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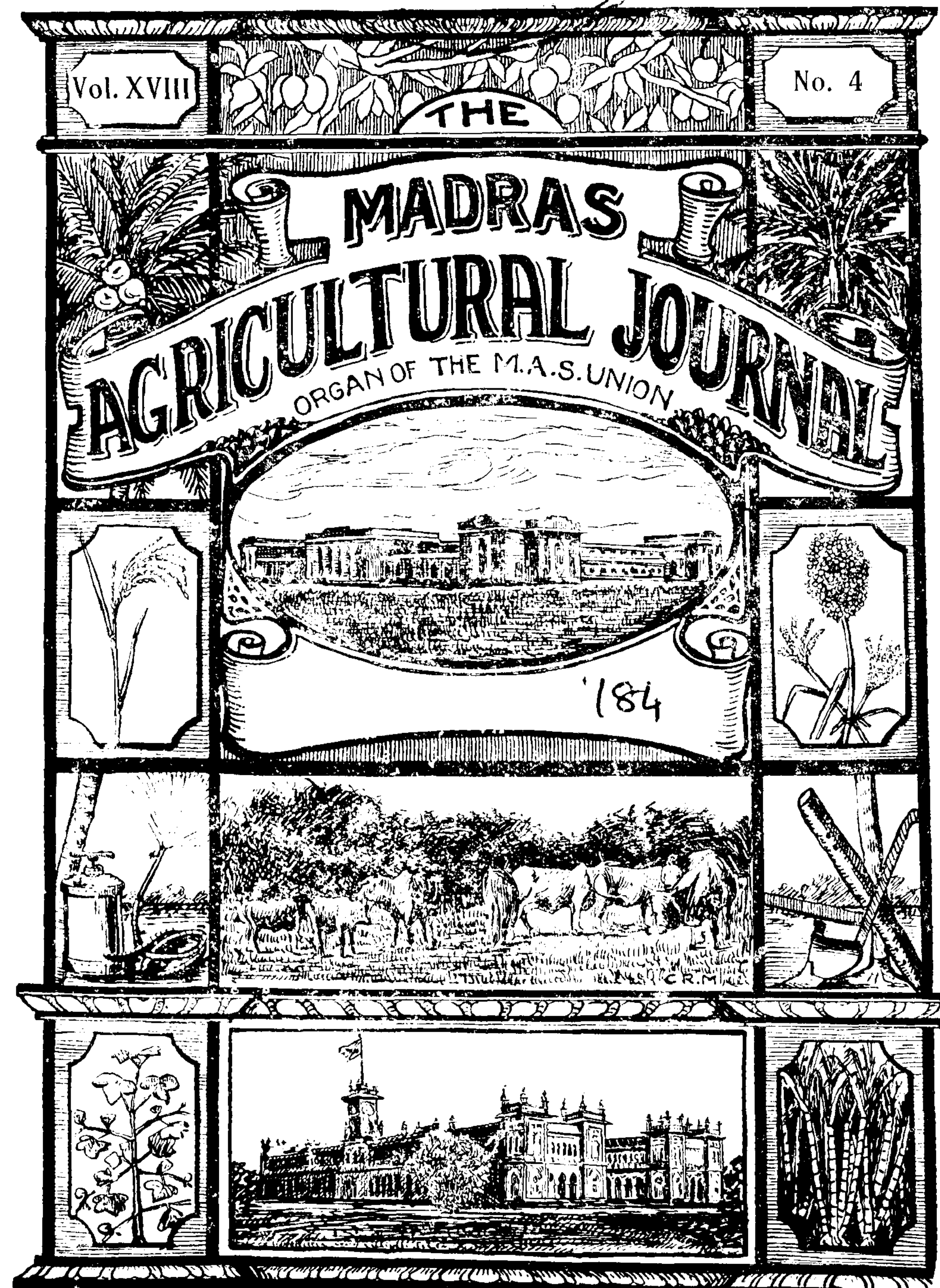

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ON THE MATHEMATICAL PROBABLE ERROR AS APPLICABLE TO FIELD EXPERIMENTS IN AGRICULTURE [1]

BY

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i. Apologia

These lectures which the author had the honour of delivering under the auspices of the University are the outcome of an attempt to place before the Agricultural experimentalist the mathematical limitations that govern his '*significance*,' and to explain to him in broad outline the skeleton of the statistical theory that forms the basis of judging inter-varietal differences or the differences between different treatments. To a pure mathematician, the distributions of the errors of statistics and their analytical properties form the crux of the problem, while to an experimentalist the applications of the theory with all its implications bring in not only inferences but suggest new problems and new spheres of work connected with his experimentations. For in fact in no other science are theory and practice so combined, so allied and so interdependent that most of the problems connected with agricultural experimentations have not been correctly diagnosed for want of sufficient progress in statistical ideas and statistical theory. Though indeed a high technical knowledge is necessary to study the peculiarities of the soil, to suggest ways and means for the economic use of the fertilisers, to test the different varieties in respect of the yield and to evolve strains out of them to produce the greatest effect, though these and other investigations are the

[1] Honorary Readership University Lectures for 1929-30 delivered by the author at Madras and Coimbatore.

province and the domain of the agricultural scientist, there is indeed the imperative need for the brains of a statistician in that the scientist's figures require a thorough sorting, scrutiny, and analysis which would lead to a scientific interpretation and inference. The nature of plot experimentation is such that not only at the final stages of the enquiry where the statistician has to interpret the results by a study of the different types of variations that are possible in the yields, but also even at the early stages of the field-trials where there should be a preliminary survey of how best the plots could be arranged to minimise the causes of the errors which hamper the nature of the enquiry, the need for a statistical technique is obviously necessary and even imperative. But mere statistical considerations divorced of the practical needs and simple methods of cultivation become only of academic interest, and here the co-operation of the experimentalist and the scientific statistician is more and more acutely felt.

ii. The basis of the scheme of plot experimentation

(*a*) General ideas

The Agricultural Research scholar is confronted with the three agencies, the *soil*, the *climate* and the *plant*. Whatever experiments are performed whether with different varieties or with different treatments, the soil and the climate are permanent factors whose influences in the final results cannot be over-estimated. Unless an experiment is repeated on the same soil for a number of years it is not possible to fix up a definite significance between variety and variety or between one manure and another. The difference between one plot and another however close they may be is so strikingly complicated, and the effects of the weather in the matter of cultivation in the same year or different years are so emphatically different that any experiment, if it should be successful, should be performed under conditions which require a preliminary study and a careful scrutiny. Next, the methods of cultivation are all important in the deduction of any inference with regard to the experimentations. High statistical significance depends upon a most careful sowing and above all upon the spacing variations of the different kinds of crops. The special effects of varieties form themselves a separate statistical study. Thus, to judge of differences in any agricultural experiment, a statistician has to study the effects of three factors—climate, soil and plant—with the due recognition of whether the experimentation has been conducted most carefully, consistent with the environment and the conditions of the soil.

(*b*) Different types of variation

Thus the technique of plot experimentation is a complicated process involving as it does a study or a simultaneous study with respect to the different plots of the differences between manures, between several varieties and between different methods of cultivation. The modern concept of statistics is that it is a science of the study of differences and nowhere either in Biology, Sociology or Economics has this concept been so much exemplified and applied as in this art of field-experimentation. Hence the *method of the arrangement* of the plots to bring out the differences between the several types of factors that produce the variation in them is all important in any scheme of experimentation. For a statistician to draw any conclusions each experiment has to be replicated and the necessity for the repetition of experiments as often as the homogeneity of the soil would allow cannot be

over-emphasised. The modern methods of replication of experiments in a limited area constitute a notable advance in plot-technique and have given a statistical import to the very arrangement of the plots on which the external agencies have to be tried. But the number of experiments or replications possible is by the very nature of the experimentation obviously limited and a statistician accustomed to exhaustive figures as in other economic enquiries has to adopt a different theoretical attitude and a different angle of vision to the limited sample of experiments under examination. The statistical necessity therefore demands that with a limited number of 4, 5, or even 10 trials for each variety or manure, the figures must not only be accurate and reliable but must supply data and details concerning all influences at work. What are those influences? Now with small-scale trials where plots of very small sizes are under experimentation such as to bring out the differences of hybridisation, though the soil differences between plot and plot close to each other may not be appreciable, yet in dealing with long strips of several families of plants to judge of their individual characters, the plot variation is a factor that cannot be easily ignored. Even more is the case of the Field-scale trials, where plots of large areas are brought under cultivation under several varieties. Here the difference between one field and another is even more striking and any judgment of the discrepancy of the yields of the several varieties cannot but recognize the innate fertility of the soil which produces sometimes differences out of proportion to the differences in treatment or the efficacies of varieties. Thus an examination of the influences at work in the yields of the different varieties brings out *three* distinct classes of variations occurring in a series of plot-trials with replications of the same variety. Firstly, what might be called *Accidental Errors*[1] which are inevitable in any statistics arises this way, that however much the plots might be homogeneous and alike and however identical might be the treatments of manuring or varieties, the accidental variations such as unequal levelling, unequal channel supply and destruction by insects or spasmodic diseases are bound to exist between plot and plot, and assume some significance particularly in dealing with plots of very small size. Though in field-scale trials such accidental differences may be taken to be *constant* from field to field, in small-sized plots these accidental variations require a study as they would affect the yields in an appreciable way. But with a careful supervision and control of such factors as would bring in these variations the accidental error could be considerably minimised. The second class of errors which we shall call *Systematic Variation* arises in two ways and in two different and emphatic directions. *Firstly*, the influences of the soil referred to already produce what is known as the *Fertility Gradient* as we pass from plot to plot. If we could analyse the innate fertility of the successive plots as opposed to the effects of the new treatments, it is found that the fertility varies in a systematic manner from point to point. To a mathematician such an analysis would bring out the form of the curve representing the change. So long as this curve is independent of the yields of the plots as the result of the experimentation it would be well if such a curve which we shall call the *Normal Fertility Curve*[2] for the entire field is settled once for all before the other types of variation in the individual plots are studied. If particularly the experimentation could be continued in the same set of plots for different years the study of this curve which could be based upon the observations for years would considerably facilitate further studies regarding the differential effects of the several

[1] In the rest of the paper, *error* and *variation* are used in the identical sense.
[2] This term is borrowed from an article in *The Agricultural Journal of India*, Vol. XX,

varieties or treatments. The other type of the systematic variation is the one due to the treatments themselves. The variations that occur from plot to plot as the effect of different manures in testing different varieties or as the effect of the same manure in producing varietal differences, have thus to be separated from the type of the systematic changes that are due to the fertility gradient. The third class of errors is what may be called *Random Errors* which arise from the inaccuracies due to measurements—either through instruments or the personal eccentricities of the experimentalist. This class of errors is inevitable and however careful one may be, unknown causes operate in producing statistical inaccuracies in the measurements of the successive plots. To a statistician, this type of errors is attributable to 'chance' and the problem is how far chance operates in producing differences between the true value and the observed value of any quantity under measurement. It is here that the statistical theory is showing fresh phases and new developments, and as we shall see later clearer ideas of the statistical limitations of the particular experimentations are necessary to judge of the difference between any two values that may arise by chance. Thus the yield of a plot under a particular variety is a concourse of these three different types of errors affecting the intrinsic yield due to the variety alone. Statistical procedure in an examination of the differential effects thus resolves into a study of these different types of errors and of the significance that has to be attached to the differences between them.

(c) The randomness of the plot arrangement

This analysis of variations leads to the question how best we could arrange the plots to get at the greatest benefit out of the experimentation. The accidental errors being supposed constant, the first type of the systematic variation must be brought to a minimum which as already explained is due entirely to the differences between plot and plot owing to the fertility gradient of the field and not owing to any external agencies. Thus any arrangement must be conceived with a view to reduce this class of errors which is entirely due to circumstances not within our control. It is obvious that one method of securing this aim is to arrange the plots *at random* with respect to the several varieties or treatments and their replications so that the differences in fertility between plot and plot may not contribute to the differences between the treatments or varieties. In the case of the small sized plots the best way of securing the randomness is to get cards bearing the names of varieties and shuffle them freely so that the replications may not occur in any preconceived manner. Thus if we are testing 5 varieties in 20 plots, so that each variety recurs four times, we may have twenty cards with the names of varieties written down and shuffle the twenty cards and produce them in any random order, such as :

A D E B B A C D A B A C B E D C D C E E

If it should be possible to conduct experiments for several years in the same set of plots this arrangement could be altered continuously year to year to produce the desired effect. Mathematically this sort of chance randomness may be produced in a number of ways, we could either shuffle cards or take the last digits of a set of values from the logarithmic tables or produce a set of figures where the systematic variations have no place. But[1] it must be recognized that any random arrangement with respect to a number of varieties is not always convenient from the point of view of cultivation and may even lead to mistakes which cannot be easily repaired. The simplicity of the arrangement combined with the randomness are features that must be borne in mind in scheming the plot-trials. But when dealing with plots of large sizes covering fairly huge blocks, even this random arrangement cannot reduce the effects of the fertility gradient and the only course open is to recognise the differences between the blocks but to secure randomness among the varieties in the individual blocks themselves. We shall be facing then two types of the fertility gradient, that due to the differences between the blocks and the one due to the plots themselves in the same block. Later on we shall be discussing methods of analysing the variances due to the several factors that cause the variation, but anyhow our aim must be to reduce these variances due to the soil to make the plot trials really effective and productive of the real significance. The following is an arrangement by which the uniformity between varieties could be secured by this process, where if ranks be given to them in the several blocks the sum total of the ranks of each variety is the same. Thus with five varieties and four blocks an arrangement like the following secures to each variety positions in the blocks whose sum is the same, and secures an even balancing to the several varieties in the blocks.

1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
A B C D E	E D C B A	A B C D E	E D C B A

where A, B, C, D, E represent different varieties and the sum of the ranks of each variety equals 12. By this method we have to a certain extent eliminated the differences between plots in the same block but still the differences between the blocks themselves remain. As each block has its own fertility gradient and as the significance of varietal differences cannot but recognise the differences between the blocks, still the block-variations can be reduced by an extended method of the above scheme of 'balancing.' Thus with five varieties, instead of having four blocks if we could have *five* so that each block has all the five varieties grown on it, then not only could we 'balance' the positions of the varieties but also we could 'equalise' their positions as in the following scheme:

1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
A B C D E	B A E C D	D E A B C	E C D A B	C D B E A

A, for example, occupies all the five positions in the several blocks so also the other varieties; so that by such an arrangement of 'balancing' and 'equalising' the plots and the blocks display more or less the same fertility differences. Thus whatever arrangement could be conceived of to suit the facilities of cultivation and environment, the conditions necessary to meet the soil inequality between plot and plot in any experimentation cannot be overlooked.

iii. Mathematical treatment of the different types of variations

(a) Systematic Variation

Whether we test different varieties or whether we test different treatments with respect to the same variety the systematic variation from plot to plot does require a mathematical understanding and study. If indeed we could have a fairly appreciable number of plots under trial, covering a fairly large area, then the study of the systematic variation reduces into an examination of the best curve that could fit in with the given data. But where there are only a few plots under examination the curve that could pass through a few

[1] *The Principles and Practice of Yield trials* by Engledow and Yule, pp. 67-68.

values only cannot be relied upon to indicate the systematic changes. Anyhow the idea of passing the best curve through a given set of values cannot be lightly brushed aside, as its applications in an examination of a large series of trials are indeed of very high statistical importance. The method of curve-fitting is usually known as 'Graduation' or 'Smoothing,' and it consists of two distinct aspects, *one* securing a suitable *smooth* curve which would remove all roughness in the data and thus secure an apparent perfection to the given set of observations influenced by the other types of errors as well; and the *other* being that not only should we obtain any *smooth* curve but *the one* which would produce the greatest agreement to the given data. The curve that would satisfy both these conditions is the one we seek for in graduating a given set of values. Thus the process of Graduation secures the *most probable* values of a series of observations influenced by systematic changes (as we observe in the plot-fertility due to the heterogeneity of the soil). Now with regard to the mathematical methods of graduation, they are indeed too full, and the particular method to be adopted depends upon the nature of the enquiry on hand. An actuary, for example, uses what is known as 'the summation formula'[1] and his literature is full of it. The summation formula is based upon this concept—that of a given set of figures each figure influences the neighbouring ones accidentally as it frequently happens in the age distribution of a population (where, e.g., a man aged 39 gives his age to be 40). Here the best method of Graduation must be the one which combines the figures so that when differences above a certain order are neglected the original function is reproduced. It is obvious that this method is not suited to a series of plot-trials, for any single observation cannot be supposed to affect any other observed result, and each figure is taken to be the most reliable. The following is a useful method[2] which we have employed in graduating 25 plot-figures (Vide Table I). Assuming a curve of the second degree $y = a + bx + cx^2$ to pass through the twenty-five values we seek the best values of a, b and c by assuming that the moments[4] of 0, 1, 2 order of the given set and the graduated set are equal. Such an assumption is tantamount to the geometrical significance that with respect to the given curve[3] and the assumed curve (in this case the second degree curve) their areas, their centres of gravity and their moments of inertia are identical. If we could think of a higher degree curve involving greater number of parameters, we have to take higher moments and compute as many moments as there are parameters. But it is not advisable to increase the degree of the polynomial, though theoretically it is possible—for with $(n+1)$ constants we can fit in a polynomial of the nth degree—, because to that extent the accuracy of the law of variation is sacrificed. Hence we could conveniently stop at the second or the third degree. The first aspect of graduation is now satisfied in virtue of which we have secured a smooth curve of a polynomial.[5] But to produce greater agreement we can make another assumption that a very small quantity ϵ can be found such that the difference between the observed and this intermediary value $f(x) = (a + bx + cx^2)$ is of the form $\epsilon\ f^1(x)$[6] following

[1] C. F. Whittaker and Robinson, *Calculus of Observations*, pp. 288–291.

