Boehringer Ingelheim

Boehringer Ingelheim International GmbH

From Dr. Julian H. Shelley

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JHS/Sgh

3rd November 1988

Professor M.S. Swaminathan FRS,
B-4/142 Safdarjang Enclave,
New Delhi 110029,
India.

Dear Professor Swaminathan,

"Social Consequences of Genetic Engineering"

I was so sorry to hear that you have been ill and I hope very much that you are now better. I am sure Sir David would join me in sending our best wishes.

Susan has retyped your paper and we have tried to match the slides to the text and have made positive copies from them for you to examine. Please let me know:

a) If the position of the slides in the text is correct.
b) If you wish to add in any further slides into your text.
b) Slide 05 gives 6 references which we will need in detail.

With best wishes.

Yours sincerely,

Julian H. Shelley

Encs.

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27 OCT 1988

ATTN: MRS HILDITCH

HOPE YOU RECEIVED REVISED OPENING STATEMENT. I AM DOWN WITH VIRAL FEVER AND SHALL SEND OTHER PORTIONS NEXT WEEK BY COURIER.

REGARDS

SWAMINATHAN
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Copy Given to
Dr Swaminathan
on 21/10/88.

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TO: INTERNATIONAL RICE RESEARCH INSTITUTE

ATTENTION: PROFESSOR M S SWAMINATHAN FRS

FURTHER TO YOUR TELEX OF 3RD OCTOBER 1988 WE HAVE STILL NOT RECEIVED YOUR CORRECTIONS TO THE KRONBERG MANUSCRIPT. PLEASE COULD YOU ARRANGE FOR A FURTHER COPY TO BE SENT BY COURIER. IF YOU WOULD KINDLY LET US KNOW THE COST OF COURIER DELIVERY WE WILL OF COURSE ARRANGE FOR YOU TO BE REIMBURSED. WE DO APOLOGISE FOR BOTHERING YOU AGAIN ON THIS MATTER BUT UNFORTUNATELY THE NORMAL POSTAL SERVICES HAVE LET US DOWN RATHER BADLY.

REGRDSM

S G HILDITCH
SECRETARY TO DR J H SHELLEY

IRRI LIAISON
NEW DELHI
19 OCT 1988
INWARD

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3130 88-10-17 11:02

TO: INTERNATIONAL RICE RESEARCH INSTITUTE

ATTENTION: PROFESSOR M S SWAMINATHAN FRS

FURTHER TO YOUR TELEX OF 3RD OCTOBER 1988 WE HAVE STILL NOT RECEIVED YOUR CORRECTIONS TO THE KRONBERG MANUSCRIPT. PLEASE COULD YOU ARRANGE FOR A FURTHER COPY TO BE SENT BY COURIER. IF YOU WOULD KINDLY LET US KNOW THE COST OF COURIER DELIVERY WE WILL OF COURSE ARRANGE FOR YOU TO BE REIMBURSED. WE DO APOLOGISE FOR BOTHERING YOU AGAIN ON THIS MATTER BUT UNFORTUNATELY THE NORMAL POSTAL SERVICES HAVE LET US DOWN RATHER BADLY.

REGRDSM

S G HILDITCH
SECRETARY TO DR J H SHELLEY

BOEHRINGER INGELHEIM LIMITED, U.K.

Union internationale pour la conservation
de la nature et de ses ressources
International Union for Conservation
of Nature and Natural Resources

Le Président
The President

16 November, 1988

Dear Dr. Shelley,

Many thanks for your letter of November 3. I am slowly recovering from the after-effects of the viral fever.

I enclose the retyped version of my paper with a few corrections. I have indicated that the position of the slides in the text is OK except in the case Figures 02 and 03. There is no need to add any more slides. I shall send you the detailed references within a few days.

I am sorry I forgot to send you the corrected pages of the discussion. I enclose the pages where my interventions appear with my corrections. Please request Susan to get the changes incorporated

Réponse à:/Reply to:
B4/142 Safdarjung Enclave, New Delhi 110029, India. Tel. (11) 679069

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Avenue du Mont-Blanc CH-1196 Gland – Switzerland
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I once again apologise for not sending you my portions on time. I hope I have not unduly delayed the publication.

With warm personal regards to you and Mrs. Hilditch.

Yours sincerely

D. S. Kothari

P.S I shall shortly return the Video-casette which you had so kindly sent.

Dr. Julian H. Shelley

SWAMINATHAN

I want to deal briefly with the scientific background of the social consequences of the genetic manipulation work done in the last 20 years with particular reference to developing countries, and then move on to what I consider the Third World point of view of a few critical issues.

During the last 20 years, a major technological change has taken place in crop management in many developing countries. This change was triggered by high yielding varieties of wheat and rice. The so-called green revolution involves the cultivation of semi-dwarf varieties of wheat and rice which can respond well to water and fertiliser, in other words to good soil fertility and water management. This became a very important starting point to use water and soil nutrition effectively.

(INSERT FIGURE 01) A point which is often not clearly understood is the fact that these semi-dwarf varieties, whether of wheat or rice, or hybrids of sorghum or corn, are capable of using soil nutrients much better at all levels of fertiliser application. For example, even at zero levels of nitrogen, both the hybrid of sorghum and high-yielding varieties of rice and wheat are higher yielding. Because this fact is usually not appreciated many social scientists have criticised the high-yielding varieties by saying that they require large quantitites of nutrients. It is true that adequate nutrition is needed to realize the full genetic potential for yield in the high-yielding varieties. The new strains are capable of translocating a considerable proportion of the photosynthates to the grain.
(INSERT FIGURE 04) The harvest index, i.e., economic yield/biological yield, can be as high as 0.5 in the new varieties, as compared to 0.2 to 0.3 in the earlier strains.

