METHODOLOGY IN AGRICULTURAL RESEARCH.

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METHODOLOGY may be defined as systematic knowledge of the best way of setting to work. In the development and progress of the sciences methodology has played a very important role. So also in the realm of agricultural research, methodology is a vital necessity, and my plea therefore is for its greatest possible utilization. General methodology is undoubtedly the most valuable tool of trade in all occupations, but is probably the most neglected of subjects. Without methodology we would possess no scientific knowledge. Logic provided the foundation-stone, then followed mathematics, and finally came statistical method. These three comprise what may be termed methodology proper. In the wider sense, however, we may include both ordinary method or practice, as represented in art and craft, and scientific method or practice--i.e., technique—as applied in the laboratory and field. In another category we have mechanical aids which are indispensable in scientific technique and which are responsible for a certain amount of modification and adaptation of technique due to their limitations.

Of these branches of methodology our knowledge is most complete in the cases of logic and mathematics. Statistical method is the latest of the branches of methodology, and should not be confused with statistics, which is very old indeed. It almost represents a branch of mathematics, upon which it mainly depends. Its greatest utility is to provide a measure of more or less large " populations " entailing variation in their attributes, and to supply an arbitrary condensed picture of the whole which is more intelligible than that obtained without its aid, when at times it (the whole) may be totally unintelligible. It also permits us to obtain measures of the degree of homogeneity in " populations," of dispersion of variation in attributes, and of relationships in multiple causation.

TECHNIQUE.

Ordinary technique is the method of the every-day person in setting about his tasks, and is more or less of the rule-of-thumb type : It forms a most valuable base for scientific technique. In scientific technique proper, however, a greater utilization of scientific knowledge is employed. In experimental and investigatory research technique is employed to overcome as much as possible the difficulties. in the control of input and influencing conditions, and in the observations and measurement -of- output and any phenomena associable with the process of conversion from one to the other. We obtain our impressions of things through the senses and depend on the brain's interpretation in so gaining them. Through being thus a stage removed conceptual relations are but aspects of factual relations. Moreover, all observation is selective.

Attributes and phenomena arc the only things from which we may gain our impressions, and they do not always take or possess a form with which our sensory agencies may satisfactorily cope, and at times can entirely escape us with or without 'mechanical aids. Technique is largely dependent on the mechanical aids available, and in cases where perceivable phenomena present considerable difficulty of mechanical measurement the position can be overcome only by the statement of the abstract qualities observed by sensory appraisal alone, either in words or in some arbitrary numerical. form. Considerable progress in later years has been made in overcoming difficulties 'of this kind, but in those instances where yet no mechanical measuring aids are available great care must be taken. in standardizing a scale, and in employing it. Technique principally applies to experimentation, relative to which the following rules are submitted : (1) Provide for co-ordination with work of others.; (2) provide for practical application of results ; (3) make provision for requirements of statistical analysis ; (4) wherever possible use simple and direct methods ; (5) cover all points pertinent to the object in view, either directly. or indirectly ; (6) do not overdo randomization or artificial conditions ; (7) arrange experiments in proper progression ; (8) divide your difficulties into as many parts as possible ; (9) devise means to get the closest fundamental measure ; (10) where possible, include all your important factors, and let one vary at a time only; (11) if you must vary conditions, provide for continuity by overlap and comparison by standard controls ; and (12) seek deeper than the first stage of cause and effect.

J. W. Mellor, in the preface to his " Modem Inorganic Chemistry," mentions the five following points as essential to the scientist : (1) Skill in observation and experiment ; (z) memory and knowledge of relevant facts ; (3) ability to reason and think in a logical systematic way ; (4) cultivation of the imagination ; and (5) development of a critical and impartial judgment.

It will be noted that points (1) and (3) are solely dependent on methodology, while methodology can assist considerably in points (2) and (5). -Under point (1) Mellor states that " the observational powers of a savage are usually keener than those of a civilized man, 'and. a student may learn to observe without gaining much beyond an increased facility in the art ; and he may become very skilful in experimenting without gaining much more than mere dexterity in manipulation." With respect to point (4) Karl Pearson states -that " disciplined imagination. has been at the bottom of all great scientific discoveries." J. Tyndall mentions that " We are gifted with the power of imagination, and by this power we can enlighten the darkness which surrounds. the world of the senses. Bounded and conditioned by co-operant reason, imagination becomes the mightiest instrument of the physical discoverer."

" Men of powerful and original views in science have an exceptional facility in drawing out the implications of principles already established in directions hitherto undreamed of, or in combining principle with principle to open up new fields of thought " (Welton and Monahan).

There are only two main divisions of methodology-namely, analysis and synthesis. Analysis provides the picture of the parts yet retains its hold on the whole it analyses ; whereas synthesis provides the picture of the whole, while retaining its grasp of the parts it is synthesizing.

Although biology is largely analytical,' a synthesis. of the results obtained at every step is the one sure basis of further advance. " One of the most important uses of synthesis is to eke out the deficiencies of analysis ; the two together have made many discoveries possible which neither could have achieved alone " (Welton and Monahan).

From syntheses we obtain hypotheses, " which are mentally constructed and quite imaginary mechanisms accounting for the facts " (Westaway). Hypotheses may be of three kinds-descriptive hypotheses, hypotheses of law, and hypotheses of cause. Laws of phenomena come first, while consideration of causes comes second. According to Hobbes and Boyle a good hypothesis must be as follows :-

" (1) A good hypothesis must allow of the application of deductive reasoning and' the inference of consequences capable of comparison with the results of observation.

" (2) A good hypothesis must not conflict with any law of nature which we hold to be true.

" (3) In a good hypothesis, the consequences inferred must agree with the facts of observation."