[2] The method is explained in full in *Calculus of Observations* (Vide Supra) pp. 303–315.

[3] The Area of the curve is the one bounded by the curve, the X axis, and the extreme ordinates.

[4] Moment of the nth order $= \Sigma x^n y \,/\, \Sigma y$.

[5] The form of the curve may suggest other Analytical types which are also necessarily smooth.

[6] $f^1(x)$ is the first differential coefficient of $f(x)$.

the expansion of $f(x+\epsilon)$ by the Taylor's Theorem. It only remains to choose ϵ and we can take a series of small values for it, ·001, ·01 and so on and test which value of ϵ would give the best agreement to the observed set of values. Table I gives the graduated values of the observed yields, and their differences, and the column 6 expresses the ratio of the difference (due to graduation) to the graduated result. Graph I is of the equation $y = 400 - \cdot 16x^2$ which is the graduated curve of the yields of the twenty-five plots, ϵ being taken to be zero. We shall, according to our theory, then take the differences between the graduated and the ungraduated due to the other types of variation.

Graph No. 1

(Vide Page 197)

Graduation of 25 plots under five different treatments. $(y = 400 - \cdot 16\ x^2.)$

(*b*) **Random fluctuations**

Now we shall consider the other type of errors referred to, that due to the random fluctuations and statistical measurements. The Theory of what is known as 'random sampling' is the basis for judging how far the difference between any observed value and the true value could be ascribed to chance. A few fundamental considerations concerning the theory may not be out of place in the discussion of its features. Our object in any statistical enquiry is a study of the characters of a population and the evolution of a mathematical expression involving constants or parameters whose correct values have to be computed from the given data. In cases of the known population, that is, in cases of the distributions whose mathematical expressions are definitely known, the parameters of the expressions have to be deduced from the *statistic* or the *statistics* as computed from the given data. An *Arithmetic average*, for example, is a statistic giving the best value as could be deduced from a given set of observations. What is known as *the Standard deviation* is another statistic describing the given set of observations Similarly other statistics could be computed which would give the best values of the parameters on whose reliable values our description of the population depends. But if the parameters of the population should be correctly deduced there is one fundamental assumption involved in it that the sample under consideration consists of a fairly large number of individuals or theoretically an infinite number. The statistics cannot give reliable values to the parameters unless they are computed from a set of data of an appreciably large number of individuals. But in agricultural experimentation, the number of experiments is obviously limited, and the general problem in dealing with this limited number of a sample of experiments is 'could we attach any significance to the statistics obtained from the limited sample?' The question which requires a statistical answer is this: Given a sample of a population, whether and to what extent could the parameters or the statistics based upon them tally with the parameters or the statistics of the whole population whose features are supposed to be known? A kindred and a more useful question is this:

Given two samples of a population, could they be samples from the same population allowing for random errors which could have arisen by chance? The answers to these questions are obviously based on the *theory of probability* based upon the kindred theory, the *theory of errors*, and the correct solutions of these two problems form the key to the innumerable number of problems that arise in the sphere of random sampling such as we have in the limited number of experiments that obtain in the field trials. For example, if one field produces 7 tons and the other 8 tons both being homogeneous, what sort of significance could we attach to this difference, after all would this difference of one ton make an appreciable difference to jump to the conclusion that the second gives a better yield than the first? Or again, if a series of plots are subjected to several varieties whose differences in yield have to be studied, could we attach any significance to the observed differences which might be small or large? Such a comparison obviously depends upon the size of the sample—greater the number of plots subjected to the same variety greater the reliance could we place upon any statistic based upon them. Thus we are led to this consideration:—Given a series of samples each of size n, how could we find out whether they are homogeneous or identical samples or whether any significance could be attached to the differences between them? If the differences between the samples arise by chance only, then the differences can be ignored and the samples can be taken to be identical, but if they should be due to factors other than chance the significance of their differences has to be deduced.

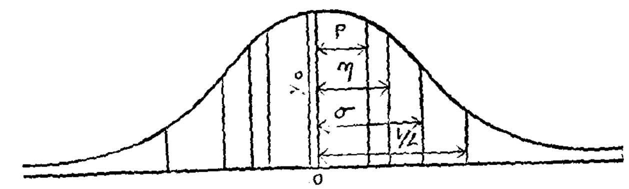
iv. Concept of Probability and Significance

(*a*) The Normal Law and its Implications

If any error should arise by chance only or by circumstances purely accidental, then the law of distribution of such errors, if one such could be theoretically deduced or even assumed, would give us an indication how far and to what extent the amount of an error could be attributed to chance or randomness. Now we shall explain the basis of what is known as '*the Normal Law of Errors*' which is the classic curve which 'Statistics' has adopted in most of the important enquiries where errors are in question, or where deviations from the best value of a sample have to be judged. First and foremost in the errors that arise by chance only, we include the types of errors such as the inaccuracy of an instrument or the personal equation of the experimentalist, whose causes cannot be diagnosed and whose aggregate sum cannot exceed a reasonably small quantity. But on the other hand, if we are able to discover the conditions and the laws of the actions of those errors however small they may be, the errors are no longer random but transform into a type of the systematic change referred to already. The Normal Law of Errors is thus based on three simple hypotheses, *firstly*, the errors are taken to consist of infinitesimally small errors whose sum total is by itself a very small quantity, *secondly* the chance of a positive error occurring is the same as the chance of a negative error, so that the sum total of the errors of a fairly large number of observations tends to zero, *thirdly* the chance of a small error is greater than the chance of a large error which is obviously a necessary condition in dealing with the errors due to chance. Now these

hypotheses are very well illustrated in the resulting graph (Graph No. 2).

GRAPH No. 2



The equation is $y = \frac{1}{\sqrt{2}\,\sigma} e^{-\frac{x^2}{2\sigma^2}}$

y_0 = maximum ordinate (when $x = 0$) or height at the mode

A = Total Area = 1

N = the total number of observations

σ = Standard deviation $= \sqrt{\frac{1}{N} \Sigma (x^2 y)}$

p = Probable error

Area from $x = -p$ to $x = +p$ is half the total area A

giving P from the relation $\left\{ \frac{2}{\sqrt{\pi}} \int_0^P e^{-t^2} dt = \frac{1}{2} \right\} = 0{\cdot}47696$

where P defines p such that $p = (P\sqrt{2}).\sigma$

$\frac{1}{h}$ = 'Modulus' $= \sigma \times \sqrt{2}$

η = 'Mean absolute error' $= \sigma . \sqrt{\frac{2}{\pi}}$

whose ordinates express the number of times each individual error occurs, as it ranges from zero to infinity. The area bounded by the curve and the x axis thus represents the total number of observations, and the area bounded by ordinates between $x = a$ and $x = b$ represents the proportionate frequency. In the form given $y = \frac{1}{\sqrt{2\pi}\,\sigma} e^{-\frac{x^2}{2\sigma^2}}$, the maximum ordinate corresponds to the zero error, and the total area is equal to 1. Thus the frequency of a total of x error ($\pm x$) is the corresponding area bounded by the ordinates for the abscessae $\pm x$. The concept of the probability of any deviation x is thus based on the assumption ot the law of errors, and the probability of the occurrence of that deviation is the proportionate area. What are known as Probability integral tables have been constructed giving the probability of a particular error happening. The tables[1] are given in different forms and the best form[2] seems to be the one which would indicate the probability P of exceeding a deviation x positive or negative. From such a table the lesser the value of P, the greater is the significance to be attached to the particular value under consideration that it has arisen by influences other than chance alone.

[1] Vide *Tables for Statisticians and Biometricians.*
[2] T. L. Kelley, *Statistical Method*, pp. 373–385.

(*b*) **The best Statistics to describe a population—Meaning of Probable Error**

Now in dealing with a population consisting of an infinite number such as a population of random errors governed by the Normal Law, the two statistics that best describe its features and in fact summarise all the information necessary regarding the population are what are known as the *Arithmetic average* and the *Standard deviation*, the first two moments of distribution usually written as $\bar{x}$ and σ. These two statistics are fundamental, one expressing the average of the whole set of values and the other the square root of the average of the squares of the deviations from that average; and the formula for the Normal Law itself indicates that σ is a very important factor as expressing the precision of that average. Hence to test the deviation x it is appropriate to tabulate the values of $\frac{x}{\sigma}$ rather than x itself from which the significance of x could be deduced. If x follows the Normal Law, it is a simple result as could be seen from the form of the equation itself, that $\frac{x}{\sigma}$ also follows the Normal Law. The following is a scheme giving the probability P of exceeding $\pm\frac{x}{\sigma}$ for a deviation x as obtained from the Normal law.

$\frac{x}{\sigma}$	P
·5	·60
·6	·54
1·0	·32
1·5	·14
2·0	·06
2·5	·02
3·0	·003

What is called 'Probable Error' is that value of x which would give a probability of just ·5; and from the above scheme it is seen that where $\frac{x}{\sigma}=·6$, P takes in a value near to ·5. The Probable Error by itself is not of much value excepting as a mathematical expression roughly equal to 2/3 the standard deviation and where the distribution is *not* normal it is certainly meaningless to attach any significance to it. Now the question is *where* and at what value of P we have to fix up the significance to any observed value. Though no hard and fast rule can be laid, it is convenient to take the point where P = ·05 as the border which corresponds to a value 1·96 for $\frac{x}{\sigma}$; and thus all deviations exceeding 1·96 σ can be regarded significant and those less, insignificant as due to chance.

(*c*) **The best statistics to describe a sample**

As referred to already, the Normal Law and deductions of significance form it are absolutely of no purpose in dealing with a sample of limited size

n as we have in an agricultural experimentation. The problem to be considered is what are the best statistics to describe a sample of n figures, which would help in judging whether the given sample is a sample of the known population or whether two samples are identical samples. The Arithmetic average and the Standard Deviation are the two statistics, as referred to already, that best describe a population normally distributed, but their best *estimates* as deduced from a sample of such a population could be computed thus:—For the Arithmetic average, the usual procedure of taking $\frac{1}{n}\times$ the sum of the figures of the sample could be taken as the best estimate; while for the standard deviation s, the square root of $\frac{1}{n-1}\times$the sum of the squares of the deviations (as analogous to $\frac{1}{n}\times$ the sum of the squares of the deviations, for the computation of σ) could be taken to be the most reliable value. $(n\text{-}1)$ is substituted for n in the computation of s, for the simple reason that the true Arithmetic average of the population differs from the Arithmetic average of the sample, and that $(n\text{-}1)$ in the denominator increases the accuracy of s. The first two moments then with the slight difference in the computation noted already could be taken for all purposes as the two statistics describing the sample, though in cases where the distribution diverges from the normal in an appreciable degree we have to take higher moments and compute other statistics to describe the sample completely. In dealing with the errors that have arisen by chance such as the differences between two samples, their law of distribution may be taken to be *normal*, and the character of the sample may be based upon the first two moments only without loss of precision.

(*d*) **Consistent and efficient statistics**

Now then to judge of a sample, the law of distribution of the original population is obviously necessary, but when dealing with a sample of errors we have assumed that the original distribution is normal. Now having fixed the characters of the sample by means of its statistics, we have to examine whether and if so how two samples differ with respect to these characters. Statistically we have to examine the distributions of these statistics as obtained from several samples. Taking the Arithmetic average for example, we have to study the law of distribution of the Arithmetic averages obtained from a number of samples each of size n. Such a distribution would indicate the significance to be attached to the difference between the average of one sample and the average of another. Just as we inferred significance from the Normal Law, this new distribution of the average would signify, so far as this particular character is concerned, how far the samples are identical or different. Similarly, we can study the law of the distribution of the Standard Deviation of the sample and deduce the significance. The principle could be extended to any other statistic or to any higher moment whose law of distribution as obtained from several samples all of the same size n could be made the subject of study. Thus theoretically, if two samples are identical they must show *stable* values with regard to *any* moment of their distribution. But two fundamental considerations arise in fixing up a particular statistic for judging the significance of samples. The first is that the standard deviation of the distribution of the statistic must decrease as the size in the sample is increased. This is obviously a necessary condition, otherwise the value of the statistic cannot reach its true value as obtained from the whole population. Such statistics whose variance[1] decreases as n is increased are called *consistent* statistics. The second condition is that the statistic besides being *consistent* must be such that the amount of variance between the several samples must be as low as possible. In other words, of the several statistics that are consistent and possible whose laws of distribution could be inferred, the one whose variance is the least should be preferred for deducing the significance of the sample. Not only should *consistency* be reached but also *efficiency*, if any statistic should be useful to deduce the probability of a particular value of the statistic or its deviation from the true value. As an example, if n is appreciably large it is a well-known result that the average of a normal sample is distributed normally with the standard deviation $\frac{\sigma}{\sqrt{n}}$ where σ is the standard deviation and n the number in the sample. Again, the law of distribution of the standard deviation itself of the sample of appreciable n is also known to be *normal* but with the standard deviation $\frac{\sigma}{\sqrt{2n}}$. Hence for the purpose of efficiency alone the S. D. of the sample is a better statistic than the A. M. We shall examine the distributions of other statistics as deduced from samples where n is very small.