Insert Figure 03 here

Another important characteristic of the new varieties is the fact that several of them possess multiple resistance to a whole series of pests and diseases. This has been achieved by pyramiding genes for resistance through planned breeding. This means the pedigrees of these varieties are complex. This is one reason why many of the new varieties are very popular with small-scale farmers. However, with changes in the micro-environment of the crop due to irrigation and fertiliser application, some pests, which were not so important before become more important. Also, new biotypes of pathogens make breeding for resistance a never ending process.

Figure 02

(INSERT FIGURE ~~03~~ 02) An attractive feature of the new varieties, particularly in the tropics and subtropics, is their high ~~day~~ productivity per day. In the tropics and subtropics where sunlight is not a limiting factor throughout the year, cropping is feasible any time of the year, provided there is water and temperatures are not too unfavourable. High per day productivity, coupled with photo-insensitivity helps to impart greater stability to production in years where monsoon rains are not regular in Asia. For example, Vietnam experienced severe drought last year, but has just harvested an excellent spring crop of rice. Formerly, the crops were all very much fixed to seasons, but today's varieties are "period fixed" and not "season-bound". We can cultivate them any time of the year provided there is water.

The other important factor is that several of the new varieties have, not only a very high harvest index in terms of total dry matter, but also in terms of nitrogen with the result that, in spite of the short duration, their protein content remains nearly the same as in the long-duration varieties.

(~~INSERT~~ see FIGURE 02) The Norin dwarfing genes in wheat from Japan and the Dee-gee-woo-gen dwarfing gene in rice from China were the major sources of

revised plant architecture in wheat and rice. New plant types and hybrids have been the major catalysts of change in the production technology of rice and wheat. Yield is a product of interaction between the genetic efficiency of the plant and the management efficiency of the farmer. Thus, high-yielding strains have stimulated greater interest among farmers in crop management.

In the case of crops such as sorghum, maize, and millet, the exploitation of hybrid vigour was the major mechanism for raising the yield ceiling. Several of the hybrids in sorghum and pearl millet are based on gene-cytoplasmic male-sterile-restorer systems. (INSERT FIGURE 05) In a self-pollinated crop such as rice, exploitation of hybrid vigour would have remained a dream but for the identification of a male-sterile line on Hainan Island in China. Hybrid rice is now cultivated on nearly 10 million hectares of the 32 million hectares under rice in China, largely because of the very efficient method of seed production. One defect with these systems is the very narrow genetic base involved. Genetic homogeneity enhances genetic vulnerability to pest epidemics. Hence, the diversification of sources of male sterility is important.

Another advantage of high-yielding strains in population-rich, but land-hungry countries is their land-saving impact. Land-saving technologies, where the pathway of improvement is productivity improvement, are exceedingly important in South and Southeast Asia.

Total food grain production, as well as grain reserves, have been steadily increasing in both developed and developing countries during the past 20 years. Formerly, grain reserves were entirely in North America, Europe, and

Oceania, but today there are fairly extensive grain reserves in China, India, and several other developing countries. (INSERT FIGURE 08) India, for example, experienced widespread drought during 1987. In spite of that, because there were over 30 million tons of grain reserve at the beginning of the drought, the stability of both food supplies and food prices was maintained throughout the country. In Asia, the countries still facing difficulties on the food front are Kampuchea, Vietnam, and Laos. All other countries, including Bangladesh, which has a high population density, have a fairly satisfactory balance between population growth and food production. Sahelian Africa is an exception in terms of the food production-population growth relationship.

In spite of satisfactory progress in increasing food production, the fact remains that the number of people going to bed hungry is increasing. The latest FAO World Food Survey, an authentic source of statistics, shows that although the proportion of the population suffering from undernutrition has declined, absolute numbers have increased, largely because of population growth. The problem of hunger is now associated, not so much with availability of food in the market, but more importantly with purchasing power and entitlements.

The term "green revolution" was coined by Dr. William Gaad, US AID director in 1968 and we can now draw up a 20-year balance sheet. (INSERT FIGURE 10) An important gain is the growth of self-confidence among developing countries in their agricultural capacity. For example, India, today can feed a population of a billion provided the necessary purchasing power can be generated among the rural and urban poor. Stable or lower food prices in real terms has been another benefit. The prices of both wheat and rice have

declined in real terms in recent years. Widespread drought or other unfavourable factors can however push prices upward.

The concerns relating to the green revolution involve issues such as economics, ecology, energy, equity, and employment. The cost-risk-return structure of farming influences the land use and investment decisions of farmers. Whether farmers with small holdings will benefit as much from new technology as farmers with large farms, and whether technologies have harmed women in relation to their traditional occupations are some of the questions relating to equity which need consideration. Regarding employment, we should know whether new technologies have been labour-displacing or have led to labour diversification. Employment issues have become exceedingly important since unemployment or under-employment is a major cause of inadequate purchasing power.

Issues relating to energy concern the question of whether productivity improvement is linked to increasing consumption of nonrenewable forms of energy, i.e., imputs dependent on fossil fuel-based feedstocks. Finally, ecological considerations such as genetic homogeneity leading to genetic vulnerability to pests and diseases, pollution problems, pesticide residues, breakdown of resistance, soil degradation, and genetic erosion are all becoming important. Thus, we have to consider equity from the point of view of both the present and future generations.

The social impact of genetic engineering has to be considered from the ecological, energy, employment, equity, and economic points of view. In addition, biosafety and nutritional considerations assume importance with recombinant DNA techniques. In the United States, the GRAS regulations, i.e.