In the progress of knowledge hypotheses are invaluable, and'although they may be only partially complete and somewhat defective they form the framework of complete " patterns " which we ultimately hope to discover. " Hypotheses are of use, not as superseding investigation, but as directing investigation to certain objects ; not as telling us what we are to believe, but as pointing out to us what we are to endeavour to ascertain " (Brown).

MAIN FEATURES AND CHARACTERISTICS INVOLVED.

In the various fields of endeavour methodology is rendered of greatest use only when specially modified and adapted to the main features and characteristics met with in each particular case. It is evident, therefore, appropriate regard has to be had for the aspects typical or peculiar to agriculture before the full utility of methodology in this sphere may be obtained.

In the inorganic and organic domains the difficulties in attack of problems vary in degree quite markedly, at least up to a point, the latter realm being generally conceded as being much the more thwarting and baffling. This may be instanced in the case of physics and chemistry on the one hand as compared with that of the various biological sciences on the other. The feasibility of experimental attack, control of conditions, observation, and measurement in the former far exceeds that in the latter. However, in such instances as electronic and molecular dynamics physical research difficulties are undoubtedly as great as any met with in the field of biology.

In the organic realm- a new force-if it may be termed such— obtrudes known as life, which harnesses and permeates the inorganic and transforms the whole aspect into another radically different.

The state of things existing here may be likened to a system of many forces in equilibrium, which possess the faculty to obtain this state through a sensitive automatic reflex feature, the state of equilibrium never being precisely the same on any two occasions, and, in fact, being constantly in a state of change, yet of such a nature as to ensure the attainment of a destined goal as represented in the life-cycle of birth growth, senescence, and decay, and perpetuation of the species.

In the biological world all is in a state of continuous change, and any and every transection made contains and involves the element of change inseparably coupled with time. Things so connected must be considered together rather than apart, or else their meaning may not be properly understood. Sometimes in cause and effect the final aspect of effect occurs or becomes manifest only at a period in time considerably rcnioved from the commencement of the operation of the cause, and because of this the connection may escape notice.

Through close association with the highly mechanized aspects of modern life we are rather apt to look upon the functioning of nature as comparable with the operating of a machine, such as a motor-car, forgetting that with the " motor-car " of nature full automatic control exists. When we interfere and give an arbitrary setting to the " spark lever " of nature we little conceive how many other controls are automatically adjusted as a consequence through induced reflex action. Such functioning has no real counterpart in the machine world, and hence the analogy is untenable. This must not be construed to exclude dynamics, which appears to have some application.

Mathematics is an abstract science, the laws of which have been found not to be perfectly demonstrable in nature. Hence we must be on our guard not to expect too much from mathematical theories in agricultural research. In farm practice and field experiments at least no two effects are ever cxactlv similar or the 'result of exactly similar causes. This may be a hair-splitting point of view to take, but, on the other hand, perhaps a very necessary one in order to maintain proper perspective in this connection. This brings us to the point where we have to concede that almost all of our difficulties arise out of variation in conditions, which in turn are responsible for variation in the behaviour of life-forms. The nature of the case which we have to deal with is one of multiple causation, and the concomitant relationships presented are amongst the most involved with which scientific effort has to contend. Too precise an analysis in our work only leads us to a point where all is different, and so we must compromise and confine the bulk of our efforts within a range of inquiry compatible with general practical purposes.

In agriculture, man, through his husbandry, exploits nature mainly in the form of plants, animals, birds, and insects ; this exploitation in its most comprehensive form-namely, grassland farming-entails the four main stages of soil, plants, animals, and animal products, each of which is affected by environmental effects due to climatic and other conditions. We know also that the exploitation chain concerns only conversion from one form to another (since matter and energy cannot be created or destroyed), and that input governs output at every stage in the chain by virtue of the number and proportions of its components and their quantitative availability in unit-time, Input has to provide for non-mineral as well as the mineral requirements, for energy requirements, for losses in conversion, and for the necessary catalysts, &c.

The scientific worker's job is to render man's interference and control in agriculture more perfect and profitable in the widest sense compatible with practicability. We therefore have agricultural research workers concerned with various aspects in each of the four main exploitation stages-viz., soil, plants, animals, and animal products, and also to a lesser degree with the environmental field, covering such matters as climate, parasitic pests, &c. Can we say that the amount of total effort expended within the total range of activities has been properly apportioned in accordance with the requirements of each group ; that all efforts have been as effectively applied as they can be ; that each worker maintains proper regard and perspective towards the whole as well as the part ; and that the practical aspects from a farm practice viewpoint, not only as applying to the individual but also to the community, are being accounted for to the best degree possible on the scores of feasibility, dependability, efficacy, and economy ?

THE APPLICATION OF METHODOLOGY TO AGRICULTURAL RESEARCH.

The following statement indicates what is more of less the ideal way from a methodological viewpoint to set about a research project involving experimentation :-

(1) Consult ail the pertinent scientific literature (pure as well as applied) available on the subject, and on subjects and sciences cognate with it.

(2) Précis all that which is considered relevant.

(3) Endeavour to form a working hypothesis from the précis.

(4) Where feasible and necessary make an observational statistical survey to amplify and revise the working hypothesis.

(5) Review the working hypothesis.

(6) Consult literature dealing with methodology and technique as applicable to the case, or consult capable workers dealing with these.

(7) Plan and carry out your experiments. Make sure the units of measurement employed provide for fundamental relation, interrelation, and applicability. (See. also points already given on experimentation.)

(8) Classify and analyse your results.

(9) Review hypothesis,

(10) Finalize report or investigate further as case'demands. Show the practical application of results, connection with other findings, and any "leads" discovered which are of interest in your own or other fields.