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some ways international research programs can assist advanced nations

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SOME WAYS INTERNATIONAL RESEARCH PROGRAMS CAN ASSIST ADVANCED NATIONS*

by
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1.1 LOOKING AT THE U. S. FROM OUTSIDE

As a result of my experience with an international research and production center, I am aware of the considerable aid provided by the United States in assisting developing countries to organize and improve their agricultural services and production.

Today, however, I would like to take a look in the opposite direction. I am going to view the United States from the outside. I will draw on my international experience with many different agricultural research approaches to discuss problems in the United States agricultural system and suggest possible alternatives.

Every country should reevaluate its systems of operation from time to time to be sure that they fit the current needs of its people, I believe that a reevaluation of agricultural research is due in the United States today.

I see duplication and wastage in research. There is also reduction in applied research thus lessening contact between government and university researchers and the farming community, with a consequent difficulty of attracting adequate public funding.

Most of the world looks upon the United States as the outstanding example of success in agriculture, backed by superior research and services. It is true, of course, that the United States has made tremendous progress in production, and has a wealth of research and services behind its agricultural industry. It is certainly true that the United States is the only country which has demonstrated a continuous sustained increase in maize production from 39.4 bushels per acre in 1954 to 83.9 bushels per acre in 1969. I understand that the 1972 crop was estimated at 93 bushels per acre. Examples in other crops are numerous.

This does not mean, however, that the United States provides the most efficient example of using research and service budgets. I suggest that the United States has many examples of duplication, with redundant research programs servicing relatively small geographical areas.

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2.1 THE LAND GRANT SYSTEM

This has grown out of our land grant college system that has a component located in every state, regardless of size, and taking no account of the homogeneity of the region. In saying this I am not criticizing the land grant college system per se, because there is a need for a growing educational system to serve a growing population. I also fully recognize the need that existed several decades ago (Pre World War II) for the research that land grant universities were doing. In those days we were less mobile.

If one looks at the current situation and beyond, there are opportunities for a reorganization of agricultural research in the universities and the United States Department of Agriculture that I believe could save money and actually improve results.

Prior to World War II, there was a relatively small private sector involved in agricultural research. Today, however, the seed industry, fertilizer industry, and other elements of the private sector are backed by their own research and services.

This sector strongly supplements public research and, together, they make available more technology to the American farmer than is available to farmers in any other country of the world.

This growth in technology has caused the universities to turn their attention increasingly towards the fundamental aspects of agricultural research. With this change, education in the Land Grant system itself has changed, providing less opportunities for graduate students interested in the broader implications of agricultural production.

3.1 MAIZE RESEARCH

I have suggested the need for change. Now let me turn to maize as a crop where some of the experiences gained in the international research institutions might have value to the United States and other advanced nations.

Worldwide, maize research has been the most location specific of all the cereals. The concepts of United States maize research have established the pattern for many of the maize research people of the world. The very rapid spread of hybrids and efforts on developing inbred lines has contributed to a great extent to the location specificity.

We all know the seed trade has divided the United States into zones, with their hybrids labelled accordingly. We further know that there are occasional hybrids that are sold over a much wider area of the United States than are others. This suggests to me that the restricted breeding and testing created the zoning, not the inflexibility of the species *Zea mays*. I will be the first to admit, of course, that the seed industry does not operate on a state boundary basis and promotes its hybrids wherever they are competitive, and some of these hybrids have a fairly wide distribution.

3.11 Germplasm.

When one discusses ways in which international research could be of assistance to the United States, germplasm always come to mind. This, in turn, is associated with concern for expected needs for disease and insect resistance.

The United States has been interested in preserving the world gene pool of maize; however, I suspect it has made less use of the available germplasm than many developing nations.

I am aware that a number of United States maize researchers want to use more exotic, or non-United States, germplasm and are looking for ways to integrate it into their programs. I believe that the demonstrations now being made by the international network of maize scientists in the uses of the vast available gene pool could be extremely valuable in assisting United States research.

I am convinced that the adaptation of maize varieties and populations need not be location specific, and that it is not necessary to lose yielding ability in breeding populations that are broadly adapted. We can learn from research experience with wheat, and practice some of the techniques that have produced wheat varieties with extremely wide adaptation and stability of yield.

To widen the adaptation of any species it is necessary to expose the material to the widest set of environmental tests --including climates, day lengths, diseases, insects -- to which the crops is likely to be exposed in commercial production.

