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A Look Ahead into the 1980s

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This statement represents an effort to look into the 80s Our priorities and activities in the future rest directly on our experience of the past

We are aware of the vast differences in production capability of countries in different parts of the world We are particularly concerned about some countries of Africa and Latin America where the rate of increase in population is exeeding that of production We are aware that some of these differences are due to environmental factors that we cannot control or are very expensive to control We are also aware that there are many factors that we can influence, and it is those factors in which we are most interested An effort is made here to identify priority considerations and to comment on how we can approach them

Objective

Our basic objective is to generate a positive change This may mean a shift from traditional to technical agriculture involving credit and other goods and services It may mean the generation of new hybrids in a competitive marketing situation where export interests are of concern As research scientists from a range of backgrounds, there are many common features in our priorities Nevertheless there are some differences We need to seek ways of working together to maximize our return on the total investment in sorghum improvement and production An end result is to provide a better living for the people that make their livelihood from agriculture

Research Organization

Sorghum is an important food grain in the semi-arid tropics Generally, the stover (stubble) is used for construction, feed, and fuel Growing conditions in much of this part of the world are harsh, the farmers frequently poor, and the supply of goods and services are inadequate or almost absent We recognize that in such conditions to attempt to maximize production with limited resources, the need is great for stability of production including resistance for important yield limiting factors We are impressed that a solution to these problems involves input from a team of scientists It is difficult to visualize an expatriate team in every country where there is need

At ICRISAT we have identified an approach to respond to our mandate—implementation will be an objective in the 80s We have divided the world into what we call geographic functional regions Environmentally, these regions, are not homogeneous In fact they contain different zones of adaptation and there are specific problems that may or may not be of concern across different adaptation zones (Fig 1) Regions have been identified in such a way that there is geographic, social, and crop continuity and they are of such a size that coordination is expected to be effective Geographic functional regions are identified in Table 1

A number of national and international agencies are involved with programs in these regions There are situations where an agency provides support both on a bilateral and regional basis Coordination across input by different agencies, if attempted, is generally undertaken by a national agency—less often is there regional coordination There is a need to improve interaction and today several agencies are concerned that a coordination activity on a regional basis is feasible and desirable

There is a rising interest among universities and research agencies in research and training relevant to the developing world This involves research and training within the university or

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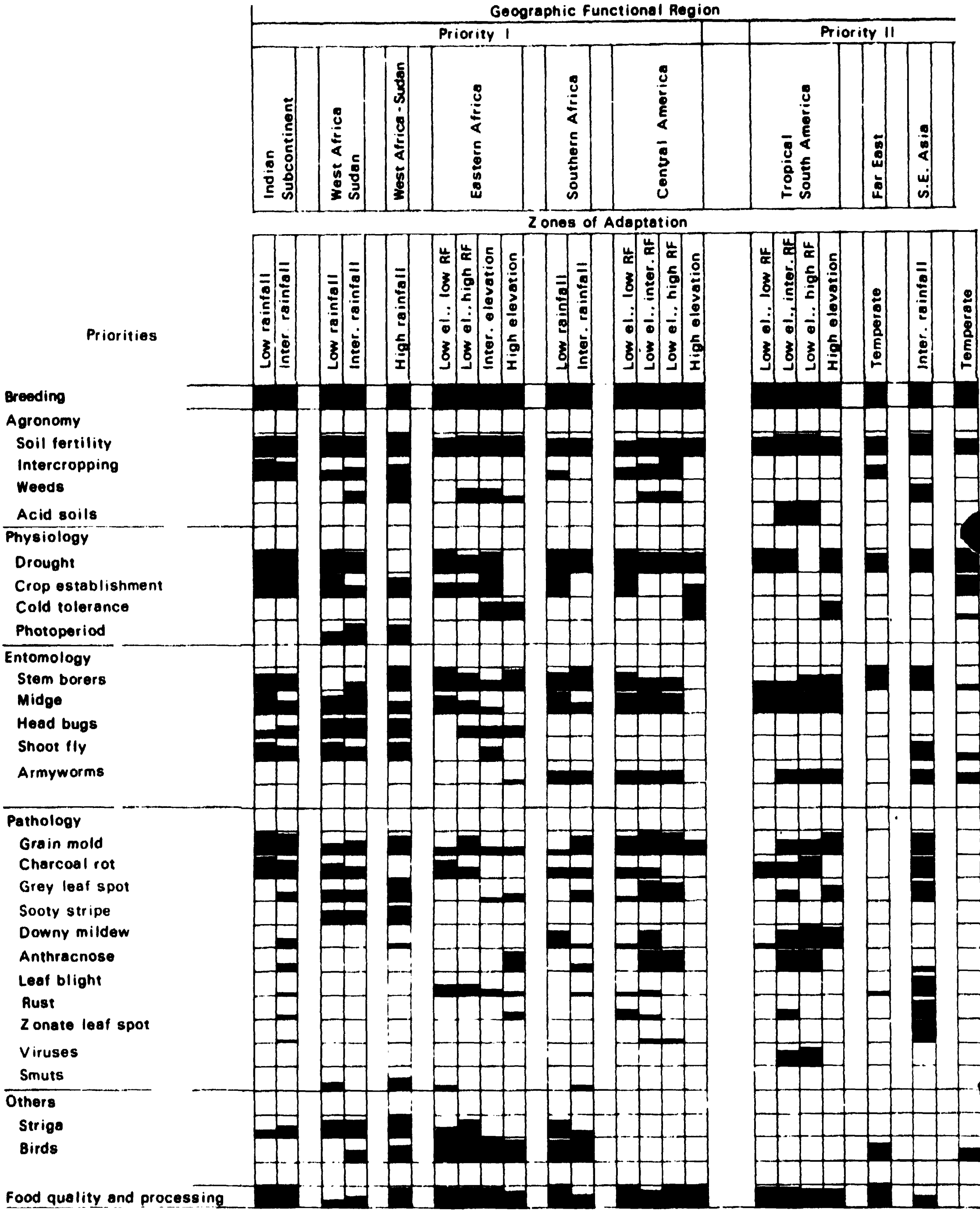