V. Distribution of s, $\frac{x}{s}$, χ^2

(a) General

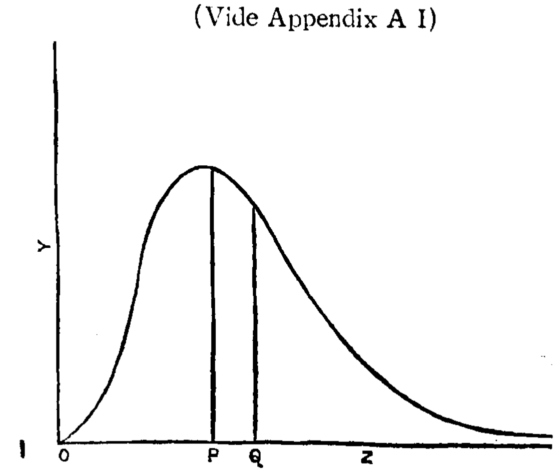
Just as $\frac{x}{\sigma}$ can be subjected to study in case where n is large, the distribution of $\frac{x}{s}$, where x obtained from a sample has a standard deviation s which differs from σ, could be studied for deducing the significance of x. Thus from a sample of n if $\bar{x}$ be its mean and s its standard deviation, the significance of the sample has to be judged from the value of $\frac{\bar{x}}{s/\sqrt{n}}$ with the help of tables of $\frac{x}{s}$. In general, if any statistical coefficient has its standard deviation known as obtained from the sample, the ratio of its value to the standard deviation could give the significance of its divergence from the assumed true value from the law of distribution of $\frac{x}{s}$. The principle is usefully extended to the case when two samples of size n_1 are compared whose means are $\bar{x}_1$ and $\bar{x}_2$ and whose standard deviations are respectively s_1 and s_2. Here if the differences between the samples could have arisen by chance only the mean of the differences of the corresponding figures in the samples can be taken to be zero, and the significance of $\bar{x}_1 - \bar{x}_2$ when compared with its standard deviation $\sqrt{\frac{s_1^2}{n_1}+\frac{s_2^2}{n_1}}$ * could be judged, and inferences drawn whether the samples are identical or not. Thus the general theorem on which the significance of a sample or differences between two samples could be based is this: If x be the deviation from the true value, whose standard deviation is s,

[1] 'Variance' used in the sense 'square of the standard deviation'.
* On the supposition that there is no correlation between the samples.

the law of distribution of $\frac{x}{s}$ would provide the necessary probability integral tables to judge of the significance of this deviation x. As in the case of the Normal Law dealt with already, the probability p of exceeding the deviation $\frac{x}{s}$ could be tabled, and lesser the value of p the greater the significance of x. But it is easily seen from our discussion that while $\frac{x}{\sigma}$ has a normal distribution when n is large, $\frac{x}{s}$ could be distributed only in a different way when n is small as s itself is subject to variation from sample to sample. We have, therefore first to study the frequency of s for samples of size n, and then deduce the frequency of $\frac{x}{s}$, assuming that the original distribution of the population is normal, which, as we have seen, is quite a legitimate assumption in dealing with the errors that arise by accident. The Mathematical deductions of these distributions are explained in Appendix A, and extracts from the Probability Integral Tables for the distribution of $\frac{x}{s}$ for different sizes are given in Table No. 9. The nature of these distributions for the size 10 are shown in Graphs Nos. 3 and 5 which would show how they differ funda-

GRAPH No. 3

(Vide Appendix A I)



$$y = y_0\, s^{(n-2)}\, e^{-\frac{1}{2} n \frac{s^2}{\sigma^2}}$$

Now when n = number of samples = 10

let $\frac{s}{\sigma} = z$

then $y = k\, \sigma^8 z^8 e^{-5z^2}$

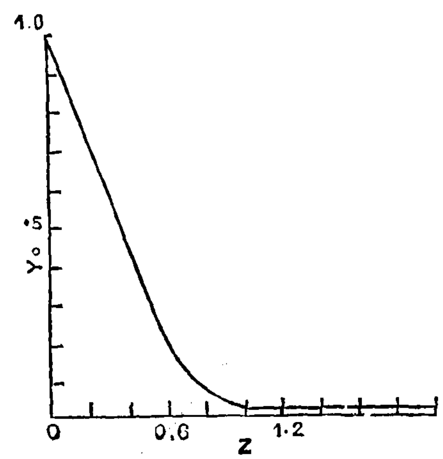
mentally from the Normal Law. It can be further seen that as the number in the sample increases the deviation decreases, and as the deviation increases the Probability decreases, and if, therefore, proper significance has to be attached to any deviation the lesser values of P are reached the greater the number in the sample.

Now for purposes of referring to the Tables, we need n, and x/s from which P is deduced. But new statistical concepts have been introduced with regard to n. It is easily seen that with a sample of n figures, whose aggregate is to remain constant, $(n-1)$ of these figures could be altered arbitrarily but the nth is automatically fixed up if the sum total should remain the same. Thus a sample of n figures is supposed to have $(n-1)$ degrees of freedom on the supposition that the sum total or their mean should be fixed. Hence instead of referring to the tables for n, the size of the sample, we could enter for $(n-1)$, the number of degrees of freedom, thus ensuring greater accuracy for the corresponding value of P. The same principle could be employed for securing a suitable value for n^1* in testing the significance of any statistical coefficient. If, for example, we are fitting a curve to the given data of size n, say a straight line which involves two constants, to this extent the number of

* n^1 = the number of degrees of freedom.

GRAPH No. 5

(Vide Appendix A III)



Now let $z = \dfrac{x}{s}$

$$\text{then } y = \frac{1}{\pi}\left\{\frac{(n-2)(n-4)\ldots\ldots4\cdot2}{(n-3)(n-5)\ldots\ldots3\cdot1}\right\}(1+z^2)^{-\frac{n}{2}}$$

when n is even

$$= \frac{1}{\pi}\left\{\frac{(n-2)(n-4)\ldots\ldots3\cdot1}{(n-3)(n-5)\ldots\ldots4\cdot2}\right\}(1+z^2)^{-\frac{n}{2}}$$

when n is odd

$$= y_o(1+z^2)^{-\frac{n}{2}}.$$

Here in the graph,

$n = 10$, z is taken to be positive

degrees of freedom is reduced by 2, as any two points in the straight line fix its position, so that the number of degrees of freedom is $(n-2)$. If again we are fitting a curve of the second degree $n^1 = n-3$ and so on. Again, what is known as the correlation co-efficient of a given number of n pairs is obtained by fitting a straight line of closest fit to pass through the n means and n^1 in such a case to test a particular value of the correlation co-efficient $=(n-2)$.

(*b*) **Significance of the Means: Illustrations from Agricultural experimentation**

We are thus in a position to attach significance to a sample of experiments or to different samples of experiments. In Agricultural experimentation, for example, we have to compare the yields of two varieties grown in two sets of plots and find out whether there is any significant difference between them. Here the problem is to find P for the difference of their means in terms of its standard deviation.

Examples are given in the tables illustrating the application of the theory. Table 3, for example, compares two varieties grown in 10 plots so that $n^1 = 9$. The mean of the difference between the corresponding figures is seen to be 67·5 whose standard deviation from the column of the differences alone is 64·57 from which P is deduced to be 0·01 shewing that there is significant difference between the varieties. It is easily seen that different conclusions could be reached if we had taken $n^1 = 10$. Again, instead of computing the standard deviation from the column of differences we could compute it from the standard deviations of the samples themselves,[1] but such a procedure is possible only if there is no correlation between plot and plot, i.e. if there is no systematic variation between the plots themselves. However, we have seen that there are systematic changes from plot to plot and therefore unless their correlation is known we are not warranted to take that the square of the standard error of the differences is equal to the sum of the squares of the standard errors of the samples. Other illustrations are given in Tables 2, 4, 5, and 6 illustrating the significance between varieties, with regard to their productivity on light and heavy soil, to bunch planting, cropping values of seeds, and manuring. The conclusions reached regarding the superiority of one variety to another are all based upon the mean of the differences being taken to be the deviation from the zero value assuming the latter to be the true value of the differences. As another illustration[2] of the theory governing $\dfrac{x}{s}$, we shall examine the significance of the correlation co-efficient obtained between autumn rainfall and wheat crop for twenty years. Here, $r = -\cdot629$ and its S.D. $= \dfrac{\sqrt{1-r^2}}{\sqrt{n-2}} = 1\cdot738$ and $\dfrac{r}{S.D.} = -3\cdot433$ giving $P < \cdot01$, shewing that the observed value of r is definitely significant. Here it is necessary to point out that it is always risky to rely upon the significance of the correlation co-efficient, or as a matter of that any regression curve, as computed from a limited number of data, for the simple reason that there is no method for knowing anything of the true values of the regression constants and that therefore to adopt statistical methods to attach any significance to the observed co-efficient is only putting the cart before the horse. Exhaustive enquiries alone could secure stable values for the co-efficients in such cases.

[1] $s^2 = s_1^2 + s_2^2$ could be used.

[2] This illustration is given in Page 158 '*Statistical Methods for Research Workers*' by R. A. Fisher.

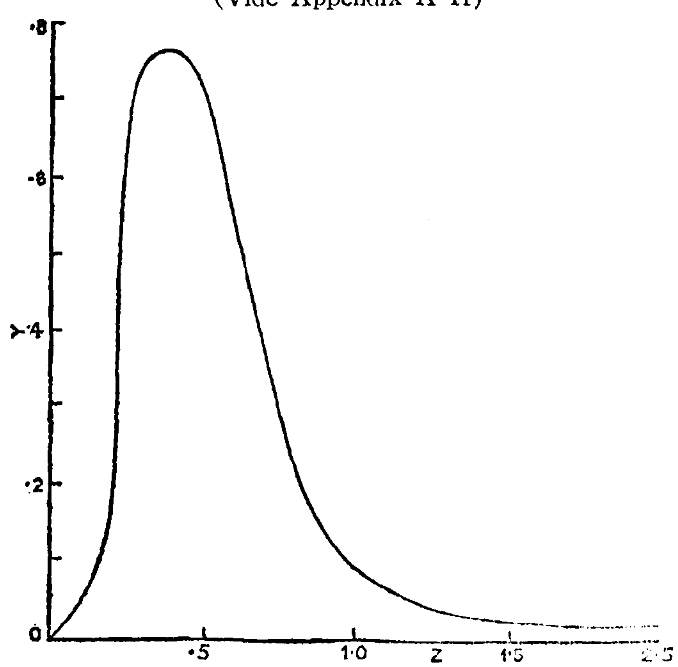
(c) Distribution of χ^2

(1) General

Till now we have been answering the only question how far we could identify two samples of experiments. The other question—the prior question put—, whether a sample is a sample of a known distribution still remains unanswered. The same method of the significance of $\bar{x}$ could be employed, but in all cases there is no guarantee that $\bar{x}$ can be very much relied upon, nor can we be sure that each difference between one sample and another measures to a reliable extent the error from the true value as due to chance. Hence we have to think of other statistics whose distributions could give the significance sought for. The problem in general terms could be stated thus: If $m_1, m_2, m_3 \ldots$ be a set of known values and if m_1+x_1, m_2+x_2, m_3+x_3, $\ldots$ be the corresponding set of observed values, what would be the bets statistic to measure the significance of these errors $x_1, x_2, \ldots$? The statistic must be the one based upon these errors themselves, and so long as we are sure of the known or theoretical set the distribution of $\Sigma\left(\frac{x}{m}\right)^2 = \chi^2$ requires a study, where we take the sum of the squares of the proportionate deviations of the individual errors. χ^2 is obviously analogous to s^2, and if n be the number in the sample $\frac{\chi^2}{n} = \frac{s^2}{\sigma^2}$. As the distribution of s^2 is known (vide Graph No. 4), the graph of $\frac{\chi^2}{n}$ or χ^2 itself is deduced. (For the distribution of χ^2, vide

Graph No. 4

(Vide Appendix A II)



$$y = y_0\, s^{n-3}\, e^{-\frac{1}{2} n \frac{s^2}{\sigma^2}}$$

Now when n = number of samples = 10

let $\frac{s^2}{\sigma^2} = z = \frac{\chi^2}{10}$

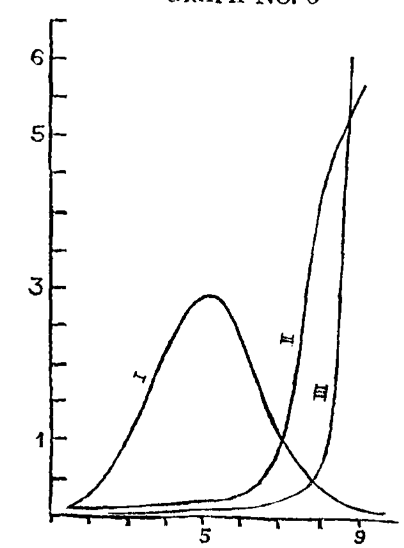
$$y = k \cdot z^{\frac{7}{2}}\, e^{-5z}.$$

Appendix A). It is easily seen that as χ^2 changes from zero to infinity, P changes from 1 to 0, and greater the value of P greater the correspondence between the theoretical and the observed set of observations. The limit of significance can be placed at P = ·05 as in the case of the other distributions considered already. Extracts are given in Table No. 10 giving the Probability of χ^2 for n^1 the number of degrees of freedom. As an illustration, the numbers with black and red eyes are observed in 33 families of Gammarus (Huxley's Data) and it is for us to test whether the Mendelian ratio 3: 1 due to linkage is followed in this case. It is found from the 33 frequencies, χ^2 = 35·620. From n = 32 it is seen that P is not small, and hence all families agree fairly closely in this particular trait.

(2) Binomial and Poisson distributions

The theoretical set referred to from which the deviations of the observed set were measured, might be one which has been decided from the past experience from similar enquiries or one deduced purely from theoretical and statistical considerations. We shall deal with a distribution that is of common use in the Agricultural experimentation, besides the one dealt with already the Normal Law of errors. If chance should be the only governing factor, it is a simple statistical result that the terms of the expansion of $(p+q)^n$ *

Graph No. 6



Binomial Curves
I $(p+q)^8$ and $p = 0·5$
II $(p+q)^8$ and $p = 0·08$
III $(p+q)^8$ and $p = 0·01$

* If p is very small and n increased indefinitely so that np is finite, the limit of the binomial is the Poisson's exponential series. (Vide Biometrica, Vol. 10, pp. 38-).

express the probabilities of happening of 0, 1, 2 . . . . n events of the sample of n experiments. The Arithmetic average of all the terms is np and the standard deviation npq. The Graph No. 6 indicates how with the changes in the value of p, the form changes continuously from one of symmetry to one of increasing asymmetry. The relation between np and npq the first two moments decides the nature of the distribution. Tables have been constructed giving the probabilities for different sizes of the sample as deduced from the binomial distribution and the observed set of figures can thus be made to correspond to the theoretical set. χ^2 could thus be computed, and from the table of χ^2 the significance of a particular value of χ^2 is deduced. Here are two illustrations exemplifying the application of χ^2. (Vide tables 7 and 8) In the first, we assume a binomial law and χ^2 is found to be $7 \cdot 740$. With $n' = 10$, $P = \cdot 654$ showing that the theoretical and the observed closely agree. In the other there is perfect agreement between the observed and the Poisson exponential.

vi. Concept of Variance—Correlation Co-efficient*

(*a*) General

The ideas of significance which we have dealt with so far lead us to a very important topic connected with the Agricultural experimentation. As we have referred to already the different types of variations and the different factors that produce the variations in the eventual yields of the plots under experimentation have to be analysed and subjected to statistical scrutiny. Though a single sample or different samples of experiments have been tested with regard to homogeneity, the problem still remains how to measure the interaction or correlation, if any, between the members of the same sample. If the whole population could be split up into n samples, each sample containing k observations or experiments, then if all the n samples are homogeneous, the statistic such as the Arithmetic average would shew consistent values in all the samples, and the standard deviation of the statistic will be indeed a very small quantity very close to zero, and thus the identity of the samples is established and there is no correlation between the individuals of the sample. But what ordinarily happens is that the standard deviation of the sample is significantly different from the standard deviation of the average of the sample which is nowhere near zero, in which case the two standard deviations have to be separated and their mutual significance has to be studied. Thus when we deal with the heights of n pairs of father and son of the same family, while the father and son of any family would give a standard deviation of its own, the averages of the father and son as obtained from n samples would give a different standard deviation. The two causes of deviation being different, the values of the two standard deviations and their significant difference based upon their individual degrees of freedom decide whether there is any correlation between any pair of observations. The result could be put in this form: The total variance† of all the n samples containing kn observations, could be split up into two different variances, one due to the deviation of the individuals of each sample from its average, and the other due to the deviations, between the several samples, of the average of each sample. If the latter variance is

* The ideas in this section are taken from several papers dealing with the Intra class correlation. (Vide R. A. Fisher, Pages 176–232).

† 'Variance' is used in the sense of 'the square of the standard deviation.'

significantly greater than the former the correlation, if there should be any, must be positive, but if less it is negative. The following simple equation explains how the total variance is split up:

$$\sum_{1}^{kn} (x-\bar{x})^2 = \sum_{1}^{kn} (x-\bar{x}_p)^2 + k \sum_{1}^{n} (\bar{x}_p-\bar{x})^2$$

where x is any individual observation, $\bar{x}$ the Arithmetic average of the whole, $\bar{x}_p$ the average of a sample. This simple principle of analysing the total variance due to two causes only could be easily extended when the total could be split up into variances due to any number of causes. If, for example, the yield of a particular plot be due firstly to the plot itself, next to manuring and lastly to the variety grown, the variances of these causes could be separately computed, and the sum of these plus the variances due to the sub-classes should be equal to the total variance if there should be no other cause of variation. Again, in the study of rainfall from hour to hour, from day to day, and from month to month each particular item of hourly rainfall belongs to a particular day and to a particular month, the total variance of all the yearly items being thus equal to the monthly and the daily variances plus the variance due to the interaction of causes and deviations in each class. One more illustration from the Agricultural experimentation of plot-trials subjected to different varieties. In the plot-technique, we insisted upon a random arrangement of the varieties in each block, and thus several blocks were dealt with which are themselves subject to variations in fertility. Now to bring out the differences between the varieties markedly, we have to compute separately the variance due to the blocks, the variance due to the varieties and the one due to the random errors of measurement, and we have to examine statistically the significant difference between one variance and another. This analysis of variance is thus a key to the solution of problems where we have to examine the differences between the several causes producing an aggregate result.

