SYMPOSIUM ON TEACHING OF MATHEMATICS AND STATISTICS IN AGRICULTURAL UNIVERSITIES AND COLLEGES

A symposium on "Teaching of Mathematics and Statistics in Agricultural Universities and Colleges was held on 12th February, 1968 during the 21st Annual Conference of the Society at Lucknow. Dr G. R. Seth, Statistical Adviser, Institute of Agricultural Research Statistics (I.C.A.R.), New Delhi presided over the symposium. Extended summaries of the views expressed by the speakers who participated in the symposium are given in what follows :

M. N. DAS[1] : *Requirements of teaching of Statistics in Agricultural Universities and Colleges*

Teaching of Statistics and Mathematics was till recently confined to the campus of Universities and a few Institutions like the Indian Statistical Institute and the Institute of Agricultural Research Statistics. Recently with the establishment of a number of Agricultural Universities in the country, the scope of teaching of the subjects has considerably increased. These Universities have provided an opportunity to study and also to teach the subjects in association with the fields of their application. As only such collaboration can lead to successful uses of statistical techniques, these Universities have the potential of developing the subjects and their application more fruitfully.

The importance of introducing adequate knowledge of statistics as an ancillary subject in the curriculum of students specialising in other fields cannot be undermined. For deriving full benefit from the subject, the agricultural or animal husbandry specialist working in any field should be his own statistician as far as practicable. When he feels the necessity of consulting a professional statistician he should be able to put his problem properly and examine the results critically. Although the professional statistician should also have some working knowledge in the field of application cooperation between the two can be successful when the agricultural scientist appreciates the approach and learns something of Statistical Methodology.

1. Institute of Agricultural Research Statistics (I.C.A.R.), New Delhi.

As almost every agricultural research worker has to use statistical techniques at some stage or other, it is very necessary that each such student must have some familiarity with statistical ideas and the common methods. They have to be equipped with the knowledge that they deal with variates subject to uncertainties and inaccuracies. Whatever finding they make, need not be taken as exact as in the field of physics, but is only indicative of what might happen in similar situations by virtue of so many uncertain factors operating on them. How infrequently we hear the phrase "on an average" in talking about agricultural performance; on the contrary an idea that the figures quoted will repeat exactly in future is attempted to be conveyed. The Agricultural Universities can do a lot to remove such notion and stimulate among students a type of statistical thinking and talking, in so far as agricultural findings are concerned.

The subject of Statistics and Mathematics should be taught in Agricultural Universities more as an ancillary subject for agricultural scientists than for its own sake. This does not mean that only elementary topics of the subject should be taught in these institutions. Research in diverse fields of agricultural and animal husbandry often needs advanced knowledge of statistics and mathematics. Often-times they call for development of new statistical methodology. Even though the agricultural scientist himself may not be able to tackle the problem in such situations, he must be able to appreciate that there is a real statistical problem and not simply proceed mechanically with whatever knowledge is existing with him. All these call for a fairly advanced knowledge of statistics on the part of agricultural scientists and not merely the concepts, and the syllabus of statistics has to be framed accordingly.

While framing the syllabus two aspects have to be kept in view. One is the common portion of the knowledge of statistics required by students in all divisions of agriculture and animal husbandry, and the other is the need demanded by the subject matter field. The latter requires introduction of special applied topics like genetical statistics, bio-assay techniques, economic statistics, and possibly a few more, particularly suitable for agricultural engineering, and agricultural physics fields. The U. G. C. is currently engaged in deliberations on the syllabus of statistics in Universities. It will be better if they associate some subject-matter specialists and some Professor from agricultural Universities in the deliberations on the syllabus as these people can put forward their views from a personal appreciation of the requirements and difficulties in these special Universities.

The next question is where the subject should be taught, i.e, whether in the respective departments of agricultural sciences or in a separate statistical department. It is a happy sign that the need for having a separate depaitment for teaching and research in statistics has been recognised. This not only provides an opportunity for the growth of the subject in relation to agricultural sciences but also economises as each division need not go for its own statistical teaching staff. At the same time the statistical department must also work in close association with the other divisions as too much centralisation may mean cutting away from reality. In addition to the need of teaching statistics for equipping agricultural scientists with the knowledge of statistics, there is a need for teaching the basic theory of statistics. Such teaching is necessary for future research workers and teachers in statistics. Such teaching should be provided at the Universities and a few institutes like the Indian Statistical Institute and the Institute of Agricultural Research Statistics, which have been successfully playing this role more for than a decade. We have already pointed out that a teacher of statistics in an agricultural university should have some knowledge of agricultural subjects with which he has dealings. The University products who do not usually have an access to these subjects thus are handicapped. On the other hand students from the Institute of Agricultural Research Statistics get an easy access to the agricultural subjects as they are given a number of courses in these fields and they can, therefore, serve these Universities more effectively. In addition to helping in the research work of agricultural scientists, the departments of statistics in agricultural universities have to conduct research for themselves also. In course of their consultation with agricultural scientists, they will face many problems requiring new thinking and development of new methodology. In addition they will find many problems in form of translation of much statistical matterial remaining already in abstract form into applicable form. All the same, their research has to be more project oriented than curiosity guided. In the field of Design of Experiments, for instance, much abstract work has been done regarding the construction of incomplete block designs. The designs have so far been applied in varietal and some other agronomic trials. The designs now available are much beyond their needs. On the other hand there are some fields having their own special needs for designing experiments where optimum designs are not available. Efforts are called for to explore how the existing designs can be given appropriate orientation so as to make them optimum in specific situations.

