1P—1 PLANT PROTECTION FOR GLOBAL FOOD SECURITY

Dr. M. S. Swaminathan

PLANT PROTECTION FOR GLOBAL FOOD SECURITY

M.S. SWAMINATHAN

International Rice Research Institute, Los Banos, Philippines

ABSTRACT

Food security is a fundamental objective for mankind. To sustain the necessary agricultural growth to achieve this objective it is essential to overcome the undulations in production which are attributable mainly to weather fluctuations and pest and disease epidemics which are often inter-related. Public policies should also be directed to ensuring stability of production. Agricultural scenarios reveal trends towards increased productivity, but there is evidence that production is becoming more unstable and there are disturbing regional differences. Plant protection has a crucial role to play in increasing production and safeguarding yield but a co-ordinated inter-disciplinary approach is needed to ensure most effective progress. This is illustrated by reference to the work of the International Rice Research Institute. Progress in research must be backed by effective extension and education, appropriate government action and encouragement for active involvement by individual farmers.

Agricultural growth with stability of production

Food is the first among the hierarchical needs of man. Hence enduring food security has been a long cherished goal. Hopes have been expressed from time to time that human beings can be insulated against hunger through agricultural production plans involving an appropriate combination of political will, peasants' participation and professional skill. At the International Conference on Food and Agriculture held in May 1943 at Hot Spring, Virginia, USA, at the initiative of the late President Roosevelt, the participants declared the belief that "the goal of freedom from want of food, suitable and adequate for the strength and health of all peoples, can be achieved".

Even as the above declaration was being adopted, a great human tragedy was in the offing in the Bengal region of undivided India. The great Bengal famine of 1943-44 was in part triggered by the widespread devastation caused to the monsoon season rice crop by *Helminthosporium oryzae*. Interest in plant protection measures hence grew.

Historically, two major factors have been responsible for large undulations in crop production from year to year. The first is weather aberrations such as drought, floods, cyclones, typhoons and hailstorms. The second factor is pest epidemics. Often the two are inter-related. For example, some plant pathologists believe that the epidemic of *Helminthosporium oryzae* which reduced the yield of rice by 40 to 90 percent in different parts of Bengal during 1942-43 was largely due to heavier than normal rainfall which led to the leaching of nutrients from the soil and also unseasonal rain in winter which favoured the release of spores by the pathogen. Knowledge of the relationships between weather patterns and pest epidemics has helped the development of techniques for forecasting pest outbreaks and also procedures for raising disease free crops, as for example in potato in North India where seed potato crops are raised during the September-December season when the population of the aphid vector of virus diseases is minimal.

With progress in the process of agricultural modernisation, which implies the larger use of purchased inputs and reliance on markets for obtaining return from the investment made, public policies of Governments in areas such as input-output pricing, marketing and distribution, investment on rural communication and energy supply and land reform including land consolidation and levelling become equally important for ensuring stability of production. Thus, weather behaviour, the incidence of insect pests, pathogens and weeds and public policies relating to production and consumption are all now important in ensuring growth with stability in agricultural production.

Current global agricultural scenario

According to FAO statistics, the world cereal production in 1982 was 1560 million tonnes. This is about 3 percent more than in 1981. World grain stocks are now at record levels; at 21 percent of annual consumption they are much above the estimated needs for minimum food security. The improvements in food output witnessed during the last 20 years in many developing countries of Asia and Latin America are to a great extent due to the expansion in irrigated area and the cultivation of improved varieties of crops coupled with greater attention to the care of the soil and the health of the plant.

The current world cereal stocks amount to about 330 million tonnes, out of which nearly 47 percent are in the United States along. Also, a considerable proportion of the stocks is in the form of feed grains. Further, there is some evidence to believe that the world grain production while increasing at an adequate average rate, is tending to become more unstable (Table 1).

TABLE 1

Co-efficient of Variation[1/] over the Trend

(a) in yield per hectare of cereal crops

	1949-1959	1960-1970	1971-1981
World	0.20	0.20	0.27
North America[2/]	0.49	0.37	0.80
Soviet Union	0.87	1.23	1.44
France	0.51	0.57	0.87
Australia	1.44	1.44	1.70
Argentina	0.76	0.92	0.92

(b) in total cereal production

	1949-1959	1960-1970	1971-1981
World	0.22	0.23	0.28
North America[2/]	0.54	0.65	0.28
Soviet Union	1.01	1.13	1.55
France	0.50	0.61	0.93
Australia	1.92	2.05	1.80
Argentina	1.89	1.30	1.25

[1/] Defined as the standard error divided by the mean over the relevant period.

[2/] United States and Canada.

Source: FAO

Cereal production declined rather sharply in 1954, 1964 and 1974 in North America. Above all, the virtual stagnation in food production in many countries of Africa leading to a decline in per caput food production in 23 out of 42 African countries has made Africa the continent of concern on the food front. Consequently, the levels of cereal imports by developing countries have been increasing steadily. In the early 1970s agricultural imports represented some 40 percent of total exports in Africa. By 1981, agricultural imports were 25 percent greater than exports. To add to the difficulties, the terms of trade of agricultural commodity exports from developed countries have deteriorated by 9 percent since 1981. The prospects for food production during 1983 are clouded by unfavourable weather in several parts of Asia, Africa, Oceania and Europe and by the land set-aside measures in the United States for the purpose of reducing stocks and improving prices. The capital needed for the modernisation of agriculture in developing countries is becoming scarce. Thus, in spite of some spectacular progress during the last decade in parts of Asia and Latin America, there is no time to relax. Eternal vigilance is the price of good and stable agriculture.

The cost, risk and return structure of farming determines farmer's decisions on land and input use, wherever land is individually owned. In 1981-82, world fertilizer production declined for the first time since World War II. According to FAO, there was a sharp drop of over 15 percent in the consumption of fertilizers in Latin America. The increase in fertilizer consumption in Africa was less than 0.5 percent. Investment in new fertilizer production capacity is being deferred and there is every possibility that fertilizer supplies may fall short of requirements from 1986-87 onwards, unless something is done immediately to reverse the constraints in fertilizer use by small farmers, thereby generating the climate essential for greater investment in fertilizer production.

The above trends have to be viewed in the context of the growing number of undernourished people in the world on the one hand, and the feasible methods of enhancing production on the other. It is estimated by FAO that currently there are about 450 million undernourished people in the world and that this figure may go up to 600 to 650 million by the year 2000. The persistence of hunger in the midst of huge global grain stocks and declining prices arises largely from the lack of purchasing power particularly among landless poor in the rural areas of many developing countries. A famine of jobs or of opportunities for gainful employment in rural areas results in a famine of food for the poor. In the short term, this form of hunger can be conquered only by well drawn up "Food for Development" and "Food for Nutrition" programmes, somewhat on the lines of the ongoing World Food Programme. Food for Development aims at using surplus food grains for executing rural works designed to strengthen the ecological and physical infrastructure necessary for sustained agricultural advance. Food for Nutrition programmes cater to the needs of old and infirm persons, children and pregnant and nursing mothers. The two together provide the immediate method of ensuring that no child or woman or man goes to bed hungry.

