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**CROP SCIENCE: SCIENTIFIC AND ETHICAL CHALLENGES
TO MEET HUMAN NEEDS**

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Many of you sitting here today were present at the first International Crop Science Congress in 1992. Looking around the room you will recognise several of your neighbours. They may have reached more senior positions and of course their publications lists are longer. Fortunately, there are also a few more women and there is a new generation of young scientists among us. But overall, not much seems changed. As individuals, we humans are slow.

Yet, in those eight years, the world around us has transformed itself at an unprecedented pace, be it in terms of population and income growth or access to technology. And more importantly, the world of science has changed dramatically. Obviously, we must congratulate science on the major progress made in crop research, as witnessed by the fact that average crop yields increased four-fold and total crop harvest increased six-fold in the course of the last century. Agricultural research, although still under-funded, can be considered as one of the most profitable investments, something not irrelevant given the today's mood. (Nevertheless, the share of agriculture in total lending has fallen from US\$19 billion in the 1970s to US\$10 billion in the 1990s)(1).

The public at large equates biological agricultural science with the failure to protect human health, the destruction of the countryside and, above all, with the creation of 'Frankenfood'. The Prince of Wales, who is widely credited with generating this term, questions Man's right *to experiment, Frankenstein-like with the very stuff of life* (2). Popular perception has it that agricultural science has isolated itself from the man in the street (or the woman in the field), and is seeking to impose its ideas on the planet. These views are not new but have quickly become more vigorous.

In his opening address to the Iowa Congress in 1992, Vernon Ruttan covered three waves of social concerns: potential limits on growth, pollution, and environment and human health (3). These concerns are still valid, and so are his recommendations, but the picture today is definitely more complex. While agricultural science never took place in a vacuum, it now has to stand up to intense public scrutiny. So it is, above all, the agricultural scientist who should

take to heart what Sir Julian Huxley, eminent scientist, writer and international public servant – a rare combination even in his time – wrote in 1957: *It is as if man had been appointed managing director of the biggest business of all, the business of evolution...whether he is conscious of what he is doing or not, he is in point of fact determining the future direction of evolution on this earth. That is his inescapable destiny, and the sooner he realises it, the better for all concerned.*

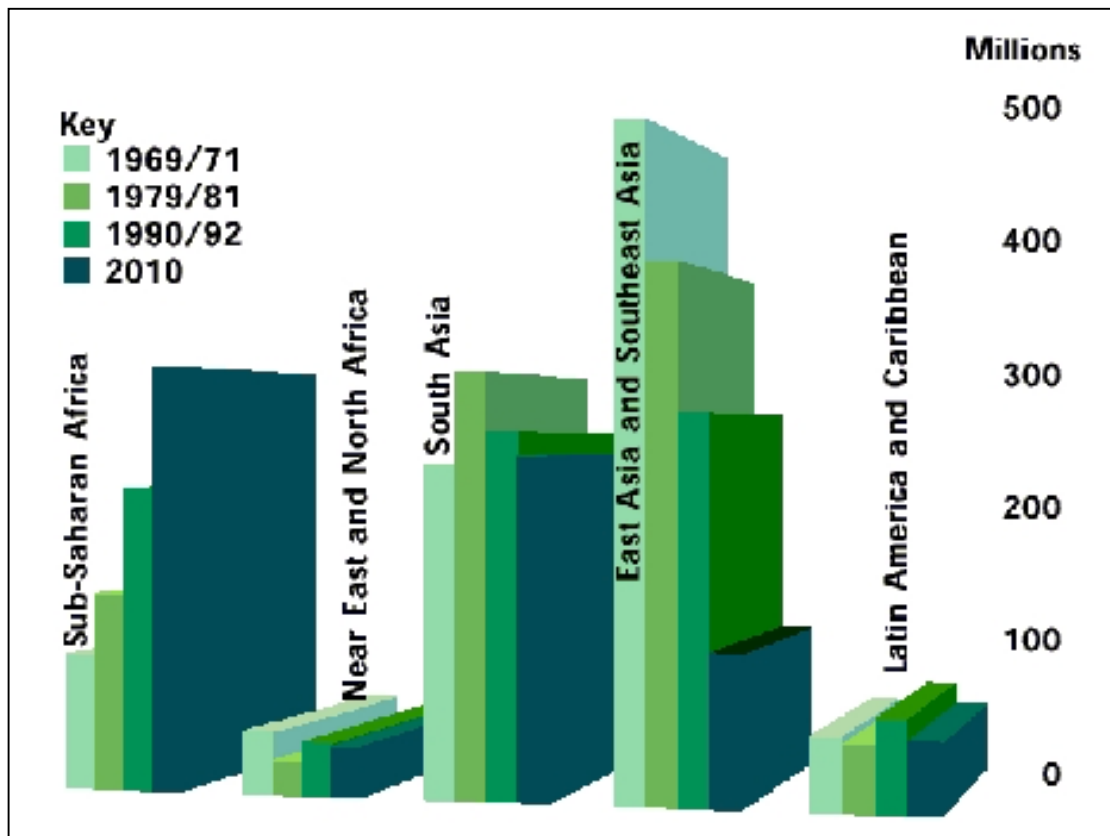
I propose here to analyse five emerging trends in the world around us from an ethical perspective and derive from these five scientific challenges for crop science.