A recent paper of Das and Kulkarni[2] in which incomplete block designs have been used for obtaining designs optimum for bio-assays has evoked good demand from applied workers in the field. Incomplete block designs have also been profitably used for providing plans for diallel crosses of use in the field of plant and animal breeding.

It is essential that the teachers, research workers and the students are kept informed with the recent advances in the subject so that they can keep a watch on the developments which might be useful in their specific works. For this purpose, the department of statistics has to be equipped with the full library facilities where all the books and journals are available within the easy reach of the teaching and research staff.

D. RAGHAVARAO[2] : *Present day teaching in Agricultural Universities and Colleges and the changes necessary in the context of developments in these subjects*

Need of Mathematics and Statistics in Agricultural Universities and Colleges :—

In Agricultural Universities and Colleges there are four different disciplines, viz., Agriculture, Veterinary Sciences, Animal Sciences and Agricultural Engineering and the need for Mathematics and Statistics is different for each of the disciplines. In Veterinary Sciences, the minimum of Mathematics is needed whereas Agricultural Engineering requires the maximum As far as Statistics is concerned Agricultural Engineering needs minimum, whereas Animal Sciences need maximum.

Mathematics is the queen and servant of any science. It develops the logical thinking in pupil and it increases the precision of the subject matter to which it is applied. The recent trend in all physical and social sciences is the use of more and more high power Mathematics. Subjects like agricultural economics, soil physics, animal and plant breeding Mendilian theory of genetics, population genetics etc., cannot be completely understood without having adequate background of algebra, trigonometry, co-ordinate geometry and calculus. In the present day agricultural economics developments linear programming is playing a vital role. To understand these sub-

2. Agricultural University, Hissar.

jects very well, appreciate them and apply them to practical problems of our country, the Agricultural Universities and Colleges must provide for adequate teaching of mathematics in their graduate and post-graduate curriculum.

To study the relation of variables, to evolve new varieties of crops and new breeds of cattle, to find the fertilizer requirements of crops etc, one has to use various branches of Statistics and it goes without saying the benefit the pupils will get by studying these courses in their colleges and Universities.

Present status of Mathematics and Statistics Courses in Agricultural Universities and Colleges :

Agricultural Universities in India which are of recent origin started functioning in the early days without recruiting suitable mathematical and statistical personnel. The mathematical and statistical courses in these Universities and Colleges were developed by some Agricultural or Veterinary scientists who have had some elementary training in Matematics and Statistics and the teaching of these courses were also undertaken by such people resulting in lack of appreciation of these subjects by the pupils. It was shocking to me to observe that one University does not teach even elementary calculus, which is so very essential in many Agricultural subjects. The recent advances in mathematics and statistics were not known to many of the earlier courses makers of the Agricultural Universities. In fact, Mathematics and Statistics have tremendously advanced through the new researches in the last 30 or 40 years in fields like linear programming, designs of experiments etc. and there is scope for including the recent developments in our curriculum at the Agricultural Universities and Colleges.

Changing the syllabus :

The process of switching over from an old syllabus to a new syllabus is always a tough problem. The main problem confronted by the top most academecians in the regular Universities is that of proper organizatian and teaching techniques of mathematics courses at the various levels of education and Agricultural Universities and Colleges are no exception. While bringing out the changes, we have also to see what and how much of mathematics and statistics can be imparted to Agricultural and Veterinary students.

The new mathematics and the purpose of the Agricultural University education :

The Agricultural Universities were established to provide a general and intensive education on problems related to Agriculture and animals. So, firstly the students must adequately receive full training in the methods and techniques needed to improve the agricultural and animal wealth of our country. Though we agree that recent mathematics is to be introduced, we cannot certainly do it at the expense of the other purposes of the Agricultural Universities. A careful look at the crowded curriculum of Agricultural Universities reveals that only limited mathematical training can be given without overburdening the student and without increasing the duration of the courses. Our subjects will find only a very limited place in their curriculum and we have to make best use of it by teaching them such mathematics and statistics that the students can easily understand, assimilate and use them in their fields of specialization with great mastery.

Teacher Problem :

It is a well known fact that many mathematicians and statisticians in India feel that they will be lost from their subjects by joining an Agricultural University or College, which results in non-availability of suitable teaching personnel in mathematics and statistics in most of the Agricultural Universities and Colleges. Whereas, if we look at the Land Grants Universities in U.S.A., we find that their mathematics and statistics staff have done first rate research from abstract theoretical to most commonly useful practical problems. In India also, we have to make our colleagues in traditional Universities realize that there is no less scope for showing their talent in Agriculture Universities than any other Universities. The scope for research work at Agricultural Universities is more than in other Universities provided that we take active interest and actively cooperate with the other field specialists.