As regards the production pathway open to most developing countries, yield improvement has to be the major and sometimes only method (Table 2).

TABLE 2

Pathways of production increase during 1975-2000

Region	Contribution to output growth (Percent)		
	Arable land growth	Cropping intensity	Yield
90 countries	26	14	60
Africa	27	22	51
Far East	10	14	76
Latin America	55	14	31
Near East	6	25	69

Source: FAO

In many parts of South East Asia, there is virtually no difference between cultivated and cultivable areas (Table 3).

TABLE 3

Cultivable and cultivated area (ha)

Region/Country	Cultivated land per capita	Cultivable land per capita
South Asia	0.27	0.27
East and South east Asia	0.22	0.36
China	0.15	0.15

Source: Colombo et al (1978). Trilateral Commission Report

Asia's ratio of land to people - 0.21 ha per person - is the lowest in the world. Thus, additional production must come from an intensification of agriculture consisting of higher yield per crop and more crops per year.

Pivotal role of plant protection in the emerging production scenario

Conditions which favour better growth of crops are often the same conditions which favour the multiplication and spread of pests. The very technologies which help to increase yield per units of land, water, time and energy are often the cause of increased threats to yields from pests. FAO estimates that worldwide, pre-harvest crop losses due to weed infestation, plant diseases, arthropods and vertebrate pests may be in the order of 30 to 35 percent. Post-harvest losses may amount to a further 10 to 20 percent. In addition, there could be qualitative damages occurring at the post-harvest phase due to aflatoxin production arising from high moisture content in grains promoting infection with *Aspergillus* species. Problems in grain drying can be compounded by the spread of photo-insensitive varieties of cereals which may attain grain maturity when the atmospheric humidity is still high. Thus, it is clear that increased attention to plant protection is essential for food security. The higher rate of production gain achieved during the last 15 years in countries like India during the winter season (i.e. November to April) as compared to the main monsoon season (i.e. May to October) is to a considerable extent due to the greater incidence of pests, diseases and weeds during the rainy season. Thus, an effective plant protection umbrella is essential during the main monsoon season for safe-guarding yield.

Plant protection : new frontiers

J.C. Harrar in his address to the first International Congress of Plant Pathology in 1968 expressed confidence that "the tragedies of the potato famine and the Bengal famine, and the great epidemics of the cereal rust, rice blast, bacterial blight and virus diseases of rice that have threatened crop production for decades, will not have their counterparts in the future". He attributed his optimism largely due to growing inter-disciplinary work leading to a better understanding of the whole plant in the context of its environment including host-pest relationships. Recent progress in chemical and genetic engineering and growing international co-operation have further increased the hope for avoiding large pest epidemics. I would like to illustrate how well planned inter-disciplinary work can help to prevent serious losses to the rice crop, taking the research underway at the International Rice Research Institute (IRRI) located in the Philippines as example.

The pest containment and management strategy followed by IRRI involves the following four major components:

Breeding high yielding varieties with multiple resistance to pests and pathogens

For this purpose, the world collection of rice germplasm material maintained in IRRI is systematically screened for reaction to major pests and diseases under a multidisciplinary Genetic Evaluation and Utilization (GEU) programme. Using the desirable donor parents, a dynamic hybridization programme is carried out. Currently 5,000 crosses are made every year at IRRI alone. In addition, all the GEU and other trainees who come to IRRI are encouraged and assisted in making a large number of crosses with varieties processing pest resistance and take the F_1 and F_2 seeds back to their respective countries. While the first variety, IR8, had a simple pedigree, most of the recent varieties like IR36, IR56, IR58 and others have many parents in their ancestry.

Varieties like IR36 have not only a very broadly based parentage including a wild species, Oryza nivara, but also are the products of selection at "hot spot" locations for major pests and diseases in different countries. For example, the breeding material which ultimately gave rise to IR36 was screened at hot spot locations in the Philippines, Indonesia (tungro virus), and in Orissa India (gall midge). As a result, IR36 has resistance to blast, bacterial blight, tungro and grassy stunt virus, biotypes 1 and 2 of brown planthopper, green leaf hopper, gall midge and stem borer. Further the variety is early (110 days in duration) and has tolerance to soil problems such as salinity, alkalinity, iron, boron and aluminium toxicities, and zinc and iron deficiency. It is no wonder that the variety achieved widespread popularity among farmers.

In view of the possibility of new biotypes multiplying selectively and thereby causing damage to widely grown varieties, IRRI has been engaged in anticipatory research in order to erect new genetic barriers against brown plant hopper (BPH), as and when a new biotype becomes important. Introduction of multiple resistance to pests is now an integral part of IRRI varietal improvement programme (Table 4).

TABLE 4

Disease and insect reactions of IR varieties in the Philippines

Variety	Blast	Bacterial blight	Grassy stunt	Tungro	BPH biotypes 1	2	3	GLH	Stem borer	Gall[1/] midge
IR5	MR	S	S	S	S	S	S	MR	MS	S
IR8	S	S	S	S	S	S	S	MR	S	S
IR20	MR	R	S	MR	S	S	S	MR	MR	S
IR26	MR	R	S	MR	R	S	R	MR	MR	S
IR36	R	R	R	R	R	R	S	MR	MR	R
IR42	R	R	R	R	R	R	S	MR	MR	R
IR56	R	R	R	R	R	R	R	R	MR	-
IR58	R	R	R	R	R	R	R	R	MR	-
IR60	R	R	R	R	R	R	R	R	MR	-

[1/] Gall midge reactions in India

The breeding strategies followed at IRRI for maintaining stability of resistance to major pests and diseases include the following scientific procedures:

Continuous identification of new genes for resistance to each of the major diseases and insects.

Sequential release of improved germplasm with different major genes to combat new races of diseases and biotypes of insects.

Pyramiding of two or more genes into the improved rice germplasm using pedigree method or population breeding approach.

Gene rotation to reduce the chances of development of races or biotypes.

Development of multi-line varieties.

Development of several varieties for a region with different genes for resistance.

Development of varieties with horizontal resistance.

Wide hybridization combined with disruptive mating to incorporate genes for resistance from wild germplasm.

Use of cell culture techniques to develop resistance to toxins produced by major fungal and bacterial diseases.

Thus, there exists in the breeders' assembly line a wide array of material which could be utilized in a scientific pest containment strategy through appropriate pre-release seed multiplication procedures.

Promoting integrated pest management

IRRI has been advocating integrated pest management strategies and demonstrating their efficiency in the farm level. The IPM procedure consists of:

Popularization of varieties with multiple resistance to pests and diseases.

Conservation of natural enemies of pests by avoiding indiscriminate pesticide sprays.

Promoting the use of effective chemical pesticides at the right time based on a survey and surveillance and early warning programme.

In addition, agronomic and cultural methods such as synchronous planting of varieties in an area are being promoted where appropriate.

