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YIELD INFORMATION NEEDED FOR THE ANALYSIS OF CROP IMPROVEMENT RESEARCH

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Introduction

The purpose of developing new crop technology is generally to increase yields per unit of land and to reduce costs per unit of product. A rather elaborate methodology has been developed to measure the rates of return from such investments, principally involving ex post analysis. Improvements to this methodology are continually being suggested.1/ Yet much of this sophisticated methodology is built on a rather limited statistical base--particularly when it comes to the actual measurement of the effect of the technology on yields.

Some of these yield measurement problems, such as the difficulties in isolating the yield effect of a specific technology when it is part of a package of interacting technologies, have long been recognized. The influence of weather and other factors must, of course, also be considered. Production functions have been an important tool in sorting out the roles of these factors.

But relatively little methodological attention seems to have been given to the basic yield data themselves. These are of critical importance in index number analysis. Just how good are the available statistics? What are their advantages? What are their limitations? What alternative sources are available? Could existing data be utilized in a better way? What additional data might be gathered?

As one who has given considerable attention over the past decade to the collection of area data on wheat and rice, 2/ I must confess to have largely neglected these questions. Yet to judge from the literature, I am not alone. Perhaps the time has come to balance improvements in methodology with concern for the basic data. The purpose of this paper is simply to highlight the issue and to try to stimulate others to explore the matter further.

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Sources of Yield Data

Despite widespread concern with yields, a rather limited array of yield data are usually available. These may be divided into those obtained at the experimental level and/or at the farm level. I suspect that most agricultural economists are considerably less familiar with the former than the latter.

Experimental Yields

These are, of course, the yield levels obtained on the experiment station or field stations. These trials are generally closely controlled to exclude or minimize the effect of other variables. But the process of doing so means that they cover a rather limited area and perhaps a limited period of time. As far as they go, however, they provide an excellent idea of the potential for the improved technology.

This initial work is often followed by more substantial testing in regional trials throughout the nation3/ and sometimes at the international level.4/ Again, the actual area planted may be rather small, but the number of replications under different conditions is increased substantially. The temporal dimension is also enlarged.

The result of this extensive testing process is that by the time a variety is released, the breeder has a fairly good idea of its wider yield potential. The yield advantage is often mentioned in the release announcement.

While this sort of data is well known to crop scientists, I suspect it is not well known by many agricultural economists. Moreover, it is often not readily available and is classified as preliminary. The introduction to one annual summary, basically a mimeograph, states that it

is a progress report,

> "...containing preliminary data which have not been sufficiently confirmed to justify general release; interpretations may be modified with additional experimentation. Confirmed results will be published through established channels. The report is primarily a tool for use of cooperators and their official staff..."5/

Confirmed results, however, are often not presented in the same comprehensive framework.6/

While agronomists go on to use such trial data in making yield comparisons.7/ it appears that the economist is seldom, if ever involved. And by himself, the economist may have some difficulty in analyzing the data. He will need to know something about how the tests were conducted and a fair amount about the varieties themselves (some may be listed only under test numbers). The result is, I suspect, that very few agricultural economists ever follow the experimental yield data very closely and/or make use of them (the paper by Orazem in this volume is one exception.

Average Farm Yields

Most economists simply utilize the data issued by most state or federal governments on average yield levels at the farm level. Published average farm yields have several undeniable advantages for the agricultural economist. They are relatively available. They are standardized. They apply to a broad area. They are costless or virtually so. And they

The disadvantages, of course, center about the highly aggregative nature of the statistics. All varieties are included; data on the specific variety is seldom included. The influence of differing cultural practices and cropping systems is not delineated. Yet, yield levels reflect the influence of many biological, economic, and institutional forces beyond the individual technology. These factors can make it quite difficult to sort out the "pure" effect of the technology.

There is, of course, a potential additional source: special farm surveys. If these are done only once in a limited area on a recall basis, there are substantial limitations to the data. But if they are well organized and carried on for a period of years over a wide geographic area, they may be of considerable validity. But how many economists outside of the international agricultural research centers are involved in such ventures?

