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CURRENT STATUS OF PLANT RESOURCES AND UTILIZATION

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INTRODUCTION

Cereal food deficits in the Developing Market Economies[1] could swell to an estimated 100 million tons by 1985, if crop production growth continues at a 2.0 per cent annual rate. For perspective, such a deficit can be compared to the total annual cereal production recently recorded for all of Latin America, North Africa, and the Middle East --an average of about 108 million tons produced during 1969-1971.

And the 100 million ton shortage can be considered conservative in light of a drop in growth rate to 1.7 per cent annually during the 1970-1974 period. Thus, production growth rate must at least double, to 4.0 per cent per year, if we are to meet the cereal food demands of 1985 and eliminate the estimated deficit.

Using the most conservative of figures, it is evident that the world will soon face a critical situation. Imaginative and effective strategies must be developed to generate a growth rate production of 4.0 per cent. Such growth might be possible under favorable conditions, but could it be maintained?

What might we expect after 1985? There is little evidence that population growth is being slowed significantly; thus we have two alternatives: the need for a higher rate of production growth for several decades to come, or the specter of increasing poverty, malnutrition and social unrest.

Now that the immensity of the population explosion is becoming more apparent, there is a growing concern that our natural resources and utilization methods may be inadequate to meet the task of increasing food production at an accelerated rate. Similarly, there is concern that our resource management techniques are inefficient and improper, with the danger that our crop germplasm has (or will) become vulnerable to wide-spread attacks by pests and diseases. With the unfavorable balance between population and food production growth, we cannot risk major crop failures anywhere in the world.

GERMPLASM DEVELOPMENT

The species of plants used for human food have been evolving many thousands of years. At first, their evolution was slow: directed solely by random mutations and natural selection. When Neolithic women began to collect and domesticate some of the species, such evolution began to move toward those plant types best meeting the needs of this evolving animal - the human.

Just as our human species is exploding in numbers, so is the development of knowledge and technology. This knowledge and technology is being applied with ever-increasing sophistication to almost all areas of human endeavour.

The evolution of crop plants has been greatly accelerated and channeled into specific directions by the application of modern techniques of plant improvement --aided by a wide array of scientific disciplines such as genetics, physiology, pathology, biochemistry. Perhaps one of our problems today is the use of over-sophisticated techniques that do not utilize the wealth of genetic diversity that is available to us. Perhaps we do not understand what kind of plants we really need.

In modern times, crop plants have been moved into a wide range of environments and geographic regions far removed from their origin. This process has helped to augment the genetic variability that we have today. Such improvement also indicates that the species are dynamic: they are not static, they are still evolving. Variability is still being generated --possibly at a greater rate than ever before, because of the adaptive process forced on the crop species by modern plant breeders and agriculturalists.

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[1] Meeting Food Needs in the Developing World: The Location and Magnitude of the Task in the Next Decade; International Food Policy Research Institute, Research Report No. 1, Feb. 1976.

THE CURRENT STATUS OF PLANT RESOURCES AND UTILIZATION

If the Developing Market Economies are to achieve a 4 per cent growth rate in production, the growth must be based on high-potential plant resources. These resources must be managed --at the research level, at the production level, and in a political, social and economic environment; so that we achieve maximum expression of the plant potential that is available, while striving for greater potential. Achieving this potential will require the most imaginative use of the world's extensive store of genetic variability.

For most crop species there are reasonably comprehensive collections of the world's germplasm distributed in many different countries. However, the conditions of storage, documentation, evaluation and utilization vary widely.

In recent years, more systematic approachs have been developed to collect and preserve plant germplasm, with special emphasis on crop species in areas threatened by modern development. FAO has a leading role in coordinating this international effort, and more recently the International Board for Plant Genetic Resources has been formed to focus priorities and to collect and channel funds into the priority areas. It is important that these germplasm collections be made and maintained for the future use of mankind --it is even more important however, that the collections should be used effectively. Much is said and written about the concern for genetic vulnerability and the need for further collections and preservation of germplasm. There is often confusion, however, because the concern for genetic vulnerability stems from the crop breeding techniques, rather than from any real danger of exhaustion of germplasm variability.

Plant breeders (in general) are not looking ahead and bringing a wide array of existing germplasm into their breeding systems. Rather, they are continually reselecting in a relatively narrow gene pool, a process that further restricts the genetic variability in use. In such location or country-specific situations, there is a real danger of limiting genetic variability and increasing the vulnerability of particular crop species to attack by pests, disease, and other production hazards.

Unfortunately, many of the narrowly based breeding programs are conducted in the more developed nations where the highest yields are obtained. Because of these high yields, it is often assumed that material from these programs represent the best germplasm available. There is no question that these are the highest yielding narrow gene pools for those specific areas; however, it does not necessarily follow that this is the best germplasm for less developed countries; or even for the security and future development of agriculture in the more developed world. In fact, it seems urgent that the more developed nations begin to look for more rapid ways of developing and increasing usable genetic variability to merge into these breeding programs.