"generally regarded as safe regulations", require that new varieties are not nutritionally inferior to the currently cultivated strains. Guidelines are essential for measuring the impact of genetic engineering from the intra-generational and inter-generational equity points of view.

On the issue of food security, FAO defines it as physical and economic access to food to all people at all times. From 1950 or post World War II to 1980, we can say that the quantitive availability of food was the most important food security challenge. Now it looks as though during this decade and the next one, the most important food security challenge is going to be economic access to food, i.e. people having enough money to buy food. Probably from the next century, ecological access to food - largely as a result of damage to our life support systems of soil, water, flora and fauna, and the atmosphere - might become the most important food security challenge.

Hence, in relation to scientific strategies, it has become clear particularly in the tropics and subtropics that productivity will have to be measured not just in terms of yield, but also in terms of effects on the environment. In other words, a new definition of productivity that incorporates a dimension of ecological sustainability has become important. For example, if we wish to add sustainability considerations in productivity calculations, it is important to develop methodologies for the measurement of the annualised gain or loss in environmental capital such as soil health and water quality. (INSERT FIGURE 12)

Stability in productivity over time or locations is a measure of sustainability. However, sustainability has to be a dynamic concept because of population growth and decreased land availability. (INSERT FIGURE 07)

Much of the population growth is taking place in developing countries. At the end of this century, of 6 billion world inhabitants, about 4.8 billion will be in the developing countries. In the next century, it has been predicted that most of the additional growth in population will be in the developing countries. If the human population stabilizes at 10 billion in 2050, more than 8.5 billion will be in the developing countries. (INSERT FIGURE 13) An important consequence of such population growth is smaller and smaller farms. For example, in India, farmers operating below one hectare in size are classified as marginal farmers. Those cultivating two hectares or below are small farmers. (INSERT FIGURE 14) The data collected during the 1980-81 Agricultural Census reveal that nearly 80 million out of the 90 million operational holdings in the country belong to the small and marginal categories. In China, the population is expected to reach 1.25 billion by the year 2000, when the per caput land availability may be only 0.3 acre. How are we going to produce more and more food, fuelwood, fodder, feed, fibre and the other needs from less and less land?

This is where biotechnology, including genetic engineering, holds new opportunities for the small farmers of the Third World. First, we can decrease the cost of production without reducing yield, and at the same time improve stability and sustainability. Secondly, in the post-harvest phase, technologies relating to bioprocessing, fermentation and microbiological enrichment have opened up new possiblities for preparing value added products from biomass. Agricultural biomass is the most important feedstock available in the rural areas of developing countries. Techniques for improving biomass utilisation are therefore relevant to enhancing agrarian prosperity.

The changing pattern of organisation of research in developed countries, namely more and more privatisation of applied research, also has important implications for the Third World. For example, the applied part of the Cambridge Plant Breeding Institute, where I did my PhD degree, was sold to Unilever last year. What are the implications of this changed owership for developing countries?

I want to deal with the major implications, they fall under three headings: implications for training, choice of problem, conservation and ultilization of biological diversity.

TRAINING

Institutes like the Cambridge Plant Breeding Institute were not only research institutes but also very important training institutions for Third World scientists. When such Institutes are privatised, will training opportunities continue to be available to scientists from developing Countries?

CHOICE OF PROBLEM

I fear that the choice of the problem for investigation will obviously be based on commercial rather than humanitarian considerations. Every company will make its choice of problem from the point of view of ultimate marketability and profitability. Let me cite one example.

In tropical and subtropical soils one of the major constraints for increasing production is often not the genetic make-up of the plant but the ability to provide the nutrients necessary for realising its genetic potential for yield. The energy needed to produce a ton of grain in barrels of oil equivalent has gone up from 0.44 to 1.14 since 1950 for reasons relating to soil and plant health and the nature of agronomic practices. (INSERT FIGURE 17) If we take an intermediate level of nitrogen application of 180 kilograms of nitrogen per

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hectare as Western Europe's average application, FAO data reveal that in developing countries the average application of nitrogen fertilizer is below 25% of the level reached in Western Europe. (INSERT FIGURE 18) The early expectations that genetic engineering techniques will help to introduce the capacity for biological nitrogen fixation in cereals have clearly proved to be premature. However, we now have opportunities for breeding efficient nitrogen fixing green manure crops. For example, the identification of stem nodulating species such as Sesbania rostrata by French scientists in Senegal has opened up the possibility of breeding legumes which fix nitrogen not only in the rhizosphere but also in the stem. (Insert Figure 19) The organism associated with the stem nodules has been classified as Azorhizobium. It can grow under free living conditions and assimilate its own fixed nitrogen while root nodules belong to the genus Rhizobium. Now by a combination of the two mechanisms we are able to get 60-70 kilograms of nitrogen fixed in the soil in about 45 days in the case of Sesbania rostrata. With a little investment on research in green manure crops, for example in developing photo-insensitive strains of S. rostrata, we may be able to help resource-poor farmers more speedily than through large investments on the transfer of nitrogen-fixing genes to non-legumes. Another area of research worthy of greater attention is inter-specific hybridization in the genus Azolla. This fern is capable of fixing nitrogen because of its association with a blue-gree algae. In addition to combining the desirable features of different Azolla species, we can also change the algal partner. Similarly, the improvement of blue-green algae and Rhizobia may yield good dividends. (INSERT FIGURE 21)

Insert Figure 19 here

To indicate how we can deal with the real needs of Third World farmers, I wish to deal briefly with a genetic engineering network supported by the Rockfeller Foundation. The Rockefeller Foundation chose rice for support because of the fact that rice is predominantly grown by small farmers and

practically all consumed at the places where it is cultivated. The international trade in rice during 1987 was only about 11 million tons, Thailand being the major exporter. The Rice Genetic Engineering Network is organised in such a manner that a mutually reinforcing activity has been initiated in the following areas: (INSERT FIGURE 22, INSERT FIGURE 23)

(a) Enhancing the knowledge base of rice genetics and the construction of conventional and molecular linkage maps;

(b) Standardisation of techniques for protoplast fusion and regeneration and for DNA transfer to obtain transgenic plants; and

(c) Utilisation of the basic information and protoplast and tissue culture and recombinant DNA technologies for transfering genes across sexual barriers.

