with terminals and capability of multitasking this problem has almost disappeared.

2.4 Computer oriented research through system analysis and model building were making remarkable strides in all countries where agricultural research was being done. Unfortunately in our country we had enormous setback in this regard because training in such methodologies were not available and also because the existing microcomputers did not have compilers for languages more suitable for this purpose. Another reason, perhaps for this is the fear for mathematics among Indian biologists and reciprocal feeling towards biology by the statisticians. Some steps in this regard were taken by the IIHR. If not in a full scale some elementary activities in model building and system analysis was attempted. But in comparison with the work that is being done abroad, this was very very puny.

(5) Some attempts were also made to impart training in computer programming to horticultural scientists. To our gratification it was found that the discipline of programming was well received by them and a more thorough understanding of the computers on their part helped us to work better.

3. Future

With the possession of newer and powerfull microcomputers a general feeling of euphoria has set in, in most of the ICAR Institutes. To detail some pessimistic thoughts at this juncture appears to be a sin. But it is felt that some of these bitter truths have to be discussed, so that when one comes face to face with these problems, one is ready with solutions.

3.1 Many of the scientists of the ICAR institutes are not aware that the beautifull, scientilating and powerfull microcomputers that they have purchased have a short life. This is because of the fact that most of the models which the industry is manufacturing now are old models of some firm abroad and within another 2-3 years, the principals would have gone in for better models with better capabilities. This would cause non-availability of spare parts and possibly within another 5-8 years all the microcomputers would become junk and it would be necessary to replace them. Normal administrative rules do not allow for such a thing. It is to be emphasised here that the scientists assembled here should pass a resolution about the possibilities of a shorter life of computers and request the government to allow write off of computers in shorter periods. Another alternative is to go in for refurbishment of the old model with the latest from the some company. This is a painfull excercise within the frame work of the present rules. It would be necessary to amend the administrative rules, so that such a refurbishment could be done with ease.

3.2 When any organisation purchases the microcomputer they are not aware that about 10% of the cost of the new equipment has to be spent on servicing every year and 5-10% on the stationary requirements every year. If no provision is made in this regard it is quite possible that the computers may not work. It is suggested that in view of the large number of microcomputers installations ICAR can call for tender and approve few suppliers of computer stationery so that red tape in purchase of such items can be avoided.

3.3 Perhaps the most serious of the repurcussions of the computer usage in our country is the slow disappearance of the art of fine statistical interpretation and analysis. Some years back when each statistican was analysing a few sets of data with the conventional calculators, he had time and necessity to probe into individual results and find out why a particular method worked in a particular case and if it did not work to find out alternative method which could be used. This way whatever little data was analysed, an indepth interpretation was made and newer and newer methodologies came to the fore. But with the handing over of statistical analysis to the computer, while one has to agree that the mass of statistical analysis has increased leaps and bounds, the quality has suffered due to lack of indepth interpretation. This is a sorry state of affairs because our country was justly famous for these interpretation all these years.

3.4 As has been already mentioned, there are no training facilities for microcomputers in IASRI. Languages like PASCAL, C etc. remain in the manuals without being used due to lack of training avenues. If these microcomputers are to be used to the fullest extent, it would be necessary that IASRI which has acquired several models of microcomputers to start full fledged training programmes in all these new languages.

3.5 Many of the American Universities are supplying software suitable for IBM-PC computers at a nominal cost. If each Institute tries to import them it would be waste of the available meagre resources of foreign exchange. So it is suggested that to make use of the microcomputers already purchased ICAR may import these software packages and distribute to all ICAR Institutes. Unless this is done it is felt that the progress in use of these machines would not be to the desirable extent. It would be in the fitness of things if IASRI organises a workshop on latest software on Agricultural Statistics, so that the scientists engaged in software development can meet and discuss their mutual problems and even share the burden in different areas and exchange such software.

These are some of the thoughts which have arisen as a result of experience in use of microcomputers for the past 12 years in Horticultural Research. Since it was always our feeling that computers were only a tool for better research, we do not have any experience as to the relative merits and demerits of different makes. Naturally this is a very important aspect and we hope that IASRI gains the expertise and advices all of us in the optimum choice of proper equipment. It is wished that all these aspects are discussed in a dispassionate manner so that the scientists in all the ICAR Institutes would benefit greatly. It would be extremely useful if a permanent committee of top computer professionals in ICAR be established, so that all these suggestions can be carried out in a shortest possible time.

In order to achieve maximum efficiency, complete automation can be recommended in the following way :

> 'Each part of the factory for example, feeding, milling, liming, evaporation, etc. may be controlled by an individual microcomputer with a second a standby, price permitting. Each of these control stations may be interconnected with the others by means of an information bus. A control station connected to this bus permits an operator to interrogate successively the individual processors and to display all the process stocks. The information bus interconnecting the individual processes is not indispensible to the operation of the factory but prevents accumulation of raw material at any point in the factory and optimizes the complete installation. For example, a stopping of the mills will immediately reduce the feed to the boiler.'

Again, there are several other possibilities of computer uses. In foreign countries, there are process computers in sugar refining and computers for controlled pan boiling. Sugar refining is basically a series of separation processes employing most of the chemical engineering unit operations. Similarly, instrumentation of the pans includes, for each, a level transmitter, a consistency transmitter and supersaturation measurement based on boiling point elevation. In the above two situations, computers could certainly be of much use to a sugar mill.

With these digital systems all around in a sugar factory, they could be further utilized for the following purposes by way of adopting appropriate statistical yardsticks :

i. Optimization of the crushing programme.
ii. Yield prediction model for deciding on ratoons.
iii. Insect survillance or early warning of outbreak of pests and diseases.
iv. Controlling of irrigation and other abiotic stresses.
v. Assessing maturity of the crop for harvesting and arresting post-harvest losses.
vi. Establishing the optimal law of cane feeding and imbibition water application

Computers as management tools to sugarcane grower

The main effect of new production technology in sugarcane agriculture has been the general trend towards large scales of production. Sugarcane growers are loaded with lot of technological knowhow. How will these efficient farms be managed in an environment of ever changing information flow and technology ? Good management in these settings is clearly more important than ever. It is also clear that sugarcane management technology has not kept pace with production technology. Microcomputers and personal computers are handy tools which can be used to manage more complex farming operations. In other countries, many writers have

3.4 POSSIBLE AREAS FOR FURTHER COMPUTERIZATION IN SUGAR-CANE INDUSTRY AND AGRICULTURE

S. SHANMUGASUNDARAM
Sugarcane Breeding Institute, Coimbatore

Introduction

Computers have been accused by their critics and some humourists of everything from debiting a tooth brush purchase with huge amount to assigning a fibre of fine quality to well grown plant can. Agriculture, however, is making increasing use of their speed and intricate calculation ability. Sugarcane is grown in more than 80 countries throughout the world. There are several areas in which the computers are utilized for obtaining maximum efficiencies in sugar mills output. The flexibility and amplitude of the scientific computer combined with programmed features, make its application to raw sugar factory operations, a real advancement in the potential for obtaining maximum efficiency and capacity of existing facilities. The impact of computers on sugar industry is hard to predict. During 20th century, sugarcane agriculture has also undergone a large scale revolution in production technology. The main effect of new production technology has been the general trend towards large scales of sugarcane and sugar production. Today's sugarcane grower has been given a vastly more complex managerial task with virtually no new tools with which to make decisions and utilize information. The role of computers as time saving and management enhancing devices in sugarcane industry and agriculture is to be explored further in this paper.

Scientific computers in sugar industry

Recently, micro-computers and micro-processors are heavily found in the following spheres of a sugar mill :

1. Processing of cane sampling data (i.e.) a control system for sampling of first expressed juice.
2. Supplying of the cane farmer with cane, delivery and analytical records (Farmer center).
3. Processing of laboratory data to provision of factory and/or refinary balances and inventories of materials in process (materials in balance and in process, daily and weekly laboratory reports).
4. Process control and monitoring.

likened the impact of microcomputers on agricultural management as being similar to that of tractors on agricultural production. In USA and other parts of the world, farmers are purchasing microcomputers and are using them in a wide variety of applications. Sugarcane cultivators in our country also can now take advantage of this new development. Until recently, computers have removed an unlikely tool for most farmers because of their high prices. The microcomputer or the personal computer is designed to be relatively easy to use, not to take up much space, to operate effectively in a normal office environment and to sell at a relatively low price. Their prices are ever-changing but advance systems can be purchased for lower costs in future.

Specific uses for these computers in sugarcane operations can fall into five different categories :

1. Record keeping
2. Decision analysis
3. Information gathering (or communications)
4. General office management
5. Control systems.

1. Records may be field records, financial records and non-financial records. A set of good field records is usually difficult to maintain by hand and making effective use of handkept field records is even more difficult. Financial records such as general ledgers, balance sheets, tax records, accounts payable and accounts receivable, all surface in different types of agricultural operations. In many farming situations, non-financial records are also essential to good management. Those in livestock have herd records, others may have equipment inventories to track and still others may need information on grain stock in on-farm storage bins. Computers of the above types are often ideally suited to streamlining the task of keeping these records.

2. The computer may do something as simple as calculate loan payments to help a farmer decide on a plan for financing an equipment purchase. On the other hand, it may be utilized to do a complicated capital budgeting analysis to determine the proper time to replant sugarcane fields. The decision areas in which computers could be applied are thus namely machinery acquisition, budget analysis, cash flow analysis, land purchases and marketing.

3. In communications, the microcomputer is connected to a larger central computer by means of telephone lines or direct satellite hak up. As there are plans for district-wise planning and direct funding of village panchayats from centre, the computers at these centres may be utilized in this area. Information stored in the main computer can then be transferred to the microcomputer so that individual managers can make use of that information while it is still current. Further, market

information and crop production information are other good candidates for this type of computing.

4. The area of general office administration is another potential computer application and often includes the processing of pay roll records; other good office applications being mailing list maintenance and word processing.

5. One final are of computer applications is that of computer control of production operations. Computers have been shown to be effective in automating irrigation systems, in controlling of milling operations and in controlling greenhouse environments in other countries. We may consider jaggery grading and manufacturing also in this category to our growers.

Few other important areas in which computers could be utilised by a grower are viz. sugarcane land valuation determination, cane diversification, allotment of raw material to various categories, market analysis and construction of field maps and its history.

There may be several operational problems in developing countries like ours. Sugarcane is a very important crop throughout the world. For many developing countries, it is the major source of foreign exchange. Cyclical fluctuations in the price of sugar often force many producers out of business. In order to operate successfully, producers must make the best possible decisions with the aid of computers.

Conclusions

The personal computer and microcomputers offer tremendous possibilities for sugarcane management. Computers are now powerful enough and affordable enough so that almost all sugarcane managers (both millers and farmers) could make good use of them if the right programmes are available. Making those programmes available is a challenge we must all work together to meet. Such automation will be of interest to Government agencies, bankers who work directly with cane producers, research and extension personnel and private consultants who may wish to keep abreast of technological advances in the sugarcane industry.