Promoting government action which will help to bring about varietal diversification

Through its GEU, IRTP and other network programmes, IRRI supplies a wide range of breeding and advanced generation material to all interested national programmes. These and the material generated under the national programmes form a pool of valuable genotypes for resistance to pests and diseases as well as to adverse soil factors.

IRRI advocates a varietal diversification programme in every country where rice is important. Ultimately, however, it is the farmers who decide which varieties they will grow. Rice being a self-pollinated crop, farmers tend to keep their own seeds until they decide to opt for a new strain. Extension work should therefore aim at convincing farmers of the need to grow several varieties instead of only one in large contiguous areas. This will be possible only if breeders in national research systems identify several varieties for each area, all possessing a good yield potential and acceptable grain quality but different genes for resistance. Thus in the national rice production programmes, provision for varietal diversification and periodic varietal replacement will have to be made an inherent part.

Adding plant protection as an essential determinant of multiple cropping sequences

Scientific multiple cropping can become a valuable instrument of pest management. By growing crops with non-overlapping pest sensitivity in multiple and inter-cropping sequences, the pest problems can be greatly minimised. This is also true in the case of weeds. The incidence of wild oats in wheat fields in North India became less serious after the rice-wheat rotation became popular. Phlaris minor and wild oats were both serious before the spread of the rice-wheat rotation. Similarly, pink boll worm infestation in cotton became less of a problem after the early maturing cotton variety, Bikaneri Nerma became popular following the introduction of cotton-wheat double cropping sequence. The use of true sexual seed for propagating potato has opened up the possibility of avoiding the transmission of the major potato virus diseases, although the potato spindle tuber virus and two minor viruses may be transmitted through true seed. Thus, plant protection based cropping systems research can become a useful tool for pest management.

Social engineering and farmers' participation

The average size of a farm holding in many developing countries is less than 1 hectare. If all the farmers in a village or a watershed will co-operate in crop and varietal choice and in the adoption of plant protection measures, efforts in the pest-proofing of an area will be more effective and less expensive. In countries like China where land is socially owned, community plant protection systems exist. In recent years a household responsibility system of crop production has been superimposed over social land ownership. This provides a mechanism for blending collective management of farm operations such as plant protection and irrigation with individual enterprise and incentive. In countries where land is individually owned, new systems of small farm management should be promoted which can help marry individual initiative with group endeavour. Agricultural research and development organisations can help by demonstrating how enlightened self interest demands that farmers living in a watershed or village participate co-operatively in operations that can elevate and stabilise yield per unit of cash input.

The major emphasis in all plant protection demonstration projects should be on the active involvement of farmers in the processes of crop protection. Farmers have the great capacity to adapt new techniques to local situations and hence should not be treated merely as passive consumers of pesticides. Only when this happens will the scientific concept of integrated pest management become a reality at the field level.

2P—1 TRENDS IN THE WORLD ECONOMY
Dr. William A. Johnson

2P—2 FUTURE DEVELOPMENTS IN WORLD AGRICULTURE
Professor C. R. W. Spedding

TRENDS IN THE WORLD ECONOMY

WILLIAM A. JOHNSON

Chief Economist, Tenneco Inc., Houston, Texas, USA.

ABSTRACT

The general global economic climate within which all agricultural and crop protection activities must operate is reviewed. Recession, unemployment and high interest rates have created considerable problems, but there are now signs of recovery. It is vital that protectionism is resisted if this recovery is to be sustained.

INTRODUCTION

Monetary policies

Until recently, the predominant response to the 1979-80 oil price shock by most western governments was to try to contain and diminish its possible inflationary effects by relatively restrictive monetary policies. The fiscal policies of these governments, on the other hand, have generally been expansionary. This has led to lower rates of inflation in Europe, Japan and the United States. It has also led to most governments of the industrialized world being forced to borrow more heavily on private capital markets to finance their deficits. This, in turn, has contributed to relatively high rates of interest and low levels of investment.

During the past year, there has been some erosion in this common policy of monetary restraint. Monetary authorities in the United States, Japan and most European countries have begun allowing higher rates of money growth in an effort to stimulate recovery and reduce unemployment.

However, the U.S. Federal Reserve, while relaxing its tight money policies, has not changed its fundamental objective of a lower rate of inflation. Rather, by July 1972, the Fed recognized that its policies had resulted in greater tightness in money supply and a lower rate of inflation sooner than it had anticipated. Because the U.S. inflation rate had fallen more rapidly than expected, the Fed had greater room to manoeuvre. It could sacrifice some of this improvement in inflation for a short-term stimulus to growth. It could also add greater reserves to the U.S. banking system in order to help offset fears, both in the United States and abroad, of a possible financial collapse.

The easing of monetary policy in Europe and Japan varies from country to country. While West Germany's Bundesbank is still following fairly restrictive policies, the Bank of France has been directed by the Mitterrand Government to adopt substantially more expansionary policies. Of the other western European countries, only Switzerland and the Netherlands have been able to match West Germany's relatively restrictive credit policy and low rate of inflation. As a result, the European Monetary System is being strained to the point of collapse.

Interest rates and prospects for growth

Because of the loosening of monetary policy in most industrialized countries, lower rates of interest and higher rates of growth are likely within the next year. For the time being, substantial excess productive capacity should tend to dampen any inflationary pressures that might result. Over the long run, however, one can expect somewhat higher rates of inflation than would otherwise occur.

Europe and Japan have routinely blamed relatively high U.S. interest rates for their inability to bring down their own interest rates without causing further depreciation of their currencies against the dollar. Yet, even though U.S. interest rates have now fallen sharply, these rates remain relatively high and the dollar surprisingly strong. The reasons for this have been, for the most part, internal to western Europe and Japan. With unemployment reaching new highs, governments around the world are under increasing pressure to refocus their policies on creating jobs rather than fighting inflation. However, already large budget deficits leave little scope for further fiscal stimulus. High government deficits in western Europe, especially, have drained available domestic savings away from productive investment.

Some responses to high unemployment

In addition, to help lessen the social and political consequences of higher unemployment, most European countries have forced their private sectors to assume an increasing share of welfare payments and unemployment benefits that would normally be borne by the public sector. In effect, these governments have forced their private sectors to finance some of the fiscal deficits that they have not been able to finance by other means. This has happened in the United States also, but to nowhere near the same extent as elsewhere.

For example, restrictions on lay-offs have increased in many European countries. So, too, has redundancy pay to employees who are dismissed. In many European countries, labour representatives in work counsels participate in and, in some instances, can veto key decisions by management. Several countries have adopted or are considering measures that would require companies to indemnify communities for the closing of plants, while Sweden is adopting "wage earner funds" that would allow the purchase of equity and eventual ownership of companies by labour. These policies have contributed to capital flight to the United States. This, in turn, has helped keep the dollar strong despite declining U.S. interest rates.

