

MAIZE IMPROVEMENT: A MULTI-DISCIPLINARY APPROACH

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INTRODUCTION

In thinking about integrated agricultural research and production, our thoughts should span the complete process -- the activities and functions involved from first crossings in the breeding nursery through harvest at the farm level. When we think in these terms, we quickly see that many disciplines must be counted upon.

The term "team approach" has been used to describe this process; but like most such terms, it is used in such a general and excessive way that its precise meaning is lost. Thus, "team work" or "team efforts" and similar expressions, become a kind of jargon for agricultural research and production workers.

All research groups, -- universities, institutes or Departments of Agriculture -- say that they work as a team: "they cooperate". Such comments are made continually without any real thought as to their operational meaning.

The actual situation, as I have seen it in research organization world-wide, is that cooperation or the "team approach" ranges from absolutely no cooperation -- or perhaps antagonism -- among the different disciplines, to truly integrated efforts. This situation is not unique to agriculture, nor is it correlated with levels of development of nations.

Thus, since the meaning or impact of the concept "team approach" seems lost in current jargon, I shall discuss the subject under the term "integrated research and production".

ORGANIZATION

We can build our thinking around this initial question. How do we best organize a team of researchers that will assure the effective performance of all functions involved in developing insect and disease resistant crop varieties, and an economical production package? It seems obvious that the greatest degree of efficiency in terms of time, money, and staff should be of paramount concern to all responsible for agricultural research and production.

Yet, in far too many situations, we see the entomologist screening and selecting for insect resistance; the pathologist screening and selecting for disease resistance -- and each of these functions seems unrelated to the other, and to the breeding program. Such practices usually produce varieties resistant to a disease or diseases, but of little value otherwise; the same statement holds true for the entomologist's progress toward field-tolerance to insects.

The breeder, in turn, develops the variety that is as resistant as natural field infestation and infection will permit, -- if he takes diseases and insects into consideration in his selection program. As a general statement, the breeder is inclined to do the best he can to obtain insect and disease ratings -- but, in fact, he does not use them. He bases his selection, recombination, crossing program, etc. on the yield values alone.

It can be argued, of course, that disease and insects take their toll; thus levels of resistance or tolerance are reflected in yield. Seasons with low incidence of diseases and insects and escapes will tend to disrupt any uniform influence these characters might have on yield.

People using such a system pride themselves on having developed sources of resistant varieties. In reality, however, combining such varieties into a superior variety in the breeding program requires an additional, lengthy period of time.

In Hybrid programs, the pathologist and entomologist have taken standard lines, put resistance into them, and then substituted these for the original line in the hybrid. This is, of course, a contribution, but it is not adding genetic potential for yield, per se.

We see the production agronomist is sitting on the side lines, so to speak, in that he is handed a variety or hybrid that is a fixed unit for which he is to work out the most economical production package. Unfortunately, his responsibility is viewed as that of simply determining rate of seeding, time of seeding, fertility response, etc.

Plant protection people watch the occurrence of diseases and insects, and try fungicides and insecticides to determine economical packages of plant protection.

We ask: Aren't there organizational strategies to integrate all of these activities and functions to save time, land requirements, costs, that can do a more efficient job? As an example, why should the entomologists and pathologists have many separate nurseries? Why should they screen only for insects or for diseases with duplicate nurseries? For example, simply because a given disease is very damaging, thus creating a need to screen a large number of materials for resistance, we should not overlook the opportunity to seek resistance and tolerance to many other characters -- we could simultaneously search for genes for other characters, such as grain types, plant type and yield. If programs were truly integrated, every nursery would serve several purposes, and would investigate the interactions of the different diseases and insects.

In the routine breeding nurseries, couldn't the pathologist, entomologist and agronomist work in cooperation with the breeder, so that all of the disciplinary functions would have an impact on the selection process? It seems quite feasible to select for a wide range of characters simultaneously, if the program is integrated and the specialists are working harmoniously together on breeding and pest nurseries.

There are, of course, other functions that are more specifically identified by discipline. Rearing insects for artificial infestation, and producing inoculum for artificial inoculation, are specific tasks. Devising methods of inoculation and infestation also are "specifics". Basically, however, these tasks simply provide tools that are used in any well organized research and production program.

PRODUCTION LEVEL

Where does the production agronomist fit into this integration? There are many opportunities for management practice input into the breeding program, and at a level that will provide additional criteria for selection.

Thus far, we have dealt only with integrated research on the experiment station. How do all these parts fit together at the farm level? It seems obvious that all disciplines should be involved in developing a successful production package. Plant protection at this level is a production function and should be built into the on-farm research program.