3.5 AGRICULTURAL FIELD EXPERIMENTS INFORMATION SYSTEM

P.N. BHARGAVA, R.K. GHAI AND G.C. CHAWLA
Indian Agricultural Statistics Research Institute, New Delhi

1. Introduction

A large body of data on field and animal experiments is generated annually under various agricultural research programmes of different crop improvement projects, agricultural universities, ICAR institutes. Only a part of the data collected under these projects are utilised for preparation of research publications and reports. The wealth of data generated can be made use of in future by planners, management scientists, administrators, etc. for formulating research programmes, preparing projections and targets for different type of inputs etc. In order to meet the future requirements of the users, it is essential to maintain at a central place the complete records of the experiments.

National Index of Agricultural Field Experiments

The Institute intiated a project entitled 'National Index of Agricultural Field Experiments' in 1953. Under this project, the data were collected by the personal visits of the regional assistants posted at different agricultural universities/states in the Deptt. of Statistics. The activities under the project are as follows :

(a) collection of data of all the agricultural field experiments conducted at the various research stations and institutes in the country,
(b) completion of statistical analysis of the experiments and maintenance of the records at a central place in a form convenient for retrieval,
(c) summarisation of the results of such experiments over years and their publication in the form of compendia volumes, and
(d) preparation of critical summaries on important topics of agronomic or research interest.

2. Agricultural Field Experiments Information System

With the increase in the quantum of data and the availability of facilities for proper storage devices, this programme was however reoriented into 'National Agricultural Field Experiments Information System'. Type of services, the system would provide, are as follows :

2.1 Avoid duplication of research

For example a research scientist while drawing up his programme of studies may utilise the information on the extent of work done in the past, the approaches followed and the results obtained by the other scientists in the same line.

2.2 Reliable estimates of parameters for planners and extension workers

A planner who has to ensure the soundness of his projections and targets can use the data available under this system to obiain reliable estimates of yardsticks of additional production for various factors of crop production. Similarly, an agricultural development administrator or an extension worker can utilise the proven results for dissemination among farmers.

2.3 Statistical studies

The statistician can utilise the data for the development of statistical methodology for the analysis of data and the development of suitable designs. A number of investigations on the development of parameters based on past data like yardstick, plot size and designs useful to scientists and planners can be carried out.

In order to meet the above requirements, the system has to be comprehensive and should have a built-up capacity for systematic maintenance of data at a centralised place on different experiments. The system should also provide arrangement for the collection of extensive data on comparable basis, their scrutiny and appropriate statistical analysis. The coverage of the system should be complete in order to be free from serious biases on account of selectivity of data. The information for an experiment should be complete in all respect including the ancillary informations like cultural and other practices.

3. Constraints—Data Collection

In the past, it has been experienced by the regional staff of the project that data which are scattered and available with the departments of different disciplines in the universities are not maintained properly. Sometimes, the data available are quite incomplete and not analysed properly. At the time of the visit of the regional staff, data made available by the scientist are very few in number which do not commensurate with the efforts made by the technical assistant. In a number of cases, the information filled-in is inconsistent and quite often, has to be referred back for clarifications etc. which results in delays in finalising the data and putting them in proper format. Over the period of time, the number of experiments available for collection has increased manifold at regional and national level and it is increasingly becoming difficult for the Institute to manage timely processing of the entire data.

4. Processing of Data

In view of some of the problems for storing the data at a centralised place, it is proposed that this work may be decentralised and the responsibility of storing and maintenance of the data for a particular region be taken up by some of the agricultural universities and institutes adequately equipped with computer facilities and having qualified statisticians. The present staff available under the project will continue to help these regional centres in the collection of data and can also be utilised for processing and putting the data on tapes/floppy disks.

The format of storage and collection of data will have to be uniform since the entire data collected by different regional centres will be passed on to the IASRI for centralised storage i.e. the entire data so collected by the regional assistants will be validated locally and stored on the floppies. These floppies will however be transmitted to the IASRI for further processing and storage. The IASRI will also have the responsibility of bringing out a directory on the data available at national level giving the summary details of the experiments like object of the experiment, site of conduct of the experiment, year etc. which will be circulated to all the agricultural universities, research stations etc. free of cost.

To discuss the various issues on the functioning of this information system, the meeting of different agricuitural research scientists involved in the execution of the information system will be held twice a year at IASRI or some other regional centre.

5. The role of Statisticians/Seientists

As a first step, the statisticians working in different agricultural universities or Institutes should try to develop a system by means of which the entire data generated under different agricultural experimentation programmes of different disciplines are made available to them. This will ensure the maintenance of data at central place in the institute/university. This will also enable them to develop close interaction with the scientists of the Institute and in undertaking methodological investigations utilising the data. The assistance of regional staff can be taken to the extent possible. I believe that over a period of time, the staff provided under the project may become inadequate and once the importance of the project is realised by the Heads of the institutions, the additional hands can be obtained in due course of time locally.

For the collection, processing, storage and retrieval of the data, the Institute has already finalised all the necessary infrastructure etc. Some of the details like preparation of data for computerisation and the programmes for their retrieval will be presented in the present talk.

3.6 AGRICULTURAL EXPERIMENTS INFORMATION SYSTEM FOR ANIMAL SCIENCES

Similar to the collection of data of agricultural field experiments, the programme of collection of data of experiments in animal sciences was initiated in 1966 on a modest scale. During the last two decades, quite a large number of experiments in animal sciences namely, relating to Animal Nutrition, Animal Physiology, Poultry Nutrition and Physiology, Animal Breedidg and Genetics, Disease Control etc. have been collected from different premier ICAR institutes and agricultural universities by the personal visits of the staff of the Institute. Among the premier institutes of ICAR, the data were collected from IVRI, Izatnagar, NDRI, Karnal and its regional stations, U.P. College of Veterinary Sciences and Animal Husbandary, Mathura, Veterinary College, Madras, Allahabad Agricultural Institute, Allahabad, Ranchi Veterinary College, Bihar and many others. Based on the data so collected from different disciplines and institutions, about 21 compendia volumes were brought out discipline-wise and institution-wise.

With the increase in the number of experiments available for collection and the facilities available for proper storage devices, programme of documentation of the resnlts of the experiments in animal sciences has also been modified. The publication of the compendia volumes has now been discontinued particularly in view of considerable time-lag in the receipt of data at this institute and its publication. However, this modification in documentation will help in reducing the time-lag in the processing of data and making the results available to the scientists on request. For the operation of the system similar to the agricultural field experiments, the necessary data preparation sheets for making the data amenable for storage on tapes necessary software for its storage and retrieval have also been finalised. For the use of field staff, the necessary instruction manual for data preparation etc. has also been prepared.

In this system also, statisticians engaged in the analysis of data for animal sciences shall have to share the responsibility of the collection and maintenance of data in the format developed by the Institute. For this purpose, the services of the reginal assistants posted at ICAR institutes/agricultural universities may be utilised to the extent possible. Due to constraints in the collection of data, the statisticians at different ICAR institutes may like to develop a system of centralised collection of data in the Deptt. of Statistics in respect of experiments planned in different disciplines in their institutes. The data so collected in uniform format will also help in taking up number of studies of statistical interest by the scientists at their end. The annual directory similar to the agricultural field experiments will also be brought out periodically by IASRI.

Acknowledgement

Authors are thankful to the Director, IASRI for providing the necessary facilities in the preparation of this paper and S. Manjit Singh, Stenographer for typing the manuscript and cutting the stencils.

TECHNICAL SESSION—IV

RESEARCH AND TEACHING COORDINATION AND LINKAGES BETWEEN ICAR INSTITUTES AND AGRICULTURAL UNIVERSITIES

July 20, 1989 (Thursday)

3.15 P.M. to 5.15 P.M.

Chairman :	Prof. Prem Narain, Director, IASRI, New Delhi
Rapporteurs :	1. Dr. Randhir Singh, IASRI, New Delhi 2. Sh. R. Rangaswamy, TNAU, Madurai
Speakers :	1. Dr. S.K. Raheja, IASRI, New Delhi 2. Dr. Randhir Singh, IASRI, New Delhi 3. Dr. M. Murugesan, TNAU, Coimbatore 4. Dr. Umed Singh, HAU, Hisar 5. Dr. K.C. George, KAU, Mannuthy

4.1 RESEARCH AND TEACHING COORDINATION AND LINKAGES BETWEEN ICAR INSTITUTES AND AGRICULTURAL UNIVERSITIES

S.K. RAHEJA
Indian Agricultural Statistics Research Institute, New Delhi

Rapid advances in research in different disciplines of agriculture have led to specialisation in almost all its branches. Agricultural scientists thus became agronomists, breeders, soil scientists, etc. and now it is wheat agronomist, pulse agronomist, maize breeder and so on. Teaching of agriculture has similarly been given a separate entity by setting up agricultural universities in almost every state to meet the growing demand of well trained cadre of agricultural scientists in the country. In keeping with these developments, agricultural statistics which has relatively recently emerged as a full fledged discipline of agriculture in India has also come of age. As in other branches of agriculture, specialisation has also taken place in agricultural statistics. Thus, we have survey statisticians, statisticans specialising in design of experiments, inference, etc.

Research in agricultural statistics is mainly of two types-basic and applied. Basic research deals with development of the agricultural statistics as a pure science and is, therefore, instrumental in opening new frontiers of knowledge in the subject. Applied research deals with developing improved and better techniques for solution of specific problems or situations. Thus while basic research tends to become more or more individual oriented, applied research is problem oriented and is directed at finding an appropriate solution. Since, real life problems normally would not be concerned with only one discipline, applied research has necessarily to be a collective effort of specialists of different disciplines relevant to the problems under investigation. It is in this context that the inter disciplinary or collaborative research has assumed great significance particularly in the field of agriculture in the last two to three decades.

Research in various disciplines of agriculture is conducted mainly by scientists working in different ICAR Institutes while teaching of agricultural courses is done in the State Agricultural Universities as also in some of the ICAR Institutes disignated as deemed universities. In the field of agricultural statistics IASRI has the dual responsibility of conducting research in agricultural statistics as also teaching of regular courses leading to the award of degree and certificates at different levels.

Similar'y, research in computer applications in agriculture and teaching of M. Sc. course in the subject are also undertaken at the Institute.

Some of the areas where collaborative research in agricultural statistics could be undertaken between scientists of IASRI and other ICAR Institutes are as follows :

Design of experiments

Planning of experiments for study of plant and animal growth is one area where there is considerable scope of active collaboration between scientists in different fields of agriculture. Experiments are planned by scientists in almost disciplines in agriculture. Development of suitable experimental designs for use in agriculture has therefore, been a continuous process for over 50 years right from the inception of the ICAR. Different types of designs to meet the vastly varying needs of experimenters involving control of hetrogeniety in one or more directions, block size, number of replications, etc. have been evolved. For certain situations and problems, fairly efficient designs have been developed which provide estimates of parameters with high precision. However, most of the newly developed designs have not been adopted by the agricultural scientists who continue to use the conventional designs perhaps on grounds of simplicity of analysis procedures. A study undertaken recently at the IASRI on the basis of data of experiments collected from all over the country showed that more than 80% of the experiments were based on simple designs like C.R.D. and R.B.D. and about 15% on latin square and split plot designs. Designs like the BIBD which require much less experimental material were used in less then 1% of the experiments. This is one area of collaborative research in which the scientists of IASRI and agricultural scientists in other Institutes can undertake collaborative resea rch in the planning of experiments using improved and efficient designs The IASRI scientists can also undertake the experimental layout and data collection work as also their analysis by appropriate statistical procedures.

