SYMPOSIUM

AGRICULTURAL EXPERIMENTS AND THEIR ECONOMIC SIGNIFICANCE (1)

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Most agricultural research is in the applied field and makes use of principles borrowed from basic chemical, physical and biological sciences. When basic principles are established, the application of which may be relatively simple, applied research becomes less necessary. However, Myers (1953), Shaw (1953) and others have pointed out that much agricultural research must of necessity be of the trial and error type due to a paucity of established principles.

In Queensland, we must devote much of our attention to short-term applied research and extension. With short-term research applied to practical problems and the application of known principles, we can greatly increase production from the potentially arable area of 23 million acres. Shortage of scientists demands that we make the best use of those we have. Once having progressed along the road to development, the more important problems requiring fundamental research will become more apparent.

The results of applied research need, however, to be available in economic terms. A farmer requires accurate information before he can be persuaded to change his programme. Without information on costs and returns, the extension worker is in a weak position to convince the farmer.

To assess the value of experimental work conducted by a State Department of Agriculture to the farmer, Pearse (1955) made a survey of the investigations conducted during the twenty-six years from 1929-54. His conclusions were: "It has been conclusively shown that a new approach to experimental design in agricultural research is required. Such designs should provide for data to be obtained in a form suitable for economic analysis. The present technique of comparing a few practices on different production functions does not provide information on the best practice for any time, as it may be a practice which has not been considered." There is no doubt that a similar situation would be found if the survey were extended to other States.

THE DESIGN OF EXPERIMENTS

The inferences derived from experiments become the nucleus for making decisions. Mason (1957) reminds us that one of Fisher's basic contributions was the clear elucidation of the principle that the plan and design of an experiment determines the form of the statistical analysis. He states: "It is not uncommon to find after a set of experiments has been made, (a) that one or more important variable has been overlooked, (b) that more could have been learned if the factors could have been varied over different ranges, (c) that some transformation of the variables would have been more appropriate, (d) that some more elaborate pattern of experiments is needed to elucidate the situation."

One of the most important factors is to define and delimit the population so that experimental results from a specific population are not erroneously applied to the whole. In crop experiments, the geographical area, soil type, slope, cultural and other conditions, which are not actual treatment variables, should be stated.

Prior knowledge of variability can be used in the stratification and allotment of the experiments. Variability of weather conditions is an important factor which must be reduced by experimentation over a long period of time, and the results weighted according to a frequency distribution of seasons. The financial capacity of farmers and the opportunity for alternate use of capital in other enterprises are forms of prior knowledge helpful in design.

Finally, randomisation of experiments from all fields to be covered in subsequent investigations is desirable to provide an unbiased estimate of the means and variance of the treatment response.

COMPLEX v. SIMPLE EXPERIMENTS

My own view is that simple exploratory experiments should be laid down over a wide range of soils and climates until the general picture of response is obtained. Following this, a more detailed design can be adopted to sort out refinements and interactions. This approach will clarify the questions to be asked in the large-scale experiment and also help to select representative sites for the complex experiment. It is important that the correct questions be asked.

Our Queensland climate is variable and complete failure of our crop experiments probably occurs more often than in other States. It is better, therefore, to spread experiments over a wide area so that at least some have a chance to come to fruition. I have selected four sites situated approximately 250 miles apart on which to conduct cropping trials in the under-20-inch wool-growing areas of Western Queensland. Only one of the four sites yielded a harvest in the dry 1957 season.

THE DURATION OF EXPERIMENTS

The duration of experiments needs serious consideration. Classical experiments, such as the continuous wheat crop on the famous Broadbalk field at Rothamsted, can show by how much and when soil fertility changes. Many soil fertility experiments must be designed to serve a long term because changes in organic matter, structure, and soil nutrients take place very slowly.