In my opinion, varieties and hybrids should be tested in large plots under farm conditions before being released. Such testing provides three advantages: (1) the larger-scale plantings under farm conditions allow assessment of varieties under conditions that will be encountered by the farmer, (2) the farmer and research staff are brought together, involving the farmer in research, (3) the researcher is "forced" off the experiment station, and brought face-to-face with the realities of production problems at the farm level.

At the farm level, we are not concerned with testing new insecticides, for example, but we should be very much concerned with the rate and number of applications of an insecticide that will give the greatest economic return with the variety, the fertility level, etc. Therefore, to really put together the best production package it seems to me that breeders, entomologists, pathologists and agronomists must all be involved. This is true, even though, in general, I would agree that the production agronomist should be held responsible for conducting the work.

I have touched very briefly on the systems that are more commonly used, and have suggested the need to integrate all of the functions (and therefore personnel) in agricultural research and production. Intentionally, however, I have not gone into the many field techniques and systems of management that are required to implement an integrated program. This, I am sure, will be covered by a number of papers that are to follow.

RESTRICTIONS TO INTEGRATION

At this point, perhaps we should ask why, if this integration leads to more efficiency, all programs are not automatically operated in that manner.

Science is a process of evolution, of acquiring knowledge and putting pieces together as they fit. In the early days of scientific endeavor, biologists were taught to observe and try to understand what they saw. Later more precise experimentation was employed. Over the years the various disciplines, such as breeding, entomology, pathology and agronomy, became fields of full time study -- each in their own right. Now, these broad fields have evolved or bifurcated and specialized to delve more deeply into scientific investigation. This process provides the tools that the applied agricultural scientist needs.

Unfortunately, however, administrative systems have not evolved in a parallel fashion with science. Thus, we are still organized administratively on a departmental basis of breeding, pathology, entomology, agronomy, etc. The more fundamental aspects of the disciplines have been spun off into departments of basic biology, etc. This further bifurcation is quite common; however, only in a very few cases have there been an amalgamation of disciplines at the applied level.

This process has left the work of the applied agricultural scientist separated by departments or divisions. They are reporting to different administrative heads and competing by department or division for scarce resources (which in many situations are provided on the basis of the number of projects that can be submitted).

These departments are often set apart by professional jealousy, and by their desire to maintain a disciplinary identification so that they will be "counted" in the fraternity of their discipline. That is, they must publish -- and the number of articles (pages) seems to be more important to their superiors than the actual contribution that they may have made to increasing food production. Further, disciplinary scientific journals (that are overcrowded with articles) have evolved to a point that they will not accept the type of meaningful article that could be written around the applied and integrated work that I am promoting. In other words, our scientific journals have followed the evolution of the fundamental scientists and have left the applied-oriented cadre without a journal or avenue for publication of their legitimate applied technological work.

REORGANIZATION ON A COMMODITY BASIS

In answer to some of the above problems, I argue for the reorganizing of agricultural research on a commodity basis for the major food crops. The immediate counter-argument is that "we cannot afford to have an entomologist spend full time on maize". I ask "Can we afford not to?"

There are several points that support my argument: (1) industrial crop research has traditionally been commodity oriented, and has been far more successful than has our food-crop research and production, (2) in many situations, a commodity team organization would not require more people per discipline than already available within the departments or divisions, and (3) with world population growth rapidly exceeding our capability to produce food, we must look for more efficient means of accelerating food production very, very quickly if we are to prevent large scale famines.

Simply shifting the organizational approach from a disciplinary to a commodity-team administrative structure is not likely to produce instant success. Regardless of system or organization, success or failure still depends on the people involved. Thus, there is a genuine need for researchers who fully understand the importance of integration and who recognize that the coordinated effort of all will lead to greater individual accomplishments than would be likely through work done separately.

In an integrated program, cooperation and spirit is essential for success, and by the same token they are the product of dynamic and successful programs.

Besides an integration of effort to increase efficiency there is a genuine need on the part of most countries to: (1) more clearly define their objectives, with (2) a sharper focus on the research and production activities that will assure the greatest payoff in terms of increased production in the shortest possible time.

In other words, we have discussed integrated research efforts without defining the magnitude of work that should be done or the number of people necessary for such a team. These needs, obviously, will vary from one country to another, depending upon the importance and acreage of the crop. The actual team that can be fielded will also depend upon the number of qualified people available in that country.