Sample survey techniques

Primary data collection is an important component of statistical research pertaining to applied aspects. This is all the more relevant in agriculture for which various types of statistics like acreage and production of crops, adoption of new agricultural technology, etc. have to be collected and updated on a regular basis. A number of methodologies have been developed at IASRI for collection of data for estimation of area and yield of crops, production of livestock products, marine fish catch, inland fishery resources and fish catch, area and production of fruits and vegetables, etc. These techniques are currently being used in different states in building up statistical data base for i mportant commodities. Some of the areas, however, need further research study like estimation of acreage and production of oilseeds and pulses and other important minor crops, perennial crops like arecanut, coconut, spices, etc. Collaborative research between the agricultural scientists dealing with these crops and agricultural statisticians at the IASRI and other Institutes would greatly help in identifying the factors limiting the production levels of these crops which have remained stagnant over the last two decades or so. This would require appropriately planned surveys of the areas important for these crops and data on various aspects like soil, crop varieties, practices, etc. would need to be collected for indepth analysis to bring about improvement in the productivity of these crops.

Estimation of damage to crops and livestock by natural calamities like flood, drought, pests and diseases attack, etc. is another crucial area where proper survey methodology is not yet available. While pest and disease attack may be controlled to some extent by use of chemicals. flood and drought may cause havoc overnight and it is important to obtain quick and reliable estimates of the losses in terms of crop production and other damage to land and property. Apart from the immediate loss to crop and livestock, there may be long term damage like soil erosion, water logging, etc. Inter-disciplinary approach of collaborative research programme by subject matter specialists in different fields would be essential not only to develop suitable statistical methodology to provide reliable estimates of loss/damage but also to suggest remedial measures to minimise the long term effects of such calamities.

Statistical research in animal genetics involves developing of stochastic models for various genetic parameters which are of interest in the study of quantitative and population genetics. Collaboration of statisticians with subject matter specialists in these areas is indispensable. Research in this area would involve planning and layout of experiments, collection of data and their analysis by appropriate procedures and statisticians should be associated in all these stages for a proper meaningful interpretation of results obtained. Similarly, for undertaking research in developing statistical models for isolating interaction between genotype and environment in plant and animal breeding, there is a great scope for collaborative research between statisticians and plant and animal breeders. A large body of data under the All India Coordinated Research Project on different crops and livestock are being collected in the ICAR system. Adoption of improved procedures and designs like partial diallel cross would greatly help in improving the information base for these experiments. The problem of deciding the optimum level of exotic inheritance for stabilising the breed also needs to be examined more carefully. All these aspects can be studied in depth by adopting inter-disciplinary approach of research covering relevant fields of statistics, agriculture, animal husbandry and allied areas.

Stochastic modelling and ecology

Another problem area that requires collaborative research effort is bio-metry, bio-assay and stochastic modelling. Environmental and ecological statistics has assumed greater importance in the recent past on account of the acute need felt for maintaining the ecological balance. This is particularly true in agriculture where apart from use of large amount of chemicals attempts are being made to bring additional land under cultivation by cutting down forests and resorting to shift in cropping pattern (from pasture to cropped area) which are highly detrimental to the ecological balance of the region. Management and control of pest and disease attack and epidemiological studies are the other related fields where agricultural statisticians and scientists in other disciplines can undertake a joint research programme with a view to formulation of appropriate procedures and recommendations.

Irrigation statistics

Serious discrepancies have been observed between the figures of area irrigated as available from land utilisation statistics and those from irrigation departments of the states. There is also considerable gap between irrigation potential created and utilised. The main factors for this gap are power shortage, untimely renovation of canals, irregular and disproportionate release of water in the canals, damage to irrigation structure, etc. Similarly, the assessement of impact of an irrigation project by way of increased area irrigated, higher productivity rate and improved economic status of the farmers in the command area merits and indepth study to find out how far the objectives and anticipations of the irrigation project have been realised. However, no suitable methodology has yet become available to determine the gains in terms of parameters mentioned above from the command area. Inter-disciplinary team of research scientists can obviously tackle these problems in proper scientific manner.

There are numerous other problems and areas of research which require attention of the agricultural scientists and research workers. Research in agricultural statistics is developing fast and new and improved methods and procedures are being developed in almost all its branches. Scientists engaged in research in other disciplines of agriculture need to be properly trained in the use of these latest techniques. Also, it is the responsibility of research statisticians not only to develop new methodology or to modify and refind the existing techniques but also to train and upgrade the knowledge and expertise of scientists engaged in research in agriculture and allied fields. This would also help in better understanding and rapport between the agricuitural statisticians and scientists in other branches of agriculture thereby facilitating the collaborative research ventures in a meaningful way.

Computer application in agriculture

This is a newly emerging field of research and is developing very fast on account of the wide and varied applications of computer in all branches of agriculture. The emphasis has so far been and preparing computer programmes for data processing or to get familiarity with the use of software package for solution of specific problems.

This approach would obviously narrow down the scope of use of computer to data processing and analysis by standard techniques without any involvement of the research scientists in the choice of alternatives. However, what needs to be emphasized is that we should develop the ability to understand and even manipulate the agro-biological system and mechanism that operates in different branches of agriculture. For instance, simulation techniques can be used with the help of computer for expeditious and efficient decision making process which otherwise would take much more time and may not be the best option available. Development of expert systems is another grey area which can help the farmers in choice of proper cropping system given the soil, climate and resource availability conditions. This is a challenging field and can be tackled only by a multi-disciplinary research efforts involving agricultural scientists, statisticians and computer experts.

Teaching of agricultural statistics and computer application in agriculture

Apart from teaching of courses leading to Master or Doctoral degrees called the formal courses, teaching of informal courses are also conducted in both the disciplines at IASRI. The latter are mainly inservice training courses designed to upgrade the knowledge and competence of scientists in different relevant fields of agricultural statistics or computer application in agriculture. Adhoc training programmes are also organised to cater the specific need of scientists in a particular discipline.

Formal degree courses leading to M. Sc. and Ph. D. degrees in agricultural statistics was started at IASRI in 1964 in collaboration with IARI. Similarly, formal degree course in computer application in agriculture at the M.Sc, level was started in 1985. The Institute also organised certificate and diploma courses till recently. However, with the establishment of agricultural universities in different states, it was thought that non-formal training courses should be conducted by these universities and accordingly these courses were discontinued at the Institute. It was, however, soon realised that this strategy was not practicable or workable since agricultural universities in a state would cater to the needs of agricultural scientists within the state. The main difficulties faced are firstly, the universities are not equipped with adequate facilities and trained manpower for organising the non-formal training courses and secondly, the number of agricultural scientists in a state interested in inservice training course is adequate for holding of the course every year. In case inservice training course is to be organised on adhoc basis, say once in 3-4 years, it would have to be organised by existing academic staff and this would become extra burden on the teaching programme of the universities. It has, therefore, been realised that non-formal courses like Senior Certificate Course and Professional Statisticians Certificate Course should be reintroduced and organised on a regular basis as was the case earlier. An important aspect of these courses is the opportunity that they provide for mutual discussion and exchange of views between agricultural statisticians working in different ICAR Institutes. It also services as a catalytic agent for cross fertilisation of ideas and often times in the process solutions become available to statisticians for their problems back at home. It may be mentioned in this context that the ICAR has been approached by the different state departments and ICAR Institutes and the matter is under active consideration of the Council.

There is, therefore, an urgent need to develop appropriate procedures for co-ordination and linkages between the scientists in IASRI and other Institutes for a meaningful and active programme of collaborative research for developing new methodologies as also for obtaining meaningful and reliable solutions to problems in agriculture. The teaching programme may also be reoriented to provide appropriate and analytical tools for meeting the needs of scentists and research workers in agriculture, animal husbandry and allied fields.

4.2 INSTRUCTIONAL STRATEGIES, CURRICULUM DEVELOPMENT AND EVALUATION-LINKAGE BETWEEN I C A R INSTITUTES AND AGRICULTURAL UNIVERSITIES

RANDHIR SINGH
Indian Agricultural Statistics Research Institute, New Delhi

1. Introduction

The important aspects of any successful training programme are establishing a procedure for continuous curriculum development and up date, an appropriate method for students evaluation and examination, to ensure full participation of the faculty and finally proper faculty evaluation programme. All these issues are interlinked for improving the class instructions and have to be always examined together. Any let up or lack of seriousness for any of these issues will result in weakening the whole training programme. The State Agriculture Universities and the ICAR Institutes have the responsibility of training personnal to man the research and teaching responsibilities in the field of agriculture research and education. Most of these Institutions have a common original character and pattern of education and evaluation system borrowed heavily from the land grant institutes of USA. All these Universities follow the course credit system of education and internal assessment and grading are the important evaluation proctices, However, there is still lot of variation even within the agricultural universities and ICAR institutes on several of these aspects. The present paper seeks to high light some of these issues in relation to the teaching and training programmes in the ICAR Institutes and the State Agricultural Universities.

2. Curriculum Development

For any Teaching and Evaluation System to be effective the most important component becomes the curriculum development. What is to be taught to the students and at what level? There is always a continuous need for updating the syllabi for different courses/topics keeping in view the rapid advanced in different fields of research. Each course topic has to have a very clearly defined goal and objective and there has to be a permanent watch and review committee to keep the syllabus up to date by deleting/modifying the obsolete topics and by adding the more recent and appropriate topics in the syllabus.

The description of the syllabus is quite important for facilitating what is to be taught and at what level and in what sequence. At IASRI and IARI we maintain two types of syllabus the one which is sort of permanent and printed and which gives the main topics and contents of the course. The second is an ellaborated version of the first one which is prepared by the Course Instructor to be given to the class in the beginning of the Session. This will also specify number of hours allotted for each topic and the sequences in which the topics are to be taught. (A course proforma at Annexure A describes the two types of syllabi for a course on Statistical Methods). Any efficiently designed and well described syllabus will form the foundation for better dissimination of knowledge and better evaluation.

A systematic approach to curriculum aims at improved design of learning situations and to specify the objectives of each course clearly to make the best use of time and resources. The course outline should be prepared clearly for stating the objective of the course. A well planned and structured teaching reduces greatly the stress of the teacher. The process of formulation of curriculum require that the curriculum contents are sub-divided into a number of units or instructions (courses). The objectives of the course should have direct link with the over all objective of the curricula. A clear statement of the objective will subsequently be helpful to both the teacher and the learner in the process of evaluation. A detailed discussion on the main issues associated with the syllabi of M.Sc. and Ph.D. courses in the discipline of Agricultural Statistics in the Agril. Universities as well as the ICAR Institutes like IARI/IASRI, IVRI and others were discussed at a National Workshop on Teaching/Training in Agricultural Statistics held at IASRI New Delhi during 19-20 Nov. 1985 which finalized a list of courses including Core Courses as well as electives.