Let me hasten to note, at this point, that a major exception has been the United Kingdom. In the U.K., the Thatcher government, especially since 1981, has implemented a number of policies that have increased unemployment, discouraged work stoppages, and lessened the power and influence of unions. The end result, I believe, will be a much healthier economy in the long run, with higher growth in productivity and greater competitiveness relative to the rest of Europe.

Other factors influencing capital flow

Other factors have also resulted in a flow of capital from Europe, Japan and Latin America to the United States. The United States, for example, appears to have obtained better control over its inflation rate than most of its trading partners. Also, during the past two years, the Japanese have kept their real interest rates at extraordinarily low levels. This has encouraged investment by Japanese financial institutions and businesses in the United States. In several countries, including Argentina, Brazil, Canada, France, Mexico, Spain, and Sweden, the climate for private investment, and foreign private investment in particular, has deteriorated during the past two years. Because of this, each of these countries has suffered fairly massive outflows of capital, much of it to the United States. This, too, has kept the dollar strong.

There has also been a notable increase in political instability worldwide. There have, for example, been changes in governments or, at least, heads of governments in most major countries within the past 18 months. Countries experiencing these changes include: Australia, Austria, Argentina, Belgium, Denmark, Colombia, West Germany, France, Greece, Italy, Japan, Mexico, the Netherlands, Norway, Portugal, Spain, and Sweden. The direction of these changes seems to be about evenly split between left, right, and no perceptible movement either way. The great instability of many foreign governments and the seeming inability of moderate parties, especially, to form workable majorities in most countries is one more reason for a growing lack of confidence by investors abroad. By contrast, the United States has become a relatively safe and stable haven for investment in both physical and financial assets. For this reason, too, both the value of the dollar and the level of foreign investment in the United States have remained strong despite sharply lower U.S. interest rates.

To some extent, this may be changing. The Conservatives' re-election in the United Kingdom on June 9th and the establishment of reasonably stable right-of-centre coalitions in West Germany and the Netherlands could, over time, help stem the movement of capital to the United States.

Trends in inflation and demand

There has been a significant slowdown in inflation worldwide. However, there are also significant differences in the degree of disinflation from country to country. Most important, the inflation rate in the United States, as measured by the GNP deflator, has fallen from nearly 10% in 1980 and 1981 to about 4% to 5% at present. This has brought the U.S. inflation rate to well below the average for all industrialized countries for the first time since the mid-1970s. On the other hand, inflation rates in a number of other countries, including Argentina, Brazil, Canada, Colombia, France, Italy, Mexico, and Spain, remain stubbornly high at double-digit and, in some cases, triple-digit levels. Among the world's major economies, only those of the United Kingdom and Japan have posted a better inflation performance than the United States.

Relatively modest wage increases in a number of countries, especially in the United States, the United Kingdom, and West Germany, have contributed to widespread disinflation. However, they have also contributed to a drop in real disposable income and lower domestic demand throughout most of the industrialized world. Interest rate- and income-sensitive expenditures on housing, consumer durables, and inventories have been cut back. The prolonged weakness of consumer demand has been a major reason for depressed levels of aggregate demand in most countries. Government expenditures, on the other hand, have been the only major component of aggregate demand that has generally been strong.

Regional problems

By far, the greatest economic and political deterioration has occurred in Latin America. Regional GDP growth decelerated from 5.8% in 1980 to 1.3% in 1981. This is the lowest rate of growth for Latin America recorded since reliable data have been available for the area as a whole. The economic performance of Brazil and Argentina has been the poorest in the region.

Growth in Mexico's economy was quite brisk in 1981, but has now collapsed. Together, these three countries account for 85% of Latin America's GDP.

A major reason for this regional slowdown is that many Latin American countries, pressured by severe constraints on their external accounts because of low commodity prices, high interest rates, and an extremely strong U.S. dollar, have been forced to cut their spending and tighten their monetary policies. In addition, the real prices of most commodities produced in Latin America, expecially metals, are now at their lowest levels in decades. A major reason for this is a lack of speculative interest. Declining inflation and real interest rates have discouraged the holding of inventories and reserves of these commodities.

The softening of oil prices, while undermining the economies of Mexico and Venezula, has brought some relief to Latin America's oil-importing countries. However, overall, the region's current account deficit deteriorated from $28 billion in 1980 to $34 billion in 1981, forcing a net decrease of almost $2 billion in its internatinal reserves for the second year in a row. In an effort to finance their current account deficits, most Latin American countries have resorted increasingly to short-term borrowing. Loans to countries in the region with repayment periods of less than one year rose to nearly $90 billion by the end of 1981. As the following table indicates, one result of the region's attempt to live beyond its means is that four Latin American countries -- Brazil, Mexico, Argentina, and Venezuela -- now have the dubious distinction of being the world's four most indebted countries. (Table 1).

TABLE 1

The World's Largest Debtors
(billions of U.S. dollars)

	Total Foreign Debt	Loans from Private Banks
Brazil	$87.0	$67.5
Mexico	81.0	68.0
Argentina	36.6	27.5
Venezuela	35.5	29.0
South Korea	35.0	21.4
Poland	26.0	24.0
Indonesia	21.9	9.6
Egypt	19.0	5.5
Chile	18.2	12.0
Philippines	18.0	11.6
Colombia	10.5	6.4
Thailand	10.2	6.0
Nigeria	10.0	8.0

Source: Wall Street Journal, Sept. 15, 1982

Latin America is also in a class by itself in its inflation rate. As measured by the consumer price index, Latin America's combined inflation rate was 73% in 1982. This rate has now accelerated for four consecutive years. Latin America will continue to face serious inflationary pressures throughout the 1980s.

As a result, most Latin American countries will have to take drastic measures to avert a serious currency crisis. Among other things, they will have to abandon efforts to peg their currencies to the U.S. dollar, not only to prevent overvaluation with respect to the dollar, but with respect to other relatively hard currencies as well. Barring some restructuring and rescheduling of debt, several Latin American countries could be forced into default within a year or two. In any event, they will be faced with weaker export markets, more severe debt service requirements, lower growth rates, higher unemployment, and, most likely, substantially greater political and social unrest.

Future prospects

The world economy is now bottoming out of the recession, the longest recession since World War II. The U.S. economic recovery began in January. U.S. real GNP grew at a 2.5% seasonally adjusted annual rate in the first quarter of 1983. There are also signs of recovery in Europe. However, real GDP in Germany is at 1979 levels; real GDP in the United Kingdom, at 1975 levels. Industrial production in most European countries has fallen to 1977 levels. There have been many corporate bankruptcies in both financial and non-financial sectors in both Europe and the United States. Unemployment was a record high 32 million people in the OECD countries at the end of 1982. Europe, especially, has a long way to go before it regains pre-recession levels of performance.