Variety trials can be continued for too long. These trials require frequent short-term experiments to incorporate new varieties produced by plant breeders. This means the maintenance of one standard variety throughout and rejection of all but the best few varieties from each experiment to make room for the new material for testing. Bieske (1957) has provided an interesting study in his experiment to show the great advance in cane breeding during the past twenty years. Taking old varieties such as M.1900S and P.O.J.2725, popular twenty years ago, and planting them alongside modern developments like N.Co.310 and Q.50, he obtained the following yields:

Variety	*Cane per acre tons*	*C.C.S. in cane per cent.*	*Sugar per acre tons*	*Gross return per acre less harvesting costs* £ *s. d.*
N.Co.310	43.33	16.22	7.02	178 1 11
Vesta	42.63	14.81	6.29	152 5 6
C.P.29/116	45.24	13.79	6.20	144 4 2
Q.50	40.72	15.01	6.11	148 11 8
Q.47	36.48	14.19	5.16	121 17 10
P.O.J.2878	31.12	14.93	4.64	112 19 2
M.1900S	31.32	13.68	4.26	98 12 8

Experiments like this give a great deal of satisfaction to the industry.

TRANSFERRING EXPERIMENTAL RESULTS TO THE FARM

Experiments under controlled conditions are often needed before fertiliser field trials. Water cultures containing chemically pure nutrients are frequently used nowadays to first indicate the plant's nutritional requirements. Parallel pot tests using vermiculite as a substratum perform a similar service. After this, the next step is to conduct pot tests using soil from the area under investigation. Such factors as temperature, light, moisture content, are controlled. Lastly come field trials.

Without taking such precautions, an entirely erroneous conclusion may be drawn from experiments. An instance is the control of Denmark "Wasting Disease" in Western Australia in stock by the provision of small amounts of cobalt. It has been found that limonite would cure the disease and it was assumed that the iron of the limonite was the effective agent. Administrations of iron, however, failed to remedy the condition and subsequent investigation proved that traces of cobalt were present as an impurity in the limonite and that, actually, cobalt was the effective cure.

Transferring results from pot tests on soils, even into the same soil type in the field, can give varying results. In the field, it is impossible to obtain controlled conditions, and the interaction of numerous factors like temperature, light, moisture, nutrients, microflora, insects, diseases, may give entirely different results. It may mean taking the experiments back into the laboratory to control another variable found in the field.

The problem of soil variability is most important. The soil is not a static, but a dynamic body and variations in micro-relief, slope, drainage and structure can occur within a few yards. Hence, it is important in experimental work to carefully select the site on a known typical soil—preferably a number of sites—with sufficient replications to iron out soil differences.

The husbandry of field experiments is always better than on farms, because the plot size is restricted, extreme care is taken in land preparation, weed control, insect and disease control, and the seed planted is usually certified seed of high quality and vitality. Yield adjustments are made for plant stand, missing plots, and other factors, and so yields would be generally higher than those obtainable on farms. A truer picture could be drawn by first transferring the experimental results to a small but random sample of commercial farmers and adopting the yields from these farms as the basis for recommendations. This usually transfers responsibilities from the research man to the extension man, but I am a firm advocate of the idea that a research man should launch his own findings in the commercial field and make his own judgment of their practical application. Having successfully launched the results to a selected group, the extension man can then take over from there.

Australian, and especially Queensland, rainfall variability is such that experiments must be conducted over a long term to gain what we might call an idea of the average yields likely to be encountered. A great deal of brain power and time are wasted annually in climatic analyses in relation to crop production in Australia, which, in the aggregate, can give only general information. We have not yet sufficient data to establish workable formulae for specific areas. If the economist or agronomist tells a farmer he can expect certain yields two years out of five, he wants to know "which two years?" If he doesn't know, and he cannot, he can involve himself in heavy expenditure without claiming the harvest. I always advocate the Boy Scout's motto: "Be prepared", to utilise the rainfall when and where it falls. In our work in cropping for fodder conservation in the under-20-inch rainfall belt in Queensland, we conducted a climatic analysis based on the most modern concept of length of the growing season which revealed that, at no time, could we expect a crop of sorghum. However, over the past few years, we have put away approaching 100,000 tons of sorghum silage on thirty properties as a drought reserve! This has been accomplished by strategic use of over-average rainfall combined with fallowing techniques. No climatic analysis which ignores the soil's capacity to absorb and store moisture for subsequent cropping is of any use in Queensland.