In any case, it is widely recognized that there is usually a substantial difference between experimental yields and farm yields (though this is certainly not always the case, and in some instances, the situation may be reversed). The reasons, of course, may be many, ranging from environmental to cultural and management conditions. Even where many of these factors are standardized, there may still be yield differences favoring the experimental plot.8/ The yield limitations faced by the farmer have recently been studied in considerable breadth and depth in the case of rice in Asia.9/ How have these yield differences been handled in evaluations of crop research?

Examples of Approaches

It would be instructive to examine most or all of the studies that have been done on the rate of research to determine how the estimate of increased yields was determined (except where derived from production functions). I have not had the opportunity to do so. But a few examples may be cited to show something of the range of approaches.

Griliches, in his pathbreaking study on hybrid corn, simply assumed a figure of 15%, based on industry estimates ranging from 15 to 22%.10/ Three such estimates were cited, dating from 1940, 1942, and 1952. It is uncertain to what degree these sources made use of primary data. In this case, however, the hybrid varieties had been in use long enough so that a rather clear perception of their yields advantages may have emerged. Still, I can't help but wonder about them.

A subsequent study of cotton research in Sao Paulo, Brazil, by Ayer and Schuh was more precise in its yield estimates.11/ The estimates were derived from carefully controlled test plot experiments conducted by the government from 1924 to 1967. The increments were divided into five periods and varied somewhat. The internal rate of return was also calculated with yields 10% above and 10% below these estimates, with little change in the result. When the use of such estimates was criticized by Saylor as being too high in terms of farm level results, 12/ Ayer and Schuh noted that (1) after 1936 the test plot comparisons were extended to all major producing regions and were also initiated on privately owned and operated farms which were contracted by the state for seed multiplication, (2) fertilizer and insecticide applications were set at approximately the state average rather than output-maximizing levels, and (3) each variety was entered for several years.13/

Saylor proposed utilizing changes in average state yields from a base period.14/ This approach was in turn criticized by Ayer and Schuh on three counts: (1) the base period data were

of questionable quality, (2) there was a small area of cotton in the base period which subsequently expanded sharply, and (3) there was a sharp change in relative product prices during the period. In short, they suggested that Saylor's computations were not based on data which adequately reflected differences in productivity that resulted from varietal change.15/ Saylor's approach was later also criticized by Musalem 16/ because (1) it took into account the full adjustment process that followed after the initial shock of pure technological innovation, and (2) it involved a shift parameter that includes all factors affecting yields. 17/

A third study was conducted of several crops in Colombia by Hertford and others.18/ In the case of rice, their yield levels were based on 665 individual field trials conducted by the Colombian Agricultural Institute (ICA) during the 1957-71 period.19/ The trials, pruebas regionales, were conducted on commercial farms; farmers ran the trials but materials and instructions were provided by ICA. Similar data were obtained for cotton (499 observations from 1953-72) and wheat (1,016 observations from 73).20/ Production functions were used to sort out the influence of other factors influencing yields. While the basic data summarized by Hertford, et. al. may have had some limitations 21/ they represent a promising extension of the approach taken by Ayer and Schuh.

In my own studies of high-yielding varieties in Asia, I have found it quite difficult to obtain reliable estimates of the varietal effect under comparable field conditions. In one case, I used the best estimates I could find and then subjected them to a crude sensitivity analysis. 22/ In a recent study of wheat and rice in the United States I summarized a number of experimental results, but didn't find anything quite comparable to the field trial data utilized by Hertford, et. al.23/ Such data may, however, exist somewhere.

Of the various approaches, the use of farm trial data would appear particularly promising. What do we know in a general sense about such trials?