A. Some World Agricultural Trends Seen from an Ethical Perspective

1. The Basic Trend: the Uneven Distribution of Food

Food production has increased dramatically over the last 35 years: in spite of a 70% increase in world population, per capita supply has increased by almost 20% (4). In developing countries, population has almost doubled while per capita supply grew by almost 30%. As a result, the percentage of hungry people was halved from 36% in 1970 to 18% in 1995-97. In absolute numbers the decline is less spectacular: 790 M people in developing countries and 34 M in developed countries are still undernourished.

Fig.1 Chronic undernourishment in the developing world.



At the 1996 World Food Summit all countries committed themselves to bringing down the world's hungry to 415 M. However, our latest assessment indicates that 580 M individuals would still be undernourished by 2015, with 23 countries having more than 25% of the population undernourished (5). Notwithstanding urbanisation, the majority of those suffering from food insecurity remain in rural areas. Cereals will remain the principal source of food supplies, accounting for about half of daily calorie intakes. Around half of the projected increase will be for food, and about 44% for animal feed. Feed use, especially in developing countries, will be the most dynamic element driving the world cereals economy.

The unbalanced availability of food is mirrored by the uneven application of improved production technologies. The inequalities refer to effective demand, productive capacity and economics. For example, the production of one ton of rice costs approximately 1,000 US\$ in Japan, 300 US\$ in Italy and in Niger and 80 US\$ in the Philippines. A detailed analysis is required to understand these differences.

Although, to a large extent, the uneven application of technology is caused by factors outside the realm of science, there is no reason for complacency. Scientists do bear a part of the responsibility for the selective applicability of technologies to more favourable ecological circumstances. The ethical questions here relate to what crops are addressed and what type of production systems are targeted.

2. The True Global Trend: Globalisation

In recent years, the world has expanded beyond the global village to the global market with ever increasing mobility of capital, labour and goods. Globalisation is not only a question of size, but also of kind: it is inextricably linked to privatisation. It sets afoot major economic restructuring in both developed and developing countries, and has greatly changed the balance of public and private sectors, also in science, especially because of privatisation of knowledge through intellectual property.

Globalisation, moreover, results in concentration. For the seed and agro-chemical industries, for example, it has been estimated that the world's top ten industries account for about 85% of the global market. In 1998, just four companies controlled 69% of the seed market in the USA (6). What will be the effects of the development of such huge conglomerates on the direction of scientific research, in particular in view of the evolving food needs?

In many countries, agricultural production for export is seen as one of the motors for development. This implies control over the various phases of production and a dependable export certification programme to meet regulations of importing countries. Although the World Trade Organisation's SPS agreement has set sanitary and phytosanitary standards, this has not yet resulted in less regulation and easier market access. Harmonisation, through the setting of international standards, is a process that still needs considerable efforts.

Whatever its potential benefits, the balance is mixed. Globalisation may exacerbate the existing differences among countries and regions and calls for specific strategies to be developed according to different needs. On the other hand, it has offered opportunities to the poorer countries, and driven rapid development and local capital accumulation.