Many of the conditions are definitely not available in any one state of the U. S.; therefore, a national program, rather than individual state programs should be more successful in incorporating new germplasm into commercial hybrids and varieties.

The recent U. S. experience with the T strain of Helminthosporium maydis is an excellent example of what could happen with other diseases. The T strain was not new, as it had been reported in 1961 in the Philippines. If a truly international program had been operational at that time, the danger of this disease could have been recognized and steps taken to remove the vulnerability of the uniform Texas male sterile cytoplasm.

I would also call attention to corn stunt, streak virus and the downy mildew complex. These diseases are not of economic importance to the United States, but they are very important in some parts of the world. Some of the mildew species and corn stunt are found in the southern states. Streak virus, in Africa, is serious within climatic conditions that exist in the United States. What is to stop these diseases from becoming of wide-spread importance in North America? Is there resistance in the United States germplasm? Is resistance available outside the United States?

This leads me to the concern for long-term stability in yield, and broad or horizontal resistance to the hazards of maize production. The world gene pool offers great possibilities not presently being used in the United States. It is not being used, presumably, because of the difficulty of moving non-adapted material directly into the United States Corn Belt. Systems of cooperation have not been worked out for integrating new germplasm into the genetic backgrounds of the United States breeding programs. We consider that present materials being grown here are based on a very narrow range of germplasm.

Over the last several years, breeding studies have shown that a three percent year gain in yield can be made in the United States traditional open-pollinated material. This has been compared with progress that is made through the conventional hybrid breeding programs. Gains made in these studies were related to the genetic variability in the populations and the selection pressure applied. How much faster, and how much greater progress could be made in populations with more genetic variability and a greater breadth of adaptation?

I think this is an unknown, and perhaps the populations are not now available. However, they are being developed in the international programs. These materials could benefit the United States maize program in the broad sense. Some materials now are grown in a few locations, but the effect would be much greater if a testing system was developed that would allow the incorporation of acceptable adaptation to the entire corn belt. This would provide new materials to all breeding programs.

4.1 AN ALTERNATIVE RESEARCH PROGRAM

In reference to my stated concerns for duplication of research efforts and lack of use of the world gene pool of maize, let me present a concrete program. I believe this program could be operated in the United States and be of assistance to all maize growing countries. It could also assist in the training of graduate students interested in applied maize research.

If the United States were to plan a national maize improvement program designed to provide materials and technology for all the maize growing areas of the country, I think the approach would be much different from that now used by the federal and state research system.

Several questions would need to be asked and answered before such a plan could be made. I will attempt to ask these questions and give some answers on the basis of my experience in international research. For this purpose, I shall think of the United States with a national maize research program, rather than the individual state program.

In this revised concept, it is necessary to think in terms of crop-oriented teams, rather than departmental organizations based on a discipline. Thus, a national headquarters research team would consist of breeders, agronomists, pathologists, entomologists and agricultural economists, working together with the help of a team coordinator. This is in contrast to the organization along disciplinary lines, under a separate administrative heads, that now exists.

How many national maize research headquarters would be needed? One would suffice, in my judgement. In addition, about four regional stations would be needed to provide the zonal testing network that would sample the economically feasible maize growing environments of the United States.

How would this work? An appropriate university, or United States Department of Agriculture station, representing the center of the major environments would be chosen as headquarters and four of the existing universities or United States Department of Agriculture centers would serve as the regional stations. There would be no necessity for a regional station in each state. Further it would not be necessary for every university now working with maize to engage in integrating new germplasm into the United States program.

There is a wealth of data suggesting that significant gains can be made in population improvement programs. There is also considerable data on different breeding methods for different situations, such as one, two or three generations per year. Thus, adequate knowledge is available for handling populations. What has not been stressed in the United States, even with breeding methodology studies, is a wide range of progeny testing to obtain broad adaptation. This lack has resulted from programs being conducted at the state, rather than the national level.

4.11 CIMMYT's Program

CIMMYT has a wide range of genetic materials in population improvement programs. In general, we are using various versions of a full-sib family approach and we usually grow two generations per year. These populations vary from pure tropical, to temperate, to grand mixtures of unrelated germplasm. We test the progeny regionally every cycle in as many different environments as possible. The more, the better. In Mexico we use six locations that probably represent a wider range of environmental conditions that exist within the United States maize growing areas. In the resynthesis cycle we put back into the population those progeny that have performed well at all test sites. We believe that this automatically develops wide adaptability in the populations.