Farm Trials

Although one might expect that farm trials of the sort conducted in Colombia have long been a normal part of the testing process for new varieties, this does not appear to be the case. I have found a few references which provide suggestions for farmers wishing to conduct their own trials 24/, but essentially relating to farm trials conducted under the supervision of the research organization. The international centers have had some involvement with such trials; and while several of their publications bear on them, 25/ they have not yet been the subject of a definitive treatment. This, however, may be a case where more is known than seems to have been written down.

Sanders and Lynam at the International Center for Tropical Agriculture (CIAT) in Colombia have utilized such trials for beans and cassava and have recently commented briefly on their experiences.26/ They note that farm trials differ from normal experimental trials in that with the farm trials:

*inputs and management are at relatively normal levels (rather than at the high levels often used in experimental trials to maximize the treatment effect);

*little effort is made to separate individual input or factor effects;

*the variance within treatments between farms is a vital measure or indicator of the other farm level research problems or factors influencing technology; and

* a large number of trials is needed.

The principal limitations of farm trials are their site-, time-, and variety-specific nature. And some cost and supervisory time is involved. From the economist's point of view, three major questions need to be answered:

1. Are there significant differences between the treatments?
2. Is the new technology more profitable than farmers' practices?
3. Does the new technology fit into the farmers' production system?

In the process of answering these vital questions, the economist (and the trials) can provide important feedback to the scientists.

Farm trials are thus a form of ex ante analysis that preceeds commercial adoption. Even though they are more indicative of what may happen at the farm level than the experimental work, they may still not be fully representative because of the supervision of the scientists and the likely above-average nature of the farmers involved. This may be difficult to accomplish if the ex ante character of the trials is to be maintained. One might think of conducting farm surveys of early adopters, but these necessarily would involve a time lag and again the farmers involved may not be typical. This problem merits further study.

In evaluating trials it should be realized that in addition to providing feedback to the scientists, they may be of considerable educational value in disseminating the technology among farmers. In fact, they are only one small step away from farm demonstrations--long a basic technique in extension or outreach work.27/

Farm trials, however, may not be needed in every case. In areas where research has long been carried out and there is a well-known rela-

tionship between experimental and farm yields, they might be bypassed.28/ And when the new technology moves rapidly into use, the trials may also be of less immediate need. There is unquestionably a cost connected with farm trials and this must be balanced against the returns from the process.

On balance, farm trials would seem to merit much more attention than they have in the past. They can provide vital feedback to the biologist, needed information for the economist (though the results may need further deflation), and serve as an educational device for farmers. Still, they may not be appropriate in every case. Before much more can be said about them, they need to be the subject of further analysis.

Conclusion

Improvement in the methodology for the evaluation of research on crops needs to be matched by improvements in the measurement of the basic yield data. The initiation or expansion of farm-level trials offers one promising way to obtain more robust data at an earlier date. But they are likely to remain only in the promising category until more is known about them--the extent to which they are actually utilized, and their more precise advantages and limitations.

Economists should be involved in such an appraisal, just as they should be involved in the conduct and analysis of trials results. Despite the potential importance of such an activity, many economists may not find actual involvement in trials an attractive prospect. It would involve fairly long-term field work and the results are not likely to lead to spectacular results. Time spent on such activities is time away from other activities where the economist might feel more at home or which might be thought to lead to fame or fortune.

But until such steps are taken, we simply may not have a very sturdy empirical base for evaluating the potential yield effect of a new technology at the farm level. There is, moreover, an increasing need to know more about the effect of improved technology at an earlier stage of the game than has hitherto been possible. This necessitates earlier and fuller involvement of economists in the measurement of yields.

Footnotes

1/See, for example, R.K. Lindner and F.G. Jarret. "Supply Shifts and the Size of Research Benefits." American Journal of Agricultural Economics, February 1978 (Vol. 60, No. 1), pp. 48-58.

2/Dana G. Dalrymple. Development and Spread of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations, USDA/OICD (in cooperation with USAID) Foreign Agricultural Economic Report No. 95, Sixth Edition, September 1978, 134 pp.