3. The Emerging Response: Diversification of Diets and Crops

Partly in response to globalisation, but mostly as a result of rising incomes and urbanisation, global food demand is becoming more diversified and more quality oriented. This trend

appears also in developing countries, albeit with a time lag. As affluence increases further, we also observe consumer demand trends for food produced with technologies that are regarded as being environmentally sustainable, especially organic agriculture. But diversity is not just for the urban rich. There is convincing evidence that the low intake of micronutrients by the poor has lasting detrimental health effects (7). For the poor too, diversity in food production and consumption is essential.

New crops for food and industrial purposes may open up rural employment opportunities. The widespread adoption, recently, of sunflower as an oilseed in the Loess plateau of China is but one example. Similarly, the production and marketing of local traditional crops and varieties may satisfy urban demand and become a motor of rural development as in the case of indigenous leafy vegetables being grown for urban markets in eastern and southern Africa. Similar examples of the value of local varieties of foods are known in Europe.

Diversification of crops and products and increasing nutritional qualities demand a sophisticated scientific approach. Here, the ethical issue is again how choices are made and priorities are set with respect to the needs of specific underprivileged target groups.

4. The Background Trend: Agricultural Services to Society

The diversification of diets and products does not imply diversification of cropping systems *per se*. Intensive monoculture is still very much the trend in market economies. However, there is growing recognition that agriculture provides more services to society than just producing calories or dollars per hectare. By nature, agriculture deals with common goods and public concerns. Next to its economic services, the agricultural sector is increasingly held responsible for environmental services such as the preservation of watersheds, the protection of agricultural biodiversity, the sequestration of carbon, and possibly the production of renewable energy. Moreover, balanced national development implies maintaining rural livelihoods and traditions to keep remote areas liveable. As a result, rural activities such as nature conservation and agrotourism set new standards and limits for agriculture production systems. In fact, the term sustainability thus acquires an even broader meaning than before. Such multipurpose land use systems also herald an era of decentralised and participatory decision making. The ethical question for the scientist is how to provide an objective scientific basis, including indicators of environmental, economic and social impact, to allow adequate decision making on balanced agricultural growth.

5. The Overwhelming Trend: the Information Revolution

Information technology is shaping agricultural science and its application. Developing countries are quickly taking advantage of this situation. But we know that on the Internet scientific excellence and nonsense exist side by side. While information technology may be a great transboundary equaliser, the need for reliable sources of scientific data is growing. The ethical issue here is whether scientists, in the private and public sectors alike, are sufficiently sharing their results, including their doubts and failures.

B. The Scientific and Technological Challenges

Much is at stake for crop science: in order to contribute to poverty alleviation, sufficient food and a balanced diet for an increasing world population, intensive cropping systems need to be developed that have a beneficial or at least non-harmful effect on the environment and

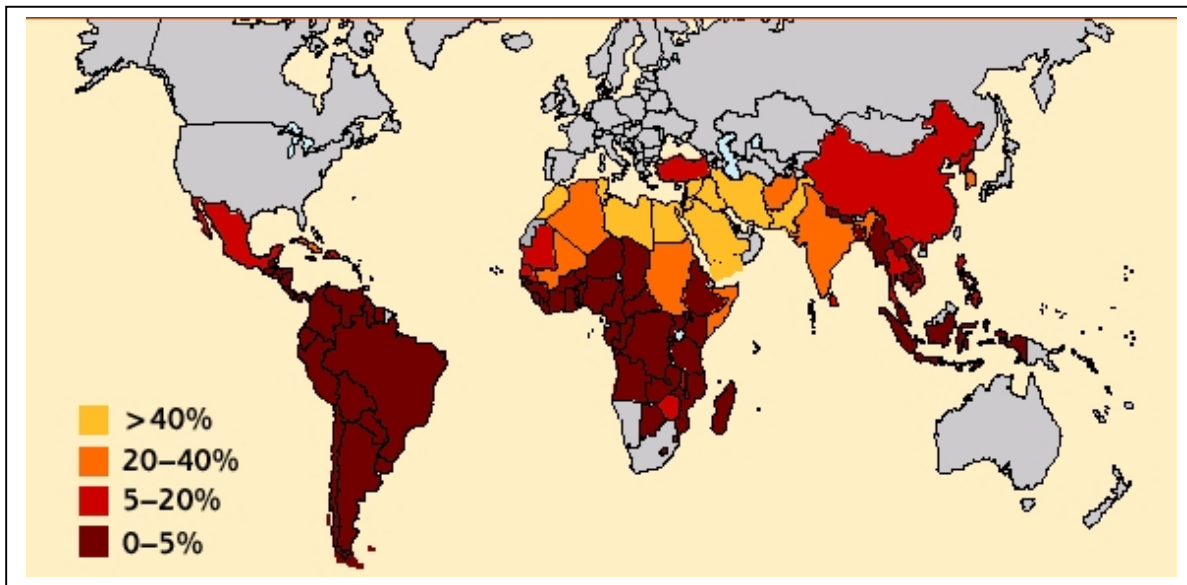
provide a multitude of services to society. Let me highlight five specific scientific issues in this respect.

