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Developing Resources

- New Technology

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ABSTRACT

In reorientating the high input/high risk land and crop management systems some significant approaches are emerging that could make a very valuable contribution in managing the farming systems, particularly in the tropics. This provides an opportunity for greater contact and collaboration between agricultural scientists and farm managers from all parts of the world. The need is for a more rapid evolution of technologies which can not only maintain a high level of production but must also safeguard the basic values of an equitable society and a viable farming community.

1. Introduction

Although only about one half of the World's potentially arable land is presently being cultivated, the expansion of crop land plays a very small and steadily declining role in increasing food production. Its contribution averaged about 0.2% annually during the 1980's. Total world food production rose on the average 2.2% annually over the last decade since the year of the World Food Conference in 1974. During this same period world population growth had slowed down to 1.8% annually and hence world food production has made substantial progress and per capita food production increased by 0.4% annually. It is particularly significant that the less developed countries reached an annual average of 3.3% growth as compared to less than half that for the developed world. However, this favourable position was partly offset by a high population growth of 2.1% annually but still leaving a net increase per capita of 0.5% for the developing countries.

Unfortunately Africa did not share in this positive development; on the contrary its per capita food production declined steadily which of course means that other regions such as Latin America, East Asia and China achieved a higher growth figure than 0.5%.

Most if not all of the increase in production was the result of the application of existing or new technologies and better knowledge of the biological and physical environment under which these technologies were applied by the farmer.

2. The changing perception for high-level technology

Before the biological, chemical and physical sciences triggered the technological revolution in the USA sometime in the early fifties, good deep soils and good rainfall with high solar radiation in the growing season were considered the key factors for successful farming. It was a general belief that the good and successful farmers were all found on good land and the poor farmers on poor land. This dominating role of the soil, although remaining a key asset for a successful farm operation, diminished in importance as new technologies in crop varieties and plant nutrients were developed. The soil became more and more a medium in which plants could root and grow as long as they were properly fed with plant nutrients. The best illustration is found in very advanced horticultural enterprises where plants are not rooted in soil but in sterile rock wool, completely devoid of any possible pest infestation such as nematodes and other micro-organisms which could adversely influence the plant's growth.

Nevertheless, in the general evolution of agriculture good soils remain very important and most of the easily accessible good quality soils in the world are now cultivated. For this reason intensification of land management and crop production with the introduction of

high-yielding varieties, a balanced nutrient supply and control of pests, and sometimes the integration of other enterprises and the utilization of by-products are now dominating features in an advanced agriculture both on small- as well as on large-scale farms. As the systems have become more complex, organization and management ability are the deciding factors in successful farming, rather than land resources.

No doubt we will see further advances in genetics, in the application of computer sciences and in the use of more sophisticated plant nutrient inputs and farm machinery. Yield levels of crops and performance levels of animals will further increase and so will the output per man. However, I expect this to happen at a much slower pace than in the past because of a rethinking of man's ultimate objectives and destiny. This rethinking and consequent reorientation of scientific endeavours is the result of a number of important observations, considerations and events.

(a) As the farming systems became more sophisticated and complex, with very large requirements in capital investment and recurring operating costs, the risk factor also became increasingly larger and the crucial role of management more important and demanding. This risk factor is conditioned by fluctuations in economic as well as physical circumstances. The individual farmer has very little possibility to influence or change the economic climate. The recent recession in the United States and Europe has clearly demonstrated the vulnerability of the production systems and of the financial structure of many farms. The farmer can protect himself however to some degree against the elements of nature such as the weather. In this respect we will see a further increase in the use of supplemental irrigation as a protection against dry periods and in mechanization for greater timeliness of operations. The modern farm will further move towards more capable investments and recurring costs, so much so that the already high capital investments are becoming an insurmountable obstacle for many farmers especially by transfer of ownership either within or outside the family. The traditional family farm structure tends to gradually be replaced by a corporate structure with all its consequences for a more complex management structure.