RELUCTANCE TO USE NEW GERMPLASM

In spite of the above situation, breeders are reluctant to bring new germplasm into the system. Instead,their approach to reducing genetic vulnerability is to collect and preserve materials developed by nature and man over the years; with the hope that such germplasm contains individual genes to solve any problem that might arise. Also, they hope that they will be able to pull out such wonder genes and use them to remedy the problem, as simply as they might take a tablet from a medicine chest. It is time for the breeders to forget such wishful thinking and face the realities.

Are such breeders being realistic in developing highly specialized and narrow gene pools, or are they taking an easy, unimaginative way out --hoping that the predictable dangers will never occur? We are all aware of examples of wide-spread failure to crop varieties with a narrow gene base --failure due to the appearance of a new race of a disease; a heavy build up of the inoculum of a disease; or environmental conditions which favor the spread of a disease or pest. Yet a close look at the breeding programs around the world suggests that the breeders would prefer to put out the fires that might start, rather than develop relatively fire-proof breeding programs and varieties.

It is not realistic to assume that a breeder can go to his germplasm bank and immediately pull out "fire extinguisher" genes. Although the germplasm banks undoubtedly abound with useful genes, they often occur in very low frequency, and important characters are often conditioned by a large number of additive genes. A lengthy and often complex procedure involving different environments is necessary to identify and select the required genes and incorporate them into the cultivar --to provide a buffering mechanism and background so that the cultivar can withstand a range of unforseen and unfavorable conditions.

The concept of germplasm preservation is based on collecting and storing samples of economically important species of historic origin. Usually such materials have evolved and become established as land races in localized areas. When any of these materials are cross-pollinated with location-specific modern varieties, or even if two modern varieties from different environments are crossed, there will be a dilution of the desirable characteristics of the modern variety in its adapted environment.

Overcoming this diluting effect requires years of time and patience, which is the main reason the average plant breeder prefers to work in a narrow advanced gene pool with an occasional injection of a gene or two for resistance if the need arises. And because of this common approach by breeders, most germplasm collections are being poorly evaluated and utilized.

The ease with which favorable genes can be identified in a collection is dependent upon the genetic reproductive system of the species. For example, it is generally easier to identify gene effects in a self-pollinated than in a cross-pollinated crop. Any collection of a self-pollinated crop will have relatively homozygous plants, and may or may not be heterogeneous. Hopefully, such collections will have sufficient variability to allow the scientist to more easily select types of interest to him. This is often not the case in cross-pollinated crops,where each plant is genetically different. Many of the characteristics are multigenic in nature, and occur in a heterozygous condition where the favorable recessive genes are masked.

Undoubtedly, there are more favorable genes in most collections than we are able to identify, especially when the sample is grown at only one location. However, if collections could be tested in several very different environments, more favorable genes would be identified. Then, by the use of appropriate pollination techniques at each site, the process of accumulating those genes could begin. Intercrossing the resulting progeny from each site would allow a further accumulation of favorable genes. Such an approach is essential, in that many characters are controlled by a multigenetic system and different environments --thus allowing more of the gene complex to express itself.

Most users of the maize germplam bank at CIMMYT are the scientists interested in academic and fundamental studies. Other scientists want to screen the collection for disease and insect resistance,or some other trait. Although the collection probably carries genes for resistance to diseases and insects, it is unlikely they will be found by a simple screening of a cross-pollinated crop such as maize. The concern for locating the genes is genuine; however the approach used often offers little hope of success, because the gene frequency is so low that resistance will not be expressed.

Germplasm collections of all species promise many benefits to modern agriculture, but it is essential that breeders and other plant scientists understand the need to set up programs to effectively utilize the stored variability. Because of the complexity of the breeding programs and the range of environments necessary to conduct a wide range of selection for different adaptive and agronomic characteristics, the programs should be organized to provide broadly based genetic material of value to many nations. This approach contrasts with the use of a germplasm bank as the source of single genes, which supposedly will provide magic answers.

It will not be the collections per se, but the accumulations of the desirable genes from the collections,that will make an important contribution to world food supplies.

STRATEGY FOR EFFECTIVE USE OF GERMPLASM RESOURCES

During the process of evolution, a crop genus becomes adapted to a wide range of specific environments --some lines adapting to high cool mountains, other lines to lowland tropics or the edges of deserts, etc. However, few, if any, of these individual lines will grow successfully in a wide range of different environments. Yet, through a gradual process of domestication and adaptation, a majority of crop plants are being grown today within environments and geographic regions very different from their original areas of adaptation.

With the modern techniques of genetic engineering now available to plant breeders, the vast resources of germplasm could be utilized for the development of broad-based pools as a source material for production of suitable cultivars for various agro-climatic conditions. But how is this to be done --particularly for the developing countries with limited resources and limited trained personnel? The developing countries are in urgent need of broadly-based, high yielding cultivars that can resist the attack of diseases and pests, as well as vagaries of weather. How then can the germplasm collection be used effectively?