3. Teaching Strategies

After finalising the detailed course outline the next important activity is to develop and finalise the teaching strategies. A teaching strategy includes teaching tools or methods to be used in teaching such as tutorials, team projects, simulations and interactive case studies. Teaching strategies also include the use of modern Audio-visual aids like the overhead-Projector, slide projector for providing more information in short period and the use of electronic calculation to the Personal Computers for condensing quickly information from a larger amount of data in a limited period with minimum costs. The adoption of the newer modern teacning strategies will extremely influence thė entire instructional system including the syllabi, as well as the evaluation methods.

4. Evaluation of students/Examination Systems

Students Evaluation/Examination is one of the most difficult and most discussed topic in the entire education system. There are different types of examination systems each one with its merits and demerits. Most important of these systems are the free response examination (written examinations and limited response, multiple choice generally called objective types examination). For any examination system one basic rule is to have a puropose of the examination clearly in mind to make a careful decision how best this objective can be achieved.

The Evaluation System in Agricultural Universities is perhaps wider in scope than the examination system in the other traditional universities. It signifies a comprehensive performance of students in learning behaviour habits and attitude of social responsibility and not merely what he knows of the subject matter. The Agricultural Universities are established mainly on the pattern of land grant colleges of the United States of America, starting in 1960 when the first agricultural university was established at Pant Nagar U.P. Most of the States have now their own Agricultural University, and thes universities have borrowed heavily the pattern of evaluation system for the Land Grant Institutions of USA. Most of these universities follow the course credit system of education irrespective of their having adopted trimester and semester. In these systems internal assessment and grading form an integral part of the evaluation. The internal evaluation system often advocated to be better than external evaluation has been routinely followed in agricultural universities However, the system has developed certain weak points over time, such that many times the entire contents of the courses are not covered because of the fact that students are examined only from portion covered in the class. There is also likelihood of difference in grading at different places, by different teachers for different courses. Many times the grades are awarded on humanitarian and sympathetic consideration rather then the competence of the students. Even in the grading system there is lot of variation from one Institute to the other in term of 3pt, 4pt, 5pt to 10pt grading system. Efforts were made at the Vice-Chancellors of Agril. Universities meet several years ago to find an optimum uniform grading system which can evaluate the performance of students at a more uniform level throughout the country But not much headway has been made in this line, though the 10 pt GPA being adopted at AP Agril. Universities is more likely an acceptable condidates. There is lot of scope of discussing the merits and demerits of systems of evaluation based on external and internal assessment. Adoption of the internal evaluation system was hoped to do away with some of the major disadvantage of the traditional annual examination system but after realising the many weeknesses of the system, many Institutions, Universities are opting out for external evaluation or a combination of internal and external evaluation systems.

5. Evaluation of Teachers

Basically the present education system in the country emphasises more on evaluating the learners and does not realise the importance of having a system of evaluation for the teachers as well. However, in recent times the evaluation of teachers is being discussed and talked a lot more then it was done earlier. There is always a scope for self evaluation and self improvement by a teacher. Such a system of self improvement adopted at IASRI/IARI requires each teacher to hand out a well prepared perfoma to the students at the end of each course. The students give their frank opinion about the teachers ability of dissimination to the students. The proforma are collected from the students without any identity of name of the students and the teachers himself examines proforma of the students and tries to improve his weak points. No Administration, Establishment action is involved. However, this evaluation system serves only limited purposes. However the Evaluation of the teachers by the Employer, Supervisor, outsideis or most importantly by the students for purpose of his assignment of courses trimesters etc. is debatable. Some Universities have adopted some kind of students ratings of teachers.

References

Proceedings of the National Workshop on Teaching/Training in Agril. Statistics and Computer Applications held during Nov, 19-20. 1985 at IASRI New Delhi.

Proceedings of Workshop on Evaluation and Testing in Instructional Systems held during Aug. 9-12, 1988 at NAARM, Hyderabad.

ANNEXURE—A

INDIAN AGRICULTURAL STATISTICS RESEARCH INSTITUTE
POST GRADUATE SCHOOL

Proforma for introduction of new coursee/revision of courses

1.	Name of discipline in which course is to be listed	: AGRICULTURAL STATISTICS
2.	Title of the course and Course No.	: Statistical Methods AS—161
3.	Course content	:

Moments and cumulants. Discrete probability distributions : Point distribution, Bernoulli, Uniform, binomial, Poisson, geometric, hypergeomatric, Negative binomial, Multinomial. Continuous probability distributions : Rectangular, exponential Cauchy, normal, gama, beta, weibull, lognormal logistic.

Association between attributes. Correlation and regression. Partial and multiple correlation and regression, correlation ratio. Analysis of categorical data, loglinear models.

4.	(a) Number of credits (Theory and Practical)	: 3L+1P
	(b) Number of theory lectures per week and duration	: 3
	(c) Number of practical Lectures per week and duration	: 1
5.	To be offered	: Trimester No. I Yearly
6.	Need for revising the course	: Some new topics have been included
7.	Relation to other course	:
	(a) Pre-requisite(s) if any	: AS-160
	(b) This course is to be a formal pre-requisite for course No.	: AS-162

(c) In your judgement, does this course overlap to a considerable extent, with any other course whether : No in your discipline or in another discipline. If so, please name the common topic and the course :

Topic	Course
(i)	(i)
(ii)	(ii)
(iii)	(iii)

Please indicate the reasons why overlapping is justified.

8. Would the introduction of this course necessitate any addition to the staff strength of the division concerned : No

9. (a) Name of the Course leader :
   (b) Name(s) of alternate course leader(s)

10. Topical outline of course separately for theory and practicals (give under major and minor heading the principal topics covered in this course together with the approximate number of class hours be devoted to each topic. Please be specific and inclusive).

Theory

S. No.	*Topic*	*Number of lectures*
1.	Moments and cumulants	2
2.	Point distribution	1
3,	Bernoulli and uniform distributions	2
4.	Binomial distribution	1
5.	Poission distribution	1
6.	Geometric and Hyper-Geometric	2
7,	Negative binomial distribution	2
8.	Multinomial distribution	1
9.	Rectanguler and Exponential distribution	1
10.	Cauchy distribution	1
11.	Beta and Gamma distribution	1
12.	Normal distribution	2
13.	Weibull distribution	1
14.	Longnormal, logistic	2
15.	Association between attributes	2
16.	Correlation and Regression	4
17.	Correlation ratio	1
18.	Analysis of categorial data	3
19.	Log-linear models	3
20.	Partial and Multiple Correlation and regression.	3

Practical

1.	Problems based on moments and cumulants	1
2.	Problems based on discrete distributions	2

3. Problems based on normal distribution 1
4. Association between attributes 2
5. Fitting of binomial poissi on and normal distributions. 2
6. Calculation of correlation and regression coefficients 2
7. Correlation ratio 1
8. Analysis of categorical data 1

11. List of reading and reference material required for the course :

(i) Fundamental of mathmatical statistics—S.C. Gupta and V.K. Kapoor
(ii) Discrete and continuous distributions Vol. I and II—Johnson and Kotz
(iii) Systems of frequency curves—Elderton and Johnson.
(iv) Elementary theory of mathematical statistics and its applications—G. Sankara Narayanan

12. Class room laboratory, equipment and other facilities required and whether they are available. Yes

13. Examination and weightage.

Type of examination	Number	Weightage to be given for final grading (in terms of %)
(a) Quizzes		10
(b) Mid-term		10
(c) Term paper/assignment		10
(d) Practical		20
(e) Final		50
(f) Other type of examination		—

14. Sequence of action required prepared by : Date :
Approved by the board of Studies : Date : /2/9/87
Approved by the Standing Committee on courses and curricula Date :
Approved by the Academic Council Date :

4.3 TAMIL NADU AGRICULTURAL UNIVERSITY AND ICAR INSTITUTES IN EDUCATION AND RESEARCH COLLABORATION

M. MURUGESAN

Tamil Nadu Agricultural University, Coimbatore

The need for achieving a substantial progress in Agricultural production after independence necessitated a complete change in the agricultural education in the country. Based on the recommendations of the First Education Commission (1949) headed by the late Dr. S. Radhakrishnan and the recommendations of the First and Second Indo-American Teams, the Government of India decided to establish Agricultural Universities in the country, and the first Agricultural University was set up in Uttar Pradesh in 1960. Agricultural education was given an impetus with the establishment of a Division of Agricultural Education in 1966 in the Indian Council of Agricultural Research (ICAR). The ICAR provided technical and financial support to the Agricultural Universities established in the states.

In the field of Agricultural Education the ICAR performs a role similar to that of University Grants Commission (UGC). Now there are 27 Agricultural Universities including the four deemed Universities, viz., Indian Agricultural Research Institute (IARI), New Delhi, Indian Veterinary Research Institute (IVRI), Izatnagar, National Dairy Research Institute (NDRI), Karnal and Central Institute of Fishery Education (CIFE), Bombay.

The State Agricultural Universities (SAUs) have the responsibility of the under graduate and Post-Graduate education in the respective States. Many Agricultural Universities have developed facilities and capabilities for offering Post-Graduate education in various fields of specialisation. Therefore there have been a view that ICAR Institutes should not be involved in educational programmes. It is a fact that many of the ICAR Institutes are well equiped with scientific equipments, research facilities and trained man power in areas of basic and applied research which is an ideal situation for Post-Graudate education and research As the ICAR Institutes may not take up full time educational activities, these institutes can have collaborative Post-Graduate educational programmes with the SAUs in their region.

TNAU and ICAR Institutes in Post-Graduate Programme

TNAU and the the Sugarcane Breeding Institute, Coimbatore are examples for inter institutional arrangement for Post-Garaduate education and research. A

Master's Degree programme in sugarcane production was started in TNAU in 1980 in collaboration with the Sugarcane Breeding Institute, Coimbatore. So far 52 scholars have combleted the M. Sc. (Sugarcane Production) programme. In this programme, part of the courses are offered by TNAU teachers and part by the scientists of Sugarcane Breeding Institute on specialised topics on sugarcane production The research work is carried out completely in the Sugarcane Breeing Institute. The advisory committee of the student consists of Scientists from both the institutions. This programme is being succesfully run since its introduction from 1980. This arrangement facilitated the teachers of Tamil Nadu Agricultural University to serve as chairman or member of the Post- Graduate Advisory committees for students from the Sugarcane Breeding Institute and vice versa.

Similarly facilities are also availed by the Scientists of Central Institute for Cotton Research Regional Station, Coimbatore in Post-Graduate degree programmes of the Tamil Nadu Agricultural Unversity.