(*b*) Significance of the difference between two different types of variance—Illustrations

Thus we are led to this statistical problem—what is the best statistic to signify the difference between the variances due respectively to n_1 and n_2 degrees of freedom? In the ideal case when n_1 and n_2 are infinite and when their distributions are normal, the chance that the two variances are equal is just $\cdot 5$. The best statistic z that would bring out the difference of one variance and another is half the difference of the logarithms between the two which is found to be distributed normally with the standard deviation $\sqrt{\frac{1}{2}\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}$* and thus the Normal Law Probability Integral Tables could be used to measure the significance of the difference between the two variances. Tables are constructed giving for any value of half the difference of the logarithms of the two variances the probability P corresponding to n_1 and n_2.

Here are two examples illustrating this principle of analysis of variance:

[1] (1) A plot of land is divided into 36 patches on which 12 varieties are grown and each patch is divided into three lines at which three different manures are tried. Thus the yield depends upon the particular patch, the

* This is strictly true only if n_1 and n_2 are appreciably large or when they are equal. In other cases the significance is obvious from the variances themselves.

[1] This example and the explanations are taken from Fisher (Vide Supra), page 203.

particular variety and the particular manure. The following is the analysis of the variances due to several causes:

The cause of variance	Number of Degrees of Freedom	Amount of variance
Between varieties ..	11	3·967
Between patches of the same variety ..	24	·727
Between manures ..	2	·175
Differential response of varieties ..	22	·010
Differential response in patches with same variety ..	48	·168
Total ..	107	·670

From the above analysis the following inferences are easily drawn: Firstly while 24 degrees of freedom for the patches give a variance ·727, 48 between the patches growing the same variety give only ·168 proving the significant difference between the plots when compared with the effects of the varieties on the plots. Again, among the varieties themselves for the 22 degrees of freedom the variance is only ·01, which is enough to indicate that there is not much difference between one variety and another. The difference between the manures gives only ·175 which is not very high when compared with the differential response of varieties, shewing that the manures do not demonstrate any significant difference.

[1] (2) Five varieties are grown each in 6 different plots. The total variance is split up into variances due to several causes. Thus we have this scheme:

The Cause of variance	No. of Degrees of Freedom	Amount of variance
Between varieties ..	4	41·36
Between plots growing the same variety ..	25	1715·72
Between plots of the same number serially arranged for the same variety ..	5	424·30
Between varieties taken two and two grown in plots of the same number ..	50	3228·40

[1] This example is taken from '*The Principles and Practice of Yield Trials*' by Engledow and Yule, page 18.

From the above analysis it is clear that while varieties exercise a variance of 41·36 the plots themselves produce an abnormally large variance, showing the decided effect of the plots when compared with the varieties. A further examination shows that in the experiment a fairly high randomness has been secured in the replication of varieties as the variance between the serial numbers of plots is comparatively low. Lastly there is not much significant difference between the adjoining plots and between plots growing the same variety. In every one of these cases the actual probability could be deduced from the tables, and the significance deduced.

APPENDIX A

I

Distribution of s*

Let a sample consist of n data $x_1, x_2, x_3\; x_n$; let the original distribution follow the normal law; and let the averages of the sample and of the original population be respectively $\bar{x}$ and m. Then obviously the probability of the n values occurring = Constant $\times e^{\frac{-\frac{1}{2}\sum (x_s - m)^2}{\sigma^2}} \times \delta x_1 . \delta x_2 \ldots . \delta x_n$. (1)

Now if $s^2 = \frac{1}{n}\sum (x_s - \bar{x})^2$, after transformation (1) reduces to = Constant $\times e^{-\frac{1}{2}\left(\frac{n s^2}{\sigma^2} + \frac{n(\bar{x}-m)^2}{\sigma^2}\right)} \times s^{n-2}\,\delta \bar{x}\, \delta s.$

From this the law of distribution of s is seen to be

$$y = \text{Constant} \times s^{n-2} e^{-\frac{1}{2}\frac{ns^2}{\sigma^2}} \text{ (Vide Graph 3 for } n=10). \quad (2)$$

II

Distribution of s^2 and χ^2

From (2) the frequency of s^2 is easily deduced. Since Q (s^2) $d(s^2)$ = Q $(s^2) \times 2s\, ds$, it is seen that the law of s^2 is obtained by dividing the frequency of s by $2s$. Thus the frequency of s^2 = Constant $\times (s^2)^{\frac{n-3}{2}} e^{-\frac{1}{2}\frac{s^2}{\sigma^2}}$ (3)

The law of χ^2 is again inferred from (3), as $\frac{\chi^2}{n} = \frac{s^2}{\sigma^2}$. This gives that the frequency of χ^2 = Constant $\times (\chi^2)^{\frac{n-3}{2}} \times e^{-\frac{1}{2}\frac{\chi^2}{n}}$. (4)

(Vide graph 4 for $n = 10$).

* Vide Biometrica, Vol. 10, pp. 522-523

III

Distribution of $\frac{\bar{x}}{s}$

(Biometrica, Vol. 6, Pages 1–25)

Now it is a well-known result that $\bar{x}$ obtained from samples of n is distributed according to the normal law with a standard deviation $\frac{\sigma}{\sqrt{n}}$ so that the frequency of $\bar{x}$

$$= \text{Constant} \times e^{-\frac{n\bar{x}^2}{2\sigma^2}} \qquad (1)$$

To deduce the frequency of $\frac{\bar{x}}{s} = z$, first we shall take s to be constant from sample to sample. The distribution of $\frac{\bar{x}}{s}$ is then :

$$= \text{Constant} \times s \times e^{-\frac{ns^2z^2}{2\sigma^2}} \qquad (2)$$

But as s varies the probability of s occurring

$$= \frac{\int_s^{s+ds} s^{(n-2)} e^{-\frac{ns^2}{2\sigma^2}} ds}{\int_0^{inf.} s^{(n-2)} e^{-\frac{ns^2}{2\sigma^2}} ds} \qquad (3)$$

(from the distribution of s.)

Hence the frequency of $\frac{\bar{x}}{s}$ is obtained by multiplying (2) and (3) and summing for all values of s which reduces to

$$y = \frac{\text{Constant} \times \int_0^{inf.} s^{n-1} e^{-\frac{ns^2(1+z^2)}{2\sigma^2}} ds}{\int_0^{inf.} s^{(n-2)} e^{-\frac{ns^2}{2\sigma^2}} ds}$$

By a process of reduction, this integral reduces to

$$y = \tfrac{1}{2}\,\frac{(n\text{-}2)\,(n\text{-}4)\cdot\;\cdot\;5\cdot3}{(n\text{-}3)\,(n\text{-}5)\cdot\;\cdot\;4\cdot2}(1+z^2)^{-\frac{n}{2}} \qquad \text{(if } n \text{ be odd)}$$

or

$$= \frac{1}{\pi}\,\frac{(n\text{-}2)\,(n\text{-}4)\cdot\;\cdot\;4\cdot2}{(n\text{-}3)\,(n\text{-}5)\cdot\;\cdot\;3\cdot1}(1+z^2)^{-\frac{n}{2}} \qquad \text{(if } n \text{ be even)} \qquad (4)$$

Tables are constructed giving the probability integrals of (4), by the substitution of $z = \tan\theta$ which gives for $(1+z^2)^{-\frac{n}{2}} dz = \cos^{n-2}\theta\, d\theta$, which could be easily integrated.

TABLE 1

Graduation of 25 plots under five different varieties

Variety	Plot	Observed Yields	Graduated Values	Difference of (3) and (4)	The Ratio of (5) to (4)
(1)	(2)	(3)	(4)	(5)	(6)
A	1	450·00	399·84	50·16	·13
	2	340·00	392·16	−52·16	·13
	3	430·00	372·96	57·04	·15
	4	370·00	342·14	27·86	·02
	5	380·00	300·00	80·00	·27
B	1	410·00	399·36	10·64	·03
	2	320·00	399·04	−79·04	−·19
	3	400·00	368·64	31·36	·09
	4	310·00	356·00	−46·00	−·13
	5	290·00	315·36	−25·36	−·08
C	1	370·00	398·56	−28·56	−·08
	2	370·00	387·04	−17·04	−·05
	3	360·00	364·00	− 4·00	−·01
	4	400·00	353·76	46·24	·13
	5	400·00	329·44	70·56	·21
D	1	430·00	398·44	31·56	·08
	2	410·00	384·00	26·00	·07
	3	360·00	380·64	−20·64	−·05
	4	330·00	343·16	−13·16	−·04
	5	330·00	322·56	7·44	·02
E	1	370·00	396·00	−26·00	−·07
	2	480·00	389·76	90·24	·23
	3	400·00	376·96	23·04	·06
	4	400·00	359·04	40·96	·11
	5	360·00	307·84	52·16	·17

To illustrate the significance of means

TABLE 2

(Extracted from Biometrica, Vol. 6)

Soft and Hard seeds on light and heavy soils

	1899 Light	1899 Heavy	1900 Light	1900 Heavy	1901 Light	1901 Heavy
Soft seed ...	7·85	8·89	14·81	13·55	7·48	15·39
Hard seed ...	7·27	8·32	13·81	13·36	7·97	13·13
Difference ...	·58	·57	1·00	·19	−0·49	2·26

	Average
Soft seed ...	11·328
Hard seed ...	10·643
Difference ...	·685

$n^1=5$; S. D. $=\cdot778$; $z=\dfrac{\bar{x}}{s/\sqrt{n}}=1\cdot93$; P $=\cdot18$ (nearly).

The difference is not significant, when compared with the soil.

TABLE 3

(Extracted from Agricultural Journal of India, Vol. 20)

To illustrate the difference between varieties

Plot Number	Yield of variety A	Yield of variety B	Difference
1	703	670	33
2	705	630	75
3	653	560	93
4	640	615	25
5	700	542	158
6	715	667	48
7	647	702	−55
8	848	750	98
9	918	758	160
10	870	830	40

(1) Average of Difference = 67·5

(2) S. D. of Difference = 64·57

$z=\dfrac{\bar{x}}{s/\sqrt{n}} = 3\cdot00$

$n^1 = 9$

$P = \cdot01$ (nearly.)

The difference is clearly significant.

TABLE 4

To illustrate the problem of Bunch Planting

Variety	Singles Grain	Singles Straw	Doubles Grain	Doubles Straw	Difference Grain	Difference Straw
A. ...	300	500	305	520	5	20
B. ...	250	320	280	315	30	−5
C. ...	380	600	360	616	−20	16
D. ...	400	620	420	630	20	10

	Grain	Straw
Average Difference	8·75	10·25
S. D. ...	22·07	9·75
$z = \dfrac{\bar{x}}{s/\sqrt{n}} =$ ...	·67	1·83
$n^1 = 3$ ...	...	...
P = ...	·56 (nearly)	·17 (nearly)

Difference not significant in grain but comparatively significant in straw.

TABLE 5

To illustrate the cropping value of seeds

	Main		Thalus		Nursery		Difference between 2 & 3	
	1		2		3			
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Variety A. ...	400	606	410	620	405	630	5	-10
„ B. ...	425	635	420	625	415	600	5	25
„ C. ...	500	700	515	725	525	730	-10	-5
„ D. ...	480	650	490	680	500	620	-10	60
Average ...	451	648	459	662	462	645	-3	17
S. D. of the difference ...	...	...	...	...	...	...	8·67	32·28
$z = \frac{\bar{x}}{s/\sqrt{n}} =$ ...	...	...	...	...	...	...	·7	1·05

$n' = 3$.

Since P is large, there is no significant difference between (2) and (3).

TABLE 6

To illustrate the yields due to different treatments

Plot No.	Treatment A.		Treatment B.		Treatment C.		Treatment D.		Treatment E.		Treatment F.		Treatment G.	
	Gr.	St.	Gr.	St.	Gr.	St.	Gr.	St.	Gr.	St.	Gr.	St.	Gr.	St.
I.	40	100	45	120	48	120	50	115	52	125	55	110	47	94
II.	35	80	[illegible]	90	40	120	42	108	42	95	40	100	39	92
III.	38	90	40	102	42	95	39	98	42	100	45	120	38	90
IV.	48	120	50	110	48	120	47	115	50	110	52	115	54	120
V.	50	110	52	120	55	112	60	90	58	120	60	125	62	130
Average ...	42	100	45	109	47	110	48	105	49	110	50	114	48	105
	Gr.	St.												
Average of the average ...	47	108												
S. D.	1·02	1·74												

$n' = 6$

P is very small and there is no significant difference between one treatment and another taken all together, but a similar method could be employed to test the difference between any two treatments.

SIGNIFICANCE OF x^2

TABLE 7

(Extracted from Biometrica, Vol. 10)

Suicides of Women in Eight German States

Number of Suicides.	0	1	2	3	4	5	6	7	8	9	10 and over	Total
Observed frequencies ...	9	19	17	20	15	11	8	2	3	5	3	112
Theoretical or Binomial Frequencies.	12·6	18·4	18·8	16·4	13·2	9·9	7·2	5·1	3·5	2·4	4·5	112

$x^2 = 7 \cdot 740 \quad n' = 10 \quad P = \cdot 654$

This shows that the observed and theoretical closely agree.

TABLE 8

(Taken from Biometrica, Vol. 10)

Number of deaths	0	1	2	3	4 and over
Observed frequencies	109	65	22	3	1
Poisson's Exponential frequencies...	108·7	66·3	20·2	4·1	0·7

Here $x^2 = \cdot 441 \quad n' = 3 \quad P = \cdot 92$

This shows perfect agreement with the theory.

TABLE 9

(Extracted from R. A. Fisher, p. 137)

Probability for $\frac{x}{s}$

n'	P = ·9	·8	·7	·6	·5	·4	·3	·2	·1	·05	·02	·01
3	·137	·277	·424	·584	·765	·978	1·250	1·638	2·353	3·182	4·541	5·841
4	·134	·271	·414	·569	·741	·941	1·190	1·533	2·132	2·776	3·747	4·604
5	·132	·267	·408	·559	·727	·920	1·156	1·476	2·015	2·571	3·365	4·032
6	·131	·265	·404	·553	·718	·906	1·134	1·440	1·943	2·447	3·143	3·707
7	·130	·263	·402	·549	·711	·896	1·119	1·415	1·895	2·365	2·998	3·499
8	·130	·262	·399	·546	·706	·889	1·108	1·397	1·860	2·306	2·896	3·355
9	·129	·261	·398	·543	·703	·883	1·100	1·383	1·833	2·262	2·821	3·250
10	·129	·260	·397	·542	·700	·879	1·093	1·372	1·812	2·228	2·764	3.169

5

n' = the No. of degrees of Freedom.
P = the Probability.

The figures in the body represent the deviation $\frac{x}{s}$

TABLE 10

(Extracted from R. A. Fisher, p. 98)

Probability for x^2

n'	P = ·99	P ·90	·70	·50	·30
3	·115	·584	1·424	2·366	3·665
6	·872	2·204	3·828	5·348	7·231
9	2·088	4·168	6·393	8·343	10·656
10	2·588	4·865	7·267	9·342	11·781
32	14·953	20·599	25·508	29·336	33·530

n' = the No. of degrees of Freedom.
P = the Probability.
The figures in the body represent x^2.

CHOLAM AS INFANTS' FOOD

BY

FEMINA

[We are indebted to an esteemed lady contributor for the following note on 'Cholam as Infants' Food'. A lengthy article on the subject appeared in our December issue (1929). The future of cholam malt for home-made infants' and invalid food rests entirely in the hands of women, both from the point of view of propaganda and experimentation for the production of recipes of varied tastes. We are happy to note that the subject is receiving the attention it deserves and we have great pleasure in publishing the note by our esteemed correspondent.—Ed. M. A. J.]