The Rockefeller Foundation-sponsored project is a long-term one, with committment of financial support for 10 to 15 years. Many laboratories from different parts of the world are participating in this network. Substantial progress has been made within two years in the standardisation of techniques for protoplast fusion and regeneration and for DNA transfer. In rice, unlike crops of importance to temperate regions, even today there are differences in chromosomal nomenclature. This illustrates the need for greater attention to conventional genetic and cytogenetic studies in tropical crops. (INSERT FIGURE 24)

CONSERVATION AND UTILIZATION OF BIOLOGICAL DIVERSITY

A third implication of privatisation relates to the conservation and utilisation of biological diversity. I wish to make a brief reference to the need for the conservation of biological diversity and the collection of seeds of wild species. One of the criticisms of the Green Revolution has been that the biological diversity is being reduced as a result of greater homogeneity in varieties. Genetic homogeneity promotes genetic vulnerability to pests as well as abiotic stresses. However, it is not often recognized that the modern cultivars of crops like rice or wheat have complex pedigrees. We find, for example, that one recent variety of rice has 73 parents including 20 land races. These then are some of the implications of privatisation of applied research.

Obviously, there will be a continuous change in the need for new gene pools. Tomorrow's gene pool may be very different from today's gene pool, if we take into consideration possible climate change, higher incidence of ultraviolet radiation, and changing consumer preferences and processing techniques. (INSERT FIGURE 27) The increase of "green house' gasses in the atmosphere can cause changes in temperature and precipitation, ocean warming and the possible inundation of coastal areas in several parts of the world. For example, the President of Maldives said last year, at the UN General Assembly, that while others talked about endangered species, he wanted to talk about an endangered country. He said, "My country will get submerged if the sea level rises by two metres as a result of ocean warming". Now there are fortunately in nature plants like the floating and deep water rice strains, which can keep above rising water tables. Therefore, we can initiate an anticipatory research programme involving the transfer of the elongation gene to other plants. (INSERT FIGURE 28, INSERT FIGURE 29) Thus,

for every problem there is also a solution. This is why we must preserve our rich genetic estate. Now, in these deep water areas the other great advantage is that we can grow fish and rice, and other kinds of mixed aquaculture and agriculture systems. Such integrated farming systems are being adopted on a small-scale but there is need and scope for extensive adoption. However, for spreading on a large scale integrated aquaculture-agriculture farming systems, we should refrain from using chemical pesticides. This is where genetic engineering opens up new opportunities. There are wild species of rice and other crops which carry genes for resistance to a broad spectrum of pests. Work on the transfer of such genes is now in progress. (INSERT FIGURE 30)

Tropical rain forests which are rich in associated flora and fauna are unfortunately getting destroyed at a fast pace. Destruction of habitats is an important cause of species extinction. We should promote in every country an integrated conservation strategy involving both in situ and ex-situ as well as in vivo and in vitro methods of conservation. (INSERT FIGURE 31)

The conservation and utilisation of crop genetic resources, are also beset with controversies. Much of the wild and valuable germplasm comes from developing countries. Plant breeders' rights are becoming the rule in developed countries, where much of the plant breeding is in the private sector. In fact in countries like the Netherlands plant breeders' rights have existed for the last 50 years. The centres of origin of most economic plants, including medicinal plants, occur in developing countries, where farmers, particularly farm women, have taken particular care to conserve genetic diversity. (INSERT FIGURE 33) Women have been traditionally seed selectors and they have carefully selected strains with resistance to pests

and diseases and with adaptation to climatic stresses. Therefore, in the forum of FAO, the concept of Farmers' Rights has been proposed in order to focus attention on the role of farmers in the preservation of biological diversity. Thus, we are witnessing an attitude of confrontation in the extension of patent rights on the one hand, and the demand for some form of compensation to the centre of origin countries in the form of Farmers' Rights. It will be unfortunate if such controversies harm the cause of conservation of biological diversity for the benefit of current and future populations. Therefore suitable methods of assisting the centre of origin countries in both conserving their genetic endowments and utilising them for the welfare of their people should be developed soon. Biotechnology research in developed countries is largely in the private sector. What are the implications of intellectural property rights for the rapid transfer of new technologies to Third World Countries? Can we foster institutional diversity, i.e., an optimum blend of public and private sector efforts in plant breeding? These are questions which merit analysis and action. I am confident that Dr. Schell will throw much light on questions relating to the potential impact of genetic engineering on crop improvement. I am not dealing with the environmental and biosafety aspects of recombinant DNA research, since we are considering them separately.

tolerant as well, that they were until now mostly mutations, where the target has been mutated and not the result either horizontal transfer which would be a direct transfer maybe through pollen, or through the soil. Ultimately I think that there is no question that given enough time and enough selected pressure horizontal transfer by whatever mechanism will occur. This I think is certainly true, I don't see that - really if you think about it as a major problem because there is this type of transfer would give tolerance to a particular chemical and there would still be other chemicals to control that weed, and in terms of environment, if you no longer use that particular chemical there is no damage to the environment of course.