RESEARCH PROGRAMMES AND EXTENSION RECOMMENDATIONS

Heady (1953) draws attention to a concept which is of extreme importance to research programmes and extension recommendations—the input-output or production function.

It refers to the output of product relative to the input of material or resource such as fertiliser applications. The Mitscherlich curve is typical of this response with diminishing returns for each additional increment of fertiliser, but data to support such curves are not common.

The agronomist usually commences his fertiliser investigations with an exploratory trial to determine where there is a response. In the Mulga and Mitchell grass downs areas of Western Queensland where information was previously lacking, I have used shot-gun mixtures of major and micro-nutrients to first determine if there is a limiting nutritional factor. Having found the limiting factor—phosphorus in the Mulga soils—the optimum rate can then be determined by a series of replicated incremental applications to obtain a response curve. It is important that exploratory trials be followed up to obtain these data. The application of superphosphate at a landed cost of £1 per cwt. to country which can be purchased at less than 30/- acre requires, however, very serious economic consideration. Hence, I have adopted an experimental procedure of row fertilising of grass seed sown in wide rows for the establishment of nucleus seed reservoirs, from which it is hoped seed will spread to intervening ground.

The Queensland Bureau of Sugar Experiment Stations has conducted fertiliser trials for sugar cane for several years and a good illustration of input-output relations is given by Vallance (1956) in his results of the effect of nitrogen as sulphate of ammonia applied to plant cane (sugar cane in its first year of growth) following a previous green manure crop. Six replications of six levels of nitrogen—0, 1, 2, 3, 4 and 5 cwt. of sulphate of ammonia per acre were used as top dressings following a basic planting mixture containing phosphorus and potash.

The curve representing the input-output function follows the general trend in fertiliser trials in Queensland's cane areas and shows a marginal product of one ton of cane for the first 1 cwt. of sulphate of ammonia, ¾ ton for the second, ½ ton for the third, ¼ ton for the fourth, and little response for the fifth cwt. application.

Such experiments enable first-hand information to be given to the farmer upon which to base his decisions.

Vallance (1952) has gone further and summarised the complete figures for plant, first ratoon and second ratoon crops of sugar cane at Moresby under varying fertiliser treatments to show the financial return from varying levels of fertiliser application of varying mixtures to a red schist sandy loam soil.

Fertiliser applied (lb. per acre per annum)			*Increase in return per acre for three crops*			
Sulphate of Ammonia	*Super-phosphate*	*Muriate of Potash*	*£*	*s.*	*d.*	
nil	nil	150	4	2	6	Gain
		300	14	7	6	"
	210	nil	19	12	6	"
	210	150	3	17	6	"
	210	300	1	17	6	Loss
	420	nil	15	12	6	Gain
	420	150	9	12	6	"
	420	300	1	15	0	Loss
210	nil	nil	37	2	6	Gain
210	nil	150	51	15	0	"
210	nil	300	45	10	0	"
210	210	nil	35	2	6	"
210	210	150	29	15	0	"
210	210	300	50	7	6	"
210	420	nil	42	7	6	"
210	420	150	44	5	0	"
210	420	300	18	5	0	"
420	nil	nil	14	10	0	"
420	nil	150	48	10	0	"
420	nil	300	44	10	0	"
420	210	nil	45	10	0	"
420	**210**	**150**	**88**	**0**	**0**	"
420	210	nil	51	2	6	"
420	420	300	45	17	6	"
420	420	150	73	5	0	"
420	420	300	52	2	6	"

The value of correct fertilising is evident from these figures which show that, by far, the most profitable return was obtained when 420 lb. of sulphate of ammonia, plus 210 lb. superphosphate, plus 150 lb. muriate of potash was applied per acre to each of three crops. This application increased the value of the crops (after deducting fertiliser and harvesting costs), by £88 in the aggregate, or £29.6.8d. per acre per year.