V. G. SHARMA[3] : *Teaching of Statistics and Mathematics in Maharastra State* :

An Agricultural University is being established in Maharashtra very soon and hence the subject of the symposium is of immediate

3. Directorate of Agriculture, Maharastra State, Poona.

interest to the State. In fact the syllabi for statistics and mathematics are under scrutiny at present with a view to examining the need and the extent to which they would have to be modified so as to enlarge their scope and coverage for meeting the requirements of the department. Moreover, Maharashtra is one of the States in the country where the important role of statistics in the field of agriculture is not only recognised widely but actually statistical techniques are being used regularly in agricultural experimentation and research. Hence the urgent need for equipping the graduates and post-graduates in agriculture with the requisite knowledge of statistics has been engaging the attention of the concerned authorities during the past few years.

Again, the statistical organisation of the department employs over 200 agricultural graduates for manning various technical posts. For discharging their duties efficiently, it is necessary that adequate knowledge of both mathematics and statistics is imparted to them at the agricultural college itself. Even the other research sections of the department would like to employ graduates with such qualifications; but this has not been possible to the desired extent in view of their shortage. Actually, the specialists are finding themselves handicapped in carrying out research on a more efficient and expeditious manner due to shortage of technical personnel trained in statistics and mathematics. It has not been possible to get the departmental officers trained in large numbers in these subjects because of :

(*i*) the limited grants available for the entire training programme covering all the disciplines in the field of agriculture ;

(*ii*) limitations in the admission of departmental officers to the statistical courses conducted by the recognised institutions ; and

(*iii*) the few number of technical assistants who could actually be deputed for training in statistics outside the State, in view of the competing requirements of post-graduate training in other subjects.

The need for such training has assumed special importance, in recent years, particularly since the State Department of Agriculture, as in other States, would very much like to recruit mostly agricultural graduates only even for statistical posts at the higher level. Moreover, it is well recognised that in post-graduate research in any field of agriculture, relatively more advanced knowledge of mathematics and statistics than that at present has become quite essential to research

workers for planning the research itself on a proper basis to start with and subsequently in interpreting the results of the research. This awareness of the utility of and interest in statistics have gathered momentum during the past one decade or so. Simultaneously, the extent of application of statistical methods and principles of modern experimental designs in the field of agriculture has also increased appreciably.

It is accepted that the knowledge of both mathematics and statistics imparted at present in agricultural colleges is quite below that required by the specialists or the department. At the post-graduate level, there is no regular course in statistics or mathematics included in the syllabi at present. Normally, it is observed that due to the meagre marks allotted to these two subjects and consequently the less importance given to them, the students also have a tendency to generally give less attention to them and not to exert themselves to assimilate even the elementary knowledge being imparted at the college. Hence they find it very difficult and also feel diffident in handling statistical computations and in the actual application of statistical theory in their day-to-day work. Even after a few years' experience they tend to be rather mechanical in their work. Intelligent application of statistical methods in the work allotted to them is found to be very much lacking.

An important recent development which is favourable to the introduction of a fairly advanced course in mathematics and statistics both at the graduate and post-graduate levels in that several of the students being admitted in agricultural colleges are reported to have had a satisfactory academic career at the high school and do well in the above two subjects in the college also. In the past, a student who could not get admission to any other course was in a position to join an agricultural college without any competition or difficulty. He was generally weak in mathematics and therefore, was not in a position to assimilate statistical knowledge beyond a very elementary one. Now students who have secured higher marks at the high school level can only get admission in the agricultural colleges because of limited seats available and larger number of students seeking admission. Moreover, the enhancement of pay scales and much better chances of early promotions to higher grades, which are better than those which a graduate in mathematics or any other non-professional subjects could get, have also been largely responsible for attracting brighter students to the agricultural colleges.

The recognition of the need for including relatively more advanced course in mathematics and statistics in the agricultural colleges

and universities is a good augury for the advancement of agricultural science and research. At the same time it needs to be mentioned that there is an acute shortage of teachers in statistics and mathematics even though there has been an increasing number of universities all over the country and practically every university has a full-fledged department of mathematics and statistics turning out several graduates and post-graduates in these two subjects every year. Apparently, they find other jobs more lucrative and even those who enter a university or college as a teacher are not sure to continue there after the first few years because of more attractive jobs outside. Hence it is first necessary to recruit sufficient number of qualified teachers and then to retain them in these jobs by making the pay scales sufficiently attractive.

C. DAKSHINAMURTI[4] : *Mathematics in Agriculture*

Introduction

Recent advances in a range of problems encountered in agriculture and biology are mostly due to the impact of the fundamental sciences, mathematics and physics. The quantitative methods of reasoning of mathematical physics when applied to the fundamental laws of natural sciences, result in spectacular developments. The essential characteristic of such an analytical approach is that it leads to a quantitative theory of the studied phenomena expressible in mathematical language. Application of mathematicnl physics to a few problems in agriculture are illustrated below by way of examples.