In the developing countries, a similar evolution is taking place, still on a limited scale and in a different form. In countries with a free enterprise and a capitalistic structure and with abundant land resources, industrial companies are establishing large, 10,000-20,000 acre operations based on the same technology packages as large farms in the United States and Europe. In the socialist countries, cooperatives and state farms of a size large enough to apply modern technology have been established. Under both economic systems the results have generally been disastrous either because of the unappropriateness of the technical package under the particular ecological conditions or because of the inadequacies of organization and management. These negative experiences are not helping to raise agriculture in the esteem of policy and decision makers of countries, where agriculture in the past has not been given the required priority in development strategies.

(b) Coupled with the recognition of the economic vulnerability of the high technology packages in modern agriculture is the increasing awareness of the potential dangers for disturbing the equilibrium in the

ecosystems, through the intervention and control of plant and animal life with biological, chemical and mechanical means at man's disposal.

For too long the appropriateness of technology packages has been judged almost entirely on the basis of the potential increase in productivity with very little concern for other possible side effects and consequences. Far more attention needs to be given to the stability of nature, and to the sustainability of any new introduction without constantly new high input requirements.

A dramatic example of disturbance of nature's equilibrium was the appearance of the cassava mealy bug in Africa. In the early seventies cassava material was brought into Africa from Latin America, but with the planting material came also the mealy bug, a small insect which feeds on the leaves of the plant. This insect spread at such an enormous rate that by the early eighties it had covered most of the cassava growing belt south of the Sahara where cassava is the main staple food for some 200 million people. In Latin America, the area of origin of the mealy bug, no real economic damage was experienced since the insect is controlled by its "enemies". In Africa however, these enemies did not exist and consequently it spread at such a rate that the economic loss in 1983 was estimated to be around \$2 billion.

Another example is the enormous expansion of aphids in the wheat growing areas of N. Africa. It is quite certain that this expansion over the last 10-15 years is the result of using certain insecticides for the control of pests in another major crop grown in the area. However, in the process the lady beetle, an insect which normally controls the excessive expansion of aphids, has almost been eliminated. New major expenses are now required for insecticides to control the aphids.

Still another example is the deterioration of large areas in the tropics. Because of the wrong land clearing methods and subsequent inappropriate cultivation methods, it is estimated that some 2 million ha of land are destroyed each year. It may take 10-20 years to regenerate this land, if ever.

(c) Another major influence will be the consequences of the nuclear disaster at Chernobyl in the USSR. It, more than any other event, caught the imagination of the world in illustrating the difficulties and dangers of controlling man's own inventions. After Chernobyl the perception of technology, its development and application will be given new dimensions in the minds of scientists, politicians and especially the man in the street. Is man really capable of controlling his own inventions as science and technology proceed further? This consideration will undoubtedly have a profound impact on the allocation of resources in the public, but also in the private sector.

The road ahead

In the light of what has been stated before it is quite certain that the direction of research and the development of appropriate new technologies will receive a certain reorientation in the future. Already research activities are moving towards finding ways and means for less dependency on high recurrent operating costs. This, among others, will mean less dependency on chemical and more on biological inputs.

Also research work for the creation of new high yielding varieties will have different objectives. More attention will be given to the creation of varieties which are not necessarily higher yielding but are genetically resistant to pests and diseases and have greater adaptability to the vagaries of nature especially drought resistance. This reduces inputs and risk. At the same time more emphasis will be placed on the ability of the plant to produce under lower input levels and the plants' susceptibility to accompanying beneficial effects of other organisms in the air or in the soil.