3/These are often known as nurseries. A number of uniform nurseries are, for example, conducted for the major market types of wheat in the United States as a cooperative USDA-state venture. See, for example, P.S. Baenziger and J.G. Moseman, "Results from the Cooperative 1978 Uniform Southern Soft Red Winter Wheat Nursery," USDA/SEA/NE Region in Cooperation with State Agricultural Experiment Stations, Beltsville, Md., PGGI-78/9, October 1978, 39 pp.

4/See, for example: K.D. Wilhelmi, et. al., Results of the Eighth International Winter Wheat Performance Nursery Grown in 1976, University of Nebraska Agricultural Experiment Station (in cooperation with USDA/SEA and USAID), Research Bulletin 285, July 1978, 232 pp.; and Report of the Third Conference, May 30-June 2, 1979, International Rice Testing Program for Latin America, CIAT (with IRRI), Series 03ER-3 (February 1980), 62 pp.

5/Baenziger and Moseman, op. cit., p. 1.

6/As part of a recent study, I tried to summarize the reported yield advantage for semidwarf wheat varieties as reported in the variety announcements in Crop Science. This process produced many figures, but they were not highly standardized and were not easily compared or summarized. In some cases, only a nonquantitative general statement was given, such as "greater than" or "superior to." And as might be expected, the figures represented widely different periods and growing conditions Dana G. Dalrymple Development and Spread of Semidwarf Varieties of Wheat and Rice in the United States: An International Perspective, USDA/OICD (in cooperation with USAID) Agricultural Economic Report No. 455, June 1980, p. 103.

7/For a recent example, see L.G. Campbell and H. N. Lafever, "Effects of Locations and Years Upon Relative Yields in the Soft Red Winter Wheat Region," Crop Science, Jan.-Feb. 1980 (Vol. 20, No. 1), pp. 23-28.

8/In one Australian study where many of the production factors were standardized, the differences were thought to be largely due to greater labor availability and hence improved timing of operations under the experimental conditions. Bruce Davidson, "Crop Yields in Experiments and on Farms," Nature May 5, 1962 (Vol. 194, No.4827), pp. 458-459; B.R. Davidson and B.R. Martin, "The Relationship Between Yields on Farms and in Experiments," Australian Journal of Agricultural Economics, December 1965 (Vol. 9, No. 2), pp. 129-134, 138-139.

9/The study was led by IRRI economists and involved cooperating national researchers. Results are reported in Farm-Level Constraints to High Rice Yields in Asia, 1974-77, IRRI, 1979, 411 pp. Also see R.W. Herdt and Randolph Barker, Multi-Site Tests, Environments, and Breeding Strategies for New Rice Technology, IRRI, Research Paper Series No. 7, March 1977, 32 pp.

10/Zvi Griliches: "Hybrid Corn: An Exploration in the Economics of Technological Change," Econometrica, October 1957 (Vol. 25, No. 4), pp. 516-517,; "Research Costs and Social Returns: Hybrid Corn and Related Innovations," Journal of Political Economy, October 1958 (Vol. 66, No. 5), p. 42.

11/Harry W. Ayer and G. Edward Schuh, "Social Rates of Return and Other Aspects of Agricultural Research: The Case of Cotton Research in Sao Paulo, Brazil, American Journal of Agricultural Economics, November 1972 (Vo. 54, No. 4), p. 558.

12/Gerald R. Saylor, "Social Rates ... Comment," American Journal of Agricultural Economics, February 1974 (Vol. 56, No. 1) p. 171.

13/Harry W. Ayer and G. Edward Schuh, "Social Rates ... Reply," American Journal of Agricultural Economics, February 1974 (Vol. 56, No. 2), p. 175.

14/Saylor, op. cit., pp. 171-174.

15/Ayer and Schuh, op. cit. (1974), pp. 175-176.

16/Alberto R. Musalem, "Social Rates ... Comment," American Journal of Agricultural Economics, November 1974 (Vol. 56, No. 4), p. 838.