1. Responsible Land and Water Use

The optimal use of land and water is the basis for land use intensification. Today, the world average per capita cropland has decreased to only 0,27 hectares, while in China it has dropped to 0,08 hectares per capita (8). We estimate that over 25 billion tonnes of topsoil is lost yearly (4), mainly due to deforestation and overgrazing. Erosion and cropping system-induced soil chemical changes all require research aimed at a better matching of crop species and cultivation systems with specific environments.

In Africa alone, average per capita fresh water availability has dropped from 20.6 to 5.1 thousand cubic metres between 1950 and 2000 as a result of population growth (9). A case in point is Morocco with a projected availability of only 780 cubic metres per person in 2025, while irrigation currently represents 92% of all water use in the country (4).

Fig.2 Agricultural water withdrawals as % of total renewable supplies: map of 93 selected developing countries showing where water withdrawals are critically high.



A maize crop producing about 8 tonnes/ha of grain consumes more than 5 million litres/ha of water during the growing season, requiring approximately 1,000 mm of rainfall or 10 million litres of irrigation water (10). Balancing the requirements of agriculture with those of population and industry forces crop science to re-examine crop yield performance. If crop yield is expressed per unit of water rather than per unit of land, and if realistic water pricing is applied, this may drive a significant shift towards crops showing a high return per unit of water. The expected shift from rice to wheat in China in the next 25 years for instance will have important implications in terms of water saving (5). More research is needed, not only on physiological mechanisms to increase water use efficiency, but also on simple techniques such as water harvesting that can both reduce risk and increase yields.

Tab. 1 *Irrigation efficiency and withdrawals for irrigation as a percentage of renewable water resources, 1996 and 2030*