SWAMINATHAN

There's one problem here in relation to the tropics. Many times ~~it is~~ farmers adopt mixed cropping, ~~people~~ i.e., they don't grow a single crop, but a mixture of crops. ~~particularly~~ particularly this is true in rain-~~fill~~fed areas, ~~then when you have~~ if one crop is tolerant to a herbicide, another may be sensitive ~~tolerant one strain,~~ ~~let us~~ say, that is ~~sprayed, your~~ companion crop ~~will also go,~~ may be destroyed. ~~so it's somewhat according to the~~ Therefore, the Hence an entire cropping system or ~~the~~ farming system will have to be used as the basis for the formulation of management practices in the tropics and sub-tropics.

SCHELL

This may of course require to transfer the same tolerant genes into different crops, and as I pointed out this is in fact a fairly straightforward technical problem, provided you can manipulate the different crops. You can introduce the same tolerance in all of them.

Swaminathan:

I think ~~there~~ This seems to be a polygenic trait. One of the future areas of manipulation will ~~lead to~~ deal with this very precise problem, how to make the C3 plants to C4, like sugar cane and maize ~~and so on~~. But at the moment we do not know enough about ~~how to~~ methods of manipulating this character. It has been mentioned that ~~lots of~~ many crosses have been made. ~~Those~~ It is true crosses ~~that~~ have been made in sorghum and in maize, but we'll have to make inter-generic crosses in order to get desirable combinations. ~~That also has become difficult~~. ~~Will~~ Such wide crosses are likely to become relatively simple in the coming years.

Hess:

Now, this means that you really have to do much more research.

Swaminathan:

Right. Basically, we should know something more about the genetics of the character itself and how to manipulate it.

Hess:

Can I ask another question concerning diversity that has been mentioned by both of you? Do you see any danger, let's put it this way, that diversity might be restricted? I don't see any danger at all, but I'd like to know your opinion. For theoretical reasons you would never expect that diverse species would converge or be reduced.

Swaminathan:

Well, as you know, in ~~agriculture itself~~ human food systems, in spite of the fact that the world contains probably a million plant species, ~~about ten or fifteen~~ only about 20-30 species are of major agricultural importance. About 90% of the world's food comes

Only in recent years, there is a growing interest in underutilised plants. from only a few plants. ~~That itself is a restriction in terms of other species~~. The danger of loss of biological diversity ~~in relation to~~ because of genetic homogeneity is a real one. ~~ideas that one might put in~~: we might be very successful in covering millions of hectares with a few crop varieties, but ~~and~~ then a new pathogen comes in and does considerable damage. We ~~should~~ hence ~~swap. So how do you~~ consciously build into our strategy of productivity ~~cultiva-tion~~ improvement enough room for genetic diversity. ~~This will be possibly one lead if we have plants with equal yield~~. After all, the farmers are going to cultivate only those varieties which are high-yielding or which are satisfactory to them in terms of return and marketing value. ~~quality~~. We ~~One~~ will have to consciously ~~build in~~ breed here a large amount of material which have certain characteristics in common, ~~in terms~~ such as of maturity period, ~~in terms of harvest time, in terms of~~ yield potential and consumer quality, and which at the same time have ~~somewhat~~ different genetic backgrounds ~~in terms of~~ with reference to resistance to pests and diseases. This has been talked about - ~~multiple~~ multi-line varieties and so on. But I personally think, so long as we have enough ~~for the~~ of genetic diversity ~~conserved with us~~ available, and if there is a good monitoring system with an early warning ~~as you have in~~ mechanism as has been developed in Europe, ~~In~~ in fact in Europe most of the races of rust ~~and so on~~ wheat are very well monitored, ~~but if you have~~ and ~~a~~ a new rust ~~it~~ biotype takes a couple of years to build up the in population to make an impact ~~in terms of production~~ adverse on yield. ~~There will be time to change the varieties~~. So one could quickly substitute varieties or diversify varieties. But it's more difficult to do ~~it~~ this in the tropics and sub-tropics. That's why ancient systems of cultivation have always relied on a considerable degree of genetic diversity in the cultivated populations, ~~they grow~~, both in terms of mixtures of crops and in terms of varieties. The whole area of biological diversity is now being discussed more in the context of genes whose values we may not know about or recognize today and which may get lost for-

ever, because ~~as I said~~ of, the destruction of the habitats, ~~the tropical forests and other habitats, have disappeared.~~ such as tropical rain forests. A shrinkage in genetic diversity leads to a shrinkage in the opportunities for successful genetic engineering.

Bartels:

In regard to the safety of releasing into the environment genetically engineered organisms, do you think that in developing countries we will be in a position to develop mechanisms for regulating this kind of release, to assess carefully what the logical consequences of a proposal are? I am thinking particularly in terms of the Argentinian case of the rabies vaccine that was released without Argentina having the mechanisms to assess the hazard or the safety of that proposal. And furthermore, the situation in Australia, for example, where there is no mechanism at all by which one has to notify anybody of a planned release. These are two countries that are reasonably developed In less developed countries, perhaps the problem is even greater.

Swaminathan:

This is a hot topic. You know, every country is discussing this question of testing. ~~Sometimes~~ often there's the feeling that some tests ~~have been~~ are being done in developing countries which are not allowed in the developed countries ~~and so on~~. And obviously every country will have to develop its own methods of assessment ~~in what you want to test and how to test it, what safeguards are necessary.~~ on what should be tested and how. Guidelines will have to be developed with regard to bio-safety regulations. In India also there has been considerable discussion on the testing of vaccines and so on, and maybe Dr. Siddiqi may be able to supplement. But when I talked about bio-safety, Jeff, ~~there was also a question of not~~ I was not thinking only transgenic plants. Some

people are ~~very much~~ afraid that some transgenic plants, like your petunia, for instance, could become ~~a very~~ an aggressive weed. In fact, many of the exotic weeds are very aggressive, ~~but are small in terms of pathogenes, in terms of working with pathogenic organisms. We have to~~ The other area which needs attention is the genetic manipulation of pathogens hybridize and so on and ~~create new strains~~. There are problems in testing new ~~terms of testing~~ strains of pathogens in the natural environment. ~~So the point is well taken, but I suppose~~ Every country will have to develop its own capabilities in deciding for itself ~~what~~ how safe is safe. ~~in the overall interest of what is necessary~~.