Figure 1. Distribution of priorities for sorghum improvement by geographic functional region and zone of adaptation.

Table 1. Geographic functional regions for sorghum improvement.

1.	Indian Sub-continent
2.	West Africa—low-intermediate rainfall
3.	West Africa—high rainfall, long season
4.	East Africa—Yemens
5.	Southern Africa
6.	Central America
7.	Tropical South America
8.	Far East
9.	South-east Asia
10.	Mediterranean—USSR
11.	Oceania
12.	Temperate Americas

agency or cooperative research with an institution in another country. INTSORMIL, a program of USAID, in the USA consists of a group of universities participating in and receiving grant funds for research both in U.S universities and overseas. Institutions such as the Commonwealth Overseas Pest Research organization, the Max Planck Research Institute, and others conduct research with international objectives and inputs.

Particularly in West Africa there are several regional agencies interested in sorghum. With SAFGRAD, CILSS, Institute du Sahel, and ICRISAT, cooperative working mechanisms have been developed and are being further developed.

It is apparent that we have a research need requiring a team approach. The team should operate regionally, largely if not completely, within the national program structure and there should be a substantial component in training. This mechanism provides expertise in the array of disciplines required—and the composition of the team can change with developments. It is economic in keeping numbers of specialists low, and is structured to strengthen national program capability as a function of the regional program. The better we can organize our input into research and development, the faster will be the rate of progress and achievement.

Support from funding agencies may be essential for national and regional activities. The regional program needs identification and can be associated with agencies such as ICRISAT, INTSORMIL, FAO, and others. The regional base provides a vehicle for other inputs, such as coordinating regional trials in Africa by SAFGRAD. Cooperation with institutions primarily in the developed world is essential to the solution of relevant more fundamental aspects of the problem. Important to all of this activity is the strengthening and ultimate independence of local research organization. I am reflecting, to a considerable degree, concepts being developed at ICRISAT. This is a way much of the input has to be developed. At ICRISAT we are seeking to respond to our mandate—we realize that this will be an important aspect of our activities in the 80s. Within ICRISAT, we visualize considerable independence of regional activity. There are situations where it may be desirable for ICRISAT to base a regional program and situations where others should do this and ICRISAT cooperates.

The Technical Input

A list of traits of priority concern for research for different geographic functional regions is presented in Figure 1. This array of traits has been developed at ICRISAT for our 10 year projection based on contacts with numerous sorghum workers over the world. This is not a static array of priorities but we have gained confidence that at this time, it is reasonably accurate. The relationship between environment (zones of adaptation) and traits of priority concern, are associated in this future.