Ground Water Movement

Drainage is a must and should be properly worked out for agriculture under irrigation. Lack of proper drainage facilities turned out many a fertile lands into saline or alkali soils. The direction of water flow and the magnitude of the hydraulic gradient determine the proper layout of the drainage channels for maximum interception of the streamlines of flow. Using water levels in three piezometric wells in the area under investigation (fig. 1) it is possible to deduce equations both for the direction and magnitude of the ground water movement. If A, B, C are the three wells and Ha, Hb and Hc are the depths of these wells on the three corners of a triangle with sides a, b and c the maximum hydraulic gradient and the direction of flow are given by equation 1 and 2.

$$M\,H.G.=[a^2H_{BA}H_{CA}-b^2H_{BA}H_{BC}+c^2H_{CA}H_{CB}]^{\frac{1}{2}}\ (ac\ \sin\ ABC)\ldots(1)$$

4. Indian Agricultnral Research Institute, New Delhi.

$$\text{Sin } Q = [a(H_{BA}/H_{CB}) \text{ Sin } ABC]/AP \qquad \ldots(2)$$

Measurements carried out in the farm area of the Indian Agricultural Research Institute (Rao, *et al* 1963) for a number of years gave valuable indications of the factors responsible for the rise in ground water level as well as the change in the direction of ground water flow. These results also indicated the steps required to be taken to improve the drainage system

Cation exchange capacity of soils and Isoconductivity Value

Cation Exchange Capacity of a soil or clay depends upon the negative charge on the clay. It is because of this negative charge, clays behave like salts and partly dissociate in water or electrolyte and add their contribution to the conductivity of the system. Every clay-electrolyte or soil-electrolyte system is characterised by a critical concentration of electrolyte where with increasing concentrations of clay or soil added, the conductivity of the system would remain the same as that of the electrolyte. This critical concentration of the electrolyte is called the "Isoconductivity Value" of the clay or soil and is found to be a linear function of its exchange capacity (Dakshinamurti and Chandool 1966). In a system described above the adsorbed and free ion Na and Ne per centimeter of gel with relative mobilities La and Le, tortuosity factors Ta and Te react with a solid system of density P and a gel of bulk density BD and exchange capacity, EC. If a fraction of the adsorbed ions fa participate in conductivity, the exchange capacity EC is related to the rest of the factors and isoconductivity K is by the equation :

$$EC = \left[\frac{e + (BD - e)\,\frac{Le}{Te}}{BD\,\frac{La}{Ta}\,fa.\,C^{k}} \right] K\,iso$$

The term in the bracket is fairly constant with reasonable relationships known between them. Thus the experimentally observed physical constant could be theoretically substantiated and an expedient and accurate physical method for the determination of the cation exchange capacity worked out.

Plant Nutrient Ions

Manures and fertilizers added to the soil partly get fixed up as insoluble compounds The fraction available to the plant roots exists

in an ionic form around or between the negatively charged clay particles. A knowledge of the distribution pattern of the nutrient ions between the platy clay particles is essential in understanding the mechanism of migration of plant nutrients their concentration in leachates or drainage. Using the concepts of ionic double layers developed by Gouy (1910), Stern (1924) and Grahme (1947) the distribution pattern of the ions has been worked out (Dakshinamurti and Mansharamani, 1966). The distribution of cations between two clay plats with unit area of cross section, charge potential and separated by a distance $2d$ is given by the equation.

$$NT=\sqrt{\frac{2n+KT}{Z^2e^2}}\int_{y_o}^{y_a}\frac{y^2dy}{(y^2{}_a-y^2)^{\frac{1}{2}}\left(\frac{1}{y_a{}^2}-y^2\right)^{\frac{3}{2}}}$$

where

$$yd=Exp.\left(1-\frac{Zod}{ZKT}\right)$$

And the rest of the parameter have the usual significance. A solution of this equation when y is less than 1 can be obtained either by the use of elliptic integrals or by a summation process using an electronic computer (Mansharamani and Dakshinamurti 1965). Tables give the total ionic population for different values of, and have been worked out for use in soils with different clay minerals, as well as in problems connected with the reclamation of saline and alkali soils.

Soil tilth and seed germination

It is often suggested that a seed bed should have a good tilth. The temperatures near the surface and below considerably differ in a cultivated and uncultivated soil. Germination in the seed bed and *first* growth are stimulated in a cultivated soil. Soil is rearranged and brings about a change in pore space in a tilled soil. This cultivation results in changing the heat conductivity and the volumetric head capacity, C. Knowing the pore space and water content the thermal properties of a soil can be worked out.

General temperature variations down the surface of the soil require Fourier analysis, Laplace transforms as to evaluate the thermal conductivity and volumetric heat capacity of the upper few centimeters of the soil which are in general considerably different from those of the deeper soil layers owing to a different structure, composition (organic matter) and water content. In studies (1) of the heat

balance, (2) of the distribution of heat between air and soil (3) of evapotranspiration from a soil etc., a knowledge of the thermal properties of the soil very near the surface is essential.

Laplace transform of temperature is very convenient aid in the study of soils as well as the air near the ground. (W.R. Van WIJK, 1963). The Laplace transform $\alpha\{f(z, t)\}$ of a function $f(z, t)$ is defined by the relationship.

$$\alpha\{f(z, t)\} = \int_0^\infty f(z, t)e^{-pt}dt$$

The Laplace transform of the temperature at a depth z can be as

$$\alpha\{T(z, t)\} = \alpha\{H_{so}(t)\}\frac{1}{2}\sqrt{\frac{a}{p}}\, exp\left(-Z\sqrt{\frac{p}{a}}\right)$$

where P is the pressure, a thermal diffusivity, *HSO* is the Heat flux density of soil and λ the thermal conductivity of soil. By solving this equation graphically and $C=\lambda/a$ with the relation both λ and C can be calculated.