Soil Conservation Research Centre, Ootacammund, Central Plantation Crops Research Institute, Kasargode are the other Institutions which are recognized as Post-Graduate research centres for their scientists to carry out reseach work leading to the Post-Graduate Degrees. It would be worthwhile to consider to start Post-Graduate Degree Programmes similar to the M.Sc. in Sugarcane Production degree programme of TNAU-SBI, Coimbatore in SAUs-ICAR Institutes which are in close proximity.

It is generally felt that many graduate and post-graduates in Agriculture and allied dieciplines have acquired their degrees from one University and are continu. ously employed in the same Univerity. This leade to a considerable degree of intellectual inbreeding. This aspect was felt by many participants in the Regional Seminar on Agricultural Education also which was held at Tamil Nadu Agricultural University, Coimbatore July, 3-4, 1989. Hence it is felt that the movement of scientists from one Institute to another Institute for education as well as research must be encouraged with liberal financial support from the ICAR.

In addition to inter-institutional Post-Graduate education and research programmes, it is also possible to have inter-institutional Research projects to avoid duplication of research work on the same aspect in SAUs and ICAR Institutes. Computers, sophisticated and costly scientific equipments and Library facilities available in Agricultural Universities and ICAR Institutes may be made availabe to students and scientists of these institutions freely for developing new methods and innovation. The research workers may be admitted to SAUs and complete their course work in SAUs and do their thesis research work in ICAR Institutes.

It is logical since both the organisations are involved in Agricultural Production technologies and strategies for improving them, collaborative programmes in both education and research fields will go a long way in improving Agricultural Production. To accomplish the above in practical reality, free and liberal exchange of Scientists from SAUs and ICAR Institutes is the only way. This will facilitate to achieve advances in areas of specialisation and encourage inter-institutional harmony. The ICAR may give liberal financial assistance to such scientists exchanged in between organisations.

4.4 RESEARCH AND TEACHING CO-ORDINATION AND LINKAGE BETWEEN ICAR INSTITUTES AND AGRICULTURAL UNIVERSITIES

UMED SINGH, L. S. KAUSHIK & LAJPAT RAI
Haryana Agricultural University, Hissar

An imminent need to bring about a rapid increase in agricultural production during the years succeeding independence necessitated a complete overhauling of the education system in the country including agricultural education. It was realised that the goal of increased production could be achieved only through the application of science and technology to agriculture and that an appropriately trained man-power is vital for development of science based agriculture and for promoting agricultural education in the country. To achieve this objective the Government of India based on the recomendations of first education commission (1949) headed by late Dr. S. Radhakrishan and the first and second Indo-American team, decided to establish agricultural universities in the country.

In a complex industry like that of agriculture involving more than three fourth of the working population of the nation, collection of reliable data and their clear statistical analysis would contribute more than anything else for faster success in the field. Though the role that the Science of Agricultural Statistics has played in planning for achievement of increased food production over the years deserves the gratitudes of the whole nation yet it also needs introspection regarding teaching and research co-ordination among statisticians of different institutions. With the multi-farious direction and increased tempo of research in various disciplines of agri-culture, the scope for application of statistical techniques has widened and the need for methodological investigations in collaboration with agricultural scientists has increased.

So far 26 agricultural universities have been established in the country and three institutes under the ICAR system, namely IARI, New Delhi, IVRI, Izatnagar and NDRI, Karnal have been conferred with the status of deemed universities. The agricultural universities in the country provide education facilities both at under-graduate and post-graduate level. At post-graduate level, the training is being imparted in more than 50 disciplines. In addition, there are 36 agricultural colleges affiliated to centrol and state universities.

Teaching Co-ordination

At present the State Agricultural Universities have the primary responsibility of under-graduate and post-graduate education in Agricultural Sciences in the concerned State and many have developed physical and technical facilities and capabilities for providing post-graduate education in various fields of specilization. As the standard of education differs from university to university due to variation in admission requirements course contents, evaluation methods, grading system, etc. So ICAR and Agricultural Universities should formulate guidelines for the course contents of various under-graduate and P. G. courses so as to maintain the uniformity in academic standards. Agricultural colleges affiliated to agricultural universities have somewhat better academic standards and interaction with ICAR and other Central Institutions but the Agricultural colleges affiliated to traditional universities need to improve their academic standards in comparison to agricultural universities and other ICAR institutions and also there is a need to strengthen the co-ordination of these colleges with the above mentioned institutions.

If we go through the courses formulated by various Agricultural Universities/ Institutes for their M.Sc. and Ph.D. programmes in Applied Statistics (more precisely Agricultural Statistics), we find considerable variation in courses. Even core courses are not common. In our opinion core courses for a programme in Applied Statistics are supposed to be universally common. There are M.Sc. (Stat.) programmes at several agricultural universities and these programmes do not include a full course in Applied Regression Analysis. If one surveys the programmes offered at U.S universities in Applied Statistics there would not be an exception where a course is not offered in Applied Regression Analysis. Likewise there are several courses which must find place in the programmes for Agricultural Statistics viz., Statistical Computing, Analysis of Multi-dimensional cross classified Data etc.

There is an urgent need to evaluate the degree programmes in Agricultural Statistics at various Agricultural Universities/Institutes. Efforts are required to be made to make these programmes uniform to some extent and core courses should be common for the programmes at Agricultural Universities/Institutes. Preferably we should prescribe the text books for these core courses to achieve uniformity in academic standards at all Agricultural Universities/Institutes. For this, there should be a standing committee constituted by the Director, IASRI to monitor the programmes in Agricultural Statistics. This committee should continuously evaluate after some regular intervals the programmes run by various Agricultural Universities/ Institutes. With the rapid advance in Science and Technology there is a need for continuous evaluation, upgradation and reorientation of the programmes in Agricultural Statistics. The proposed national committee constituted by the Director, IASRI should frequently up to date the programmes in Agricultural Statistics and this committee should also provide inputs for the service courses as well.

Not only the uniformity in course curriculum is required but the uniformity in evaluation method and grading system is also to be ensured. As evaluation and grading systems are integral part of education system and they are greatly varying in different Universities/Institutes so this aspect also needs immediate attention.

Research Co-ordination and Linkage between ICAR Institutes and Agricultural Universities

As present the Departments of Statistics and State Agricultural Universities are primarily entrusted with the teaching work for graduate and service courses. Regarding research it is mainly done by individuals in their personal capacity. There is no co-ordination and linkage between ICAR Institutes and Agricultural Universities so far as the discipline of Agricultutral Statistics is concerned. This linkage is very essential for many reasons of vital importance.

IASRI is conducting surveys in different parts of the country either directly or through State Government agencies without involving the agricultural universities. For the Scientists of IASRI, it is not possible to have the effective control and supervision over all remote places, so IASRI should entrust the supervisory work to state agricultural universities This is all the more necessary because state agricultural universities are more familiar with their local conditions and problems. Thus IASRI should develop some ICAR financed co-ordinated projects for carrying out research studies on statistical aspects of some problems related to agricultural disciplines in collaboration with statisticians in state agricultural universities. The development of any other such mechanism for affecting co-ordination between IASRI and agricultural universities is the need of the day.

Quality of Data collected through All India Co-ordinated Projects can be improved with the involvement of faculty and staff of the Departments of Statistics at state agricultural universities. Effective supervision through the involvements of Statistics persons at state agricultural universities will definitely improve the quality of data gathered by IASRI.

Huge volume of Data Sets have been collected under various projects run by IASRI and to our knowledge routine standard analysis have only been carried out. With the involvement of state universities complete exploration of data collected so far would be possible.

Many techniques have been invented in Design of Experiments and in Mating Designs in the recent past. These research findings have not been/adopted/applied in practice. With the close collaboration between State Agricultural Universities and IASRI it would be possible to test and practise these new developments in Agricultural Statistics Research through their applications in various fields. Also close collaboration between state universities and IASRI can be useful in identifying problems for investigation for local conditions peculiar to the states.

Information on various Natural Resources is very essential for all planning purposes. Data Banks need to be created for all natural resources at State Levels for proper planning and utilization of resources. This could be achieved if IASRI in collaboration with the Departments of Statistics at State Agricultural Universities identifies and plans such surveys. For this the Department of Statistics at state agricultural university need to be strengthened to share the additional responsibilities of collaboration in surveys to be conducted under the over all control of IASRI. Also the impact of the advances in Science and Technology need to be evaluated nation-wise through the collection of multi-dimensional count data through surveys jointly conducted by IASRI and the state agricultural universities.

Another way of achieving co-ordination and collaboration in agricultural research and teaching is by making the research students mobile as far as possible enabling them to move from one institution to the other and take advantage of the facilities, excellent guidance available in the different institutions. The collaborating institutions should recognise each other for research purposes. Eminent Scientists of other institutions may be adopted as Honorary or visiting Professors of the Institutions. The students may be encouraged and provided with adequate funds like TA/Fellowships etc. by the parent institution if they choose to work on research problems in other institutions which have attained excellence in that particular field of specialization

For the co-ordination of research efforts both at the post-graduate training level and at the institutional levels, it is necessary to know what the institutions are doing in that field of specialization. This can be helped by publishing at least at yearly intervals, if not at shorter intervals, titles of research projects assigned to the post-graduate students and other research scientists in other institutions. Such a publication will be useful in avoiding duplicating of efforts and will stimulate new ideas in the scientists of other institutions also.

Considerable importance should be given for exposing the Scientists to outside environments. The research workers should be provided frequent opportunities for attending seminars, symposia, workshops, conferences etc. Exchange of scientists from one institution to the other for a specific period for higher training should be very common. Persons for short training in specialised fields to acquire knowledge and skills in latest techniques be deputed to other institutes where such training facilities are available or experts be invited from such institutes for imparting training to persons of intending institutes. For close linkage between IASRI and the state agricultural universities deliberations in depth be conducted to identify research projects for each state to be undertaken jointly which will avoid both the wastage of time and money by ensuring better utilization of resources. This will also avoid the repetition and duplication of work. This co-ordination can be further strengthened if there are some mutual arrangements of representations of universities and institutes in the research bodies of the respective organisations. This will not only ensure the exchange of thoughts and ideas but would help in planning programmes on sound basis.

A modest beginning in this regard must be made without further loss of any time. In some sense it is sad to note that the linkage between IASRI and the Departments of Statistics at the State Agricultural Universities is all together missing. Linkage should have been established long back. Better late then never, let us make a modest beginning. It may not be irrelevant to purpose a committee to go in far more details on this aspect. Director, IASRI may constitute such a committee or may entrust this responsibility to a committee proposed for teaching co-ordination.