The role of rhizobia in legume plants is well-known and their ability in fixing nitrogen from the air through such crops as alfalfa and soybeans has been practiced in this country for many years. Perhaps it is appropriate to say that alfalfa in the thirties and forties was the main supplier of nitrogen in the maize-based cropping systems of the United States. Gradually this changed towards greater dependency on N-fertilizers so much so that alfalfa on many farms disappeared. Today we may wish to rethink this course of action. While chemical fertilizers will continue to play an extremely important role in agricultural production, new developments in research will emphasize the potential of fixing N or other nutrients through organisms especially generated in association with the growing of a crop without interference with that crop. The International Rice Research Institute (IRRI) - the international research centre primarily responsible for the green revolution in rice in Asia, has been intensively working in the last five years on the biological N fixation in flooded rice fields. Among the various N₂ fixing systems Azolla algae symbiosis has been extensively studied. Azolla is a tiny aquatic fern living in aquatic habitats of temperate and tropical areas. It multiplies rapidly in nitrogen deficient conditions because a bluegreen algae - Anabaena-azollae - lives in a small cavity of the azolla leaf and utilizes atmospheric N₂. IRRI has now a collection of 150 azolla species from all over the world with different potential for N₂ fixation. An objective of 100# of N₂ fixation per acre is not unrealistic. Incidentally, azolla has already been used very extensively in rice production in China for the last 25 years.

While the role of rhizobia and algae is fairly well-known in N₂ fixation, much less is known about the existence and the potential application of Mycorrhiza. At the International Institute for Tropical Agriculture, sweet potatoe clones have been developed with yield potentials of 30-40 tons per ha. without fertilizer. Such a production level cannot be explained on the basis of natural soil fertility. Some other organisms are likely involved supplying additional nutrients to the sweet potatoe plant. There is every indication that they are Mycorrhiza. It is not far-fetched to believe that in the future certain plants can be injected with Mycorrhiza which provide all or part of the plant nutrients from elements in the soils, which are normally not available as plant food.

Another application of "plantassociation" is the alley cropping system which has been developed by the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria. Under this system leguminous trees or bushes are planted in rows at a distance of about 4 meters. In between these rows the various crops are grown. The quick

growing nitrogen fixing plants are pruned at regular intervals, 4 to 5 times during a 6 months rainy season, which is often enough for the Lucaena not to interfere with the associated field crops. The clippings are put in the cultivated rows to form an organic mulch which provides soil cover, minimizing fluctuations in temperature and supplying about 40-60 kg of utilisable nitrogen (N) per ha. This system also provides a nutritional recycling system of other elements similar to that of the traditional forest and savannah fallow so that the land can now be used on a permanent basis. Alley cropped fields at IITA have produced in rotation yields of 3 tons of corn, 15 tons of cassava and 1,000 kg of cowpeas per ha. for nine years without interruption. The rows of shrubs planted on the contour and combined with minimum tillage have also proven to control soil erosion better than contour banks. This new system presently being applied on farms in some five different countries could be a major contribution to raising agricultural productivity and output per man in the humid and sub-humid tropical areas.

While in the United States soybeans in rotation with corn have always been appreciated for their nitrogen contribution, perhaps in future more emphasis needs to be given in plant breeding to develop legumes such as soybeans and alfalfa, not necessarily with higher yield potential, but with greater capacity for N₂ fixation. There are great differences among various varieties for their capacity to fix nitrogen in different soils. For instance, the American soybean varieties do not nodulate in the tropical alfisols and oxisols without inoculation. IITA has found species which nodulate very profusely and hence are well adapted to the tropical conditions producing yields of 2-2.5 tons per ha. without inoculation and nitrogen fertilization.

In plant breeding, genetic advances for higher yields will continue to be an objective but certainly more attention must be given to the plants ability to produce satisfactorily on a sustainable basis under lower input levels, and to their susceptibility for accompanying beneficial effects of organisms in the soil and in the air. Simultaneously great efforts should continue in finding plants which have horizontal resistance to various diseases and greater tolerance for insects. While insecticides and fungicides will continue to play an important crop protection role, at the same time the role of beneficial organisms and insects and the biological control of pests must receive more consideration. A number of Research Organizations around the world are now organizing biological control units as an essential part of their plant protection research work, thus contributing to an integrated pest control program. Cultural practices, chemically and biologically balanced programs needs to be the objective of our technological package in pest control.