NERVE POTENTIALS

Electrophysiology is an interesting field in biology. The nerves in a biological system act like cables in conveying electrical impulses. All the theories of cables worked out by Lord Kelvin proved useless for biological communication where the amplitude of the impulse and its form remain unchanged along the conductor. This peculiar performance of the cell has a tremendous importance in understanding the specificity and toxicity of insecticides for their expedient and economic applications in field operations. The characteristic nerve potentials are illustrated in Fig. 3.

The question what made the nerve impulse go had been theorised considerably only to indicate the complexity of the problem. Computerised facilities are constantly on demand to correlate the rapidly accumulating evidence for membrane structure and composition as to arrive at a reasonably satisfactory model.

The above examples are only a few amongst many applications of mathematics to solve problems in Agriculture. Study of mathematics has become a must to understand several problems in Agriculture. The level of teaching at the undergraduate and postgraduate stages has to be aportioned properly depending on the field of specialization.

K.A., SESHU[5] : *Teaching of Statistics and Mathematics in agricultural colleges and universities.*

INTRODUCTION

The general recognition of the need for teaching in a systematic and rational way the principles and procedures of Statistics as applied to agricultural research at the Agricultural Colleges and post-graduate Agricultural Research Institutions in India is quite recent. While the recognition, such as it is, has been there at the Colleges and Institutions themselves, such recognition canot be said to equally prevail in the administrative echelons of the States. This is partly due to a general notion that all agricultural satistics is being looked after by the Statistics Department of each State and little more needs to be done about it. This idea has gradually given place to some understanding at least, of the need for providing statistical help to agricultural research and extension. The Agricultural and Animal Husbandry Departments of several States now have full-fledged statistical sections to cater to the needs of teaching and research in their institutions and other States are on the way to establishing such sections in the near future.

The Indian Statistical Institute has done a good deal of pioneering work particularly in the methods of sampling and sample survey and some limited training of Statisticians and awarding diplomas which presuppose an all round knowledge of statistical principles. But, to the Indian Council of Agricultural Research and particularly to its Statistical Wing belongs the credit of creating the awareness of the need for applying statistical principles and methods for an objective appraisal of the results of agricultural research work. From modest beginnings of sponsoring and financing a few agricultural research schemes and interpreting the results of research, it has grown into a premier research and teaching institution of an All-India character. This institute, along with several other activities, also imparts training in research Statistics consistent with the needs at different levels of agricultural research and is creating, as it were, uncleii of statistical personnel in the States for the teaching of agricultural statistics at the Agricultural Colleges and Institutions and for providing adequate statistical help to agricultural research.

5. Agricultural College and Research Institute, Coimbatore,

Teaching Agricultural Statistics

While it may not be disputed that statistical methods are the *sine qua non* of any intelligent and purposeful research programme, it is equally true that the personnel to man such schemes who come from the Agricultural Colleges and Institutions have to be equipped with the statistical knowhow to lead the work to a successful culmination. The problem is a vast one and a Central Institution alone cannot solve it completely. The States would need to have at least a nucleus of well trained staff for imparting statistical training to agricultural research and extension personnel. Specialised training in particular branches may be imparted by a Central Institution. The process of equipping such personnel has necessarily to be gradual and has to commence, at any rate, at the undergraduate level. The approach in teaching Agricultural Statistics needs to be imaginative having regard to the agricultural background and associations and intellectual equipment of the students. Any topic discussed should be accompanied invariably by appropriate and familiar illustrations. Briefly, the approach in teaching needs to be elaborately descriptive rather than cryptic or symbolical.

Background Equipment for Students of Agriculture

The elaborate and descriptive approach in teaching agricultural statistics is both tedious and fatiguing in the extreme to teacher and taught alike. The position can only be remedied, at least partly, by improving the capacity of the pupils for analytical reasoning and ability to grasp concepts, which is quite low in an average student of an Agricultural College. The reason for this state of affairs is not far to seek. Students of mathematics at the pre-University level are not now being admitted into the Agricultural Colleges at least in Madras State. And of all the sciences, mathematics is the one that inspires and develops analytical and conceptual thinking which are so necessary in any research work. We are probably thus keeping out a good proportion of the cream of the student population from these Colleges. It is, of course, for consideration whether pre-university mathematics would be adequate to confer better receptivity to statistical principles. But that is another matter. There is little doubt that the standard of instruction in Agricultural Statistics would be much better than now if the portals of Agricultural Colleges are thrown open to mathematics and natural science students alike. It may also be mentioned in passing that students of mathematics of the pre-university would not be at a disadvantage at the Agricul-

College in regard to natural science because, both Botany and Zoology are taught from first lessons. It is indeed an experience of the author that students of Intermediate mathematics had come to the top in these subjects consecutively for several years.