~~Would you like to supplement?~~

Siddiqi:

Well, from India's point of view, the critics of doing all these things have a fertile imagination very often, and any argument you can make which sort of implies that the populations of these countries are going to become guinea pigs for doing anything, then there's a very natural reaction. One has to be very, very careful about that. You just cannot ignore it. I would like to make a comment; I would suggest to Dr. Swaminathan and to Dr. Schell - I agree that in principle there is no great difference between doing engineering by traditional methods and engineering by the new methods with plants, but there is a practical difference which is this: the ease with which genetic engineering based on modern methods can be spread in third-world countries, it's not so easy; it's very difficult. Most of the progress in the green revolution could be done by conventional breeding methods without paying much attention to basic science in third-world countries, as far as I can see. There wasn't really any great development of genetics in contemporary genetics in our own country, while a successful breeding program could be

established. I don't see that sort of thing happening in the case of genetic engineering and bio-technology. In fact I think it is very unlikely that it can be done unless third-world countries develop a very strong base of research capability in bio-technology. I sort of think it's a very difficult problem, because you have an extraordinary difficult of developing this capability. Very often there is an inclination to assume that by having training programs and things of that sort you can develop this capability. I don't think that this is an easy problem. It's going to be - and I also feel that the administrators of science are in general not aware of this difficult, they think they can treat this as ...

Swaminathan:

Just one comment, Jeff, before you begin. I think both ~~I think the question of what~~ Jeff and I emphasized ~~was successful farming by using~~ that genetic engineering will be an invaluable ~~as an~~ additional tool if used in an appropriate way. The question whether we can do it in developing countries or not will depend on how we organise the work. ~~immediately~~ The kind of research cooperative ~~network which~~ I mentioned in the case of rice is one way. ~~if you have~~ Given the basic ~~building blocks or the~~ breeding material, the transgenic ~~plant~~ genetic has could be used ~~again~~ as parents in crosses by plant breeders, like any other material ~~a cross, and so on. So long as that particular material containing the gene which we require is available somewhere~~. For example, in the case of rice ~~now~~, there's a program of ~~putting~~ incorporating some novel genes. ~~Sometimes the wilder~~ The introduction of viral genes can give a cross-protection effect in the variety itself, and so on. If one has desirable ~~that~~ them material, from Jeff's lab or somewhere else, one could then use it in ~~a hybridization program~~ a conventional breeding program, and develop the kind of variety which ~~you~~ is needed. I suppose in relation to

the problem one wants to solve, one will have to develop ~~almost~~ an effective appropriate strategy.

Schell:

To this point, I think that what one could very well make is the reciprocal statement to the one you made. One could say that genetic engineering will be very easily accessible to third-world countries, provided the proper international organization is put in place for it. Let me again stress the point that what is really intensive, both in terms of finances and in terms of need of higher, sophisticated research, is the molecular biology of the matter. And maybe at a lower level still of technology is the tissue-culture work. This already has spread fairly well, and I think there are examples which say that it can easily be transferred. And then, which I didn't mentioned, now one is working on fairly straight-forward methods, where breeders can use. For instance, uptake of innata into dried seeds, and then simply by an acceleration analysis to go for those offspring that will come from a germal line in which genes have integrated. So that my prediction is that the transfer mechanisms, which is part of the technology, will become low-tech and easily available. What will remain high-tech and intensive is the analysis of the relevant genes, and now they interact with others, and that complexity, provided the international research is organized such that it is sufficient open and provided one takes care of the resources and the willingness to share the knowledge, then I think locally sufficient capacity will be available to make use of those genes when they are available to

it's welcome if we can produce more food, but I'd like to ask what the evidence is about the actual results on access to food by the poorer groups in the countries most at risk here.

Swaminathan:

Well, may I first of all say, when ~~you have~~ there is enough food ~~on~~ in the market there is a great degree of stability of price. That's very important. Number two, countries like India ~~and so on~~ have been able to recycle some of the surplus food in fairly substantial food-for-work programs or food-for-development programs ~~and so on~~. In fact we have ~~the~~ in the state ~~in which~~ where Dr. Siddiqi works ~~on~~ a program called Employment Guarantee Scheme. ~~It's an unskilled job, not a skilled job. So there are~~ This program provides to all those in need of employment jobs which can help them to earn their daily bread. (Maharashtra (MAHARASHTRA) Thus, there) are new possibilities of using food itself as an internal resource ~~and commodity~~. So certain things which we could never have done before, had there not been this agricultural progress, have now become possible. ~~opened up.~~ But still the puzzle remains about finding opportunities for skilled employment in rural areas. This is a real challenge. When one talks about entitlements and so on, he is talking about entitlements for food, that means an ability to purchase the food. ~~That is, why I can't go into detail~~. I think certain aspects of bio-technology could generate ~~some more~~ opportunities for downstream employment. A large number ~~lot~~ of people are employed only ~~on~~ in the primary sector in developing countries. The challenge is how to take a part of them into secondary and tertiary sectors. How do you design the resource use in such a way that more jobs and income can be generated? This will have to be done, and thought is being given to them, but if we had not had the agricultural progress, ~~then nothing would have been possible and there would be an enormous disaster.~~ planning for quality of life improvement would not have been possible.