The recession in the industrialized economies has reduced the overall volume of world trade. It has also increased demands for protection in Europe, Japan, and the United States. This, I believe, is the greatest threat now facing the world economy -- not high U.S. interest rates or a strong U.S. dollar. A local content law, which is now being debated in Congress, "anti-dumping" import duties and continued protection for inefficient and out-of-date industries, which is common in Europe, and non-tariff barriers to trade, a favourite of the Japanese government, are all undermining world trade and, in this way, raising prices to consumers, lowering real income, and discouraging demand for goods and services worldwide. This could, in turn, weaken the recovery and plunge Europe, and the world, back into recession.

2P—2

FUTURE DEVELOPMENTS IN WORLD AGRICULTURE

C. R. W. SPEDDING

Director, Centre for Agricultural Strategy, University of Reading

ABSTRACT

The main forces shaping world agriculture are examined, for both developed and developing countries. The central issue currently is overproduction in the former and millions of hungry people in the latter. The solution to overproduction must involve the development of alternative systems of production, such as fuel cropping, that do not suffer from the same defects. Food aid, exports and lower input/lower output systems may also play a part. Other factors that will influence developments are concern for animal welfare, conservation, amenity, pollution and relationships between diet and human health. In developing countries, the essentials are to encourage food and fuel production by those most in need.

INTRODUCTION

Although the future cannot be predicted with any certainty, it is important to think hard about it, partly because it can be influenced. One way of considering the future of world agriculture is to examine the main forces that will shape it. These differ in different parts of the world but can be looked at in relation to (a) developed and (b) developing countries. The backcloth against which all this has to be seen, however, consists of certain major facts that will affect all of us. Chief amongst these are the gross inequalities that exist between people, within and between countries, to which the Brandt Commission drew attention in their Report (1980), in terms of their wealth and well-being.

After years of concern about population increase and the capacity of world agriculture to produce enough food, it is now clear that we are currently faced with massive undernutrition on the one hand and substantial overproduction on the other (Table 1), although it is difficult to be sure how long the latter may last. There are dangerous risks of oversimplifying both issues but they cannot be ignored.

TABLE 1

Estimated number of people undernourished	800 million destitute 12 million children (under the age of 5) die of hunger (1978 alone)

Source: Brandt (1980)

Overproduction of cereals (all grains)	World consumption (M tonnes)	Stocks as % of use
1960	831	24
1967	1016	19
1970	1142	14
1978	1433	16
1979	1442	14
1980	1452	12
1981	1466	15

Source: F. T. Rees (1983)

OVERPRODUCTION

Let us start with overproduction, as the most pressing EEC agricultural problem, and let us accept that (a) producing too much may be a great deal better than not producing enough; (b) since agriculture is so weather-dependent, producing enough in all years is bound to mean overproduction in the favourable years; and (c) the quantities produced in excess of current demand may not represent a high proportion of amounts consumed or even traded.

Even so, the cost of disposing of such surplus has become so high that something has to be done. Thus the shape of Agriculture in developed countries is bound to be influenced by this problem and by the way in which it is solved. It is likely that the problem will not fade away but will continue to grow, and with high fixed costs farmers feel forced to produce more even if (or especially if) the price for the product falls. Of course, if it fell sufficiently, some farmers would go out of business - unless they were supported by what would increasingly be seen as a social subsidy. This would not necessarily reduce production unless land was farmed for lower output or not at all (hard to advocate in a hungry world).

Much thought has been given to ways of reducing overproduction by applying sanctions or disincentives to those involved: but such farmers must have sufficiently attractive alternatives and much less thought appears to have been given to the possibility of encouraging farmers currently producing, for example, milk or cereals, to move into other enterprises that are needed but may not yet be economic.

Fuel cropping is one example (Carruthers & Jones, 1983), where there is no danger of overproduction, where current oil prices make biofuels less than profitable but where it is likely to be quite different in the future. Financial encouragement would lead to rapid, practical development of the technology and might be a cheaper way of reducing surpluses than present methods of disposal.

There are thus 5 main ways of tackling the problem of overproduction: (a) expansion of exports; (b) food aid; (c) conversion of surpluses into new products (including fuel); (d) development of new enterprises; and (e) adoption of lower input/lower output systems. In the longer term, exporting food from the EEC to developing countries is feasible, provided that their incomes rise. In the meantime, in spite of the well-known deficiencies of food aid (Jackson, 1982), some direct aid of this kind will probably be necessary (Brandt, 1980).

The adoption of lower input systems does not necessarily imply lower output per unit area but it could do so if profitability could be maintained: this would depend a good deal on the level of fixed costs. Many inputs are used wastefully, including fertilisers (Greenwood, 1982) and many are used unnecessarily, in the sense that they are applied as an insurance (many sprays and anthelmintic drugs) against disease even when it would not have occurred. Since these inputs are very costly, low input systems are bound to be considered, especially if the alternative is that land may be put out of production in order to reduce surpluses.

Agricultural research has tended to focus on greater output per ha (and per man) and may have gone too far in these directions. Land is not the only important resource and, at least to those who own their land, may not be the most expensive: labour is not a scarce resource any longer in the developed countries and has not been in the developing countries except at critical times. The possibilities of profitably using more people and lower physical inputs have not been adequately explored but production systems of the future may well move in this direction (Spedding, 1982). Certainly, it is likely that more selective use of inputs will be the aim, in order to reduce cost, risks of pollution and risks of a build-up of resistance in disease-producing organisms.

However, in spite of the importance of economic factors, other forces will also shape the pattern of agriculture in developed countries. Chief amongst these will be concern for (a) animal welfare, (b) conservation, (c) amenity use of land, (d) pollution and (e) human health in relation to diet.

(a) Strong public pressure will probably force change in the ways that sows, calves and battery hens are kept. It is no use arguing about right and wrong, what is cruel and what is not or whether this can be measured or proved. In a civilised society a consensus has to be formed that judges some practices acceptable and others not: there are clear signs that some current farming practices are judged not to be acceptable. In these circumstances, research should be aimed at devising acceptable alternatives.

(b) Conservation of natural beauty, and of rare plant and animal species is also strongly felt about and logic may have little to do with it. It is a legitimate interest and thought has to be given as to how it is to be paid for.

(c) The use of land is of concern to all citizens and needs other than those of agriculture and forestry have to be considered.

It is worth noting that (a), (b) and (c) would probably result in lower output (arguably desirable) but higher cost per unit of product or additional costs in other directions. (d) and (e) are related and concern about the interactions between methods of food production and human health is growing rapidly. The interest in organic farming is one reflection of this but the issue is much wider (Robbins, 1978; Jollans, 1982) and includes effects of processing, additives and the relationship between diet and the incidence of, for example, coronary heart disease (Passmore, Hollingsworth & Robertson, 1979).

NEW ENTERPRISES AND NOVEL PRODUCTS

The majority of agricultural research appears to be directed to the major products and the processes underlying their production. Perhaps too little original thought is devoted to quite new products and production processes. Reasons for devising new production systems have already emerged in relation to low-cost systems, those devoted to raising animal welfare standards and improving human health. But there are also straightforward agricultural reasons, of greater variety and flexibility, of ability to use wastes and integrate enterprises, so that the waste outputs of one enterprise are the input for another.