Syllabi in Agricultural Statistics

A close examination of the syllabi in Agricultural Statistics prescribed by some of the Universities reveals the need for better uniformity in the topics included. It would be very desirable to draw up a common syllabus for all Agricultural Colleges and Post-graduate Research Institutes in India by some Central Institution, having regard to the needs of agricultural research and extension. Provision has also to be made at the post-graduate level for imparting statistical training to scholars undertaking research in different disciplines, like, sampling techniques for Agricultural Economics, Biological Assay for Entomology and Plant Pathology, Biometric Statistics for Genetics Plant Breading, just to mention a few. In teaching agricultural statistics to post-graduate students in Agriculture, one real handicap to the teacher is the difference in attainment in the subject, of students from the several States. This lacuna could also be remedied by prescribing a common syllabus for all under-graduate students in Agriculture.

As regards examinations in Agricultural Statistics, the Madras University has provided for half a paper along with Agronomy forming the other half at the end of the third year of the four year integrated course in Agriculture. Agricultural Statistics is prescribed at the post-graduate level as an ancillary subject for all the disciplines with a full paper at the end of the first year of the two year course. While the scheme of examination at the post-graduate level may remain as it is with the addition in the syllabus of a few special topics and deletion of some of the preliminary topics already covered at the undergraduate level, at the undergraduate state, it seems preferable to spread out the teaching of Agricultural Statistics over the third and fourth years so as to include topics relating to Genetics and Cytology, Farm Management, Agricultural Economics, Horticulture, etc., which are taught in the fourth year so that the statistical treatment of connected problems sound more realistic than imaginary. The present syllabus does not include statistical instruction relating to these subjects. It appears also preferable to have a full paper in Agricultural Statistics at the end of the fourth and final year of the post-graduate course. Finally practical work by oneself can alone

reinforce ideas and carry conviction to the student of Agricultural Statistics in employing statistical methods. The provision of enough number of Calculating machines would accelerate work and enable greater coverage of topics.

CONCLUSION

It would indeed be a laudable ideal to aim at equipping every research worker in the country with an intelligent understanding of the need for an objective assessment of the results of his work and of employing the statistical tool to this end. At the present moment, it would be an achievement if it were possible to equip at least the senior members of research staff in charge of such schemes at every Research Station, Section or Institute with sufficient statistical knowledge for laying out their experiments and simple surveys and analysing and interpreting the results thereof. The position has very much improved from what it was a few years back with the expanded syllabus and better training in Agricultural Statistics imparted in recent years. Particular mention may be made of the post-graduate scholars in whom the need for application of statistical principles to agricultural research seems to have been well impressed and who are in a position to give a lead to their coworkers in this regard. But, much leeway has yet to be made for giving training to existing senior research staff. This is best done by conducting short in service training programmes, refresher courses, etc., in turns at some Central Institution of the State where facilities for imparting such training and instruction should be provided for.

The recommendations that seem to emerge from the foregoing discussion may be stated briefly as follows :

1. The provision of fullfledged sections of Agricultural Research Statistics with trained staff and facilities for teaching and research at all Agricultural Colleges and Research Institutes.
2. The admission of students with pre-university mathematics or natural science into Agricultural Colleges.
3. The drawing up of a common more comprehensive syllabus for under-graduate and post-graduate students in Agriculture.
4. Provision of adequate number of calculating machines for practical work by the under-graduate and post-graduate students.

5. The conduct of refresher courses and inservice training courses in Agricultural Statistics for the members of staff at a Central Institution in the State.

Mistry P.D.[6] and Ranjibhai M. Patel[7] : *Teaching of Mathematics and Statistics in Agricultural Colleges of Gujarat State*

Introduction : Mathematics and statistics have formed a part of curriculum for the first degree in agricultural sciences, ever since the degree was instituted. The syallabus has also been modified a number of times. The modification was by and large dictated by the need to see that the syllabus was in consonance with the background of the pupils entering the doors of the college, rather than by the needs of the learning of sciences involved in agriculture The situation in this respect was rather discouraging in the sense that it was difficult to coordinate effectively the two aspects, namely the continuity with the precollege syllabus and the needs of the agricultural sciences. The authors do not know of any attempt made in the past to discuss collectively this problem and it is heartening to note that this society has been the pioneer in directing the attention of the teachers in agricultural colleges towards this vital problem. The importance of having an adequate background of mathematics and statistics has never before assumed the dimensions which it has now done in view of the present reliance of agriculture and its development on modern sciences.

The present position in Gujarat : At present, the students, who have passed the Secondary School Certificate Examination (S.S.C.E.) of Gujarat State or any equivalent examination recognised by the respective universities to which the agricultural colleges are affiliated, are admitted to the preparatory year of the degree course in these colleges. The entrants must have taken English as a compulsory subject at the above examination in order to qualify for admission. The requirements in respect of the subjects Science and Mathematics are varied in as much as the student may have taken any one of the science subjects titled (*i*) General Science, (*ii*) Physics-Chemistry, (*iii*) Botany-Zoology or (*iv*) Physiology-Hygiene and either Elementry Mathematics or Algebra-Geometry under Mathematics. Preference is given to those who have opted for agriculture as one of the subjects at the S.S.C. examination. In view of this diversity in the admission requirements, a heterogeneity exists among the student-mass of the Preparatory Year in respect of the background of Mathematics.

6 and 7. B.A. College of Agriculture, Anand.