No, the idea is not to feed simple cholam grains to babies and young children!

So long ago as 1917, Mr. B. Viswanath, Government Agricultural Chemist, proved that in the making of malt, cholam would replace barley, a crop little grown in South India. A gold medal was awarded to his exhibit of malted foods at the Madras Industrial Exhibition held in 1917. These foods were intended to replace expensive proprietary preparations imported from abroad.

Cholam, being a widely cultivated crop in South India, is cheap and available to all classes. Its conversion into malt is quite possible in any home where a little trouble is taken. No special apparatus is necessary.

The value of malt as a pre-digested food, suitable for young children and invalids, is so well known that there is no need to dwell upon it. A doctor in South India has just prepared a quantity for use in his hospital, and wishes that the use of cholam in this connection were more widely known. Ragi may also be used but the grains are too small for easy preparation.

The preparation of malt on a larger commercial basis would be possible to a man with a little capital. This would add a useful indigenous industry to India's resources. Information on this subject is available from the Government Agricultural Chemist at Lawley Road, P. O., Coimbatore.

Method of preparation. Take good, sound, cleaned cholam. Soak it in clean water for one day, and one night, changing the water four times. After soaking heap up the cholam, covered with a wet cloth till the sprouts appear. Then spread it thinly and evenly on a clean mat, occasionally sprinkling water over it.

When the sprouts are about three-quarters of an inch long, dry the cholam in the shade for half a day, and then in the sun till it is quite dry.

The dried grain should be slightly moistened and pounded to remove the husk and sprouts. The latter have a bitter taste. After removing the husk the clean grain is slightly roasted over a slow fire till the grains are just brown. They are then to be ground in a coffee mill or grinding stone and sieved through muslin.

The powder may be made into a conjee with milk or water, and salt and sugar added according to taste. The malt may be added to other food. It actually requires no further cooking, but may be cooked if wished.

The following is extracted from 'Food' by Lt.-Colonel R. McCarrison.

'Vitamin A is produced when grains are sprouted after soaking in water: sprouted gram and dhal contain quite a lot of it.'

He also tells us that a deficiency in Vitamin A is associated with such diseases as inflammation of the eyes, ears, nose, throat, lungs, stomach and bowels. Night blindness may be due to a deficiency of this vitamin.

There are of course many other sources of Vitamin A besides that described here. A study of the book mentioned will show what these are.

Reference:—'Food' by Lt.-Col. Robert McCarrison, C.I.E., M.D., D.Sc., L.L.D., F.R.C.P., I.M.S.

Macmillan and Co., London; Madras; etc. Price As. 12. All profits from the sale of this book are given to certain Indian charities.

REVIEW OF THE COPRA MARKET (October 1929)

BY D. H. GRIST, Federated Malaya States,

Agricultural Economist.

INTRODUCTION. The world's marketed production of copra is estimated to be slightly in excess of one million tons per annum, of which Malaya's exports form nearly 20 per cent. The product is graded on the European market according to the country of origin; the accompanying table indicates the existing grades, the average prices obtained, and the approximate quantities shipped annually.

TABLE I

Grades and Values of Copra

Grade	Average price per ton (Nett Cash C. I. F.) London	Average Quantity Shipped per annum (Tons)
F. M. S. *Ceylon	24 5 0	95,000
F. M. S. Java	23 10 0	40,000
F. M. S. Straits	23 7 6	180,000
M. S. Straits	22 12 6	
F. M. S. Dutch East Indies	23 7 6	360,000
M. S.	22 12 6	
F. M. S. Ceba	22 17 6	200,000
F. M. S. Manila	22 10 0	
F. M. S. South Sea	22 17 6	150,000
Kiln dried South Sea	22 10 0	
Average ...	£23 1 9	Total 1,025,000 tons.

In view of what follows, it should be noted that those grades which command the highest price (F. M. S. Ceylon and F. M. S. Java) bear but a small proportion (approximately 13 per cent.) to the total quantity

*F. M. S. = Fair Merchantable Sun-dried.

marketed ; while exports of the high grade Malabar copra have entirely ceased.

The Decline in the Price of Copra. A review of the existing condition of the copra market cannot be undertaken without comparing this oil seed with the remaining oils and oil products. During recent years, the price of oils and fats generally has appreciated. Thus, taking the pre-war index price as 100, the average price of oil seeds in August 1929 stood at 137, that of oils and fats at 122, and oil cakes at 155. (It may be of interest to compare these figures with Cereals at 140 and 'Sundries' —including such widely dissimilar products as beef and iron—at 119). The only two oil seeds which do not share this prosperity are copra and palm kernels, the figures for which are 90 and 93 respectively (i.e., they are actually below pre-war level). It will therefore be observed that, at present, other oil seeds command a price approximately 50 per cent. higher than that of copra, from which it may be argued either that other oil seeds are too expensive or that copra is too cheap. Whichever of these alternatives is correct, the current opinion of many on the market is that copra has about reached its rock bottom price, but that its recovery will be slow.

The decline in price of copra is shewn by the following figures, which shew the average price of F. M. S. Straits Copra, C. I. F. London during the past few years.

TABLE II

Average Prices (C.I.F. London) for Straits Copra

Year		Price per ton	Year	Price per ton
1916 ...	...	£ 33 13 0	1923	£ 27 17 6
1918 (controlled)	...	45 10 0	1924	29 15 0
1919 ...	...	52 10 0	1925	30 5 0
1920 ...	...	56 7 6	1926	28 12 6
1921 ...	...	30 12 6	1927	27 10 0
1922 ...	...	24 15 0	1928	26 17 6

It will be observed that since 1925 the price of copra has steadily depreciated by nearly 10 per cent.

Reasons for the Decline. It should be clearly understood that the fall in the price of copra must be attributed to a number of causes and not to any one cause in particular. It has been asserted that the activities of a combine of crushers, which is said to control the European market to a great extent (especially in edible oils), has brought about the present slump. While there is no doubt that the combine can affect prices, the writer is of opinion that the principal reasons which have assisted their ends were actually outside their control.

During the past decade, there has been a very striking increase in the world's production of edible oils. The part played by copra in this

increase is shewn in the accompanying table, supplied by the Empire Marketing Board and based on figures published by the International Institute of Agriculture.

TABLE III

World Exports of Copra (in thousands of tons)

			(Average) 1909-1913	1914	1925	1926	1927	1928
British Malaya	...	...	4	92	86	104	97	95
Dutch East Indies	...	...	234	338	335	371	300	431
Philippines	...	...	128	154	145	171	196	234
Ceylon ...	...	...	41	88	113	121	99	99
South Seas	...	...	70	139	148	159	159*	...
Unspecified	...	...	68	64	80	82	62	...
	Total	...	545	875	907	1,008	913	

Similar increases have been experienced in the case of oils and fats which compete with copra. The principal competitors at the moment are groundnuts (the exports of which are shewn in the accompanying table), and whale oil.

The future planting of groundnuts will undoubtedly be liable to fluctuation according to the trend of prices.

TABLE IV

World Exports of Ground-nuts (in thousands of tons).

			1909-13 (Average)	1924	1925	1926	1927	1928
British India	...	...	192	243	463	444	475	749
French West Africa	...	...	205	312	444	480	404	386
British West Africa	...	...	64	139	176	188	160	195
China ...	...	...	39	196	168	176	...	...
Unspecified	...	...	55	102	82	89	...	...
	Total	...	55	992	1,333	1,377		

* Provisional.

The production of whale oil, which is largely used in the edible oil trade, has made great strides in recent years. Figures of production indicate an increase from 109,000 tons in 1922 to 203,000 tons in 1927 and 226,000 tons in 1928. Production in 1929 is expected to shew a further material increase. There is reason to believe that local copra producers do not realise that whale oil is perfectly suitable for margarine production, and is in no way inferior to copra oil for this purpose. The whaling industry is better organised than ever before and the number of companies engaged in whaling has increased considerably of late. Whale oil at £25 per ton is said to give a profit to the producer of 25 per cent. Little appears to be known of the habits of whales, and it is therefore impossible to compute the apex of production of this class of oil ; but it seems reasonable to anticipate that the slaughter of increasing numbers of whales must soon affect the amount of oil available from this source, by reason of the decrease in their population. At present, however, copra oil is quite unable to compete with whale oil for edible purposes. The present slump in glycerine has also had its effect on the price of oils and fats for the production of soap.

Quality of Copra. The existing method by which purchasers of copra estimate its value is entirely based upon its appearance to the eye. A visitor to the London Copra Association, a body whose sole function is arbitration between buyer and seller, will find no apparatus for chemical analysis, but merely a long bench in front of a window on which the samples are exposed to the scrutiny of the arbitrator. Although this method may appear unreliable, it should be remembered that it is based upon the experience of the valuer who appreciates the relationship between external characters and oil content ; and that this relationship is based upon the fact that good appearance indicates careful preparation ; with low moisture and free fatty acids content, and therefore a comparatively high oil content. The method has the advantage of enabling large numbers of separate consignments to be marketed without the delay entailed by chemical analysis.

In the valuation of copra by appearance, the following points are taken into consideration :—

(a) *Colour.* The colour should be as white as possible.
(b) *Size and Thickness.* The copra should be thick and should not contain too great a proportion of small pieces.
(c) *Cleanliness.* The copra should be free from extraneous matter.
(d) *Moisture.* Air-dry and free from moulds.

A white copra will produce an oil of good colour. Thick large copra facilitates crushing, and lessens the liability to development of free fatty acid. Moulds are related to a high free fatty acid content and are caused by delay in drying the copra or by subsequent damage by water. Rapid drying is essential for the production of good copra. Moisture causes copra to deteriorate very rapidly ; and once it has become wet, although again dried subsequently, the fact remains evident in the poor condition of the copra. Finally, the presence of pests naturally deteriorates the copra.

TABLE V

Quality of Copra

Origin		Percentage		
		Oil	Moisture	Free Fatty Acids
F. M. S. Dutch East Indies	...	66	4	0·8
F. M. S. Demerara ...	...	69	5	1·25
F. M. S. Straits ...	...	66	4	1
F. M. S. Jamaica ...	...	69·5	4	1·25
F. M. S. Mauritius ...	...	68	3·5	1·25
F. M S Mozambique ...	...	67	3·75	1·25
F. M. S. South Sea ...	...	67	3·5	4·5
F. M. S. West Indian ...	...	70	1·5	4
F. M. S. Ceylon ...	...	68	...	1

From the above, it will be seen that the object is to judge the copra on points which indicate a low percentage of moisture and a high percentage of oil of good colour, and economy in manufacture.

Table V gives the average quality of copra from different sources.

Samples of Ceylon copra examined by the writer with arbitrators at the London Copra Association were superior in appearance to those of Straits Copra. The meat of the former was thicker and of better colour, it was cleaner, and it had a sweeter smell. The writer is of opinion that thinness of flesh is more frequently than not due to inferior methods of preparation rather than to variety of coconuts, soil or climate. All the genuine sun-dried copra examined by the writer was thicker than the kiln-dried copra.

Improvement of Quality by Legislation. In certain Crown Colonies, attempts have been made to enforce an improvement in the quality of exported copra by means of legislation. The writer is not familiar with the standard of copra exported from these colonies prior to the introduction of such legislation ; but, judging from the few samples of copra from such sources seen in London, the writer was not impressed by their present quality, while brokers who were questioned on the subject were sceptical of the effectiveness of these measures.

Standards of Copra. As already stated, copra is bought and sold—not on analysis of a sample—but on a standard based on appearance. It should be added that a separate standard has been laid down for each producing country and that there is no general standard. The designation F. M. S. Straits for instance, means Fair Merchantable Sun-dried Copra from the Straits Settlements or Malay States. It may also apply to copra from the Dutch East Indies re-exported from Malayan ports. In passing, the writer would remark that some of the so-called sun-dried accepted on the London market appears to be kiln-dried, or a mixture of kiln and sun-dried copra.

The standard set down for each country of origin represents the average quality of copra received from that country. It should be emphasised that the purchaser of copra, knowing the country of origin of his purchase, sees no sample, but he understands that the delivery will conform to the standard agreed upon for copra of that particular origin. Should the consignment not reach that standard he will arbitrate ; but should it be superior to the standard he will naturally have nothing further to say on the matter.

From the above facts it is considered that, even if Malayan planters improved the quality of their copra, there would be no prospect of an immediate corresponding rise in price. All copra dealers state that the quality of copra from the Malay States is satisfactory, and it is therefore evident that copra of this quality fills a particular demand. It is of course possible either that a local buyer, anxious for high grade copra with which to level up his stocks, may offer a premium for special quality copra, or that a special market for high grade copra might be obtained in Europe by private arrangement. But, generally speaking, the producer can expect no higher price for copra than the standard laid down for the country of origin. It should also be remembered that any improvement in quality would probably involve an increased cost of production, which would not be justified unless a commensurate increase in selling price were forthcoming.

One important manufacturer of edible oil products definitely asserts that the quality of Malayan copra is satisfactory. He points out that modern crushing and refining machinery is competent to deal with medium or poor quality copra, so that it is far less essential than hitherto for copra to be of high standard.

From Tables II and V it will be found that the unit cost of oil from Ceylon copra is 7·35 shillings as against 6·86 shillings per unit of Malayan copra. If crushing and refining plant can effectively and cheaply deal with the latter, it seems probable that the price of Ceylon copra will tend to approximate more closely to that of Malaya. The writer is informed that there are still some factories which prefer the Ceylon product because they are less capable of dealing economically with lower grades. But it is possible that, as old-fashioned machinery is replaced, the present premium on Ceylon copra will gradually disappear, and that an up-grading of Malayan copra will not have a similar effect on its selling price.

Reference to Table I shews moreover, that the proportion of high grade copra is relatively small. This fact, in conjunction with the general satisfaction with Malayan and similar grades, adds strength to the contention that if the standard of Malayan copra were improved and were to approximate to that of Ceylon, there would be no immediate improvement in price. Later, when the market realised that the Malayan product had improved, there would be, not a rise in the price of improved copra, but a reduction of the premium allowed on Ceylon copra.

Provided that the average oil content of Malayan copra can be definitely raised, even by 2 or 3 per cent., it is possible that a higher price may ultimately be realised. But the evidence at present indicates that such an improvement in quality would not lead to an immediate rise in price. In these circumstances it is unlikely that any proposals for improving the existing quality of copra would find favour with directors or managers of coconunt estates in this country.

It may be urged that this report lays undue emphasis on edible oils and ignores the undoubted necessity of vegetable oils for soap making. But the use of oils for edible purposes is undoubtedly the crux of the question, and it is to be increased consumption of edible oils (in such

products as margarine and ghee) that one must look for any appreciable recovery of the price of copra generally.

Prospects of Consumption. Supplies of copra are at present adequate ; and as already stated, other oils are coming on to the market in increasing quantities. Perhaps the most encouraging feature of the present position is the fact that the market has been able to absorb the enormous increase of edible oil which has been thrown on the market. This absorption has certainly been at the sacrifice of price, but the absence of large unabsorbed stocks encourages one in the belief that the oil market will require constantly increasing amounts of oil to keep pace with the ever growing consumption. An important opinion was expressed to the effect that the oil market can easily absorb all production of oils for the next 20 years, as consumption is increasing by leaps and bounds.

SUMMARY

The price of copra since the War has not advanced in line with that of other oil seeds. The grades and values of copra are stated together with the approximate annual production of each. The figures demonstrate that there is a relatively small proportion of high grade copra on the market.

The causes for the fall in the price of copra are examined. It is held that the major reasons are purely economic. The two chief reasons for the present low price are the rapid increase in the world production of other edible oils, and in particular, to the strong competition of the whale oil industry.

The methods of judging copra by appearance, and the qualities which are indicated thereby, are stated.

The method of purchasing copra on standards based upon country of origin and not on sample, is explained. It is argued that any improvement in the quality of Malayan copra will not be reflected in an immediate increase in price.

The opinion is expressed that legislation to enforce improvement in the quality of exported copra has not been effective.