Energy crops have been mentioned but new oil crops may be important, too; microbial plants are being considered within a general biotechnology umbrella and this may lead to major industrial production of raw materials. Past knowledge of fibre and medicinal crops may become relevant again.

In the field of animal production, in addition to novel methods of reproduction in existing livestock, the farming of fish, deer and rabbits is developing; but the use of invertebrates (snails, earthworms, insects) is at a very early stage and only just being taken seriously in the case of earthworms. There ought to be greater encouragement of truly original thinking in this area, with a host of new ideas being explored at a low-cost level (before economic potential can even be estimated).

At what might appear to be the opposite extreme of future development are the prospects of automation and computerisation.

MINICOMPUTERS

In many ways, this revolution has already occurred and the spread of minicomputers has been considerable. Their cost may be expected to continue to decline but this is less likely to apply to software and application may depend upon the scale of degree of standardisation. Thus office work in agriculture can be easily transformed: it is less easy to see how grazing conditions will yield the information necessary for the application of computers. In developed countries, particularly those with long winters, grazing could decline and animal production could be mostly undertaken indoors. This is unlikely in other parts of the world, however, where computers would seem totally irrelevant to the livestock owners of the developing countries.

TRENDS IN DEVELOPING COUNTRIES

The hungry millions of the world are in the developing countries and the problem is essentially one of poverty: the hungry cannot afford to buy food. There is no real shortage of food or capacity to produce it; indeed, as the first part of this paper illustrates, overproduction is a major concern of the developed countries. Whether this situation will be maintained is another matter. Although the capacity to produce food is very great, current practices in many parts of the world are causing erosion and thus the loss of agriculturally-useful land. Furthermore, most of the main ways of increasing food production require high inputs of support energy and this may be a major future limitation on development.

Help is certainly needed by the developing countries and the developed countries ought, in their own interests as well as for moral reasons, to establish effective mechanisms for giving aid. Past methods have well-known drawbacks but there is a great reservoir of expertise and experience to be drawn upon in order to devise better ways of helping. Almost certainly, the problem of feeding the hungry depends upon greater local production (involving education and training and, perhaps, television), more land being used, irrigation, better use of animal traction, appropriate mechanisation and the development of efficient, low-cost systems of production. It also has to be recognised that the problem is not simply one of food production but also fuel (including fuel to cook the food). Forestry and Agro-forestry are therefore likely to be of immense importance and advice has to be of the necessary breadth to embrace all these linked requirements.

There has to be a vast increase in the agricultural productivity of the Third World and this is bound to require inputs. But they will need to be sensibly and appropriately packaged and thought needs to be given to helping small farmers especially. It is not sufficient to introduce innovatory packages that require inputs that only the large farmer can afford. Such developments may increase food production but leave the number of hungry people unchanged or even increased. Not all the hungry people are rural, of course, but agriculturally-led growth has a multiplier effect on other sectors, including those concerned with the handling of food products. As production increases, so will fluctuations in supply, due to seasonal variation, and there will be a great need for cheap but effective storage facilities. The losses, in production and thereafter, are currently so large that loss-reduction could be considered quite as important as production increase. In both, however, it is likely that inputs of agro-chemicals will be needed, combined with (and consistent with) better but economically-feasible methods of storage (and probably transportation).

Greater production will almost certainly require fertiliser on a substantial scale. However, the problems of the third world are not going to be solved simply by massive inputs: there will have to be a greater understanding of the systems to be improved and how this can best be done. Appropriate biology, as well as appropriate technology will be required, and skilful integration of all the resources used. This will include the integration of agriculture and forestry, not only to control erosion but as a simple recognition that food has to be cooked. Food and fuel production have to be considered together.

This is what agricultural research should concentrate on and it is in this area that the skills of the developed countries could be most usefully applied. The importance of agricultural research is reckoned to be continually under-estimated (IFPRI, 1982) and the returns to investment in agricultural research have always been shown to be high, wherever they have been estimated (Ruttan, 1982).

REFERENCES

Brandt, W. (1980) *North-South: A Programme for Survival*, London: Pan Books Ltd.

Carruthers, S. P.; Jones, M. (1983) Biofuel production strategies for UK agriculture. *CAS Paper No.* 13, University of Reading: Centre for Agricultural Strategy.

Greenwood, D. J. (1982) Quantitative theory and the control of soil fertility. *The Blackman Lecture, 1982.*

IFPRI (1982) The evolution of an interlinked global agricultural research system. *International Food Policy Research Institute* 4(2), 1-4.

Jackson, A.; Eade, D. (1982) *Against the Grain: The Dilemma of Food Aid*, Oxfam.

Jollans, J. L. (1982) Agriculture and human health. *CAS Discussion Paper*, University of Reading: Centre for Agricultural Strategy.

Passmore, R.; Hollingsworth, D. F.; Robertson, J. (1979) Prescription for a better British diet. *British Medical Journal* 1, 527-531.

Rees, F. T. (1983) The global market. *Symposium on "Towards the '90s - Cereals and oilseed rape"* 6 January 1983, London: RAC and BSAF UK.

Robbins, C. J. (1978) Food, health and farming: reports of panels on the implications for UK agriculture. *CAS Paper No. 7*, University of Reading: Centre for Agricultural Strategy.

Ruttan, V. W. (1982) *Agricultural Research Policy*, Minneapolis: University of Minnesota Press.

Spedding, C. R. W. (1982) Concern for the individual animal. Wooldridge Memorial Lecture. *Veterinary Record* 11(5), 345-349.

3P—1 INTERNATIONAL CHALLENGES TO THE AGROCHEMICAL INDUSTRY

Dr. A. Hayes

3P—2 INTERNATIONAL ASPECTS OF CROP PROTECTION—THE NEEDS OF TROPICAL DEVELOPING COUNTRIES

Dr. T. R. Odiambho

3P—3 TRANSNATIONAL CROP PROTECTION PROJECTS

Professor R. F. Smith, Dr. D. G. Bottrell

INTERNATIONAL CHALLENGES TO THE AGROCHEMICAL INDUSTRY

A. HAYES

Imperial Chemical Industries, PLC, IC House, Millbank, SW1.

ABSTRACT

Problems which must be considered if the technical challenges facing the agrochemical industry are to be met are reviewed. These problems fall under three headings : safety, economic and political factors. In each case the requirements are becoming more demanding, but the agrochemical industry is adapting to changing circumstances and can continue to make a major contribution to world food production given reasonable operating conditions.

INTRODUCTION

I welcome the opportunity to present this paper in my capacity as President of GIFAP, the international trade association which represents the views of industry to those international organisations with a part to play in the regulation of agrochemicals around the world. Despite my recent move within Imperial Chemical Industries PLC from the Chairmanship of Plant Protection Division I retain a firm and continuing interest in crop protection.

It is self evident that there are many challenges which the agrochemical industry must meet. This Congress is technically based, so I believe it will be useful to concentrate in this paper on those other problems which must be faced in order that the industry can meet its technical challenges. These other problems fall under three main headings : safety, economic and political considerations.