17/The discussion also took up important questions concerning partial and general equilibrium effects, but these have not been noted here.

18/Reed Hertford, Jorge Ardilla, Andres Rocha, and Carlos Trujillo, "Productivity of Agricultural Research in Colombia," in T. M. Arndt, D. G. Dalrymple, and V.W. Ruttan (eds.), Resource Allocation and Productivity in National and International Agricultural Research, University of Minnesota Press, 1977, pp. 86-123.

19/Ibid, p. 89.

20/Ibid., pp. 99, 100, 108, 109.

21/Scobie, for instance, later tried to utilize the rice data for estimating the yield superiority of improved varieties at the national level but obtained some puzzling results and ultimately did not use them. Grant M. Scobie and Rafael Posada T., The Impact of High Yielding Rice Varieties in Latin America, with Special Emphasis on Colombia, International Center for Tropical Agriculture, Cali, Series JE-01, April 1977, pp. 45-47.

22/Dana G. Dalrymple, "Evaluating the Impact of International Research on Wheat and Rice Production in the Developing Nations," in Arndt, Dalrymple, and Ruttan, op. cit., pp. 189, 190, 197-200.

23/Dalrymple, op. cit. (1980).

24/Advice for farmers wishing to conduct their own trials has recently been provided by Howard N. Lafever and Larry G. Campbell, "How to Set Up, Evaluate Yield Trials on Your Own Farm," Crops and Soils, November 1976 (Vol. 29, No. 2), pp. 13-17; and Charles E. Sommers, "On-Farm Tests --How to Put One Together," Successful Farming, February 1980 (Vol. 78, No. 3), p. 25 (published in the January 1980 edition on some regions).

25/See: S.K. DeDatta, K.A. Gomez, R. W. Herdt, and R. Barker, A Handbook on the Methodology for an Integrated Experiment-Survey on Rice Yield Constraints, IRRI, 1978, 59 pp.; K.A. Gomez, "On -Farm Testing of Cropping Systems" in Symposium on Cropping Systems Research and Development for the Asian Rice Farmer, IRRI, 1977, pp. 227-239; and R. K. Perrin, D. L. Winkelmann, E.R. Moscardi, and J.R. Anderson, From Agronomic Data to Farmer Recommendations; An Economics Training Manual, CIMMYT, Information Bulletin 27, 1976, 51 pp. and Planning Technology Appropriate to Farms; Comments and Procedures, (YMMT, Economics Program, 1980 in Press).

26/This paragraph is principally drawn from John H. Sanders and John K. Lynam, "Economic Analysis of New Technology in the Bean and Cassava Farm Trials of CIAT," CIAT, March 1980, 25 pp. (to be submitted to Agricultural Systems) and a letter from Sanders dated June 23, 1980. I have also drawn from their paper "Defining the Relevant Constraints in Crop Programs: Data Requirements to Improve Research Resource Allocation," April 1980, 14 pp. (submitted to Agricultural Administration). It is hoped the authors will spell out their experiences with farm trials in greater detail in the future.

27/Historical perspective on farm demonstration work in the United States is provided in Alfred Charles True, A History of Agricultural Extension Work in the United States, 1785-1923, USDA, Misc. Pub. No. 15, October 1928, pp. 58-65. Some more recent comments, in a global context, are provided in Johnson E. Douglas (compiler and editor), Successful Seed Programs: A Planning and Management Guide, Westview Press, 1980, pp. 155-157.

28/Some related questions which might be considered are noted in Sanders and Lynam, op. cit. (April 1980). Two Australians, as mentioned in note 8, have attempted to delineate the relation-

ship between experimental and farm yields for several crops under fairly disaggregated conditions in the early 1960s. Although the heavy data requirements for such an approach might limit its usefulness, it might be instructive to try to repeat this study for a more recent period and also in a different setting. Davidson, op. cit., and Davidson and Martin, op. cit.