The teaching of the subjects of Mathematics and Statistics in the agricultural colleges of Gujarat State extends over four years of the college. Mathematics which includes Algebra, Plane Geometry, Trigonometry and Mensuration is being taught during the first two years namely the Preparatory Year and the F.Y.B.Sc. (Agri.) whereas Biometry and statistics is taught during the third year in S.Y.B.Sc. (Agri.) and Experimental Designs during the final year. The distribution of the lectures and practicals in each class is shown below in Table 1.

TABLE 1

Distribution of Lectures and Practicals in Mathematics and Statistics

Class	*Subject*	**Lecture/week*	***Practical/week*
Preparatory (Agri.)	Mathematics	3	—
F.Y.B.Sc. (Agri.)	Mathematics	3	—
S.Y.B.Sc. (Agri.)	Statistics	2	1
B.Sc. (Agri.)	Experimental Designs	1	1

*One lecture of 45 minutes.
**One practical of 90 minutes.

Statistics of Past Performance of the candidates

The system of examination broadly comprises three short duration tests spread over the entire year and a final three-hour examination given at the end of the academic year. As an illustration of the performance of the students, the result data of the B.A. College of Agriculture, Anand for the academic years 1964-65 to 1966-67 are summarised in Table 2.

TABLE 2

Summary of the Results in Mathematics and Statistics at B.A. College of Agriculture, Anand

Class	Subject	Year	Number of students securing			Total No. of Students
			45%	46-60%	60%	
Prep. (Agri.)	Maths.	1965	60 (14)*	7	69	216
,,	,,	1966	140 (48)*	82	59	281
,,	,,	1967	159 (45)*	108	34	301
F.Sc. (Agri.)	Maths.	1965	8	150	19	177
,,	,,	1966	17	120	55	192
,,	,,	1967	61	120	46	227
S.Y.B.Sc. (Agri.)	Bio-stat. (Theory)	1965	3	108	16	127
,,	,,	1966	9	113	25	147
,,	,,	1967	34	120	25	179
,,	(Practical)	1965	3	111	13	127
,,	,,	1966	3	117	27	147
,,	,,	1967	28	142	9	179
T.Y.B.Sc. (Agri.)	Exptl. Desigr (Theory)	1965	11	119	23	153
,,	,,	1966	10	89	17	116
,,	,,	1967	4	103	35	142
,,	(Practical)	1965	5	92	56	153
,,	,,	1966	3	70	43	116
,,	,,	1967	7	93	42	142

*Actually failed since in preparatory, passing level is 40%.

It can be seen from Table 2 that on an average 45% of the students of the preparatory class, secured less than 45% of marks in the subject of mathematics whereas ..... only 20.3% scored more than 60% of total marks for the subject Thus a considerable number of the new entrants to the collegiate education fails to attain the satisfactory standard of understanding in the subject of mathematics. This is obvious in view of the heterogeneity in the academic background of the students entering the preparatory year.

The understanding is improved at the F.Y.B.Sc. (Agri.) level due to two reasons. One is the elimination of thepoor-understanding group due to failures at preparatory level and the other is the fact that the students, who remain, get well oriented to the college system of teaching. Only 14·1% of the students secured less than 45% of marks

while 20.1% secured more than 60% of marks in mathematics at the F. Y. B. Sc. (Agri.) class. A notable feature, however, is the fact that the proportion of the best group has remained the same. On the other hand, there is a shift from the poor to the average group. Similar inference is also true for the performance at the S.Y.B.Sc. (Agri.) and the T.Y.B. Sc. (Agri.) class in the subjects of Biometry and Statistics and Experimental Designs respectively.

COMPETENCIES EXPECTED OF THE TEACHING OF MATHEMATICS AND STATISTICS

Everyone engaged in education would agree that a given framework of course contents could be evaluated, only in the light of the competancies which the course is designed to develop in the learners. These competancies, as far as agricultural education is concerned, would also depend upon the subjects for which the knowledge of mathematics and statistics is essential. These subjects include Agri. Engineering, Soil Physics, Genetics, Plant Breeding, Animal Breeding, Agricultural Economics and Agronomy. A few of such competencies which the authors consider essential are listed here :

1. Ability for precise and logical thinking on problems.
2. Ability to transform and interpret a mathematical formulation in meaningful statements.
3. Ability to formulate an idea or a concept in the mathematical form.
4. Ability to develop intuition, vision and abstract thinking.
5. Ability to apply the tools of analysis to derive meaningful conclusions.
6. To inculcate manipulative skill in dealing with experimental observations for the purpose of deducing conclusions.

Limitations of the Present Course

An examination of the present syllabus reveals it does not fully serve to prepare a student to acquire the aforementioned competencies. In support of this statement, it would be worthwhile to view a few cases, wherein it could be seen how the present course contents limit the understanding of the students.

A simple illustration can be drawn from the field of hydraulics in Agricultural Engineering. The relation for the discharge through

a large vertical orifice could be obtained by definite integration of the product of area and velocity through an elemental strip of the orifice. But for want of knowledge of calculus, the relation has to be learnt through memory rather than through methodical understanding.

Problems in Agricultural Economics nowadays are studied through the use of economic models so as to achieve thoroughness. Space would not permit mention of the innumerable models used in econometrics. But it is obvious that they constitute ingenious application of mathematics the lack of which will greatly impede the understanding of a student specialising in agricultural economics, even at the post-graduate level.