THE TECHNICAL CHALLENGES

It is universally recognised that our major technical challenge is in helping agriculture throughout the world meet its obligation to feed this planet's burgeoning population. In responding to this technical challenge, the agrochemical industry has become the major innovator of products which provide agriculture with the means to improve and safeguard yield and quality. So far, most of the activity has been in the invention of novel chemicals which have produced significant advances in the control of weeds, insects and fungus diseases.

The last twenty years have seen the emergence of both general and highly selective herbicides; of new pesticides which have more than kept pace with the emergence of insect and fungus resistance; and of several novel plant growth regulators. All these developments have improved agricultural management.

In the next decade, undoubtedly, there will be breakthroughs in plant breeding techniques aimed at the production of new varieties which will have qualities not only designed to cope with insect and disease problems but which will also incorporate complementary characteristics from the agrochemical world - for example, plant varieties with a built-in resistance to certain of the herbicides that have to be used.

Outstanding developments will also be made in application systems. The great agrochemical revolution has so far been based largely upon chemicals alone. However, as technology becomes more and more advanced, it will be possible to pay closer attention to other practical and desirable considerations, such as avoiding the need for large quantities of water to carry the pesticides, or reducing the side effects of the chemicals in the environment or, most importantly, increasing safety for all concerned in their use. There will inevitably be a revolution in the means by which agrochemicals are applied to the crop.

However, we have to face up to the fact that conditions of agriculture in the developed world and those in the developing world are markedly different and that if we do not tackle the problems which are particular to the under-developed areas then all the inventiveness in the world will not enable the industry to fulfil its obligation to agriculture on a world scale.

THE SAFETY CHALLENGES

When agrochemicals are used properly there are no problems. However, for an agrochemical to be used it has to be manufactured, stored and transported and the whole chain of manufacture through to end use does mean that there are waste materials which must be safely disposed.

Most of the bad publicity which our industry faces in the developed world arises from problems associated with storage, transport and waste disposal. Fires in warehouses, accidents during transport and unfortunate consequences of bad waste disposal hit the headlines from time to time. However hard one tries, some accidents will happen. This only emphasises the importance of ensuring that all who handle agrochemicals and the waste from them are aware of the correct methods of handling the material and of ensuring that if accidents do happen there are adequate safeguards for containing the problem.

In developing countries, the difficulties are more to do with the way in which agrochemicals are used by the farmer, and with the factors arising from the way in which the materials are presented to him. It is often said to be the responsibility of the manufacturers to ensure that their products are used properly and to make the user aware of the dangers of misuse. My only quarrel with the last statement is that I would change it to say that the industry has a responsibility but that it has to be shared with other bodies. This makes it vital for the industry to work with the relevant government departments in each country, for it is only in the context of the total agricultural economy that adequate education and training can be given and it is only the authorities who are in a position to insist on them. Given that, and an official infrastructure for training, industry has a partner with whom it can try to ensure that the end users understand the correct and safe way to use agrochemicals.

Apart from the activities of individual companies which give training in connection with their own specific products, GIFAP has been busy producing guidelines for more general programmes. The first of these deals with safe handling of pesticides during their formulation, packing, storage and transport. This has been followed by guidelines on safe and effective use, giving commonsense advice for the application of pesticides and how users should take care on the farm. These guidelines are now available to anyone who wants them, from GIFAP and from the national trade associations of the twenty-four countries in membership of GIFAP. Some tens of thousands of copies have been distributed so far. Further guidelines on other important safety challenges are being produced.

On an international basis GIFAP has long been an active supporter of the FAO action in recommending to governments the harmonisation of pesticide regulation requirements : it is right that agrochemicals should be regulated for safety's sake, but not so stringently that essential materials are denied to those who depend on them. That is why GIFAP also strongly supports the view that each country should have its own pesticide registration scheme along the lines laid down in the FAO document. However, GIFAP believes that it is for each national government to determine which products should be used in its agriculture and that each government should ensure that it has at its disposal the information required for it to make that decision.

We often hear comment about the behaviour of multi-national companies operating in the Third World. Whether or not this comment has any validity in the general sense, I strongly reject adverse criticism in the agrochemical context. It is my belief, and I know that belief is backed up by many concrete examples, that developing countries usually find multi-national agrochemical companies good suppliers with a responsible record. Compared with the lesser, local companies, the multi-national company invariably has more experience and more resources, financially and technically, to draw upon when there are particular problems to be solved; and the standards accepted as normal in a multi-national company tend to be higher than they are elsewhere. And when one thinks of it, a multi-national company has most at stake to get the right answer as the repercussions of a wrong answer on its international business may be very serious indeed.

There are several specific areas which must be tackled on a collaborative basis between industry, government departments and agricultural institutions in the Third World. These include labelling - what is the best way of attempting to convey information to the peasant farmer who may well be illiterate, certainly in the technical sense? Then the whole question of persuading him to use the material in the right way and to have a system for first aid treatment in case of accidental spillages and splashing. If a country wishes its agriculture to improve, then the proper use of agrochemicals is just as important as the provision of fertiliser, land, machinery and seeds of the correct varieties; agriculture is an integrated activity in which the various inputs are inter-dependent.

THE ECONOMIC CHALLENGES

Turning now to the economic challenges. For major companies, one of the biggest economic challenges is how to keep up high levels of R & D investment. Research and development are the life-blood, not just of the manufacturing industry but of the farmers whose job it is to grow enough food to feed the world. All the kinds of technical challenge I have mentioned will depend for their successful outcome on the ability of the industry to innovate. It is becoming increasingly difficult and so increasingly expensive to sustain the amount and sophistication of R & D necessary for the development of new technology and the invention of new products. If the money which a company can earn from selling its products no longer provides enough profit to pay for R & D, then there will be no more invention.

We have noted that there will be a demand for the highest levels of safety and efficiency, coupled with the lowest possible risk and, of course, the lowest price for the products. However, all this will require a high level of technical support in the market place and for a company to provide the necessary support means that the margin on the sales price must also be enough to sustain this backing.

At the same time there is pressure on profit margins because developing countries quite naturally are seeking to minimise the expense on agricultural inputs and there is increasing competition between companies themselves in terms of the number and variety of products being brought to the market place as a result of high levels of R & D investment. As if this were not enough, there are periods of depression in the export markets for agricultural commodities, and there are other economic hazards all of which mean that from time to time countries find themselves unable to afford foreign currency to pay for agrochemical or other imports.

Thus we see a restriction of imports; an attempted imposition of a requirement to manufacture locally - which ironically nearly always increases the cost. In many centrally planned economies there is a deliberate stifling of the development of agriculture so as to avoid the need for increasing the use of agrochemicals.

THE POLITICAL CHALLENGES

Finally in my list we have the political challenges. These include those posed by national government action along the lines I have just mentioned; those posed by international agencies, such as the United Nations and the European Communities; and those of non-governmental organisations concerned with social questions, such as the environmental and consumer lobbies.