It is apparent that there are differences that will require a somewhat tailored response. Midge is almost a universal problem, sooty stripe is widespread but of priority concern in West Africa. Birds are a nuisance in many areas but a major limiting factor to production in Eastern and Southern Africa. Weeds are a greater problem in wet as compared with dry areas. Anthracnose is important in the high elevations of Ethiopia where *Striga* is not serious, but in lower elevations the reverse is true. Anthracnose is serious in northern India but not in the central nor southern parts of the country. Shoot fly can frequently be avoided by early sowing; in India shoot fly is a more severe problem in the postmonsoon season than in the monsoon season. These are examples; many more cases could be identified.

When one realizes that the farmer requires a stable crop combining many traits, and that a solution to such problems as indicated above is important to this stability, one appreciates a complexity that is staggering. It is not much help to have varieties resistant to grain mold if yield is lost to midge. Input into many of these problems has taken place—certainly, there is much that can be done to improve the situation. The problem can be approached by looking at aspects of it—the development of agronomically elite types, the development of sources of resistance and quality traits, and combining the two.

The Development of Agronomic Eliteness

Germplasm

The world collection of sorghum now has some 22 000 entries. This is a valuable source of new genes contributing to improved varieties and hybrids. Probably, most sorghum breeders in the world are making use of zera zera types originating in central Sudan and the Gambella area of Ethiopia. Interesting results are beginning to appear in segregates from crosses between cultivated and wild types. Breeders have made collections of sorghum dating back many years. This will continue for many more years and on a more professional basis through the IBPGR, the activities of the Genetic Resources Unit at ICRISAT, the seed repository of the USDA at Fort Collins and others.

Utilization of the collection has been direct, by intergression, and by conversion. It has been an important source of genetic variability and will continue to be so. It is important that we develop the necessary mechanisms and facilities for proper maintenance, evaluation, and utilization. A stronger regional capability would contribute much to making these functions more effective. Germplasm centers have developed, for example at Addis Ababa in Ethiopia and Izmer in Turkey; there is a concern for a center in West Africa. These and additional storage facilities are important. We need to decide where we need major repositories and where we need to house working collection. As yet, we have not identified a systematic way to increase and describe germplasm in areas of adaptation, preferably near to whe: ; accessions were collected. The concern to preserve germplasm has gained momentum—we must now increase our concern on its maintenance and evaluation. Free exchange of germplasm is essential to crop improvement and to the speed of crop improvement. It is important that we encourage attitudes of free exchange among all who are interested.

Breeding is central to the development of superior varieties and hybrids. The concern is very much for yield and stability of yield. The full array of breeding techniques is used—pedigree, backcrossing, and population improvement. All have contributed—all will continue to contribute.

The identification of varieties that will substantially outyield locals in environmentally harsh conditions with low input remains questionable. The value of heterosis, by hybrids or synthetics is important to this question and certainly provides one of the strongest mechanisms that we have to respond to this situation. The need to diversify the germplasm base of our A. lines to develop hybrids adapted to an array of environments is an important consideration for the 80s. I believe that we need to move cautiously ahead with hybrids recognizing the input into a seed industry that will be required—this becomes part of the strategy and is expected to be of increasing concern in t' coming decade. There is concern about gene... vulnerability, i.e., sudden occurrence of susceptibility to a pest associated with the cytoplasmic genetic male-sterility system in the seed parent of hybrids. There is also interest in the use of apomixis enabling the vegetative propagation of hybrids through seed. We are interested in other possibilities such as the farmer use of synthetics carrying one or both ms_3 and ms_7 male-sterility factors; as with hybrid seed production this may raise increased concern because of the increased susceptibility of male-sterile plants to ergot.

Superior varieties that will compete successfully with good locals are more likely in environmentally favorable situations. Increase in yield in many instances will no doubt be of sufficient magnitude to attract investment into fertilizer, water, and other inputs. Heterosis will contribute in these areas also, and increasingly varieties may be used primarily when there is a shortfall of hybrid seed. This represents a transition period through which many countries have passed, some are in the process, some will and some will not, in the 80s. The pace should be such that the system required to provide adequate quantities of good quality seed on a timely basis can be developed. It is clear that varietal improvement is a necessity of itself and to a hybrid program so the two are compatible.

The most relevant approach to increasing production will vary with the situation. If hybrids prove useful in high elevation areas, seed parents adapted to those conditions will need to be developed. Experience has indicated the need for a 40 or 50% increase in yield, from variety or hybrid and from management to initiate change away from traditional agriculture. The approach in areas of lower moisture stress will likely lead the way as yield changes justifying a greater expenditure on inputs is possible. Special techniques, such as ways to conserve moisture, may be inexpensive and feasible in dry areas, and along with good varieties and hybrids begin to start a change that hopefully would increase in rate with time. Obviously, different environmental situations will require a different approach to maximize production. It is important that relevant factors are identified.