Swaminathan continued:

About twenty years ago India had to depend on an annual import of 10 million tons of imported wheat. It used to be called ~~shipped amount existence~~ a "ship to mouth" existence. In contrast to manage its food budget, the ~~whole country's food budgeting.~~ India managed a disastrous drought in 1987 without any food import. ~~So we graduated from there, and so on. So~~

Now the challenge is the economic access to food, that means development per se, that means resources, financial, technical and natural ~~lots of countries, because of the enormous amount of foreign debt, are selling their natural resources,~~ the crippling debt-servicing burden, many poor nations are exploiting their natural resources in an unsustainable manner. Because ~~primary natural resources, like water and timber and so on, so there is a whole set of complicated factors beyond science.~~ This is why I said earlier that the major food security challenge of the 21st century will be ecological access to food

Hess: I have a short comment, too, in this context. Of course it's a network problem. I was interested in the food and problem with respect to the protein and amino acid nutrition problem, which is fairly well spread all over. If you succeed to put into potatoes or any other crop which is a protein source, another protein as you mentioned in your super-potato, I think, that certainly would eliminate on a large scale any protein malnutrition. There have been lots of experiments over the last decades how to do it, and I think, I've no doubt, because many areas in this world are still living on a one-crop culture. But if you could increase the amino-acid variety in one crop like the potato, or mice, just by adding another protein, the overall mixture of essential and non-essential amino acid in that crop would make it immeditely as such that no more protein malnutrition would occur. And that certainly would be a great success in any respect. I just wanted to add this as a

comment, and I hope that you will succeed also to put this into other types of crops like mice.

Schell: I can only repeat that the scientific conditions have been fulfilled for that. Genes coding for nutritious proteins can be transferred and made to be expressed in different crops. Whether they will be able to do it in sufficient quantities, I guess, is still a matter of further work, but to give you an example, you can get the reserve proteins of beans, you can make them to be expressed in the seeds of tobacco, without even having to modify the gene. Plants are remarkably conserved if you take a seed protein of a legume and introduce the whole gene without any modification in tobacco, that protein will be made into the seed of tobacco. So that the mechanisms regulating which organtines are expressed seem to be highly conserved and applicable to many different genes.

Swaminathan:

Certainly many possibilities have been opened up, but may I add a footnote as far as the malnutrution problem is concerned. In most of the cereal-based diets - countries with a cereal ~~base~~ as staple, either rice or wheat - undernutrition ~~and~~ (i.e.) inadequate calories intake is now widely accepted as the major problem. ~~except pre-school children. The the real problem, by and large, is undernutrition and less calories, and secondly water,~~ A second serious problem is safe drinking water. The intestinal load of infection is so high in many cases that whatever ~~you~~ a child eats like a leaky pot it goes away. ~~I think we should now adjourn for coffee.~~

SWAMINATHAN

... I think Sir John Kendrew has an observation? We continue this discussion to 11.30 when we take our next break.

KENDREW

Thank you, I only really wanted to comment on what Siddiqi said a little time ago, it seemed to me of course this morning that we really got into the real world, in Europe we have no problems compared with what we've been talking about this morning, it's the developing world that really matters as far as the future of humanity is concerned, and in this particular area there is the problem which he raised about the coupling between research and the people in poor countries. I think India's not typical because India is a developing country, on the other hand it has a very strong science base, which most developing countries do not, so I don't think we should think about India, but the real problem is coupling People like Geoff Schell and his lab to the developing world in the small, poor countries. Now, in the organisations I've been involved with, (?) the National Council of Scientific and Human (?) of course we are spending all our time organising training courses in genetic manipulation in developing countries and so on. Now, I wonder very frequently whether we're on the right track here, are we getting the kind of coupling, this is the problem known as technology transfer which as not the same and a much more difficult problem than gene transfer, and I think that we do not have the mechanisms yet, that what is happening in this plant field is a very good example because it is true that many of the techniques are such that in principle they can be done effectively in small laboratories in remote

and second, you have given us a lot of informations about social consequences of the use of this very productive rice species, but you haven't talked about the price, and some people say, okay, maybe the price of this new rice seed is so high that a normal farmer in the Third World can't buy it, is that really a problem for the farmers?

SWAMINATHAN

Well, I'll just comment on the second part and maybe Jeff could comment on the first part. As far as price is concerned, because crops like rice and wheat are self-pollinated, if you have seed for one year you can keep for five to six years so long as you keep it pure. Hence, seed is not a major issue. However one goes into hybrids where F1 seeds have to be purchased every year, then it becomes much more expensive. If the yield is good, farmers will not be reluctant to purchase the seeds. China has gone into hybrid rice because they find a yield advantage of about 20% more than the best high-yielding varieties and they have to produce more and more from less and less land and this is why land saving technologies are important. So that is a problem. I would not say that seed price has been unimportant, but the other prices like fertiliser, pesticide, electricity charges, water charges, the whole package of inputs which are necessary for higher production are equally important. In many cases it's the extension service's ability to get the management efficiency enhanced which determines the net return. None of the new technologies become, have been, because they've not been (?) because of the cost although the resources needed to take the new technology are important, not only the seed but the rest of the package, and there are government policies in countries where progress is taking

Unless the package of technology is supported by appropriate packages of services and public policies, agricultural progress is slow.