4.5 CO-ORDINATION AND LINKAGE BETWEEN ICAR INSTITUTES AND AGRICULTURAL UNIVERSITIES IN TEACHING AND RESEARCH

K.C. GEORGE

Kerala Agricultural University, Vellanikkara, Trichur

At present there are about 27 major Agricultural and allied subjects, research Institutes controlled by ICAR. These Institutions are distributed all over India, as per the needs of the locality. Out of these, four Institutions viz., IARI, New Delhi; NDRI, Karnal, IVRI, Izatnagar and CIFE, Bombay have the status of deemed Universities offering independent research programmes. The other ICAR Institutes are mainlv indulging in applied oriented research and its extension, as required by the locality and Nation, time to time. These Instiutes are, in general, specialised in various disciplines. For example, NDRI is specialised in dairy technology; IVRI is specialised in Animal Husbandry; CAZRI is specialised in research on Arid Zone; CTRL, specialised in cotton technology; IGFRI, specialised in grass and fodder research; IHRI, specialised in fruits and vegetables; JARI, specialised in Jute and other vegetable fibre crops; ILRI, specialised in lac research. CPCRI, specialised in plantation crops ; CPRI, specialised in Vegetables, especially in potato; CRRI, specialised in rice research; CSSRI, specialised in soil salinity research: IISR, specialised in sugarcane research; CTRI, specialised in tobbacco research; CTCRI, specialised in tuber crops other than potato; CMFRI, CIFRI, CIFT and CIFE specialised in marine and inland fisheries research and CSWRI, specialised in sheep and wool research. These specialisations are decided on the basis of the need and convenience of that particular Zone. These Institutes are doing a lot of fruitful research in their respective areas. A large number of renowned and reputed scientists are working in these Institutes.

In India, there are 26 Agricultural Universities at present. The main idea in the initial stage was to have an Agricultural University in each State. There are few States which are having more than one Agricultural University such as UP, MP, Maharastra and Karnataka. The main objective of these Agricultural Universities are to impart UG and PG programmes in Agriculture and allied subjects and also to conduct research in applied and basic aspects of Agriculture and allied subjects and its extension. Agricultural Universities are giving more emphasis on teaching side. A larger number of research projects of various nature have also been undertaken by these Universities. Many of these Universities have produced commendable results in the field of teaching, research and extension of Agricultural and allied disciplines. Many of these Institutions have well established names in the National and International level.

As these Agricultural Universities are mainly financed by the respective State Governments and the support from ICAR is only a minor share, the State Government will be always having a complete say about the administration, teaching, research and extension activities of the Agricultural Universities. Because of this, a lot of local politics used to dominate the decision making bodies of these Universities which in many cases adversely affect the ultimate goal of these Universities for which they were founded. This will also come in the way of its further development. Few of the Agricultural Universities are suffering due to this malady. This may also be the reason for the imbalance of the teaching, research and extension activities of the Agricultural Universities. Here, ICAR can have a major role to play for the uplift of the Agricultural Universities and for keeping a balance among all the Universities.

In my opinion, ICAR should always have a better say in the functioning of the Agricultural Universities and also should have a full collaboration with the State Government for implementing the teaching, research and extension activities of these Universities. Unless ICAR contributes significantly to the finance of Agricultural Universities this goal cannot be achieved. Hence, ICAR should act as an apex body for the coordination of all the Agricultural Universities of the Indian Union by providing reasonable finance and suitable guidance. I give below some of the useful recommendations which will lead to an amicable solution of the defects mentioned above.

Recommendations

(i) As Agricultural University and ICAR Institutions are formed with almost the same objectives of improving the economy of the farming lots, it is desired to have a collaborative approach in their research and extension activities. Very often ICAR Institutes will be having very good expertise and facilities in some specialised field related to the area in which the Institution is located, this facility the Agricultural University may be lacking, hence the need for collaboration.

(ii) As the Agricultural Universities and the ICAR Institutions are expected to do a lot of work in the field of Agricnlture and its allied fields, and has already done in this line, there is a need for continuous evaluation. This can be done by each University/ICAR Institute by establishing a cell with adequate strength needed for the purpose.

(iii) The ICAR should also strengthen the International and bilateral programmes with increasing involvement of Agricultural Universities.

(iv) Each Agricultural University and ICAR Institute should set up multidisciplinary committees to streamline research activities in certain major important and useful areas so as to cut across the departmental and faculty boundaries and bring together specialists from different branches to work on such topics of multidisciplinary nature.

(v) Teaching method seminars should be a regular feature in each Agricultural University. Besides, the ICAR Institutes should organise regional seminars on teaching methods and its evalution in the disciplines of Agriculture and its allied subjects.

(vi) Education, Research and Extension should enjoy equal priority in the Agricultural University.

(vii) Agricultural Universities should give priority for operational research on appropriate technology and for effective transfer of technology. The ICAR should support more and more of these projects.

(viii) The research evaluation models and processes may be worked out for the agricultural research system in totality and guide bank may be brought out.

(ix) The autonomy of the Agricultural University should be substantial enough to secure freedom to achieve the broad goals and objectives set up by its act and statutes.

(x) The State Government should provide a non-lapsable block grant for the Agricultural Universities after making a realistic assessment of the requirements of the funds for its efficient management.

(xi) ICAR should give adequate quantum of development grants keeping in view the stage of development of the University, the number of Campuses and colleges it has to maintain and its ability to absorb funds.

(xii) As the ICAR senior fellowships for Ph.D. degrees should be awarded to those students who plan to pursue their studies in Agricultural Universities other than the one from which they got Masters/Bachelors degree, ICAR should see that sufficient number of seats should be reserved in the different disciplines in each Agricultural University for students from other Agricultural Universities.

(xiii) In order to encourage the building up and strengthening of the various disciplines of the Agricultural Universities, the scientists may be encouraged to go from one University to another and while shifting from one University to another they may be given complete benefits of their previous services.

(xiv) The scale of pay and other benefits of the scientists of ICAR and Agricultural Universities must be uniform.

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PLENARY SESSION

July 21, 1989 (FRIDAY)

9.00 A.M. to 1.00 P.M.

Chairman : Sh. V.N. Amble, Bangalore

Rapporteurs : 1. Dr. J.P. Jain, IASRI, New Delhi

2. Sh. S Shanmaga Sundram, SBI, Coimbatore

PLENARY SESSION

At the outset, Chairman complimented the speakers for highlighting the research activities in different disciplines of statistics during the past two days' deliberations of the Conference. He then requested Dr. J.P. Jain to give a resume of the action taken on the recommendations of the 8th National Conference of Agricultural Research Statisticians held at CAZRI, Jodhpur from July 29 to 31, 1986. Dr. J.P. Jain briefed the Group that in all there were fifteen recommendations requiring action including four recommendations carried from previous Conferences. Of these, action on two-thirds (i.e. ten recommendations) had either been completed, partially completed or already initiated, while action on three recommendations would be taken up during the VIII Plan and on the remaining as and when funds become available. Annexure I is a detailed statement showing the action taken on the recommendations by the concerned Institutes/Universities and departments. Thereafter the Chairman highlighted some of the areas identified by various speakers meriting attention of the scientists in the next decade. He then, requested the Rapporteurs of various sessions to present their reports which inter-alia included recommendations emerging from the respective sessions. After prolonged deliberations the recommendations finally emerged are as follows :

A. Agricultural Statistics

(*i*) *Crop Sciences and Agro-Forestry*

1. Development of methodologies of crop forecasting and estimation of crop acreage and yield using remote sensed data for both micro and macro level planning.
   (Action : I.A.S.R.I.)
2. Development of survey sampling methodologies for estimation of acreage and production for areas under multiple cropping systems, tuber crops (other than potato), condiments, spices and other important minor crops.
   (Action : I.A.S.R.I., C.P.C.R.I. and C.T.C.R.I.)
3. Development of appropriate statistical methodologies in relation to design and estimation problems in dryland agriculture and water management.
   (Action : I.A.S.R.I & CRIDA)

4. Determination of the extent of bias due to respondents, enumerators, call backs etc. in agricultural sample surveys.
(Action : I A.S.R.I.)

5. Cataloguing of designs of various types including the new series being developed, for promoting the use of efficient designs, jointly by IASRI and SAUs.
(Action : I.A.S.R.I & SAUs)

6. Development of soil test-crop response models for judicious use of fertilizers.
(Action : I.A S.R.I., CRIDA & SAUs)

7. Initiation of an AICRP in Statistics for developing statistical procedures for analysis of data from mixed and inter-cropping experiments; studies on the size and shape of plots for experimentation with different crops including agro-forestry and intercropping.
(Action : I.A.S.R I., CRIDA, ICAR & SAUs)

8. Development of suitable statistical models for stability analysis for dryland crops research.
(Action : I.A.S.R.I. & CRIDA)

9. Development of suitable experimental designs and methods of analysis for agro-forestry experiments.
(Action : I.A.S.R.I. & CRIDA)

10. Development of suitable statistical methodologies using density estimation for determining appropriate premium rates for crop and livestock insurance.
(Action : I.A.S R.I. & SAUs)

11. Development of a more refined technique for estimation of crop losses due to pests and diseases particularly soil borne diseases.
(Action : I.A.S.R.I. & SAUs)

12. Development of survey sampling methodology for estimation of area and production of field crops in hilly areas.
(Action : I.A.S.R.I.)

(*ii*) *Animal Sciences & Fisheries*

13. Development of mixed model theory to handle the following situations
   (i) when there is certain relationship among the random effects (e.g. sires may be related);
   (ii) when in a multi-trait analysis, the observations are correlated and also when some traits are continuous and some are of categorical nature;

(iii) estimation of parameters free from selection effects; and

(iv) when in multi-trait BLUP model, the traits are non-linearly related and also when some traits are subject to inequality constraints. (Action : All ICAR Institutes and SAUs)

14. Evaluation of various selection strategies involving MOET technology to find optimum strategy.
(Action : All ICAR Institutes and SAUs)

15. Development of appropriate methodologies in the area of 'Surveillance of important animal diseases' for adjustment for time lag in case reporting; imputatiin of non-observations, detection of changes in patterns of occurrence in the incidence of disease, description of disease trends over time, identifying abberations in the occurrence of disease and for assessing the impact of health programmes.
(Action : All ICAR Institutes and SAUs)

16. Study of the response to selection in finite populations and the effect of linkage on homozygosity of a population under various in breeding systems through simulation approach.
(Action : I.S.A.R.I.)

17. Development of improved techniques for small area estimation, analysis of categorical data and for imputation of incomplete data in the field of survey sampling as applied to livestock sector. For small area estimation a combination of data from sampled respondents and supervisory survey checks may be used.
(Action : I.A.S.R.I.)

18. Development of more realistic deterministic and stochastic fish population models by incorporating various aspects such as time delays, age-structure, etc.
(Action : I.A.S.R I.)

19. Investigations into the sampling techniques for determining area & production of fodder and grasses in hilly tracts.
(Action : I.A.S.R.I.)

20. Development of sampling technique for estimation of total inland fish catch based on data from actual weighment and by enquiry.
(Action : I.A.S R.I.)

21. Definition and estimation of area under wasteland and its utilization.
(Action : I A.S.R.I.)

22.* Development of Methodology for estimation of optimum stocking rate of animals for the rangelands of Western Rajasthan.
(Action : N.D.R.I. and C A.Z.R.I.)