Population breeding has attracted a lot of attention. Progress with population breeding at ICRISAT has been rewarding in terms of useful derivatives that are now contributing in many places in the world. We may be approaching a situation where the general usefulness is being restricted by lack of broad enough multilocation testing. A resolution of how to manage populations as we respond to an international mandate is an issue immediately before us. The usefulness of populations for the simultaneous incorporation of several traits is widely recognized and will no doubt be increasingly employed. Sorghum is an important component of intercropping systems and has been used traditionally as a means of stabilizing food availability. It can also be employed in different situations to select types that "fit" better the relationship between crops and also to provide a means to better utilize a growing season. Ganga Prasada Rao is interested in exploring the use of shorter duration sorghums with a better harvest index as part of a cropping system in the longer rainy season as found in Nigeria. The cropping systems approach is a valuable approach and new varieties and techniques will continue to provide new opportunities in the years to come.

The method to identify stability is by multilocation evaluation. Such testing serves both the purpose of evaluation and the distribution of elite varieties and hybrids. There is concern that numbers of entries are balanced with the burden that such tests place on local research station capability. It is possible to so burden a local research facility, that little opportunity is left for local imagination and input. There is need for international cooperation so that contributions from anyone can first be evaluated as a function of regional centers so that only the most contributing material enters national programs. This, of course, will vary in different parts of the world. Coordination on a regional basis is obviously relevant and its further development is of continuing concern.

Experience has shown that some local varieties fail to respond economically to inputs whereas others are more responsive and also combine well with exotics providing useful selections in the F_2 and advanced generations. Evaluation of locals for broad adaptation and responsiveness to inputs is potentially rewarding both in terms of direct use with improved management, and as parents in crossing programs. Selected locals would be prime candidates for conversion for use in temperate zone sorghum improvement programs. At present, there appears to be promise following careful evaluation of locals in Mali. Experience over the last 20 years in India has established that valuable varieties and hybrids, with substantial yield increases over locals, can come from introduced material. The use of responsive broadly adapted local cultivars and good introductions, frequently involving progeny from crosses between the two, appears to be rewarding. There is concern that varieties and hybrids do respond in low fertility situations. Experience indicates that varieties that yield well under high levels of fertility do best also under low levels. Suitable testing is required to understand performance of new cultivars across an array of fertility levels. It is clear that we will see an increased input into nitrogen fixation in the decade ahead.

Breeding for Resistance and Quality Traits

The speed with which resistance and quality traits can be incorporated into elite material depends on our capability to screen and on the complexity of inheritance. The need for an agency such as ICRISAT is to develop relatively simple tests that can be readily applied to large numbers of samples. Techniques need to be developed that can be applied in the areas where a problem is important. A detailed screening procedure to screen for resistance to shoot fly has been developed at ICRISAT but is likely to be too expensive for scientists in national programs to use. Such procedures can be used to identify the source and to develop stronger levels of resistance in varieties with good agronomic traits; however, it will be difficult to introduce the trait into varietal materials adapted to environments different from the one at ICRISAT. The technique is then not useful to finally incorporate the trait into breeding stocks that must be selected for adaptation in the area for which the varietal material is destined. We find, however, that we can develop useful simple procedures and this is a major undertaking for us in the future. We are also aware of the need for scientists in a region who can develop and adapt techniques and manage screening programs.

Once sources of resistance are identified there is concern about their stability across environments. Multilocation testing on an international basis is important to this function. Experience indicates that generally, in the absence of a qualified scientist, useful results are not recovered. Again the need for specialists working as a team is apparent—and as mentioned before, this function of evaluation and screening need to be undertaken incorporating a strong training component in order to stabilize these acivities within the local structure. We should be able to make substantial inputs in this area in the 80s.

We have been interested in looking into the opportunity to find components of quantitatively inherited traits that can be simply screened for and at times are simply inherited. The problem of stand establishment is being examined from several points of view—hypocotyl length to permit deep sowing which would delay germination until the soil moisture situation was more adequate; germination through a crust; and the effect of soil temperature on emergence. The glossy and trichome traits are simply inherited and are contributing to resistance to shoot fly. The group at the Commonwealth Overseas Pest Research organization is looking in detail into the *Chilo* stem borer-plant relationship helping to identify particular traits that may be more readily selected for than stem borer resistance per se. A search for traits useful for screening germplasm for resistance and quality traits is not new; a more intensive search in the coming years is likely. These research activities offer an excellent opportunity for cooperation with institutions in the developed world.