Heady (1957) in referring to the fertiliser response curve and the principle of diminishing returns, states: "The management problem that arises from this relationship is concerned with the determination of the amount of fertiliser to be applied per acre for a given crop to give maximum profit. If there is no uncertainty as to the yield to be obtained, and if unlimited capital and an abundant supply of fertiliser are available, the optimum rate will be that amount at which the last pound of fertiliser applied produces just enough product to be worth the additional cost. If there is uncertainty as to the expected yield, or if capital or the supply of fertiliser is limited, the optimum rate of application will be somewhat less." In general, the economist would prefer the agronomist to determine this final increment. But with the many variables in field experiments the agronomist cannot prove significance in such small incremental applications of fertiliser.

Actually, the Queensland cane farmers are inclined to over-fertilise. Vallance (1957) gives the yields for a fertiliser trial laid out on a red loam soil at Innisfail with a history of heavy fertilising. The yields were as follows:

	Fertiliser per acre	*Yields Tons of sugar per acre*
1.	4 cwt. Sugar Bureau No. 2 (Planting) plus 2 cwt. Sulphate of Ammonia	5.8
2.	4 cwt. Sugar Bureau No. 2 (Planting) plus 4 cwt. Sulphate of Ammonia	5.7
3.	6 cwt. Sugar Bureau No. 2 (Planting) plus 2 cwt. Sulphate of Ammonia	5.8
4.	6 cwt. Sugar Bureau No. 2 (Planting) plus 4 cwt. Sulphate of Ammonia	5.6
5.	8 cwt. Sugar Bureau No. 2 (Planting) plus 2 cwt. Sulphate of Ammonia	5.8
6.	8 cwt. Sugar Bureau No. 2 (Planting) plus 4 cwt. Sulphate of Ammonia	5.6

These results show that heavy amounts were not required and a considerable saving in fertiliser costs could have been made. Actually, the design could have included a "no fertiliser" treatment and smaller dressings to give the extreme ranges for better interpretation. The necessity for extreme ranges in experimental design is important because prices may change upwards or downwards and render profitable fertiliser dressings which were previously uneconomic and vice-versa. In Western Queensland, in particular, with its great distances, freight rates are so high that heavy fertiliser applications to increase yields would often be economic for home-grown fodder for livestock—£20 per ton freight on purchased fodder would pay for a lot of fertiliser!

It must be emphasised that records like those of the Bureau of Sugar Experiment Stations are not available for many of our Queensland industries and a good deal of work would be required to cover our grain and livestock industries.

The residual effect of fertiliser dressings is an important consideration which is often overlooked. Heady (1957) has mentioned this problem and suggests that the supply of nutrients already in the soil might demand a new point of origin for input curves. The residual effect of fertiliser should be determined so that adjustments can be made for annual fertiliser application recommendations.

THE MARRIAGE OF AGRICULTURE AND ANIMAL HUSBANDRY

Modern agriculture is passing the exploitive phase and is settling down to obey the concept of permanent agriculture. In such a concept, grass leys and livestock grazing are regarded as indispensable. Therefore, rotation experiments need to be related to economic and biological research on livestock rations. The ration relationship is equally as important as the rotation relationship in determining the optimum land use pattern, if livestock output is to be maximised from a given land area. The economics of fodder crop and grassland farming can be determined only if feed substitution data are available over a wide range of rotations and rations. Unfortunately, it is very difficult to arrive at production functions for grassland research in Australia, and the personnel required to answer many of the economists' queries would be far beyond their present availability.

Our current University experiments in the low rainfall areas of Western Queensland are centred around the growing of sorghum for conservation as silage on the grazing properties.