B. Computer Applications in Agriculture

1. Providing appropriate and adequate computing facilities including micro and personal computers, printers, graphics, etc. in various ICAR Institutes and Agricultural Universities. These may be suitably networked by creating a KRISHINET. This network would have a nodal organisation like the IASRI to serve as central storage and dissemination body where a large powerful mainframe computer system may be provided. For ensuring uniformity and compatibility among these computer units, a Coordination Committee of experts in different areas may be constituted.
(Action : IASRI and other ICAR Institutes & SAUs)

2. Development of programs and software packages for statistical applications in various areas of agricultural research. A newsletter for exchange of programs and other developments may be brought out periodically.
(Action : IASRI and other ICAR Institutes & SAUs)

3. Development of Expert Systems in different fields of agriculture and agricultural statistics. A begining may be made with expert systems in the areas of pest and disease surveillance, crop forecasting and choice of cropping system including fertiliser use.
(Action : IASRI)

4. Development of appropriate databases as part of information technology for improved farm production.
(Action : ICAR Institutes and SASUs)

5. Modelling and simulation techniques using computers. Training courses may be organised by IASRI in these and other areas of computer application.
(Action : IASRI and other ICAR Institutes and SAUs)

6. Planning and conduct of suitable training programmes in the new programming languages, particularly, for use on PC's/Micros.
(Action : IASRI)

7. Convening of periodical meetings, workshops, etc. of agricultural scientists, research statisticians, and computer professionals for exchanging of ideas and knowledge on the latest state-of-the-art in different fields and encouraging active collaboration among scientists.
(Action : IASRI and other ICAR Institutes and SAUs)

C. Research and Teaching-Coordination and Linkages

1. A senior level position of the rank of DDG (Statistics) may be created at the ICAR Headquarters for effective coordination amongst statisticians in various ICAR Institutes and Agricultural Universities.
(Action : ICAR and IASRI)

2. In view of the increasing importance of methematics and computer science in most disciplines there should be adequate number of courses in these areas at the undergraduate level. Attempts to scale down the importance of these courses should be discouraged.
(Action : ICAR and SAUs)

3. It was learnt that some committees had recommended reduction in the number of Statistics courses for agricultural students at under-graduate level. In view of the importance of statistics in agricultural research, it was emphasised that teaching of statistics to agricultural students should be further strengthened in the various Agricultural Universities.
(Action : SAUs)

4. To bridge the gap of communication between the Agricultural Statisticians and Animal Sciences & Fishery Scientists, short-term training courses in agriculture and animal sciences including fisheries may be planned and organised for statisticians in ICAR Instiutes and Agricultural Universities.
(Action : ICAR Institutes and SAUs)

5. In-service training courses in statistics offered earlier at IASRI for the benefit of scientists in other disciplines of agriculture may be revived immediately.
(Action : ICAR & IASRI)

6. A National Standing Committee should be set up for bringing about uniformity in eligibility requirement, curriculum development, teaching strategies, etc. in both the disciplines of agricultural statistics and computer applications in agriculture.
(Action : IASRI, ICAR & SAUs)

7. A Research Direction Committee should be constituted to encourage collaboration and coordinate research between State Agricultural Universities and ICAR Institutes.
(Action : ICAR and IASRI, ICAR Institutes & SAUs)

8. All Indla Coordinated Research Projects dealing with important research aspects in agricultural statistics should be initiated.
(Action : IASRI, ICAR Institutes and SAUs)

9. Statisticians in ICAR Coordinated Research Projects should be encouraged to take up research projects in statistics.
(Ation : IASRI and other ICAR Institutes)

10. Students majoring in statistics should be actively involved in statistical consultancy work for equipping them with sound background in application of statistical techniques to real life problems in agriculture.
(Action : IASRI & other ICAR Institutes and SAUs)

11. Exchange of research scientists and teachers in statistics and computer sciences amongst different Agricultural Universities and ICAR Institutes may be encouraged.
(Action : ICAR Institutes and SAUs)

12*. To meet the emerging research challenges in agricultural statistics and computer applications departments of statistics in Agricultural Universities/ ICAR Institutes should be adequately strengthened and such departments created if not already existing.
(Action : All ICAR Institutes and SAUs)

13. In some ICAR institutes and SAUs, statisticians are scattered in different departments and Coordinated Projects. They should be brought under one umbrella and their participation in research, teaching and extension activities should be encouraged.
(Action : All ICAR Institutes and SAUs)

14. Summer Institutes/Schools in advanced statistical methods may be organised at IASRI and SAUs in specialized areas.
(Action : ICAR, IASRI and SAUs)

15. Statisticians should be associated in all aspects of planning, implementation analysis & interpretation of data in the various coordinated research projects and projects funded under NARP involving large amount of data.
(Action : ICAR Institutes)

16. For healthy growth of statistics, this discipline should function as an independent Unit and may be delinked from any other faculty wherever such arrangements exist presently.
(Action : ICAR & ICAR Institutes)

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*Recommendations made at earlier Conferences.

ANNEXURE—I

ACTION TAKEN ON THE RECOMMENDATIONS MADE DURING THE 8TH NATIONAL CONFERENCE OF AGRICULTURAL RESEARCH STATISTICIANS HELD AT CENTRAL ARID ZONE RESEARCH INSTITUTE, JODHPUR FROM JULY 29-31-1986

R 1. Development of Survey Sampling Methodology for Estimation of Area and Production in Field Crops in Hilly Areas

(Action : IASRI, ICAR Research Complex, Shillong)

IASRI, New Delhi

Before taking up such studies during the 8th Five Year Plan period the possibility of taking up this study in collaboration with ICAR Research Complex, Shillong and other state agencies is being explored.

R 2. Development of Survey Sampling Methodology for Estimation of Area and Production of Several Crops Grown in the Same Field

(Action : IASRI; IIHR; ICAR Research Complex, Shillong)

IIHR, Bangalore

Reported to have finalised estimation techniques for number of fruits (Mango, Mandarins, Sapota and Guava), vegetables (Brinjal and Tomato) and ornamental crops (Jasmine). The study with respect to Banana and sweet oranges is under way.

NDUA & T, Faizabad

The university will be taking the study as an ad-hoc research scheme in due course of time.

HAU, Hisar

Action is being taken to initiate study.

IASRI, New Delhi

Such studies are being proposed during 8th Five Year Plan.

R 3. Development of Survey Sampling Methodology with Imprfect and Overlaping Frames

(Action : IASRI)

IASRI, New Delhi

A project on survey sampling methodology for imperfect frames is likely to be completed shortly. Another study regarding overlapping frames is proposed to be taken up during the VIII Plan.

R 4. Development of Survey Sampling Methodology for Evaluation of Comparative Efficiency of Different Irrigation Systems in Canal Command Area

(Action : IASRI)

IASRI, New Delhi

A committee to suggest suitable survey design for determining yield of crops under irrigated and unirrigated conditions in a command area has been constituted in the Ministry of Agriculture to look into the various methodological problems involved. A pilot study for estimation of yield of paddy and groundnut crops has been undertaken in the command area of Lower Bhavani Canal in Periyar district of Tamil Nadu. Similar studies are planned in the command areas of Gandak Canal in U.P. and Nagar junsagar Left Bank Canal in Andhra Pradesh. The Dte. of Economics & Statistics, has coordinated the work of these studies. Technical advice and guidance on survey design and statistical aspects are being provided by the Institute.

NDUA & T, Faizabad

Proposed to develop statistical methodology for evaluation of comparative efficiency of irrigation system in command area.

R 5. Development of the Exact Test Based on LER Distribution

(Action : IASRI, CRI for Dryland Agriculture)

CRIDA, Hyderabad

Examined several sets of inter-cropping data emanating from the coordinated project of dryland agriculture. In nearly 90% of the cases the bias of LER was significant. The H-Statistic (C.R. Rao) provides a valid test for comparison of LERs whenever there is a significant bias. Hence, there is no need for developing an exact test based on the distribution of LER. In this connection, the confidence intervals for LER are also given by Jaganath and Sundararaja using Bonferroni's technique in their paper published in Vol. 39(3) 1989 of J. of Indian Society of Agricultural Statistics, Pages 289-300.

IASRI, New Delhi

This aspect has been studied at length and the test based on LER distribution has heen worked out.

R 6. Development of Statistical Methodology for Determining and Optimal Plot Size for Inter-Cropping and Agro-Forestry Experiments

(Action : IASRI. CRI for Dryland Agriculture)

CRIDA, Hyderabad

Worked out the methodology based on bi-variate analysis and a paper on the subject was communicated for publication.

NDUA & T, Faizabad

Would be conducting uniformity trial for determining the optimum plot size for inter-cropping and agro-forestry experiments.

IASRI, New Delhi

Study is in progress based on the data generated in the All India Coordinated Research Project on Agro-Forestry.

R 7. Development of Survey Sampling Methodology for Estimating Stock Rate of Animals at a given time Through time Series Data in Grazing Land and Utilization of Remote Sensing Data for Adjustment of Stocking Rate

(Action : IASRI, CAZRI)

CAZRI, Jodhpur

Remote sensing data pertaining to forage production of grazing land is yet to be made available for Remote Sensing Agency stationed in the CAZRI premises. The stocking rate of animals in the region would be worked out as and when the data from the Agency becomes available.

IASRI, New Delhi

No action could be taken up as this Institute does not have facilities for utilisation and interpretation of remotly sensed data. As and when facilities become available a study would be taken up.

Remarks : The problem is of topical interest and there is a need for developing optimum grazing system for the rangelands of Western Rajasthan. In this context the recommendation regarding developing of survey sampling methodology for estimating stocking rate of animals seems to have been made without looking into the ramificatioas involved in it. A literature search on the subject revealed that this study calls for conducting experiments under controlled conditions (Campbell, K.A.G. 1966—J. agric. Sci. Camb. 67 : 119-216) are not developing of survey sampling methodology. In view of this, CAZRI, Jodhpur may undertake such experimentation, possibly in close collaboration with NDRI, Karnal

R 8. Development of Survey Sampling Methodology for Animal Disease Surveilance.

(Action : IASRI, CARI, CSWRI, CGRI)

CSWRI, Avikanagar

For exploring the possibility of having a collaborative research project with CSWRI a Scientist of IASRI visited CSWRI in 1987. As per the discussion he had an outline of the research project was supplied to them but with no further response.

IASRI, New Delhi

A study on this subject was taken up in association with HAU, Hissar. Its report is likely to become available shortly. However, a few more studies are required in order to develop suitable sampling methodology for the purpose.

R 9. Development of Survey Sampling Methodology for Effectiveness of AI under Field Conditions

(Action : IASRI, NDRI, IVRI)

NDRI, Karnal

The questionnaire and the technical program are being finalised in consulation with IASRI.

R 10. Development of a Comprehensive Data Base at IASRI with the help of the Computer

(Action : IASRI)

IASRI, New Delhi

The Computer System at the Institute does not have adequate data base management software. The development of comprehensive data base will have to wait instalation of new computer system for which action has already been initiated.

R 11. Development of Statistical Methodology for Measurement and Quantification of Qualitative characters in Social Sciences

(Action : IASRI and ICAR Institutes)

Other ICAR Institutes

A few Institutes (CMFRI, VPKAS, NBSS & LUP, CITRI) responded with the remarks that they will be taking up this investigation as and when confronted within there regular research investigation or when resources become available to undertake this study.