With the balance of international, regional and national efforts going into crop improvement, even countries with very few well-qualified people have an opportunity to make great strides in accelerated production.

This does not suggest that countries, where the crop is important, should not have a full team for applied research and production as a long-range objective. It does argue that, in the short term, countries should plan very carefully and selectively in applying production systems that have proved useful in countries with similar physical, cultural and social conditions.

EDUCATION AND TRAINING

If this approach is correct, and I believe it is, then why should we not look for ways of training and educating students and young scientists in such a system? The answer is relatively simple -- there are very few opportunities for young or mature scientists to train in such a system, because few are in operation.

To the best of my knowledge, there are few or no educational institutions that are not organized on a fairly strict disciplinary basis. The level of cooperation or integration in educational institutions is dependent upon kinds of common interests that staff from different departments or divisions may have, and upon personal relationships. In other words, there is no structure or system that actively encourages integration. I am fully aware of the fact that the staff of any educational institution will declare that they cooperate. I ask to what extent they truly integrate and truly support one another across disciplines as I have described here?

Each department offers its own set of courses, yet there are many students who need subject matter that applies across departments. As an example, the world's severe food shortages and protein malnutrition suggests that agricultural scientists should have a better understanding of the interrelationships and genetic manipulations of cereal protein, of cereal protein chemistry, of nutrition, and of the health and social implications. Where can the student find such a course? He can get a full course in genetics, a full course in protein chemistry, in nutrition, in public health, etc. The student often is without the background or the need for a full course in all these subjects, and he is not likely to be able to synthesize all this material into the meaningful understanding that he needs, because they are not taught in that way. Instead, they are taught for the geneticist or the chemist, etc.

This is not to imply that courses in depth are not needed; however; it is a plea for much more consideration of what the student's needs and what could be provided by an in-depth approach broadened across disciplines.

In general, postgraduate students are encouraged to follow the same rather narrow area of specialization throughout their entire student program. Often the professors are responsible for this. They encourage students to overspecialize and to follow a single general subject area. As a consequence, the student is inclined to continue to research that particular small area after he finishes his studies. This is particularly disastrous, for example, when students from tropical and developing countries do their advanced studies in Europe and North America on topics that may be totally irrelevant to problems of agricultural production in their home country.

What would be wrong in encouraging students to switch from one discipline to another as they move from one level to another in their educational programs? Of course, one can argue that he will not be well educated, that he will not be able to compete with students with a high degree of specialization. Is this really true? Is it possible that he will, in fact, be better educated -- but perhaps not as well trained? Will he not have a much better appreciation for the interrelationships of causes and effects in biology, and thus much better equipped to operate successfully in an integrated program?

Perhaps another approach would be a group of students working as a team across disciplines attempting to solve a complex problem involving several aspects of the various disciplines. This would cause them to have to plan and investigate the problem as a group, with each contributing his input and at the same time sharing his time and ideas with the others in the group.

It seems to me that students obtaining their education in this way would have a much better understanding of the value of integration and the interdependence between different disciplines than would the student who follows the traditional path of post graduate education.

In no way am I suggesting that agricultural students today should receive less (or a poorer quality of) education. I am, however, arguing that it is time to take stock of the world food and population situation and explore ways of more successfully combating the stark tragedy sure to occur unless we increase food production dramatically.

SUMMARY AND CONCLUSION

When one looks at average production of maize per unit area and at the increase in yield over the years, one cannot help but be impressed with the failure, rather than the success. We have little to argue that our present system, as understood by most people, will solve our population and food problems. The easy jobs have been done.

To solve the tough production problems that remain (and we do not have much time to do it) will require an imaginative intensification of efforts to develop scientists whose education and training motivate them to work together in evolving a comprehensive production system, to increase maize yields. When food production was increasing at a rate faster than population, and when production problems were simple, the world could afford the luxury of isolated individual efforts and duplications. Today, with population growth outstripping food production, (especially in the poorer countries less capable of competing in the world food grain market), we must improve our efficiency in applied agricultural research as a first step towards improving our efficiency in production.

In this discussion, I have focused on the disciplines of breeding, entomology, pathology and agronomy. I have done this for simplicity, recognizing that many other fields such as chemistry, social science, etc., are important and should be built into the system.

Further, I have approached the subject on the basis that applied agricultural scientists are practitioners using the tools that are developed by the more fundamental sciences. I further believe that the applied scientists is one of the most important entities in the complex society of mankind and that he should proudly and boldly pursue the cause of accelerated food production -- man's greatest problem today, paralleled only by his uncontrolled population growth.