It can be argued that we are accepting mediocrity because we insist on reincorporating all those progeny that are best over all locations, rather than separating out the superior location specific types. I would agree, if we were working with materials with limited genetic variability. However, since our populations have a wide range of genetic variability we feel confident that, over generations, they will become competitive across a range of environments not previously considered possible. At the same time they will continue to carry enough variability for more location specific improvements.

With this approach we are able to expose the populations to most of the known diseases, insect pests and climates, varying from the short tropical days at the equator to the relatively cold night temperatures and long days of the temperate regions; and from sea level to altitudes where cold temperature prevents maize from growing. This wide adaptability further buffers the material to the climatic variations encountered from year to year at any given location.

There are two limiting factors to our approach: (1) quantity of seed of each progeny and (2) testing sites with qualified people to conduct progeny trials. Nevertheless, we think there are enough sites to develop materials with the adaptation we need. This is a more extreme approach than would be required to develop the adaptation necessary for the entire United States Corn Belt.

5.1 CONSIDERATIONS FOR THE FUTURE

If this can be done on an international basis, United States scientists should be able to use the same system to develop populations that would be competitive irrespective of where they were grown in the country. If this were done, imagine the potential new material that could be available for hybrid breeding after a few years. It could set the stage for a whole new group of inbred lines that would feed into United States Corn production. Further, such population improvement programs might produce varieties competitive with today's hybrids and would provide a higher base from which to develop even better hybrids.

Although no United States variety is competitive with commercial hybrids, it must be recognized that 40 years of concentrated breeding efforts have been brought to bear on hybrid production. Comparatively little effort has been devoted to varietal or population development. In the international program we have recorded yields of 250 bushels of dry shelled grain per acre in the Nile Valley with materials that are non-location specific. In fact, they have not gone through a population improvement program, but are now being worked intensively to develop new and better varieties for Egypt and other countries.

In developing improved corn materials one must begin with materials that carry the necessary genes for the attributes desired, irrespective of how low the frequency of such genes are in the population. Therefore, we continue to test new materials to locate the genes necessary for adaptation to the environments of the production field. A similar approach would be necessary for the selection of new materials to be incorporated in the proposed United States program.

To make such a program most efficient, it would be necessary to rely initially on natural infections, infestations, etc., until such time as the population has a reasonably high concentration of genes for each character. Increased selection pressure could then be applied without danger of narrowing the genetic base for other characteristics.

Since family selection in early generations is probably the best way of building up gene frequency of the desired traits, it would be well to protect a portion of each progeny row, particularly against insects, to allow the family to express itself with and without infestation. After a reasonably high average degree of resistance had built up in the population, artificial infestations could be used to increase the selection pressure.

And after a reasonable degree of tolerance to diseases had been reached, a portion of a family row could be artificially innoculated for better disease evaluation.

In our experience, families with no disease or insect damage are often escapes, or involve a single major gene. Although this does not infer that immunity is impossible, the presence of a single major gene for resistance can be dangerous.

For sake of this discussion, let us assume that a location in the center of the maize belt has been selected as national headquarters. There would be a team of competent applied scientists stationed there, working together with a coordinator. They would need testing stations in the Southeast, the Southwest, the Northeast, and probably in the dryer Western side of the United States maize growing areas. That is, one headquarters and four regional stations, as previously mentioned, could meet the United States needs for developing new germplasms. The exposure of selections to diseases, drought, hot and cold weather, etc. at the regional stations would undoubtedly lead to greater stability of performance within the corn belt itself.

5.11 Integration and use of Exotic Germplasm.

There are several ways in which the United States could organize a program to greatly accelerate the integration and use of exotic germplasm.

The simplest and most efficient method would be to organize a team of eight to ten corn interdisciplinary scientists at a central location in the corn belt, with adequate land for a large program and a minimum of laboratory installations. Facilities for growing the disease cultures and rearing insects required for field innoculations or infestations would be required. The regional stations would provide land and the professional staff to lay out and manage progeny trials originating from the headquarters staff.

The program would require a budget sufficient to manage up to 400 acres of plot work per year, including a winter station in a neutral environment. By a neutral environment, I infer one in which all materials ranging from tropical to temperate will grow and set seed. Thus, any desired cross can be effected and all crossing for program development can be accomplished at this site. This allows the main season at all five stations to be devoted to progeny and varietal testing and continued integration of new sources of germplasm.