The cost-risk-return structure of farming enterprises influences the decisions of farmers ~~place you find policies have been such that the poorer farmers have access to credit. credit is a very key issue. credit and markets are both important, and~~ Once they produce more ~~we~~ they must have an assured price; otherwise when they produce ~~something~~ more for the market and the market collapses, the price is very low, ~~so I would say the price - not so much of the seed but of the grain or the commodity they want to market,~~ then the farmers revert to low input technologies that becomes even more of a critical factor. In many countries, including the African countries where there have been food shortages, the moment production goes up the prices come down too much, that ~~the additional~~ Consequently farmers effort which has gone into extra production, ~~the people don't derive benefit.~~ little economic benefit from the additional Even in ~~in~~ I give

Regarding ~~the~~ mechanisms like the International Centre for Genetic Engineering and ~~Biology~~ Biotechnology ~~to which you refereed to~~ sponsored by UNIDO, ~~just these~~ it has two components, Trieste and New Delhi, the New Delhi component is working on some of the ~~agricultural~~ animal sciences problems, as well as on ~~and~~ human health problems, ~~under~~ The Trieste center is working more on the bioprocessing ~~and so on. It is not (?), to finding its roots, it is going to take time. Geoff?~~ and industrial aspects. It may take some more time for them to get fully operational and effective.

SCHELL

Maybe a few comments simply based on experience: first of all, I wonder whether one of the problems with the attempts made at organising courses has been that one, started very early on, if the concept at this kind of biological research would be relevant to third countries, and very early on one tried to organise the development of that research in these countries, and if one agrees with the simplified version that the initial stages, and I am talking from plant research, if this simplified model

of agriculture or other mechanisms for introducing these crops to the most remote, poorest, least educated populations?

SCHELL

I understood the question but I have to admit that I have information on this, I don't really know ...

SWAMINATHAN

~~Insofar as he said and they said you have a variety~~ with regard to varieties created by genetic engineering, there is no difficulty in fitting ~~it to~~ them into existing cropping patterns if it is a good variety of rice or wheat or corn, people take to it, so long as it fits in with their cropping pattern and consumer preference also. It depends on how they use that particular grain, if the quality is very poor then it'll suffer in market price, but otherwise ~~it's only a matter of the plant~~ recombinant DNA technique is ~~being~~ just an additional tool which is very powerful in many respects, so I don't expect any difficulty in getting it accepted.

SMITH

Could I make a rather sort of impolite comment after I've made a polite one, I think it's very good that we've had this Third World perspective today, and certainly it's made me think again about yesterday and lots of talk about very elaborate techniques for treating what at the moment are very rare diseases, and I worry a lot about this concentration of this kind of technology and know-how in large companies, and I'm very encouraged to hear you say that they may increasingly publish the result, but my impolite point is, I was very struck that a lot of the work you

three times per year to South America, to China or to any other country, that's just also for ordinary person like Professor Winnacker not possible! I'd just like to illustrate the problem and the British, what I hear from Sidney Brenner is exactly the same situation, or the French and the United States, I think it's pretty much the same.

SWAMINATHAN

Thank you, it's a good time to shift the (?), then if we have time later on we could come back to this issue if you'd like, so if you'd take over Prof. Winnacker.

there is both a desire to be part of nature, and therefore if nature is being damaged oneself is being damaged, and yet there's a desire to be over against nature and profoundly threatened by it, and I think this seems to me to point to some of the difficulties which Doctor Glover's question raised is that we're not dealing, we're dealing with, if I may use the word, it's not a very helpful word, irrational impulses. I don't wish to demean them by saying they're irrational, I think they're extremely and therefore I don't yet know how we handle this business of communication, whereas those who are making these steps, taking these steps in the scientific community and in the other brokers in our society who are trying to explain these things and by very definition their approach is rational, and their work is proceeding on rational axes, but I think there are very difficult problems which can be (?) transposed into problems of social psychology and so on, which you have to pursue really rather carefully.

SWAMINATHAN

Thank you, I think that's a good topic for continuing in the afternoon session. I have one question, you know we talked about trypanosomiasis and the work which is in progress and we talked earlier about research priorities, I have always wondered, there's a lot of work going on trypanosomiasis in relation to the possible larger scale production of European cattle breeds such as Holsteins, Jerseys, and Brown Swiss and so on in Africa. In Africa, there are indigenous breeds of trypanotolerant cattle. How much effort has gone to upgrading their productivity slightly, even by two or three liters of milk per animal. Even slight improvements in the productivity of indigenous breeds might make a larger contribution in terms of total production. The other

arising from the comments of is about

question ~~about~~ Doctor Mclaren ~~a~~, the whole area of developing countries' animal production system. Earlier we talked about human nutrition. If undernutrition is an important problem for humans, under and malnutrition is even much greater for animals. In fact we have to have only a grain-saving methodology of animal production, just as a land-saving methodology is important in land hungry but population rich countries
of agriculture. In that context I had always felt if we did more work on the microbiological enrichment of cellulosic wastes and other biomass ~~and so on~~, and make them into much better food, animal productivity will go up much faster. Even with a little better feeding even the worst of the animals will give a liter or two more ~~when they are fed a little more, and purely~~ In statistical terms, when you multiply that number in terms of production you get much higher total production I was wondering about the ~~(?) improvement, are you aware of any work?~~ improvement of indigenous breeds. Are you aware of any such work?

WINNACKER

Well, to the first part of the question, there has been efforts to improve the trypanosoma resistance in cattle, and in fact at Munich at the veterinary station this was tried for about 15 years in collaboration with two centres in Gambia, but that work was discontinued because the person in question retired, it was a very simple reason, so I agree with you that probably the genetic engineering approaches to this problem cannot be the only ones, and I didn't really mean that when I mentioned that, I think the other approaches in classical genetics are only as Doctor Schell said in outlining his talk, this is just one methodology which may or may not be used by animal breeders to improve the quality of livestock in general.

SWAMINATHAN