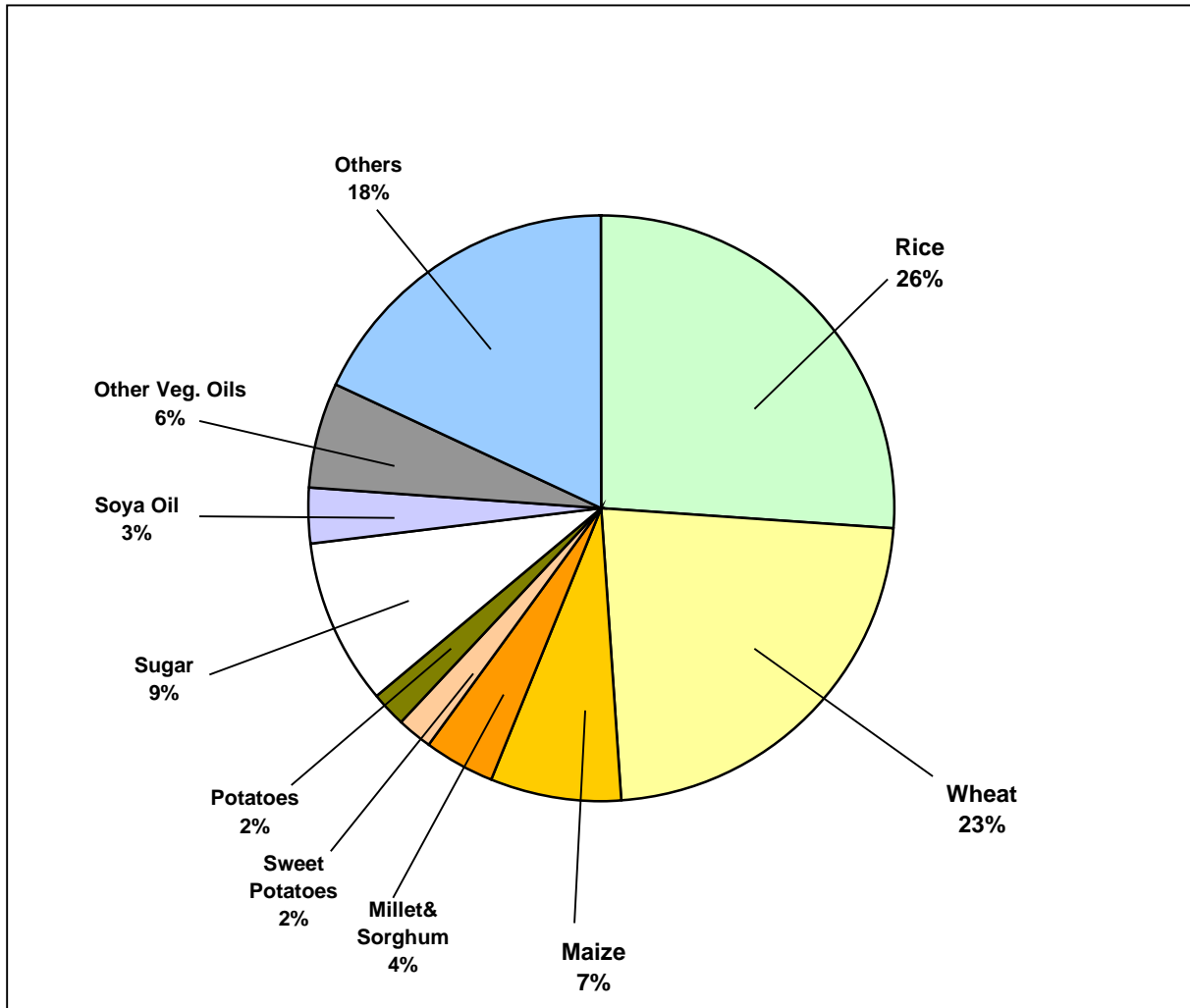
	<i>Sub-Saharan Africa</i>	<i>Latin America</i>	<i>N. East/ N. Africa</i>	<i>South Asia</i>	<i>East Asia</i>	<i>93 developing countries</i>
Irrigation efficiency (%)						
1996	42	26	50	49	38	43
2030	44	29	65	58	42	50
Irrigation water withdrawals as a % of renewable water resources						
1996	2	1	58	37	7	7
2030	3	2	67	41	8	8

We agree with the Draft Hamburg Declaration that water saving strategies in irrigated systems and better adaptation of crops to limited water availability deserve attention as such. Furthermore, within an integrated land and water approach, the logical complement to this is the development of new lines that are drought-tolerant. The revolution in molecular genetics seems to make it possible, at least in theory, to target quantitative trait loci and thus increase the efficiency of breeding for some traditionally intractable agronomic problems such as improved root systems.

2. Harnessing Diversity

Only 9 plant species alone provide more than 75% of all human food. A mere 3 plant species (rice, wheat and maize) provide more than half the dietary energy of the world's population (11).

Figure 3. Most important crops for food energy supply



Source: FAO Food Balance Sheets 1994-1996

This is largely the effect of a selective focus of agricultural science, which has hitherto neglected the domestication of a multitude of species. FAO recognises that food security calls for continuing work on the genetic improvement of the main crops. However, we also want to emphasise the need to explore a wider range of species that are already adapted to different ecological niches.

Domestication of new crops may be time consuming, but there seems to be a lot of scope in the improvement of locally important minor crops, which attract limited R&D resources. There is a key role here for international public science.