As a general statement, the environment between 15 and 20 degrees north or south latitude and altitudes of 1,500 to 3,000 feet meets the basic requirements for this neutral environment. With this system all progenies are developed in the winter season of the neutral environment and tested during the summer season, across the stations.

Another approach would be to capitalize on contracts that United States Universities have in various parts of the world. The general practice has been to move United States materials to foreign universities. Would it not be possible to organize a program so that a few United States Universities with foreign contracts could develop and test progenies in a number of overseas environments and on their home stations. If this were done, it would strengthen the program of all involved, and would provide a much better training base for both United States and foreign personnel coming from the cooperating universities.

Still another method would be to place the responsibility on each of the five stations mentioned above to select progenies, from at least two unrelated populations.

In this system, not less than 500 full sibs per population should be made. After selection at harvest, about 250 of these full-sibs should be selected and tested at each of the other stations as well as the originating station. In this way, every station would be testing 2,500 progenies every year.

As discussed above, testing should include innoculation of part of every family with prevalent diseases. It should also include protection or infestation depending on the stage of the program. This quickly becomes a large and laborious task requiring competent and experienced staff with adequate land and other facilities. However, after a few years, it would provide the United States with ten new and unrelated sources of breeding material. Of course, new lines could be pulled out of the program after only a few generations.

Simultaneously with this approach, the original population could be grown each season in isolation at its home station, letting natural selection take its course. After some years, these populations could be genetically mixed to provide new combinations.

The above system, based on only one generation a year, is very slow. This is true of any system, except location specific mass selection. One could use a type of full sib selection in the progeny tests, at the home station, whereby five or six of the best plants of a particular family are mated with one plant from each of the ajoining five or six families in the nursery. This would provide new full sibs before the actual progeny test data have been obtained.

When all field data were available, all crosses involving a family that was not selected as superior at all testing sites would be discarded.

In such a population improvement program, there are ten populations that are known to have good general combining ability. From each the best five or six families could be selected that could then be crossed with their superior counterparts in the other populations.

These combinations would be hybrids, in essence, and could go directly into performance trials at as many locations as required. Those which proved superior could go into production by using the component families in lieu of the single crosses of the normal hybrid approach. This would be classed somewhere between the variety cross hybrid and the conventional type developed from inbred lines. There should be opportunity for continuous selection and improvement in each of the two families that would result in continuous improvement of the hybrids.

To maintain a dynamic program there would have to be a continuous flow of new materials into the populations under improvement. This could best be done by growing new populations. Those that have attributes of value would be crossed to the populations being worked and gradually the desired characteristics would be integrated across the population.

In this way, the program would continue to have a range of material from unselected, through mild selection, to intensive selection within the populations providing the new material. As desirable attributes were found in any phase of the backup program, they would be fed into the breeding population.

There is no reason why a United States national program could not work with the existing international programs in a way that would be mutually beneficial. CIMMYT, for example, has a wide range of materials in population improvement programs and the progenies are being tested in environments similar to those of the United States corn belt. These could also be tested in the United States.

It would be essential that the United States organize a national program for this plan to work with a reasonable degree of efficiency.

We can work easily with a coordinated program in a country, but it would not be possible to work with all the experiment stations now working on maize in the United States.

In working with only one University, its state interests and its state problems are paramount and exchange between it and other centers, in the absence of a national program, is necessarily limited, and the result nationally is correspondingly less effective.

6.1 SUMMARY

From experience gained in international research, it is suggested that advanced nations such as the United States could greatly reduce their research costs and increase their efficiency by developing national crop-oriented, rather than state discipline-oriented, research teams.

Further, it is believed that relatively few researchers would be needed to handle a given crop, such as maize, where all seed is produced and sold by the seed industry. Much more applied research should be done. New germplasm and faster moving programs could result in more rapid advances for United States agriculture.

Advanced nations might then, if they chose, learn much from international research programs and developing nations. If the advanced nations chose to do this, they would be more closely linked to the rural needs of the country and provide more relevant educational opportunities for students from all parts of the world, including the United States.

In addition, such a program would tend to develop people more attuned to the problems of increasing agricultural production and mounting programs that will resolve problems. Such people are in great demand to staff the various assistance activities now engaged in by most advanced nations.