Two reasons are usually cited for the broad scale use of germplasm collections: (1) to widen the genetic variability and improve the species in the environments where it has become adapted over the years, and, (2) to move it into an environment where the species has previously not been able to grow and produce. Increasing evidence suggests that, if there is moisture and solar energy, the breeder can adapt any species to any environment --given time and access to a wide range of genetic variability. It can be assumed that such a widely adapted cultivar would also have the capacity for at least average production, even if the environmental conditions in a growing season were somewhat unfavorable.

If germplasm from the U.S. Cornbelt is taken to the tropics, it will be defoliated by tropical diseases. If germplasm from the tropics is taken to the Cornbelt, most of it will continue to grow vegetatively until it is killed by frost and will seldom produce any grain. This example illustrates the problem involved in the utilization of germplasm collections that have large numbers of entries collected from many environments. Although these types that are adapted to totally different environments cannot be transposed, they each have useful genes to contribute to the other. For example, although tropical maize accumulates carbohydrates as rapidly as those in the Cornbelt, they have a much lower harvest index. This suggests that there are desirable genes in the Cornbelt maize that could significantly increase the grain yield of tropical maize. North American maize on the other hand could benefit from the inclusion of a different source of European corn borer resistance that has been identified in tropical maize.

CIMMYT MAIZE IMPROVEMENT METHOD

The maize crop can be used to illustrate a method for utilizing the genes that germplasm collections have to offer. The method examined here is that used by CIMMYT for the production and continuous improvement of maize populations for developing countries. It can be used for the development of "elite" varieties by the cooperating national programs involved in wide-scale testing.

If a breeder goes to a "neutral" environment; that is, an environment that is mild enough to allow collections from any part of the world to flower and set seed, then all the types can be intercrossed. The resulting progeny may be allowed to further intercross for several generations in the neutral environment to break up linkages; or they may be selected in a series of distinctly different environments, and the superior selections brought back to the neutral environment for further intercrossing.

By these processes, the favored genes for each of these different evironments are soon accumulated to provide a population that will grow satisfactorily in any of the environments.

A superior widely-adapted population of this type provides a vehicle for moving new genes into the breeding system almost anywhere in the world. Possibly of more importance, if this process is executed effectively, it is possible to develop breeding material that is superior to any of the individually adapted populations that have been worked and reworked for many years in the same environments.

This does not argue necessarily that the new, widely-adapted populations are able to outyield the released varieties. It does argue that the breeder will have a completely new set of genes to incorporate and up-grade his breeding populations for yield improvement and other characteristics --and that this improvement, in the long run, will be far superior to that obtained by continuing to rework his existing breeding populations.

SIMILAR PROGRAMS FEASIBLE IN THE U.S. AND EUROPE

It is suggested that countries of the major maize growing regions in the developed world, such as North America and Europe, would benefit from a similar regional cooperative program to provide superior populations adapted to their regions. These could be used by national breeders to introduce much needed desirable genetic variability. Using this technique, each breeder would not have to introduce large volumes of exotic germplasm that would disrupt his program.

The authors believe that the current status of plant genetic resources to meet world food needs is far more advanced than is the recognition of the need to develop a system to effectively use the available genetic diversity.

Fortunately, for the three major cereals--wheat, rice and maize--international breeding programs are developing widely adapted, genetically broad-based populations and lines so that these resources are available to the world. Even with these crops there is a significant amount of genetic variability yet to be evaluated and made available to the world's plant breeders.

Other crop species have not advanced so far in this concept; but as the other international programs move ahead, this kind of diversity in agronomically acceptable forms will become available to increase the growth rate in production.

THE FUTURE

Although the collection, evaluation and storage of valuable threatened germplasm must proceed, more breeders should contribute to, and benefit from, larger regional and international breeding programs, bringing together and concentrating desirable genes that have been collected as one mechanism for using the existing variability.

Because of the very wide range of environmental selection pressures that will be exerted on these genetically variable populations, an increasing number of small and continuous changes are likely to occur. As those materials are brought back together for recombining, the opportunities for creating new desirable germplasm will probably outweigh the chances of losing good germplasm.

Many attempts are now underway to create even more variability for use in future crop production. The first of these crops -triticale- is just starting to enter the world food system. Crosses between maize x tripsacum; maize x sorghum; barley x wheat; barley x rye, etc. have been produced, or are being attempted, not only to intermix genetic variability within genera, but between genera.

The genetic resources now exist for significantly increasing the production potential of man's crop plants, and to guard against genetic vulnerability. The job of creating and making available the necessary variability requires the cooperation of agricultural scientists world-wide --and our rate of progress will be limited only by our imagination and our willingness to cooperate in this vital and exciting venture.