Sorghum silage is a little low in protein for adequate maintenance and production. The problem then becomes how best to improve this status. Several ways are possible—a legume can be grown with the sorghum with a loss in total yield of the order of two tons per acre; a grain legume can be grown separately and added at feeding; the sorghum crop can be cut at a younger stage to obtain a higher protein but with a significant decrease in total yield and the necessity to add molasses during ensilage to ensure a satisfactory fermentation; nitrogenous fertilisers can be applied at planting or a foliar spray of urea applied during growth; or protein concentrates or non-protein nitrogen can be purchased and added as a supplement. Further, is the non-protein nitrogen to be in the form of urea, ammonium nitrate or sulphate of ammonia? Experiments are needed to answer these problems and the ultimate decision will be on the basis of economics.

THE REDUCTION OF RISK AND UNCERTAINTY

Farmers' decisions are made after taking into consideration the risks of crop failure and the uncertainty of the prices they might receive for their product. Uncertainty arises from variability in crop yields, changes in weather, prices, land tenure, availability of capital, conditions of health and family affairs, and changes in Government. With long-term investments in buildings, equipment and orchards he faces the risk of obsolescence.

We are told that market forecasting has reached a high degree of accuracy in the U.S.A. The position is not so favourable in Australia, but with present-day access to information and facilities for rapid communication it should improve. The development of more accurate long-range weather forecasting, rain-making and frost prevention could help reduce weather risks, but answers will not be found overnight.

Flexibility in cropping programmes will generally help reduce the risk of crop failures, especially with annual crops. The Darling Downs farmers in Queensland can wait for a summer grain sorghum crop, should planting rains be unfavourable for wheat. He also has a choice between types of winter and summer crops. In Southern Australia, this choice of summer or winter cropping is not usually available.

Forecasting of crop yields would help reduce risk. Such forecasts can only be built up following many years of experimental work to yield adequate data. Little such data are available in Australia. The practice of dry-farming as carried out in Queensland's wheat-growing areas greatly assists in stabilising wheat yields which have shown a positive correlation with the amount of stored soil moisture at planting time. Moisture accumulated over a short summer fallow carries the crop to maturity in the usually dry spring and early summer. Allen and George (1956) have shown for the Callide Valley that, if a minimum of 8 in. of effective fallowing rain has been received and wet soil is present to a depth of 48 in. good crops can be obtained on the alluvials with a planting rain of $1\frac{1}{2}$ in. If only 4-8 in. of effective rain was received during the fallowing period, a planting rain of approximately 2 in. is desirable. In seasons where 4 in. of effective rain has not been received and stored in the soil, it is not advisable to plant wheat irrespective of the amount of rain at planting. Such experimental work is invaluable in enabling farmers to make decisions regarding wheat plantings. The Queensland workers have not yet published a formula such as has been done for Texas (Finnell, 1944) although sufficient data must be available. The Texas formula is:

$$\text{Yield} = .33A + 2.32B - 6.24$$

where A is the depth of moisture at planting in inches;

B is the previous July rainfall.

A is the predominant factor affecting yield.

The elements of risk and uncertainty with regard to both yields and prices are, however, major controlling factors in Queensland's agriculture and it will be impossible to reduce their overall effects to a point where relative stability will be achieved.

CONCLUSION

Shaw (1953) showed that, for 1947-51, agricultural production in the U.S.A. rose from the base period 1935-39 by 32 per cent., and livestock production per breeding unit by 17 per cent. In analysing the situation more closely, he concluded that the response of the average producer follows most research advances by a time delay of 10 to 15 years.

The farmer's decisions are made after careful consideration of all factors of production, and the more information at his disposal, the better his judgment. If he has access to an extension worker who has sufficient information, his task is easier. Sufficient information comes from adequate research data and the questions to be answered are so numerous that it will be many years before the back-lag can be made up. A huge team of agronomists and others will be required and it is important that their enquiries are directed along the right channels.

Research and extension is a two-way process, and while research results pass on to the extension worker for dissemination, the extension worker must also bring back farmers' problems to the research department for solutions. Where problems of economics are involved, there is a case for a round-table discussion on experimental design by a team consisting of an agronomist, a production economist, a biometrician and the extension worker, so that all factors for influencing farmers' final decisions can be given due consideration. Finally, such must receive the blessing of the administration.

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