Whatever the species, a promising research line seems to be for higher net photosynthetic rates. Again, new molecular technologies may increase the possibilities of adapting C4 species to new environments and of transferring the C4 metabolism to important C3 species.

Food insecure populations would also benefit from a focus on multipurpose species. Chinese scientists have demonstrated the huge potential of sweet sorghum in terms of grain and biomass production for food, sugar, animal feed and bio-energy (12). Similarly, insufficient attention has been given to Biological Nitrogen Fixation (BNF). Although it is recognised that

possibilities exist for enhancing BNF performance of crop legumes, for increasing the role of legumes in cropping systems, and for transferring BNF capabilities to non-leguminous crop species (especially the major cereals), research has been fragmented, sporadic and under-funded (13).

Furthermore, there is considerable scope for taking a fresh look at perennial crops versus annuals, because of their reduced fertiliser requirements, protection against soil erosion and their provision of shelter for useful species. Let me cite just one example of a perennial species with a high potential for irrigated arid lands: the date palm (*Phoenix dactylifera*). Recently its cultivation has been introduced successfully in arid regions of southern Africa.

Let me mention also the potential for crop diversification strategies that promote mitigation (or reduction) in the emission of green house gases and favour carbon storage. Advances in agricultural ecology may lead to cropping systems that harness a wider range of natural resources and thereby divert solar energy to non-harvest species. FAO's IPM programme has demonstrated the benefits of enhancing associated biological diversity and promoting the role of non-harvested species that are critical to ecosystem functioning, even when actual crop diversity is low.

3. Sustainability: More Empirical and Integrated Approaches

Farming systems may be deemed sustainable and efficient if organic matter, nutrient cycling rates, soil structure, erosion and ease of root penetration are all at acceptable levels, and if this is proven by crop yields that are fully satisfactory in view of yield potentials, and by acceptable rates of off-site losses (14). This implies that research institutions must become more closely involved with real farms on a long-term basis in order to ensure that advances in crop science can be adapted to the scale and reality of production, especially in food insecure regions. Such pragmatism could help to offset the risks of fleeing into modelling and neglecting the empirical and applied work that really needs to be done in the field: the high prestige work tends to be behind the computer and in the lab. I am worried that crop science has become too atomised and specialised to be able to perform the integrating function needed to achieve sustainability. Neither curricula nor career development currently allow much opportunity for the creation of a new generation of empirical agronomists with sustainable systems design in their terms of reference.

4. Genetically Modified Organisms

The most forceful public questions are being asked about the sharing of benefits and the perceived negative effects on health and the environment of the uncontrolled application of genetically modified crops. FAO's position is that we must use every means at our disposal to improve food security subject to careful assessments being made. It is undeniable that one of the promising technical ingredients for agricultural development is biotechnology, because it will allow a more precise adaptation of genotypes to environmental conditions, nutritional and dietary needs and market preferences. But is biotechnology increasing the amount of food in the world and is more food accessible to the hungry because of it?

Regarding the potential risks associated with the transfer of genes, let me say that state-of-the-art knowledge is not yet adequate to predict either the adverse effects from the inserted gene itself, or the way in which the inserted gene may alter expression of existing genes. It should be emphasised that no human health problems resulting from biotechnology have been documented to date. However, lack of evidence of adverse effects is not the same as knowledge that genetic modification is safe. Internationally, food safety is addressed in the

FAO/WHO Codex Alimentarius, while the effects of living modified organisms on biodiversity are addressed in the Cartagena Protocol. But international and national regulation and risk assessments are relatively new, and public trust in these processes is low.

Plant breeding and biotechnology depend on naturally occurring genes. Agricultural biodiversity differs qualitatively from wild biodiversity and requires specific solutions. The most important genes are held within agricultural systems, at intra- and inter-specific levels, which have been evolving in a truly international endeavour since the Neolithic. No country can now do without genetic resources from elsewhere. A number of tropical or sub-tropical countries, poor from an economic point of view, contain the centres of origin of crop plants, and are rich in agricultural diversity. International co-operation for the management of plant genetic resources as a global common good is therefore not an option, but a necessity, which FAO member countries are pursuing through negotiation of the revised International Undertaking on Plant Genetic Resources. An important step in this direction has been the unanimous recognition of Farmers' Rights as the complement of Plant Breeders' Rights. The current challenge before us is to make this concept operative and to find a solution to the problem of access to the enabling technologies and end products which are subject to patent protection.