Conclusion. Owing to the peculiar methods of buying copra on standard, producers cannot hope for any immediate improvement of price for a corresponding improvement of quality. There is probably some scope for copra of good quality—which may command a premium for grading up native-produced copra. It is extremely doubtful whether any premium obtained, either by private treaty or the recognition of the London market, would be commensurate with the extra cost of production.

For the above reasons, it is evident that the application of any results achieved by research work on the improvement of the quality of copra will not be altogether easy. It will be necessary to overcome the strong prejudice of the Trade against any change in the present methods of marketing ; while, especially in periods of market depression, any suggestion for the improvement in the quality of copra, which may entail additional expense without a corresponding immediate increase in price, may probably be received, in the first instance, with disfavour by producers.—*The Malayan Agricultural Journal, February 1930, Vol. XVIII, No. 2.*

NOTES AND COMMENTS

We note with extreme regret that M.R.Ry. V. Muthusami Ayyar Avargal, has sent in his resignation of the place of the Resident Vice-President of the Union. Connected with the Union as he has been, for over a decade, and working with whole-hearted enthusiasm, in spite of physical and other disabilities, it was hardly expected that he would send in his resignation at a time when the Journal had entered an era of great usefulness and patronage, as a result of the special efforts of the Committee. The Committee have in accepting his resignation with great regret, recorded their appreciation of the valuable services rendered by Mr. V. Muthusami Ayyar as Vice-President, as Editor and as a member of the Union.

We offer our congratulations to Rao Bahadur M. R. Ramaswami Sivan on his election to the Syndicate of the Madras University.

Our sincere congratulations go to Rao Bahadur V. N. Viswanatha Rao, lately Statistical Assistant to the Director of Agriculture, Madras, on his promotion as Collector of Tinnevelly.

State Support for Research in America

An account of the Report of the Work of the Agricultural Experiment Stations of the United States Department of Agriculture, America for the fiscal year ending June 30, 1928, given in the Editorial of the Experiment Station Record, Vol. 61, No. 7, Nov. 1929, forms refreshing reading. The report is designed to summarize the progress of the stations as a whole during this period and to discuss the work, the findings and the outlook of these institutions as components of a national scheme of research.

" The development of fundamental research with an ultimate practical aim has come to be the prevailing idea in experimental station work. The growing intensity and specialization, with laboratory and controlled facilities so largely taking the place of natural farm conditions, has not made the experiment stations or their experts any the less practical. On the contrary, it has made them more efficient and reliable, and able to reach further into an understanding of the factors and the reasons involved in complex questions—to follow much further the connection between causes and effects.

" The search for fundamental knowledge " it is stated, " frequently leads into the field of pure science, but by this means a surer foundation is laid for the solution of practical questions. It is only by such means that the 'what', 'why' and 'how' of many basic questions can be determined, and until this is done no problem can be considered intelligently solved. In the realization of this and with increasing financial support stimulated by public confidence and demand, the stations are expanding their fundamental studies along with the scope and variety of their activities, and with these things come a clearer conception of what is involved in the effective organization and execution of research."

"A further idea of the growth of the existing national system may be gleaned from the statement that in addition to the more than *fifty*

stations receiving Federal aid in the various States and Territories and more important insular possessions, there are no fewer than *114 substations* of a permanent nature connected with the State stations, designed to serve the problems of special localities or particular branches of the agricultural industry, such as cranberry-growing, the blueberry industry, tobacco growing, the cattle industry under range conditions, and the like. The work in the States is further supplemented by 59 *experimental farms*, and 255 *experimental fields* employed to carry on test of the local adaptation of crops and practices, determine the fertilizer needs of different types of soils, etc. Considered collectively it is indicated that from small beginnings the system has become not only 'the most extensive and far-reaching one ever built up for agricultural inquiry ; it is the largest organized effort for research in any branch of science or industry. And it is still a growing enterprise.

" The development of the present magnitude is a reflection of the great confidence in the power of research, especially when it is organized and is directed to the vital problems of the industry in their local and national aspects. The broad and extremely varied nature of these problems as presented by the wide extent of the country, and the fundamental relations of these problems to the ability of the industry to cope with and adjust itself to changed conditions, are an irresistable challenge to administrative officers and workers alike. And the confidence so abundantly evidenced by Federal and State appropriations and by the provision of modern buildings and other needed facilities, presents a responsibility for the effective organization and administration of this great enterprise which no one in authority can fail to realize."

" The year under review is deemed unusually prosperous from every angle. The financial support was the largest ever attained, and it was accompanied by increases in buildings and other permanent equipment and facilities aggregating in value over $1,500,000 (equalling Rs 5,000,000 nearly). The personnel was enlarged by fully 200 members ". . . . . In 1928, the total Federal contribution for the work of experiment stations alone is reported to be $3,360,000 and that from other sources such as States, etc., $11,442,773—a total of nearly 15 million dollars.

[It may not be out of place to point out that the amounts voted for agriculture in India in the Assembly and in the local Provincial Councils —all put together—do not compare favourably with the figures given above.—ED. M. A. J.]

The Malayan Agricultural Journal

From January 30, the *Malayan Agricultural Journal* has begun to appear in an enlarged form. The size of the publication is bigger ; the journal will include, in addition to original articles, reviews and abstracts from foreign publications and editorial comments on them ; and the original articles will as far as possible be couched in non-technical terms and include contributions also from allied Departments such as that of Co-operation and the Rubber Research Institute. The publication of strictly technical work will, we understand, be undertaken in future in the form of Special Bulletins. The Editorial Staff of the Journal trust that in its new form it will enter upon an increased sphere of utility and we heartily wish them success in their endeavours.

Lectures on Probable Error

A course of three lectures under the auspices of the Madras University, on 'The Mathematical Probable Error as applicable to Field Experiments in Agriculture' was delivered at the Agricultural College, Coimbatore, by Prof. M. Vaidyanatha Aiyar, M.A., L.T., Hon. Reader of the Madras University, commencing from the 7th March. Almost all the students and a large number of officers, including those from the Imperial Sugarcane Station, attended the lectures. The lectures are published in full in this issue for the benefit of our readers.

"Krishikan"

We note with regret that the *Agriculturist* a monthly Magazine in Tamil, published by our esteemed friend Rao Bahadur J. Chelvaranga Raju from Saidapet, is to be discontinued from next month. We have always felt that the *Agriculturist* has been filling a long-felt want in the Tamilnad and serving the cause of the many non-English-knowing agriculturists by taking the place of our Journal. It is unfortunate that the *Agriculturist* had to be conducted almost at a loss for the last so many months and it is surprising that it should not have had as wide a support as we had expected, being edited by so experienced and able an Agriculturist as our Rao Bahadur. We agree with the publisher when he says that there will be greater and satisfactory support for Journals of this kind when more of our educated men turn their minds to agriculture and perhaps when a larger percentage of the ryots become literate enough to be able to read and write in the vernaculars.

We earnestly hope that the Tamil-knowing Public will not allow such a valuable Journal to lapse for want of mere support. It is up to the subscribers to make the Journal widely known and agree to pay an increased subscription of Rs. 2 per annum and see that the Journal is run as usual and without loss to the publishers.

GLEANINGS

The American Diet

One of the most significant facts of the past 25 years has been the gradual change in the American diet. The amount of food taken is approximately, 1,000 calories less per day than used to be taken. The old diet consisted primarily of meat, potatoes, coffee and sugar whereas it is generally recognised that Americans are eating more fruit and vegetables and that they do pay some attention to the question of vitamins. Dr. Lovell Langstroth of San Francisco tabulated the diets of 501 persons having degenerative diseases, with particular reference to the amount of protective food substances which they ate, and with a view to finding out whether or not changes in the diet could be related to the degenerative diseases. He found that non-protective foods formed 88 per cent. of the average diet. Bread, butter, meat, potatoes and sweet desserts formed the great bulk of the diet of most of the people studied. With the exception of butter and cream which contain considerable amount of the fat-soluble Vitamin A, these diets are vitamin-poor. When the patients were put on a well-balanced diet calculated to provide proper amounts of protective substances, the percentage incidence of degenerative diseases decreased. Thus a diet containing 70 per cent. of protective foods was prescribed in 44 cases of chronic arthritis, 55 cases of chronic gastro-intestinal diseases and 10 cases of migrane. Doctor Langstroth reports that 73 per cent. of these 174 people were improved by the change in diet. There were changes in their body weight, in the appearance and feel of skin and subcutaneous tissue and in the quality and reactions of the mucous membranes.—*Scientific American, Feb.* 1930.

Colds and Roup in Poultry

There are in all probability more losses in the Poultry Yard through the neglect of simple colds, which being left unarrested, develop into roup, than all other diseases combined. Careful observation is absolutely necessary in keeping of Poultry and it will be the observant Poultry keeper who becomes a successful one. It only takes a few minutes to give the birds the necessary attention, and it pays the owner over and over again to keep a constant watch on his stock. Colds are usually on by a chill or a sudden change in the weather. Birds closely confined at night and let out into the chill, damp, morning air, will often take a cold, which if not noticed develops into roup very rapidly.

Prevention is better than cure, and proper ventilation (not draughts) free air by open-fronted houses, plenty of sunlight, ample exercise and sound food of good quality are very important factors. Birds that for any reason are lacking in vitality are always more susceptible to disease of any kind than birds kept under proper conditions. The open-fronted method of poultry housing is the most ideal and perfect system of ventilation. When birds are roosted in such quarters they are practically in the open air and rarely suffer from colds, roups and kindred ailments.

The disease may be easily checked if taken in its early stages and if a careful eye is kept on the stock, immediate action can be taken. The following will be found very useful cures :—One tea spoonful of Paraffin to one quart of the bird's drinking water. One tea spoonful of the following to half a pint of drinking water:—one ounce of Sulphate of Copper dissolved in eight ounces of water. If the heads of affected birds are held in the same amount of the Sulphate of Copper mixture until the bird struggles—about 20-30 seconds—the treatment will be found to have a very wonderful effect.—*Indian Poultry Gazette.*

Phenol Prevents Mould on Leather

It is a common experience to find mould on the surface of leather goods that have been stored away, particularly if the storage place is warm and damp. This tendency has caused no little trouble to shoe manufacturers because the growth occurs on sole leather during the process of manufacture.

In efforts to prevent this nuisance the United States Bureau of Standards Chemists have discovered that if the leather is soaked in a 0·2 per cent. solution of phenol, no mould forms. This simple expedient suggests that phenol or some phenol salt might be used to advantage in dressings for use on leather which is apt to mould in storage or in use, because of high humidity due to climatic or service conditions.—*Scientific American, January* 1930.

Removing Calcium sulphate deposits from Pipes

In hot water containing sulphates, the presence of even a small amount of lime will cause the precipitation of insoluble Calcium sulphate.

When pipe lines or integral parts become sufficiently coated to retard circulation, the removal of the deposit becomes an important problem. Calcium sulphate is not soluble in the usual solvents. Chemists of the United States Bureau of Mines have determined that a hot solution of bi-carbonate of Soda will react with Calcium sulphate to form a loose mixture which permits the removal of the bulk of the scales by the current flow of the solutions. The remaining scale is sufficiently changed so that a weak solution of Hydrochloric Acid will completely remove it from the line.—*Scientific American, February* 1930.

A Rapid Method of Testing Viability of Seeds

The usual method of testing whether seeds and grains are alive is to sow them actually and see if they will germinate. This process is necessarily long and tedious. A new test devised by a Russian Botanist —Dr. D. N. Nelubov of Leningrad—will, it is said, give the information in a few hours instead. Dr. Nelubov steeps the seeds in a dilute solution of anilin dyes—the best dye being indigo carmine—at a strength of one-fifth ounce of the dye in one gallon of water, for three to four hours. If the seeds are viable they are not affected by this treatment, while such as are dead get deeply coloured.—*Science, N. S. Vol. LXX, No.* 1804.

The Dairy Heifer

The Dairy Heifer is a unit of the potential milking herd. The breeder who knows how to grow and handle dairy heifers will add substantially to his achievement with his dairy herd.

The demand for reproduction and milk production are so heavy on high producing dairy females that every opportunity must be given for growth and development before the animal begins her lactation period.

Improper feeding and breeding at too early an age are two factors to avoid.

The time to take advantage of the growth impulse is when it is most potent and when demands for milk production do not interfere with its influence.

Do not allow the dairy heifer to get a setback by turning on to scant pasturage or by improper feeding.—*Queensland Agricultural Journal, Feb.* 30, p. 110.

Vitamin Content of Dried Fruits

Fresh fruits and vegetables are known to contain Vitamin C, which is indispensable for the prevention of scurvy, but in view of the danger of scurvy being greater under circumstances when an adequate supply of fresh vegetables and fruits is difficult to obtain, studies in the preservation of foods have been in progress with the object of finding out processes by which the Vitamin C content would be fully maintained. Agnes Fay Morgan and Anna Field of the University of California record the success of their experiments in preserving the Vitamin content of dried fruits by subjecting them to a treatment with sulphur-dioxide gas. Fresh ripe peaches were picked and dried after being cut up. Part of the dried batch was submitted to the action of sulphur dioxide overnight. Feeding experiments were then made using guinea-pigs. The sulphured fruit was found to retain the full Vitamin C content of the fresh fruit, while the unsulphured lot did not show any detectable trace of it. The sulphured, dried peaches were found to rank with orange juice, raw tomatoes, and other highly potent antiscorbutic foods.—*Science,* Vol. LXX, No. 1803.

Ajinomoto

The Japanese eat much rice and little meat. Such a diet has little energy in it. Hence the Japanese add to their food a substance which has a meat flavour but which is not meat. The use of meat in the diet is condemned by Buddhists and instead, shavings of dried fish are added to Japanese dishes to improve the flavour. The important substance is monosodium glutamate. It is now available in commerce and is said to be as common in Japanese cookery as is salt in American cookery. This substance is called in Japan 'Ajinomoto' or the element of taste. It is reported that it is manufactured by hydrolising gluten or Soy bean with Hydrochloric or Sulphuric acid.—*Scientific American,* Feb. 1930.

A Poochie Problem

In attacking any problem, it is advisable to be aware of all the factors involved. These are sometimes hidden and unexpected.

A certain South Indian firm, which supplies coffee to Scandinavia among other places, found that their godowns were the abode of a certain insect pest, with the stately name of *Araecerus fasciculatus*, of the ancient family of the Anthribidae—a coffee weevil in fact.

These industrious insects bored through the coffee beans with, as will be seen, commendable patience, leaving a neat tunnel behind them. The firm, far from admiring these activities took steps to circumvent the patient workers, knowing that the final result would be the reduction of the coffee beans to a powder.

Under the guidance of the Agricultural Department special godowns were built to store the beans, where by fumigation, the Entomologist put a stop to the life and work of the *Araecerus fasciculatus*.

So far good. Scandinavia was supplied with a cargo of sound coffee, and the firm turned its attention to other matters. The unexpected factor now emerged. Scandinavia did not like the flavour of the last consignment of coffee, and the agent there begged to be supplied with weevilled beans. Their flavour, it can only be supposed, was found superior to that of ordinary beans.

The problem now facing the firm is to limit the work of the insect to a commercially useful point, and to impart to the coffee bean the desired flavour.—FEMINA. Extracted from *Hindu Illustrated Weekly, March* 23, 1930.

Magic Among the Marrows

Marrows are grown in Godavary District as in many other districts. These marrows do not always bear properly, and their owners wish to know why, apart of course from the special malice of local demons, who harass the unlucky cultivator.

One of these latter consulted the local agricultural demonstrator, who visited the marrows when they were in flower. He showed the cultivator how to dust the pollen on to the stigma of the flower—a mere matter of routine to the demonstrator, but to the spectator a manifestation of secret powers. Anyhow the proceeding resulted in a fine crop of marrows, the flowers having been fertilized.

But in that district the Demonstrator is now a dispenser of magic charms, a bringer of luck. His work is not done. He has still to show that success in farming depends on exact knowledge and industry.

Yet who shall say that there is not magic too? The wonders of plant life and growth have been labelled with botanical terms, but not explained by those names. The mystery and the wonder remain.—FEMINA.

Extracted from the *Hindu Illustrated Weekly, March* 16, 1930.