A still more befitting illustration to point out the limitations of the present syllabus would be from teaching of Biometry and Statistics. The subject of statistics has its roots in Probability. This topic must be thoroughly understood by the students. Unfortunately the students under the present system lack in the knowledge of permutations and combinations in algebra. As a result, they find it difficult to comprehend and assimilate the fundamental ideas and implications of this important concept. Likewise, the statistical analyses of various designs involve application of calculus and as such is rather done machanically by the students than with a thorough understanding.

The above are a few of the many situations arising out of the inadequacy of training in mathematics and statistics. The student community is not the only group that is affected by these limitations. The teachers engaged in the profession are also handicapped as far as their role is concerned. It is rather difficult to render a topic lucidly before the students when the tools which help lucid rendering are unknown to the learners. For example, it is necessary to make use of theory of maxima and minima in calculus to determine the optimum dose of manure in agronomic experiments; however under, the present system there is no provision to teach calculus in agricultural colleges in Gujarat State.

Need for Revision of Syllabus

The agricultural education in India has begun to receive a new impetus. It would be in the fitness of things, therefore, that the training of students in agricultural colleges be reoriented so that the products of these colleges could play their role effectively in various disciplines concerned with agriculture. Fortunately, the idea of the

first degree course in agriculture being one of a five year duration after S.S.C. examination has met with a favourable response from agricultural educators and it should be possible to strengthen the teaching of mathematics and statistics. This would also help the students of agriculture to equip themselves with sufficient knowledge to handle effectively the new situations confronting agriculture.

The authors, on the basis of whatever little experience they possess and the personal contacts with workers in other disciplines in agricultural sciences, have pepared a model syllabus in mathematics and statistics for under-graduates in agriculture. The same is given as Appendix II.

It may be mentioned that this syllabus need not be taken as final but is subject to scrutiny by the academic bodies. It may also appear that no conspicuous changes in Bio-Statistics have been incorporated; nevertheless a little more rigorous treatment of the subject matter is expected so that a close link between statistics and mathematics and between statistics and other disciplines in agriculture becomes evident at the under-graduate level.

C.L. BAJPAI[8] : *Teaching of Mathematics and Statistics at Graduate level*

The need for teaching of statistics and mathematics particularly at the graduate level has recently been keenly felt.

The following syllabus is suggested for the purpose.

1. It is essential to introduce the subject of statistics to degree students. Elementary principles of statistics, its importance and role in a planned economy, its limitations and distrust collection compilation and tabulation of data, and simple averages together with diagrammatic representation, Field Experimentation, Layout of Experiments, Treatments, size of plots, number of replications, randomized blocks, Latin square designs and their analysis. In the early years the above items may be grouped under two heads, the one for B.Sc. Ag. Part I and the other for B. Sc. Ag. Part II. This would continue the link from 1st to 2nd year and create an interest in the subject too besides familiarising it to the students.

Besides the above there must be a practical paper which should include the frequency distribution, calculations of simple averages,

8. Crop Physiology Section, Agriculture Department, Kanpur (U.P.).

and standard deviation, Measures of Dispersion, Layout and working out of recurring and non-recurring expenditure of Farms maintained for (*i*) Profits, (*ii*) Experiments, (*iii*) Demonstration and drawing to scale of layout of field experiments on papers, calculations of statistical constants, and the students must be expected to maintain the records and to produce them at the time of final examination.

2. At the post-graduate level, there is a greater need for such knowledge, particularly in a developing country like ours, where agricultural reorganization is the dire need of the time and the B.Sc. Ag. Students are expected to take up the challenge in right earnest. With this end in view I place my suggestions for considerations before this conference. I do not claim to be original in my ideas but I do wish to have the satisfaction of bringing these ideas to light.

The Scheme is as under:

(*a*) Statistical Methods and Statistical inference to be a compulsory paper for all the students in all the disciplines.

(*b*) Special statistical course for each department in Post-graduate Agricultural Colleges and Universities.

(*c*) Departmental Seminars on "How to utilize statistical knowledge in solving problems of particular branches." This will involve the introduction of the specific topics for the students assigned to them in advance and group discussions along with the class and staff members of the Department every week.

(*d*) Publications of Researchers and mathematical results conducted by different Departments for general information and discussion.

Discussions

In addition to the above, Dr. A. R. Roy, Shri S. C. Chaudhri, Dr. S S. Prabhu and several others participated in the symposium and the subsequent discussion. Dr. Roy expressed his view that the teaching at the advanced level of Mathematics and Statistics and fundamental research in statistical methodology should remain with the University departments while the applied aspects of research in statistics should be done at Agricultural Universities, Colleges, an other Institutes. Shri Chaudhri felt that the students of statistics suffer from the disadvantage that they can choose only one additional

paper in statistics as their optional subject while the students of physics, mathematics and several other subjects get the advantage of choosing two optional subjects from their respective fields. He expressed the view that suitable action might be taken to remove the difficulty in all Indian Administrative Service examinations.

The Chairman in his concluding remarks stressed the need for careful planning of statistical education in Agricultural Universities particularly in view of the recent rapid development of agriculture and application of new agricultural technology. He felt that there should be frequent exchange of views among the teachers and research workers in these institutions by organising conferences, summer schools, and possibly through exchange of teachers.

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