5. Transparency of Information and Decision Making

At the basis of public concern is a feeling of being left out, or worse, of not being told the truth. With the wisdom of hindsight we may surmise that science, and particularly agricultural biotechnology, could have done much more to get the public on its side by being open and communicative about its pioneering work in molecular biology and genetic engineering. It seems to me that *post-factum* attempts to overcome consumers' doubts through information campaigns have not helped much in allaying suspicions which have, by now, become entrenched.

The current debate over labelling of foods containing ingredients from genetically modified organisms has highlighted the need for transparency. Food industry leaders recognise that public confidence is essential to the success of any product and are aware of the public's ambivalence towards genetic engineering. Some leading food companies have excluded genetically engineered ingredients from their products but others are lobbying strongly against the public pressure to segregate GM foods. The net result is that polarisation over the issue of labelling continues to perturb public administrations and industry throughout the world.

There can be no doubt that scientists have an absolute moral responsibility in providing objective, peer-reviewed information to the public and to refrain from publicising immature, insufficiently tested results – positive or negative.

C. FAO and the Need for Concerted International Efforts

I have referred several times to FAO and the international public sector. Beyond taking up issues of common interest for which no immediate and remunerative markets exist, let me highlight two related areas where the existence of intergovernmental fora is essential. One is the area of sanitary and phytosanitary regulations, including food standards. In this era of globalisation, international regulatory mechanisms need to be developed to maximise the potentials and minimise the risks. Despite divided opinion, FAO is confident that consensus

on GM food standards can be achieved. We also believe that the conclusion of the Cartagena Protocol is a large step towards facilitating the protection of the environment. Other International Agreements, like the International Plant Protection Convention, may play a role in the sustainable use of GMOs. FAO has just established an international "ethics committee" to discuss, among other things, the implications of modern technology for food security and agriculture.

The second area is information sharing. A massive amount of information is now quickly available. However, there are few mechanisms to enhance the access of poor countries to information and to help decision-makers to sift through the significance and applicability of bewildering and often contradictory data. We are concerned that information resulting from scientific research is not adequately shared and spread, and that the information tools used are not always the most appropriate ones. We are actively promoting ways to remedy the situation.

We concur, therefore, with the proposal in the draft "Hamburg Declaration" - that DNA sequences of plant genomes should be released to a public database. In the context of the negotiations on plant genetic resources, such proposals could perhaps be regarded as a tax in kind whereby institutions and corporations would effectively devote some of their resources to respond to world food problems and open questions about equity.

Finally,

In the eight years since Ames, we have grown older and perhaps also sadder and wiser. To be a crop scientist today is not easy, especially when we see young and brilliant minds lured away into computer science or business administration and when public opinion considers that we are interfering with evolution. However, all of us have a responsibility toward the weak and the poor even if, in our rapidly globalising world, this is not self-evident. Crop scientists need to look beyond their sub-disciplines and support policy and regulatory measures to protect international public goods.

We must distinguish between the emerging global economy – which is a reality – and global society – which has yet to be built. It is perhaps in pursuit of the latter objective that the moral responsibility of science needs to be emphasised. As global markets and privatisation are not matched by global governance, many transboundary issues of concern to humanity remain poorly solved. Such issues are phytosanitary standards and risk analysis, optimal use of the earth's land and water resources, and the mitigation and contributing role of agriculture in global change. While we are more aware of the need to manage international public goods responsibly, the political tools to do so are weak, and, in the globalised economy, small countries, small companies and small farmers have very small voices. Scientists have moral responsibilities to speak for the weak, because they sometimes best understand the likely results of not doing so.

But our first concern must be to regain the credibility and public acceptance of agricultural science. To return once more to Sir Julian Huxley: what should drive us, as scientists, as international civil servants, is, in his words:

"..curiosity, initiative, originality, and the ruthless application of honesty - much more than feats of logic and memory alone."

This is, I believe, the ultimate challenge for the crop scientist: to put these moral qualities at the service of the problems of development and food security.

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