QUERIES AND ANSWERS

1. Q. Can you tell me the best way to cure broody hens?

A. The best way is to get a box 18 inches cube with an open work bottom which will not allow of the fowl sitting but make her perch all the time. It should be open on all sides and in a cool place but not in any direct draught, preferably in sight of other fowls. Feed sparingly on hard grain and to every pint of drinking water add a pinch of Magnesium sulphate.

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2. Q. What is the cure for Chicken-pox in young chickens?

A. Obtain a bottle of *Milton*. Paint all affected parts with this. Isolate each brood that has been attacked. Keep on sweet ground and plenty of fresh drinking water to which has been added Potassium permanganate sufficient to give a slight pink tinge only.

3. Q. Last season, my groundnut crop was infected with hordes of hairy worms which were responsible, I think, for a great reduction in the yield of my crop. Please let me know what I should do to prevent such an attack and loss.

A. The hairy worm referred to is the hairy caterpillar pest commonly attacking groundnut crop defoliating and doing great harm. The most effective methods to prevent the recurrence of the pest are as follows:—(1) After a good shower in May--June employ boys to pick the sluggish moths that may appear in the fields during the evening time. The females of those moths otherwise lay hundreds of eggs which hatch out into hairy caterpillars so harmful to the crop. (2) The fields should be thoroughly ploughed in summer to bring up the underground 'pupae' which will be found in large numbers. The pupae when exposed will be devoured by birds. The caterpillars after a certain stage go into the ground and remain there as 'Pupae' which look like the seeds of a date fruit, reddish-brown in colour. They look like lifeless objects at this stage, but it is from these harmless looking objects the adult moths emerge after a certain time, when the crop is in the field and are responsible for giving rise to the numerous caterpillars ready to destroy the crop.

College News and Notes

Association of Economic Biologists.—With a view to create an *esprit de corps* among workers in Genetics, a meeting was held on the 10th February to concert measures for the formation of a local Genetic Association. Mr. K. Ramiah at whose initiative the meeting was convened, explained the need for an Association of this nature and briefly outlined its objects. Opinions having been expressed at this meeting that the Association might profitably widen its scope so as to bring in its fold people interested in other branches of Applied Biology as well, a committee was formed to define the scope of the Association and to draft a set of rules for its working. The committee having favoured the formation of a wider organization than was originally contemplated, another meeting was held on the 19th February at which it was decided to form an Association of Applied Biologists with its headquarters at Coimbatore. The draft rules presented by the committee were discussed in detail and passed. Membership, for which the annual subscription is Rs 3, is open to all who are interested in any branch of applied Biology.

Week-end trips.—The Final Year Students visited the shandy at Pollachi on Thursday, the 20th February. This shandy is considered to be the largest of its kind in this Presidency. Being centrally situated between the three districts, Coimbatore, Madura, and Malabar, Pollachi has long been known to offer excellent facilities for a weekly market where almost every produce from cereal grains to vegetables and every other article of daily necessity for the agriculturist and the trader, as well as large herds of cattle are brought in for disposal. The market is centrally situated in the town and is busiest from noon to evening. A detailed account of the total quantity of produce of different kinds and also the number of cattle and sheep coming into the shandy for sale on the shandy day, has been published in our Journal, Vol. X, No. 10.

Hockey.—The 'Krishnamurthi Rao Intertutorial Hockey Tournament' which is run to perpetuate the memory of the late Krishnamurthi Rao who died in 1928 as a student, was played out towards the close of February. All the matches were keenly contested and one between Rao Saheb Y. Ramachandra Rao's wards and Mr. S. Sundararaman's was full of thrills from start to finish. Both the teams put up a good forward line and both goals were visited in quick succession. Though the latter had a lead of two goals at the beginning, the former won the match by 6 goals against 3. In the finals which had to be played on two days, as the match on the first day ended in a draw, Rao Saheb's wards met Mr. K. Ramayya's wards and wrested the Cup winning the match from their rivals—the holders—by the only goal scored.

Cricket.—We were favoured by a visit from the Ootacamund United Club during February, who gave us a half day match on the 23rd. The Collegians won the toss and electing to bat opened disastrously losing 3 of their best wickets for a paltry total of 7 runs. The side, however, made a splendid recovery. The partnership of S. N. Venkataramanan and Varadarajan, however, stopped the rot and runs came in merrily and 118 runs were registered before the whole side was dismissed. Chockalingam for the visitors bowled well and captured 6 wickets at a cost of 10 runs apiece. The visitors who opened their innings with Venugopal and Nathan lost 6 wickets for 24 runs, the home skipper Patnaik doing havoc among their ranks with the ball. Venugopal who played a steady and cautious game, with Joseph who kept the other end intact for a longwhile, raised the score to 76 runs, his own contribution to this total being an unbeaten 44. Patnaik was responsible for capturing 8 wickets at a cost of 33 runs. The Collegians thus won the match by a comfortable margin of 42 runs.

College Colours.—The annual meeting for the award of college colours was held on the 9th March at which the Principal, the Officer-coaches and the Captains of the various games—Cricket, Football, Hockey and Tennis—met to decide the award of colours. As a result of voting the following were declared to be awarded colours during the year in the respective games.

Cricket.—Udhobo Patnaik, C. B. Sankara Ayyar and C. N. Subramanian.

Football.—K. Padmanabhan.

Hockey.—K. Padmanabhan and S. Sundararajan.

Tennis.—N. S. Vaidyanathan.

The 'Parlakimedi Cup' for the best All-round Sportsman of the year was awarded to Student C. N. Subramanian of B. Sc. III for the second time in succession.

Special Lectures to Students.—As in previous years, the specialists in different branches of Research were kind enough to deliver a series of lectures for the benefit of the Senior Students during the latter half of February, on fundamental problems and research work carried out in their sections. The Research Engineer, the Cotton, Paddy and Millets Specialists, the Agricultural Chemist, the Mycologist and the Entomologist were those who delivered the lectures.

The 'Cecil Wood Cup' Tennis (Singles) Tournament.—The finals of the series of interesting matches played for this Cup came off on the Students' Courts on the 1st March, the contestants being Vaidyanathan of Class III and Muddanna Shetty of Class II. There were a large number of officers and students present to witness the game. Vaidyanathan started in good form and being successful in his placings and quick returns won the first set. His opponent though more smart was playing a defensive game. With renewed vigour Muddanna Shetty put up a good fight and with effective services annexed the next set to his credit. With one set all and with encouraging cheers from the spectators, the pair went in for a good fight. But the senior regained his successful volleys and managed to win the third set ; but being more heavy-bodied was more exhausted. The run of the fourth set therefore showed clear signs of Muddanna Shetty gaining the upper hand. With effective services and smart net play, he won the last two sets with apparent ease as the scores below will show.

M. Muddanna Shetty beat N. S. Vaidyanathan, 5-7; 6-2; 4-6; 6-2; 6-1.

Farewell Entertainments to Final Year Students.—The Final Year Students were entertained at Tea by the First and Second Year Students on 11th March and again by the Members of the Teaching Staff and the Tutors on the 17th. On both occasions the Principal addressed the students exhorting them to act up to the traditions of the College and put forth their best when facing the practical issues in life, always remembering that they could look forward to the Members of the Teaching Staff for guidance and advice.

The Students' Club Day.—The Annual Club Day of the College Students' Club was celebrated with great enthusiasm by the students of the College on the 15th March. In the morning, there were several interesting items of sports, such as, three-legged race, sack-race, kicking the football, etc., in which a large number of students took part. In the afternoon, there was a grand Tea Party to which many of the officers on the Estate including the Teaching Staff were invited. M.R.Ry. Rao Bahadur T. A. Ramalingam Chettiar Avargal, B.A., B.L., M.L.C., who was specially invited to address the students on the occasion was also present. The competition for Fancy Dress was of a high order and the guests thoroughly enjoyed a pleasant half an hour when the different competitors vied with each other to show their skill and originality to the best advantage. The judges decided the First Prize in favour of Joga Rao, in the guise of an Andhra shepherd with his lamb and characteristic appearance, while Kolandavelu, who as curd woman got the second could easily have passed into the town at such *par excellence.* Gulam Ahmed for his originality as Lord Thyer Vadai of Erramalais personating 'Dignity of Labour' got the third and Gopalan as 'India in Bondage' was given the fourth. Mention may be made of Krishnamurthi who acted the part of Douglas Fairbanks very well as also N. S. Vaidyanathan as Sub-Inspector of Police who was at first taken to be a real invited guest. With C. N. S. Mani as Constable No. 365, the Sub-Inspector made some smart 'arrests' including one stubborn 'non-co-operator' wearing Gandhi cap.

After tea, the party moved into the Freeman Hall where the guests were entertained with delightful music. The Secretaries then read the reports for the year ending with March 15th regarding both Literary and Sports activities. This over, Mr. Ramalingam Chettiar kindly gave away the prizes to the successful competitors and made a short but instructive speech. Touching upon the hard work and difficult course they are put to in this College, he remarked that after seeing what they did on that day, he could easily see that they were a cheerful set and, with the right outlook and patience, were bound to succeed in life. He exhorted them to take life in good spirit, not to lose cheer and try to achieve what little they could. He contended that Agriculture was not a paying profession as at present and it should be their endeavour to remove the disabilities and drawbacks, so that it became a paying profession. They should carry the same enthusiasm and good cheer into the villages, amidst the grinding poverty of the villages and then if they achieve even a little, that would be very great indeed. They should move with the people, understand them and make an effort worthy of their training at the College. Mr. Chettiar deplored the existing unfavourable condition for research work, the paucity of private support and appreciation unlike other countries. So, research workers paid by Government have to carry on their work irrespective of public co-operation and appreciation, with a spirit of self-sacrifice and good cheer. He finally appealed to the students not to be down-hearted, but keep up the spirits and good cheer which should be carried with them out in the villages. Mr. P. H. Rama Reddi who presided then advised the students to ponder over and take to heart every word Mr. Chettiar had uttered. The guest was garlanded and with a vote of thanks the function came to a close.

The Association of the Upper Subordinate Officers.—A General Body Meeting of the Association was held on the 10th March 1930 to discuss and adopt the draft reply prepared by the special committee to the Government Memorandum on new schemes of pensionary benefits and also to decide upon the action to be taken on the announcement made in the Madras dailies regarding the reorganization of the Agricultural Gazetted Services and the consequent financial savings to the Government. The General Body discussed and adopted the draft reply which includes the following main points. The Association is in favour of a Contributory Provident Fund for Government Servants, the employee and the Government each contributing 8⅓ per cent. of the pay per annum and this amount to accumulate at compound interest. In addition, the Government should institute a scheme of protective assurance of Rs 5,000 for all Government Servants and which will be on a descending scale and will automatically vanish when the amount accumulated by Provident Fund Contributions equals to Rs 5,000. This amount shall be payable to all Government Servants who die prematurely.

The General Body then decided upon approaching the Government with an appeal for diverting a portion of the savings effected in the reorganization schemes, to improve the pay and prospects of the Members of the Upper Subordinate Cadre of this Department. The Secretary then placed before the members the question of requesting the Director of Agriculture for granting extra allowances to Demonstrators when in charge of more than one sub-circle. The General Body came to the conclusion that this matter might be taken up for representation after consulting the members in the mofussil. It is requested that members working in the Districts will kindly intimate their suggestions and opinions in this connection to the Secretary at an early date.

REVIEWS

Root development in Rice under different conditions of growth.—R. L. Sethi, M.Sc. (Punjab), B. Sc. (Agri.), (Edin.), M.R.A.S. (Lond.)—Economic Botanist to Government, United Provinces, Cawnpore. Price As. 14. Government of India Central Publication Branch, Calcutta.

A study of the root development of crop plants under varying influences of soil conditions, treatment and availability of plant food, is indeed very valuable both to the practical and the scientific agriculturists. It will be therefore very interesting and instructive to go through the results achieved by Mr. Sethi in his attempts to study the modifications of the root system of the rice plant, in some of its important aspects, under field conditions as well as pot cultures. The changes in environmental factors consist in differences in soil texture, soil temperature and soil aeration on the one hand and the application of different manures and different methods of cultivation and irrigation on the other. The experiments have been in the main to study the variations of size, extent, colour, etc., of the roots under (1) different kinds of soils like, clay, loam, gravel and sand, (2) various kinds of manures like cakes, Ammonium sulphate, Super Phosphate, etc. Incidentally, the differences due to varieties like early and late ones have also been studied. Dry weights of the root and shoot portions taken separately at several stages of the crop under different treatments, have been tabulated and graphically represented for comparative study. It is significant to note from the results achieved that a clay soil and green manuring afford the greatest facilities for the plant to show the greatest root development, and also loam plus Ammonium sulphate are responsible for the greatest dry weights of shoot and root.

University of Madras

B. Sc. Degree Examination in Agriculture, 1930

QUESTION PAPERS

PART I

AGRICULTURAL ENGINEERING

SATURDAY, 22ND MARCH. 7 A.M. to 10 A.M.

SIX *questions are to be answered. Questions* 1, 2, *and* 3 *are compulsory.*

1. What will be the discharge of a tank sluice with a shutter 1 ft. 6 in. wide when the shutter is raised by 6 in.? The level of the water in the tank is 5 ft. 3 in. above the sill of the sluice. The usual coefficient of 0·62 may be assumed.
2. The surplus weir of a tank is a masonry wall built on rock which has a good slope in the rear. The wall is rectangular in section and 8 ft. high. Assuming a factor of safety of 3, calculate the thickness of the wall to prevent its overturning.
3. The pitch of screw in a lifting jack is ½ in. The hand lever is 3 ft. long. Calculate the weight that could be lifted by a pull of 40 lb. on the lever arm. The efficiency of the machine can be assumed as 60 per cent.
4. Calculate the earthwork to dib a pond 50 ft. square at bottom and 20 ft. deep with slopes of sides 1½ to 1.
5. *ABCD* is a quadrilateral field, the sides *AB* and *DC* being parallel and 200 ft. and 120 ft. long respectively. The angle subtended by the side *AD* which is at right angles to the parallel sides is 60°. Find the area of the field.
6. Specify the mortar and its ingredients with their proportions which you would use in building (*a*) a farm building and (*b*) a tank sluice.
7. Write notes on—(*a*) piece work, (*b*) catchment area of a tank, (*c*) draught of a plough.

AGRICULTURAL BOTANY

SATURDAY, 22ND MARCH. 1 P.M. to 4 P.M.

Answer THREE *questions in* A *and* THREE *questions in* B. *Questions* 3 *and* 8 *are compulsory. Write answers to questions in* A *and* B *in* SEPARATE BOOKS.

A

1. Write an essay on the devices noticeable in plants which are calculated to prevent the overlapping of *leaves*, and to expose them to the sun as much as possible under natural conditions.
2. Describe, with sketches, the formation of bark in stems.
3. Mention *three* plants of economic importance belonging to each of the following families:—Solanaceae, Anacardiaceae, Aroideae, Piperaceae, Rutaceae. State the characters of any *two* of the above-mentioned families.
4. Explain (*a*) the significance of water-culture experiments, and (*b*) the reaction of the root to gravity.

B

5. Write an essay on *protoplasm* with reference to its chemical, physical, and physiological characters.
6. Describe, with an experiment, the process of *photo-synthesis*.

7. Give an account of the different adaptations in plants which help them to resist drought.
8. Write short notes on the morphology of—(*a*) cabbage, (*b*) fig, (*c*) garlic, (*d*) radish, (*e*) cashew fruit, (*f*) wood apple, (*g*) turmeric, and (*h*) pine-apple.

AGRICULTURAL CHEMISTRY

MONDAY, 24TH MARCH. 7 A.M. to 10 A.M.

Answer THREE *questions in* A *and* THREE *questions in* B. *Questions* 1 *and* 5 *are compulsory. Write answers to questions in* A *and* B *in* SEPARATE BOOKS.

A

1. A hydrocarbon gave the following results on analysis :—Carbon 93·75 per cent. ; Hydrogen 6·25 per cent. Its vapour density was 64. What is its molecular formula ?
2. How does concentrated sulphuric acid differ from dilute sulphuric acid in its action on metals ? Give examples.
3. How do you prepare ethyl hydrogen sulphate ? What reactions take place when it is heated (*a*) with alcohol, (*b*) with concentrated sulphuric acid ?
4. How is the brown ring test for nitrates performed ? What are the chemical reactions involved in the test ?