In their efforts to develop plants with desirable characteristics, the researcher of today has undreamed of possibilities at his disposal. New genetic engineering techniques such as protoplast fusion and meristem cultured multiplication accelerate his work manifold, and therefore increases the possibility of coming up with desirable new solutions.

In the field of land management traditional cultivation methods are receiving a critical review. On many soils and particularly on sloping lands minimum tillage methods or even zero tillage may well be the most appropriate for soil conservation, soil structure and soil fertility.

On the plains of our wheat growing areas, minimum tillage has been practiced for the last 20 years but I am informed it is now also increasingly being adopted in other areas of the United States including here in Minnesota. As already mentioned under tropical conditions of high temperatures, fragile soils and heavy rain storms, minimum tillage is found to be the best cultivation method except on deep, heavy soils. These latter soils are generally very scarce. Not only is it the best soil treatment, it also reduces the high recurring operational cost of modern farming and it reduces the need for large power investments.

Of course, when the soil is not plowed or cultivated the use of herbicides becomes a greater necessity unless crops can be grown either as monocrop or in association with other crops which have the capability of smothering the weeds. For instance, one or two years of alfalfa in the rotation in this part of the world is considered a good weed control measure. So is one year of *Mucuna* in the humid and sub-humid tropics. In a long-term live mulch trial at Ibadan, Nigeria, plots where live mulch (i.e. *Psophocarpus palustris*) was grown for the past five years yielded more corn than the continuously cultivated, the no till or the plowed plots. The plots had less weed infestation and higher soil organic matter and biomass activity. This is an area of new technology which on poor shallow soils requires more investigations and certainly would fit into a low input, stable ecosystem concept.

Availability of new technology

In the United States and the other developed countries, new technology in agriculture has increased yields per ha. and productivity potential of animals over the last 40 years by about 100%. Genetic improvement, the use of appropriate fertilizers and chemical pest control materials coupled with the use of labour saving devices and farm machinery have been responsible for a manifold increase in the output per man. In the developing countries of Asia and Latin America similar, although not as dramatic changes took place primarily as a result of the green revolution triggered by the semi-dwarf varieties of rice developed by IRRI and of wheat by CIMMYT. Unfortunately the developments in these continents have not been uniform and certain areas with unfavourable, often humid or semi-humid conditions, have been entirely by-passed.

As stated in the introduction, the green revolution has so far also by-passed the African continent south of the Sahara. Some writers have sought the explanation in the non-availability of appropriate technology. I do not share that opinion. The two production oriented international research centres, IITA and the International Livestock Centre (ILCA) located in Africa, in collaboration with the national research organizations have developed large amounts of appropriate high level technology in all major crops and enterprises. You will permit me to elaborate somewhat on the situation in Africa.

I do so because of the attention Africa has been getting in the news media. The catastrophic drought in several African countries and misguided and misdirected agricultural and economic policies has been given world-wide coverage. The picture presented for the future of the continent is dismal with little room for improvement. I do not share

this opinion and therefore wish to elaborate somewhat on the reasons for my optimism. During the five years I spent as Director General of IITA, I was able to get a better understanding of the African problems, of the reasons for the many failures but also of the possibilities to radically improve the situation in African agriculture and in the economy of many African countries.

In the traditional agricultural system of bush fallow and shifting cultivation, the average African farmer of today is constrained by lack of labour and by the kind of tools and machines available so that under rainfed conditions he or she can cultivate no more than 2 ha or 5 acres of land which is entirely insufficient to provide a decent living for a family. With the increase in population the pressure on the land has grown, the length of the fallow period has gradually declined until it is too short to restore fertility, crop yields are declining and the food crisis becomes increasingly severe.

The salient features of this system are its obvious instability as the fragile soils are leached and eroded, the low productivity of labour and the low yields of crops per unit of land area.