There is concern about the simultaneous incorporation of resistance for several traits into agronomically elite germplasm. We are aware that as the number of traits increases the gain per generation of selection for any particular trait is reduced and it is questionable that more than three traits can be efficiently selected for at the same time. There are indications that this is true for the population breeding approach also. More thought and experience would be worthwhile in this area. We are looking for varieties that already show promising levels of resistance to more than one trait. We feel that varieties can be blocked into maturity groups, be tan in plant color, and with visually good quality seed. On this as a common base we can couple other factors for incorporation. This coupling can be based on traits that tend to appear together; for example, drought resistance, resistance to charcoal rot, and resistance to *Striga*. Factors can be coupled based on a response need in certain environments, for example, early maturity, resistance to grain mold and to midge. There is no need to incorporate resistance to shoot fly and *Striga* into materials for the Americas or greenbug resistance into materials for Africa or Asia. We are also interested in heritabilities of different traits and how these m influence breeding procedures. For simply inherited traits, simply backcrossing into elite stocks may be the easiest and fastest without worrying about more than one trait. As we attempt to work more internationally, and our capability to screen for various traits improves, we will be more and more involved with these considerations.

Cooperation in screening can be improved and we need to seek ways of doing it. Midge is constantly severe at Sierra Talhada in north east Brazil; *Busseola fusca* is severe at Samaru in northern Nigeria. "Hot spots" can be identified for many traits of economic importance. If we could give thought to the development of a network where national or regional programs in an area could provide an international opportunity for screening it would enable us to evaluate our best material effectively and competitively and should help us mobilize useful germplasm more rapidly than at present.

We have been relatively successful in India identifying locations and seasons where we realize a different severity of attack for both insects and diseases. Where relevant, this will permit screening at lower levels of severity in early generations and at higher levels on later generations. We feel at ICRISAT that the first several years of the 80s will be devoted to development and perfection of techniques for screening and that more extensive application will follow. Again this is not new, but we must further resolve this opportunity particularly in Asia and Africa.

One of the difficulties faced while screening is to prevent another problem from interfering with the trait being measured. Stem borer can nullify a charcoal rot screen, head bugs can interfere with the screening of midge. It is necessary that all concerned clearly differentiate farming from the growing and managing of experimental crops.

Pest management is a relatively recent term, probably not fully understood by many. Pest management for midge and birds would apply immediately as farmers begin to use earlier maturing varieties and hybrids in areas where longer season traditional types are commonly grown. Midge was a problem in India building up on CSH-1 and severely damaging later maturing locals; there are indications that the same will happen in Africa. Block planting of a variety or hybrid of the same maturity at the same time has been beneficial in several places in the world, including India, and holds promise for other areas as well. A better understanding of pest management is required as well as an adjustment of our own attitudes about how or with what precautions we want to introduce new material into the farming community.

Predators can be valuable—the lady bird beetle will control aphids on sorghum in India, and a small shiny black Cocinellid beetle will contribute to the control of mites. A better understanding of this and of ways of using insecticides so as not to reduce the beneficial effects of predators is an important consideration.

Food Quality and Technology

The quality that people like in their food is conditioned from childhood. There are situations where grain of different varietal types has been refused because of food quality, and examples of where poor quality types have been accepted. It is reasonable that a variety or hybrid contributing substantially to yield will be accepted even if the grain quality is not so good. On the other hand, the closer we can approach preference, the more easily and quickly a new variety or hybrid will be accepted both because of taste and because of market value.

Major foods from sorghum can be classified as leavened and unleavened bread made from fermented or nonfermented dough; thick and thin gels or porridges; rice like preparations and beer. Grain hardness has been found to be an important criteria for different preparations assuming there is no bitter taste and that the color is acceptable. It is possible to develop relatively simple procedures to evaluate these preparations. Reproduceability and a capability to identify good from not good, are basic. It is clear that visually attractive grain may not make a good food and that grain from some varieties is good across a number of preparations; CSH-5 is in this category. Input into food quality considerations has expanded in the last few years and is destined to be an important aspect of crop improvement in the future. International evaluation involving traditional food preparations, milling, industrial food preparation, and determination of physicochemical parameters has already begun, representing a coordinated input to evaluate selected grain types. This is certainly an example situation that should be encouraged in other areas also.