B

5. Describe in detail the weathering of silicates in the process of soil formation.
6. Write short notes on—hydrolytic acidity, exchange acidity, and free acidity in soils.
7. Write what you know about the retention of plant-foods by soils.
8. Describe a method of measuring biological activity in soils, and point out its relation to soil fertility.

AGRICULTURAL ZOOLOGY

MONDAY, 24TH MARCH. 1 P.M. to 4 P.M.

Answer any SIX *questions, including Questions* 6 *and* 8.

1. State clearly how the following feed :—(*a*) a bee, (*b*) a bed-bug, (*c*) a butterfly, (*d*) a house-fly.
2. Describe life in a termite colony. What, briefly, are the methods of control of the pest ?
3. What is hypermetamorphosis ? Describe the phenomenon as met with in insects.
4. Give an account of oviposition in insects.
5. Write an essay on tropisms.
6. In the absence of a fieldman to be sent to demonstrate spraying against tobacco aphis, you are asked to furnish full instructions by post to the correspondent who has sought the help of the Department in regard to the matter. Write a letter setting forth the instructions.
7. Classify the more important pests of cotton. Give a brief account of any *two* of them.
8. On what principles are the following remedies based :—(*a*) oiling the top layer of pulses against pulse beetles, (*b*) oiling against mosquito larvae, (*c*) hand-picking, (*d*) trenching ?

AGRICULTURE. I

TUESDAY, 25TH MARCH. 7 A.M. to 10 A.M.

Answer THREE *questions in* A *and* THREE *questions in* B. *Questions* 1 *and* 5 *are compulsory. Write answers to questions in* A *and* B *in* SEPARATE BOOKS.

A

1. Explain shortly the principles underlying metal plough construction, and indicate with sketches the advantages which are obtained when using beam draught as against pole draught.
2. (*a*) Describe in detail what points you expect to find in good legs and feet in a draught ox, and explain their value.
(*b*) In heavy draught road work does a heavy animal find the work easier than a lighter one ? Give reasons for your conclusion.
3. State, giving reasons, the rations for a 1,000 lb. bullock (*a*) on light work, (*b*) on heavy work.
4. Explain, with reasons, in what respects the cultivation methods of the black cotton soil tracts differ from those on the red soil tracts.

B

5. Explain how the daily atmospheric temperature and pressure data are made use of in forecasting rainfall.
6. Give an account of the underground conditions which give rise to the best wells and of the factors which influence the capacity of such wells.
7. State in what ways weeds spread on the farm, and describe how they can be controlled, illustrating your answer with reference to (*a*) bulb grass, (*b*) striga, (*c*) touch-me-not.
8. What circumstances determine the seed rate per acre ? Illustrate your answer with reference to (*a*) cotton, (*b*) sunnhemp, (*c*) cholam, giving the rates under the different conditions you mention.

AGRICULTURE. II

ANIMAL HYGIENE

TUESDAY, 25TH MARCH. 1 P.M. to 4 P.M.

Only SIX *questions are to be answered. Questions* 2 *and* 3 *are compulsory.*

1. Explain anatomically the process of respiration in cattle.
2. What are the functions of (*a*) the heart, (*b*) the spleen, and (*c*) the liver ?
3. Describe cattle plague in detail under the following heads :—definition, causal agent, animals susceptible, symptoms, prognosis and treatment (preventive and curative).
4. How will you diagnose the following ailments :—(*a*) chocking, (*b*) tympanitis, (*c*) impaction of the rumen, and (*d*) parasitic bronchitis of the sheep ?
5. Mention the different kinds of wounds and their treatment.
6. What is the surgical treatment of (*a*) broken horn, (*b*) abscess on neck, (*c*) torn eye-lid, and (*d*) gathered nail ?
7. Give the actions and uses of the following drugs in cattle :—(*a*) magnesium sulphate, (*b*) pulvis nux vomica, (*c*) camphor, and (*d*) iron sulphate.
8. Define Epizootic Aphtha, and write short notes on the symptoms and treatment of this disease.

PART II

AGRICULTURAL BOTANY. I

WEDNESDAY, 26TH MARCH. 7 A.M. to 10 A.M.

Answer only FIVE *questions. Question* 6 *is compulsory.*

1. Describe, with sketches, the origin and structure of the *ascocarp*.
2. Point out the striking difference in respect of the life-history between the lower plants like the Algæ and the higher plants like the Ferns. Trace the changes that take place when the spores of a *moss*, a *fern*, and a *lycopod* are allowed to germinate.

3. Mention the chief hedge-plants commonly grown in our Presidency, and show how far peculiarities of structure and growth enable them to hold their own in unfavourable situations and to do their work efficiently.

4. Write notes on the nature and structure of the fruits of the following plants :— *Achras sapota, Terminalia catappa, Pyrus communis, Anacardium occidentale, Psidium guyava,* and *Anona squamosa.*

5. Describe the structure and development of the *laticiferous tissue.* Explain the nature of the contents in this tissue, and show how some of the plants possessing it are economically important.

6. Give an account of the fungoid diseases observed in the following crops :— paddy, ground-nut, and sugar-cane. Describe the characteristics of the fungi, their spread, and the methods of control.

AGRICULTURAL BOTANY. II

WEDNESDAY, 26TH MARCH. 1 P.M. to 4 P.M.

Answer only FIVE *questions. Question 6 is compulsory.*

1. Illustrate with the help of *three* examples how a knowledge of the life-history of a weed assist you in its successful eradication.

2. Give full botanical descriptions of the following plants :—(*a*) Brinjal, (*b*) Snake Gourd, and (c) Horse-gram.

3. Choose any cultivated plant commonly known to you and point out the different *variations* you have noticed in it.

4. Describe fully the principles and practices involved in the horticultural operation of pruning.

5. Write critical notes on—(*a*) lodging in cereals, (*b*) natural crossing, (*c*) vegetative reproduction, (*d*) mutation.

6. The cucumber growers in the tank beds of Coimbatore are yearly confronted with the recurring presence of a few bitter-fruiting plants, however careful they be in selecting their seed. Assuming bitterness to be a simple recessive factor, use your knowledge of Mendelism to plan out a method for eliminating this defect.

AGRICULTURAL CHEMISTRY. I

THURSDAY, 27TH MARCH. 7 A.M. to 10 A.M.

Only FIVE *questions are to be answered.*

1. A foodstuff contains 30 per cent. digestible protein, 12 per cent. digestible fat, and 12 per cent. digestible nitrogen-free extract and fibre. State, with reasons, why you should not use it alone for feeding cattle.

2. In a farm, thirty cart-loads of fresh young cholam plants are available. State, with reasons, how you would advise their disposal.

3. Give a brief account of proteins and the part they play in the nutrition of animals.

4. How would you distinguish between butter and butter substitute ?

5. What is the proximate composition of milk ? What fermentative processes are of importance in dairy work, and what constituents do they affect ?

6. Can the quality and quantity of milk given by a cow be influenced by the food it is given ? If so, how ?

7. What do you understand by the terms ptyalin, trypsin, and lipase ? Where are they found, and what are their functions ?

AGRICULTURAL CHEMISTRY. II

THURSDAY, 27TH MARCH. 1 P.M. to 4 P.M.

Only FIVE *questions are to be answered. Questions 2 and 4 are compulsory.*

1. Write short notes on—Humus theory, mineral theory, law of minimum, minimum cropping value of a soil, exchange acidity, and base exchange in soils.

2. Name the plant food elements, and state the forms in which they are taken up by plants and their functions in plant growth.

3. Describe a laboratory method of finding out the manurial requirements of a soil.

4. State what you know of the action of sulphate of ammonia, nitrate of soda, superphosphate, carbonate of lime, and quicklime on heavy clay soils.

5. What do you know about the composition of juice from sugar-cane during various stages of its growth ?

6. What are the soil micro-organisms that take part in enriching the soil in nitrogen ? Can they be controlled and utilized ? If so, how ?

7. Describe a method of making artificial farmyard manure, and explain the principles involved in this method.

AGRICULTURE. I

FRIDAY, 28TH MARCH. 7 A.M. to 10 A.M.

Only FIVE *questions are to be answered. Question 1 is compulsory.*

1. It is found in a dairy herd of 20 cows that the average age of the heifers at first calving is 3 years and that after the cows are 8 years old the milk yield declines. Discuss the steps you would take to (*a*) improve the yielding capacity of the herd without purchasing female stock, (b) keep depreciation of the stock at a minimum figure.

2. Calculate the cost of buying, entering, and stocking with live and dead stock a holding of 20 acres of red soil garden land (2 wells) in the Coimbatore District.
Indicate a suitable rotation for such land, showing the area under each crop.

3. Explain the terms (*a*) *bulk selection,* (*b*) *single plant selection,* (*c*) *cross-breeding* in crop improvement, *stating how and when each is employed.*
What method of lay-out of plots would you suggest in comparing the yields of single plant selections in the field ?

4. Discuss shortly the relationship of grazing areas in the foothills of Coimbatore District with the surrounding arable land.
How can the returns from such grazing areas be increased ?

5. Give full details of the cost of producing an acre of tobacco, and show the profit which may be expected.
What is the seed rate per acre for—
(*a*) *Sorghum vulgare* (fodder) ;
(*b*) *Pennisetum typhoideum* ;
(*c*) *Arachis hypogæa* ;
(*d*) *Eleusine coracana* ?

6. If you were in charge of a scheme for sending sweet milk from Coimbatore to Madras city, describe the arrangements you would make to ensure that it arrived in Madras in good condition and was of good keeping quality.

AGRICULTURE. II

FRIDAY, 28TH MARCH. 1 P.M. to 4 P.M.

Only FIVE *questions are to be answered. Question 6 is compulsory.*

1. A Ceded Districts farmer cultivates an area of 160 acres of black cotton soil. Give a list of the equipment in such a farm, including live stock, with the approximate cost of each. If the farm is cultivated with cotton and cholam in equal portions, what will be the cost of (*a*) harvesting, threshing, and stacking the cholam, and (*b*) picking and storing the cotton ?

2. Explain what points you would pay attention to in deciding upon an installation of pumping machinery for irrigation. Describe how you would make use of the co-operative movement in the concern.

3. (*a*) Under what cropping conditions would you prefer (i) sulphate of ammonia to nitrate of soda, (ii) superphosphate to bone meal, (iii) artificial manure mixture to cattle manure ?
(*b*) Suggest suitable artificial manure mixtures for (i) paddy, (ii) sugar-cane, and (iii) potatoes, and give the approximate cost per acre of the mixtures.

4. Give an account of the methods of leasing out land common in the Presidency, and discuss the merits of each.

5. Explain, with reasons, what causes the following :—
(*a*) in the threshing of grain (*ragi*) by the threshing machine (i) too much breaking of grain, (ii) imperfect threshing ;
(*b*) in the making of butter (i) butter being too slow in coming, (ii) soft butter ;
(*c*) in the making of jaggery (i) jaggery turns out dark, (ii) jaggery is too difficult to set.

Departmental Notifications

First Circle : Mr. D. Bapayya, Farm Manager under Entomological training, Anakapalle, leave on average pay for one month from 17/3/30 and permission to suffix Easter hoidays from 17/4/30 to 22/4/30 ; Mr. V. Achyutaramayya, Farm Manager, Anakapalle, leave on average pay for one month and a half from 23/4/30 with permission to affix Easter holidays ; Mr. N. Ramadoss, Agricultural Demonstrator, Chodavaram, extension of leave on average pay for fifteen days in continuation of leave granted on 1/3/30.

Third Circle : Mr. K. Jaganatha Rao, Agricultural Demonstrator, leave on average pay for one month from 24/3/30 with permission to avail Sunday the 23rd.

Fourth Circle : Mr. M. Govinda Kidavu, Deputy Director of Agriculture, temporary, to be Deputy Director of Agriculture, permanent ; Mr. C. Narayana Ayyar, District Agricultural Officer, Tindivanam, leave on average pay for two months from date of relief ; Mr. K. Varadachari, Farm Manager, Agricultural Research Station, Palur, leave on average pay for three months from 3/3/30.

Fifth Circle : Mr. P. S. Atmarama Ayyar, Agricultural Demonstrator, Kumbakonam, confirmed from 12/3/30.

Sixth Circle : Mr. B. Ramayya, Deputy Director of Agriculture, temporary, to be Deputy Director of Agriculture, permanent.

Seventh Circle : Mr. K. Unnikrishna Menon, District Agricultural Officer, sub protem to be District Agricultural Officer, permanent ; Mr. A. Gopalan Nayar, Headmaster, Agricultural Middle School, Taliparamba, leave on average pay from 2/4/30 to 30/4/30 ; Mr. B. Narasimha Pattathan, Assistant Agricultural Demonstrator, Mudabidri, confirmed from 14/3/30.

Eighth Circle : Mr. K. Avadinayagam Pillai, Agricultural Demonstrator, to act as District Agricultural Officer, Tindivanam, vice Mr. C. Narayana Iyer granted leave ; Mr. M. C. Krishnaswami Sarma, Assistant Agricultural Demonstrator, extension of leave on average pay for six weeks in continuation of one month's leave already granted ; Mr. P. V. Raghavendra Rao, furlough for two months from 25/2/30 in continuation of leave already granted.

Government Entomologist's Section : Rao Sahib Y. Ramachandra Rao, Government Entomologist, temporary, to be Government Entomologist, permanent ; Mr. M. C. Cherian, sub protem Assistant Entomologist, to be Assistant Entomologist, permanent ; Mr. V. Tirumala Rao, Assistant, leave on average pay for one month from 22/3/30 ; Mr. R. Narasimhachari, Sub-Assistant, extension of leave for 21 days in continuation of leave already granted.

Paddy Specialist's Section : Mr. S. Dharmalinga Mudaliar, Assistant, leave on average pay from 3/4/30 with permission to suffix Easter holidays ; Mr. C. Rajasekhara Mudaliar, Assistant, leave on average pay for two weeks from 3/4/30 with permission to suffix Easter holidays.

Millets Specialist's Section : Mr. P. Krishnamurti **Nayudu**, Assistant Farm Manager, transfer to first circle. (Anakapalle.)

Live-Stock Section : Mr. T. V. Krishnamurti, Farm Manager, Live-Stock Research Station, Chintaldevi, transfer to first circle ; Mr. A. Gopalakrishna Ayyar, on the expiry of his deputation is posted to Live-Stock Research Station, Chintaldevi ; Mr. P. A. Narayan Nambiyar, Assistant Dairy Manager, leave on average pay for one month from 2/4/30 or date of relief ; Mr. A. H. Subramania Sarma, Farm Manager, Live-Stock Research Station, Hosur, transfer to the Coimbatore Dairy.

Government Systematic Botanist's Section : Mr. V. Narayanaswami, Systematic Botanist, on probation in a temporary vacancy to continue on probation in a permanent vacancy ; Mr. M. Ratnavelu, Sub-Assistant, extension of leave on average pay for one month and two days from 10/3/30.

Curator, Government Botanic Gardens and Parks : Mr. S. Madhava Rao, is appointed as officiating Upper-subordinate, Agricultural Section, V Grade vice Mr. P. Abhishekanatham Pillai, Farm Manager, on leave.

Government Agricultural Chemist's Section : Rao Bahadur B. Viswanath, Government Agricultural Chemist, temporary, to be Government Agricultural Chemist, permanent ; Mr. T. Lakshmana Rao, sub protem Assistant Agricultural Chemist, to be Assistant Agricultural Chemist, permanent.

Principal's Section : Mr. H. Shiva Rao, Lecturer in Chemistry, temporary, to be Lecturer in Chemistry, permanent.

OFFICE-BEARERS FOR 1929—30

The Council (25 Members)

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„ M. U. Vellodi (Salem).
„ T. R. Venkaswami Rao (Tiruvalur).
„ K. M. Venkatachalam Pillai (Namakal).

Working Committee (14 Members)

The Resident Vice-President and the ten resident members with the following student members form the Working Committee.

Student-Members (3)

Kunhirama Kidavu—Class I
Thangavelu, T. K. „ II
Renga Rao, G. „ III

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M. C. Cherian.
S. V. Duraiswami Ayyar.
Rao Sahib Y. Ramachandra Rao.
K. M. Thomas.
C. S. Krishnaswami Ayyar.
vacant (*Student*).

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