IASRI, New Delhi

No action has been taken so far. However, it is proposed to undertake a study for developing indices of agricultural development during the 8th Five Year Plan.

R 12.* Formulation of coordinated Project for Assessing the Benefits of crossbreeding Programmes in Important Tracts in the country

(Action : IASRI and ICAR)

IASRI, New Delhi

Action will be taken up in due course of time.

R 13.* Holding a Summer School or Seminar of 2-Weeks on "Quantitative Methodology in Inland Fisheries Research".

(Action : IASRI and CIFRI)

CIFRI, Barrackpore

As per the recommedation a summer school has been conducted.

R 14.* Study on Straw to Grain Ratio for crops other than Paddy, Wheat, Jowar and Bajra also

(Action : IASRI, Agricultural Universities and State Departments of Agriculture)

PKV, Akola

PKV, Akola has completed this study in respect of groundnut, sunflower linseed, tur and mung.

NDUA & T Faizabad

NDUA & T would be taking up this study for different crops.

IASRI, New Delhi

Action is being taken to initiate study on straw to grain ratio for major pulse and oilseed crops based on experimental data gathered under ICAR All India Coordinate d Agronomic Research Project.

R 15.* Development of Statistical Methodology for Supply and Demand Projection with Reference to Livestock Products was Reiterated Taking into Account Studies Already made by Various Organisations for the Purpose

(Action : IASRI)

IASRI, New Delhi

Development of suitable methodology for supply projections with respect to foodgrain crops has already done. The work with respect to livestock products will be taken up.

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*Recommendations made at earlier conferences.

ANNEXURE—II

NINTH NATIONAL CONFERENCE OF AGRICULTURAL RESEARCH STATISTICIANS

T.N.A.U., Coimbatore

List of Participants

Andhra Pradesh

1. Ramanatha Chetty, C.K., Principal Scientist (Agril. Stat.), CRI for dryland Agriculture, Santosh Nagar, P.O. Saidabad, Hyderabad-500659 (AP)
2. Subba Rao, D.V., Scientist S-2 (Ag. Stat.), C.T.R.I., Rajahmundry-533105
3. Balakrishnan, R., Scientist (SG), Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500030

Gujarat

4. Patel, N.M., Prof. of Agril. Stat., B.A. College of Agriculture, GAU, Annand Campus, Anand-388110
5. Dixit, S.K., Statistician, Gujarat Agril. University, Junagarh

Haryana

6. Singh, Umed, Prof. and Head, Deptt. of Maths. and Stat., HAU, Hissar-125004
7. Singh, Bhupal, Scientist S-3, Div. of Dairy Economics, Statistics and Management, N.D.R.I., Karnal-132001
8. Katyal, Vijay, Scientist S-2, (Ag. Stat.), Central Soil Salinity Research Instt., Karnal-132001 (Haryana).

Himachal Pradesh

9. Kaistha, B.L., Associate Prof. (Statistics), H.P.K.V.V., Palampur-176062
10. Mahajan. P.K., Asstt. Prof. (Statistics), University of Horticulture and Forestry, Solan-173230 (HP)

Karnataka

11. Sundararaj, N., Director of Instruction (BSH), Head of Deptt. of Stat., College of Basic Science and Humanities, GKVK, Bangalore-560024
12. Seenappa, K., Junior Statistician, Project Coordinating Unit (Sunflower), UAS. GKVK, Bangalore-560065
13. Bhagavan, S., Scientist S-2, NDRI (ICAR), Adugodi, Bangalore-560030

14. Ramachander, P.R., Principal Scientist (Statistics), Div. of Eco. & Stat, IIHR, Hessaraghatta Lake Post, Bangalore-560089

15. Rajasekhar, M., Project Coordinator (AICRP on Disease) Monitoring and Surveillance, Institute of Animal Health and Vet. Biologicals, Hebbal, Bangalore-560024

16. Amble, V.N., 391, Cross 42, Block 5, Jayanagar, Bangalore-560041

17. Mukunda, P., Bio-Statistician, Institute of Animal Health and Vety. Biological, Behhal Bangalore-560024

18. Siddappa, L., Associate Professor of Stat. UAS, Dharwad, Karnataka

Kerala

19. George, K.C., Prof. and Head, Deptt. of Stat., Kerala Agricultural University, Mannuthy, Trichur (Kerala)

20. Mathew, Jacob, Principal Scientist, Central Plantation Crop Research Instt., Kesargod-670124 (Kerala)

21. Abraham, Jose,

Scientist S-2 (Agril. Stat.), National Research Centre for Spices, P.B. No. 1701, Marikunnu, P.O., Calicut-673012 (Kerala)

22. Lakshmi, K.R., Scientist, C.T.C.R.I., Sreekariyam, Trivandrum-695017 (Kerala)

Madhya Pradesh

23. Ali, M.A., Head/Officer-in-charge, Deptt. of Statistics and Maths., Indra Gandhi Krishi Vishwa Vidyalaya, Krishak Nagar, Raipur-492012

Maharashtra

24. Nimbalkar, C.A., Statistician, All India Coordinated Pearal Millet, Improvement Project, College of Agriculture Campus, Pune-411005 (MS)

25. Mahajan, S.V., Prof. of Stat., PGI, MPAU, Rahuri, Pin-413722 (MS)

26. Sapate, B.G., Assoc. Prof. of Statistics, Department of Agricultural Economics, Punjabrao Krishi Vidyapeeth, Krishinagar, Akola-444104

New Delhi

27. Narain, Prem, Director, IASRI, New Delhi-110012

28. Raheja, S.K., Joint Director, IASRI, New Delhi

29. Kathuria, O.P., Principal Scientist, IASRI, New Delhi

30. Jain, J.P., Principal Scientist, IASRI, New Delhi

31. Bhargava, P.N., Principal Scientist, IASRI, New Delhi

32. Singh, H.P., Principal Scientist, IASRI, New Delhi

33. Prajneshu, Principal Scientist, IASRI, New Delhi

34. Rai, S.C., Principal Scientist, IASRI, New Delhi

35. Singh, Randhir,
Principal Scientist,
IASRI, New Delhi

36. Jain, T. B , Scientist (SG),
IASRI, New Delhi

37. Doshi, S. P., Scientist (SG),
IASRI, New Delhi

38. Aneja, D.S., Scientist
IASRI, New Delhi

39. Tomer, O.P.S.
IARI, Scientist
New Delhi

Orissa

40. Mohanty, S., Prof. and Head,
Deptt. of Stat, OUAT,
Bhubaneswar-751003

41. Rawle, S., Principal Scientist,
O-I-C, Statistics Sect., CRRI,
Cuttack-753006, (Orissa)

Rajasthan

42. Gupta, B.S., Scientist (SG),
Central Arid Zone Research
Institute, Jodhpur-342003

43. Agrawal, B.L.
Assoc Professor (Stat.),
Rajasthan Agricultural
University, Karni Road,
Sriganagar-335001.

Tamil Nadu

44. Jayaraj, S., Vice Chancellor,
TNAU, Coimbatore.

45. Balasubramanian, A.,
Associate Professor
(Agronomy), TNAU, Coimbatore

46. Palaniappan, S.P., Dean,
T.N.A.U., Agricultural College and
Research Institute.
Coimbatore-641003

47. Murugesan, M.,
Prof. of Agrl. Stat., T.N.A.U.,
Coimbatore-641003

48. Suyambulingam, C.,
Prof. of Mathematics, TNAU,
Coimbatore-641003

49. Gopalakrishnan, V.,
Associate Prof. of Agril. Statistics,
TNAU, Coimbatore-641003

50. Ayyaswamy, M.K.,
Assoc. Prof. of Agril. Statistics,
TNAU, Coimbatore-641003

51. Dhamu, K.P.,
Asstt. Prof. of Agril. Statistics,
TNAU, Coimbatore-641003

52. Ratnan Nadar, C.,
Asstt. Prof. of Agril. Statistics,
College of Agril. Engineering,
TNAU, Coimbatore

53. Kailasam, C , Asstt. Prof. (Maths),
(ID), O/O Deam (PGS),
TNAU, Coimbatore

54. Suresh, M.,
Asstt. Prof. (Stat), Computer
Centre, TNAU, Coimbatore

55. Rangaswamy, R.,
Assoc. Prof. of Agril. Statistics,
Agril. College and Res.
Institute, Madurai,
Pin-625104 (TN)

56 Ram Kumar, P. K.,
Asstt. Prof. (Stat.),
Fisheries College
Tuticorin-628008 (VOC Distt.)
(T.N.)

57. Sankaranaryanan, M.,
TNAU, Coimbatore

58. Sundaram, S.S.
SBI, Coimbatore

59. Hanumantha, Rao, H.K.,
Scientist (Selection Grade)
Agri. Stat., CICR, Reg. Station,
Coimbatore-641003

60. Vankatesan, R.
Prof. and Head, Deptt. of Animal
Husbandry Statistics, Madras
Veterinary College, Vepery
Madras-600007 (TN)

61. Mani V., Assoc. Prof. (Stat.) (ID),
O/O Dean,
(PGS), TNAU, Coimbatore

62. Ranganathan, C.R.,
Associate Professor (Maths)
AC and RI, TNAU, Coimbatore

63. Sreerangaswamy, S.R.,
Director, School of Genetics,
TNAU, Coimbatore

64. Krishnamurthy, Meera,
Asstt. Professor (Maths)
AC and RI, TNAU, Coimbatore

65. Naidu, Mohan, Director,
SBI, Coimbatore

66. Mathew, W.T.,,
Technical Assistant,
TNAU, Coimbatore

67. Salvaraj, Laxmi Devi,
Asstt. Prof. (Maths)
AC and RI, TNAU, Coimbatore

Uttar Pradesh

68. Singh, S. P.,
Scientist S-1 (Stat.),
National Bureau of Fish
Genetics Resources,
2 Bagambari Housing Scheme,
Shivanagar, Allahpur,
Allahabad-211006

69. Chandra, Rakesh,
Scientist S-1 (Stat.)
General Institute of Horticulture
for Northern Plains, B-117, Indra
Nagar, P.O. Ram Sagar,
Mishra Nagar, Lucknow-226016

70. Garg, R C.,
Principal Scientist and Incharge,
Computer Centre, Project
Directorate on Cattle (ICAR),
G-123, Shastri Nagar,
Meerut-250005 (UP)

71. Dube, L. K.,
Asstt. Prof. (Stat.),
NDUA and T. P.O. Kumarganj,
Faizabad, Pin-224229 (UP)

72. Biswas, P.G.
Prof. of Statistics,
College of Basic Sciences
and Humanities, GB Pant
University of Agriculture
and Tech., Pantnagr-263145
(Distt. Nainital)

West Bengal

73. Sasmal, B. C, Head,
Deptt. of Agril, Stat.,
Jute Agricultural Research
Institute, 24, Paraganas,
Barrackpore-743101

74. Chattaraj, J., Scientist,
Incharge of Statistical Unit
Eastern Regional Station,
NDRI, Kalyani-741235 (WE)