In many traditional societies grain is pearled by pounding. This is generally done by women using a heavy wood pedestal with grain in a wooden-mortar. It is a laborious time consuming job frequently not continued in urban situations. During the 70s, steps have been taken, notably by the IDRC, to develop simple effective pearling machines and they have reached pilot operation in several places. Dr. Perten, working in the food technology laboratory in Khartoum has contributed to processing sorghum to be sold in stores in sealed bags. We have not yet evaluated varietal variation enabling one to make foods normally from pounded (pearled) grain, but without pounding. I have been impressed that if a solution could be found to this problem we would reduce a daily burden of many women. Sorghum flour has long been blended with that of wheat and maize—this is still a topic of research that will continue into the 80s.

We were encouraged by the genes contributing to high lysine found in two accessions from Ethiopia (IS 11758 and IS 11157) and from mutation studies at Purdue (P 721). Problems have developed in their use that conjure up the complexity of problems encountered with opaque-2 maize. There is some division of opinion about the effort that should be placed on nutritional traits but there is a universal consensus that yield and yield stability is a higher priority than work on nutrition. Considerably more has been learned about tannin, but many food grains are low in these compounds and where they are not, the grain is generally made into beer or treated with wood ash that reduces or eliminates undesirable nutritional aspects. This has been of concern in relation to bird resistant sorghums and a research input in places where *Quelea* is a problem may deserve consideration.

We have been concerned about results reported from feeding children in Peru where sorghum has been found poor in terms of nitrogen and energy retention. This is a flag that should stimulate more research—particularly the effect of food preparation on these retention aspects. Work along this line is already under way at Purdue University and is apt to expand in the decade ahead. Interest will be in terms of selection criteria (Purdue has developed a test) and in terms of trying to extend different preparation procedures that enhance nitrogen and energy retention. This could be a more rewarding effort for the 80s in the area of nutrition than a concern for lysine.

Conditions of Research

I have long been concerned that a great effort is made on an international basis to educate scientists, and very little if any thought is given to the conditions of research in which these scientists work. The opportunity for many scientists to effectively utilize their education is all too frequently lost because conditions of research are poor. Frequently, experiment station development and operation is poorly understood and the so-called farm superintendent has no stature with the scientific community. In many countries, I suspect that 50% or more of the useful results that could come from field research are lost because of poor station development and management. This is costly in terms of time and money.

This is not a particularly attractive area for donors who frequently want easily identifiable results to justify expenditure. Yet, as we enter this decade a much greater input is required in this area if our progress is to be as rapid as it can be. Increased levels of education and training would help and International Institutes should look more seriously at this. Education is required for those who will actually manage an experiment station as well as for administrators who need to better understand experiment station personnel requirements. Universities could help by insuring that their students from other lands are adequately exposed to their own experiment station management operations. This is an important need for the 80s.

The Community of Goods and Services

The concern that we have is to increase and to sustain an increased production of food with sorghum being important among the food grains. The objective in some places is to shift traditional agriculture to a more technical agriculture, and where the agriculture is already highly technical, to increase production even more than it is now.

A look at locations with a highly technical agriculture indicates the kinds of goods and services required. These include a range of inputs: rural credit in support of short term production goals and for long term investm[ent] —wells, equipment, etc; increased availability [of] fertilizer and other chemical inputs; established markets and facilities for postharvest management of the grain; an established seed industry with quality control; an effective extension agency; government awareness of needed changes and the establishment of policies that encourage and support new technology; availability of improved farming equipment and the services required to keep it running; and ultimately food processing and marketing systems to supply packaged food of known quality. This is a complex array of diverse inputs, but all are relevant. A well developed and proven technology can fail or yield only a limited reward if government policy is discouraging.

A proper seed industry requires inputs into propagation of seed by breeders, foundation seed stocks agencies, and producers of the commercial seed. Quality control requires seed laws, certifica[-]tion, and seed testing laboratories. An input in[to] processing equipment is required as well as a marketing system for the seed. This aspect of availability of quality seed is in itself a complex of diverse inputs. Significantly, many of these inputs are being considered in this symposium.

The situation that we face in the 80s is diverse—in some countries these inputs are effective and efficient; in others, they exist, but efficiency could be improved; and in others these inputs must essentially still come. There will be changes required in all of these areas if we are to move forward in the 80s.