While much remains to be done to find solutions to these seemingly untractable problems, research at the International Institute for Tropical Agriculture in cooperation with National African Research Organizations, has identified the components of appropriate new technologies which offer great hope. They consist of low input systems which minimize soil erosion, nutrient leaching and weed growth and maximize nutrient recycling, labour productivity and crop yields so as to permit a stable, permanent agriculture to replace the bush fallow and shifting cultivation.

I refer here to soil and land management systems which are suitable for small and large farms in which minimum or zero tillage and the use of mulches and crop residues greatly decrease rainfall run-off, soil erosion and soil temperature while improving the soils permeability, its fertility and its physical structure for root growth. Herbicides, in combination with dead and live mulches, control weeds and newly designed small machines decrease the drudgery of the present traditional labour input.

As labour is released from the annual task of bush clearing, more land can be cultivated and more productive work can be performed. Hence the size and the productivity of the small farm can be increased and the productivity of labour is greatly improved. With the introduction of small hand-operated or inexpensive two-wheeled tractors which are already being manufactured on a limited scale, and with the limited use of herbicides the farm family now cultivating 2 ha of land should be able to increase its holding to 5 ha which is considered to be sufficient for a viable unit.

While appropriate land and soil management practices lie at the heart of the future strategies for increased food production in Africa, they must go hand in hand with the production, efficient distribution and adoption of new crop varieties..

Such new varieties, with resistance to a number of previously destructive pests and pathogens, and with adaptation to a wide range of Africa's agro ecologies, are now becoming available for all major food crops. Let me give you some examples.

For maize, open polinated varieties resistant to lowland rust and blight and with resistance to maize streak virus, give yields of 3 to 4 tons per ha compared to the 1 to 2 tons from unimproved local varieties.

Tropical hybrid maize developed at IITA, gave yields on farms last year of 4-5 tons in the Nigerian humid forest zone and 5-6 tons in the Savannah zone. Four months ago, 4 new rice varieties were released in Nigeria with yield potential of 3 tons per ha for upland conditions and 6-7 tons for irrigated conditions.

Cassava clones resistant to the historical constraints of bacterial blight and mosaic virus diseases are now widely available in West and Central Africa with a potential of three times the tuber yield of the unimproved old varieties without the use of fertilizer.

Cowpeas or black eye peas, a major grain legume in Africa, have also made great progress. Improved varieties with resistance to all major African pathogens and with tolerance to some of the field pests are now available in a wide range of plant types. They have been widely tested on farms and are now being distributed in 28 countries in Africa.

Finally new sorghum varieties, both polinated and hybrids, are now available with double the yield potential of the local varieties.

With these examples and there are many others, I have illustrated that, contrary to the widely held view that a lack of appropriate technology is holding back agricultural development in Africa, great and exciting prospects are ready to be realized. I strongly refute the suggestion that new technologies are not available in Africa. The great task ahead is now the transfer of these technologies on African farms. Greatly increased efforts must be made to give farmers the opportunities to assess, and if they wish, to adopt the new improved varieties and farming systems.

I would like to see a major programme to involve small and large farmers in on-farm demonstrations in their local communities. This form of agricultural extension has played a significant role in agricultural development all over the world, including here in Minnesota. It need not be different in Africa.

As the African soils are fragile, the infrastructures are weak, the financial means of the small farmers are almost non-existent and government policies ineffective, the new technologies developed by research in Africa are based on meeting the necessity for stability of the environment with low risk and low input requirements for the farmer. Sustainability of the ecosystems, while making full use of nature's ability to create a stable equilibrium, is the basic characteristic of these new technologies.

Conclusion

In the reorientation of our high input, high risk, land and crop management systems, certain elements and approaches of the farming systems now emerging for the developing countries, especially in the tropics, can offer a valuable contribution. I am therefore urging for a greater contact and collaboration between agricultural scientists and farm leaders from all parts of the world. This International Farm Management Congress is already providing a good forum to discuss future trends in new technology. Perhaps it could lead to some concrete action for promoting a more rapid evolution of technologies which on the one hand will maintain a high level of production but at the same time safeguard the basic values of an equitable and sustainable farming community.