The major UN agency in our field is of course the FAO, with whom the industry, through GIFAP, has a long established close and fruitful co-operation, by making available a wide-ranging expertise. The FAO clearly recognises the essential role which the chemical industry must play in the development of world agriculture and of course FAO does have to ensure that it has the support not only of the UN General Assembly, but of other UN agencies such as WHO, UNEP and UNIDO.

Also, there are many groups in the environmental and consumer field who have understandable and sincere concerns about the use of agricultural chemicals around the world.

We must not treat their concerns lightly because they are real and they matter to us as people, too. Sometimes they may lack scientific knowledge and understanding or they may be one-sided, pre-occupied with the risks rather than the benefits. We have to recognise that they are no less genuine for that and one of the crucial political challenges facing industry in the years ahead will be to find common ground with these groups and to create a dialogue not of confrontation but of co-operation.

The agrochemical industry has a strong case to make for the responsible prosecution of its business. We have seen over the recent past the increase in activity of GIFAP by its involvement with these international agencies and this will certainly continue. However, GIFAP must also continue to encourage local/national associations, particularly in the Third World, to work with government and academic agencies in their own countries because, with the agricultural and political situation varying so much from country to country, there is a need for industry to appreciate and help with specific issues which may not be universal.

CONCLUSION

This paper began with reference to the technical challenges faced by the industry. My concern has been to try to demonstrate to you that if the industry does not meet the safety, economic and political challenges then we may not get the opportunity adequately to meet the technical challenges.

My conviction is that the agrochemicals industry has to develop new means of crop protection by which agriculture can be further improved and mankind benefitted; and that only the industry is really equipped to do this. But the conditions under which we are able to work have to be right. With that in mind, we must all put rather more effort into explaining to governments, UN and inter-government agencies and to other concerned groups, that we are a responsible industry willing to sit down and work out in a responsible way solutions to the problems posed by the use of our chemicals in agriculture, anywhere in the world.

3P—2

INTERNATIONAL ASPECTS OF CROP PROTECTION - THE NEEDS OF TROPICAL DEVELOPING COUNTRIES

T.R. ODHIAMBO

The International Centre of Insect Physiology and Ecology, P.O. Box 30772, Nairobi, Kenya

ABSTRACT

The need to maintain and increase agricultural production is greatest in many tropical developing countries where pest and disease attack can be particularly severe. Requirements for crop protection are therefore often most demanding in such regions but many technical, economic and organisational problems must be overcome in developing effective crop protection measures. Needs and solutions will be discussed.

TRANSNATIONAL CROP PROTECTION PROJECTS

R.F. SMITH, D.G. BOTTRELL

Consortium for International Crop Protection, Berkeley, California, USA

ABSTRACT

Pest problems and pest control technologies are important links in an ever-tightening chain of interdependence among nations. Nations can benefit from pooling their resources and scientific personnel in tackling the common pest problems. Transnational crop protection projects offer special benefits to the very small and poor Third World countries. Projects in research, operations, and training have been organized under a variety of institutional frameworks. The International Agricultural Research Centers are ideally situated to advance the concept and application of integrated pest management in the Third World. Regional training consortia that bring together universities and research centers that have close cultural, political, economic, and geographical links are a potentially effective means of increasing the Third World's indigenous capacity in crop protection. However, none of the transnational crop protection projects is a panacea. Budgetary problems and a number of other serious problems presently limit their effectiveness.

INTRODUCTION

This paper sets forth the argument for transnational projects in crop protection, examines the institutional framework and the specific kinds of projects, and discusses their limitations and needs. Transnational projects in integrated pest management (IPM) in the less developed countries (LDCs) are given special emphasis.

There are countless numbers of transnational crop protection projects. Space will not permit a comprehensive review of these projects or even a mention of most of them. The Proceedings of Symposia, (Volume I), IX International Congress of Plant Protection (Entomological Society of America, 1981) and the Annual Review of Entomology article by Lee Ling, "Plant Pest Control on the International Front," (19, 177-196, 1974) are suggested for more complete discussions.

ARGUMENT FOR TRANSNATIONAL PROJECTS

This is a time when nations of the world are being drawn into one another's economic, political, and technological web at an unprecedented rate. International trade is growing by leaps and bounds, and companies, banks, transportation and communication systems, science and technology, and currencies are spilling over national boundaries and spreading rapidly throughout the world. The result is a far more diffused global economy and a new array of political and economic relationships among nations, especially among those of the so-called North and South. We now have a global economy that binds the industrial world to the burgeoning power of the "poor" in the Third World. All of these factors may affect pest problems and influence the direction of programs in crop protection.

Increased international trade of agricultural products and the rapid intercontinental mobility made possible by jet aircraft greatly increase the threat of foreign pest intoductions into new countries. The chances of successful entry and establishment of harmful pest species are much greater in the LDCs where the quarantine procedures are often inadequate. Recent introductions of the cassava mealybug (Phenacoccus manihoti) and cassava green mite (Mononychellus tanajoa complex) into West Africa have seriously jeopardized the production of cassava, a critical food crop of subsistence farmers in much of Africa. Preventing the introduction and establishment of foreign pests into new areas is presently a major challenge for crop protectionists; the challenge can only be expected to increase as the frequency of contact between nations increases and strong migrant pests such as locusts and armyworms invade new territories.

While science and technology are generally increasing crop yields in the LDCs, the genetic base of most important food crops has been rapidly narrowing. The adoption of high-yielding varieties over large areas in the LDCs has increased the crops' susceptibility to plant diseases and insect pests. Third World farmers are therefore using more pesticides to protect their crops. Trends indicate that overall use of pesticides in LDCs is rapidly increasing. In Africa, for instance, pesticide use will more than quintuple during the decade ending in 1984, according to some estimates. Corporations in the USA, UK, and Western Europe are exporting more and more pesticides to the LDCs. An estimated 49% of the pesticides exported from the UK in 1979 were consumed by LDC markets. Pesticide exports from the USA now account for 30% of the total domestic pesticide production; a significant but unknown portion of these exports go to the LDCs.

The exports from the Western nations include dozens of unregistered pesticides or pesticides considered too dangerous for unrestricted use in their countries of origin. Use of these materials greatly increases the health hazards of Third World inhabitants. But inhabitants of the exporting nations may be victims too. Pesticide exports create what is known as a "circle of poison," a concept advanced in 1981 by David Weir and Mark Schapiro in the book Circle of Poison (Institute for Food and Development Policy, San Francisco). The circle begins in the exporting nation where the pesticides are made. Then it moves abroad where the pesticides are sold. The circle is completed when unacceptable pesticide residues turn up in food shipments that are imported into the nations that supplied the pesticide materials.

Some newly industrializing nations of the Third World are also exporting pesticides to other LDCs, and a growing number of multinational agrichemical firms are establishing repackaging plants, formulating plants, or distributor outlets in these nations.

Pesticide use in the LDCs is further encouraged by various donor governments that provide aid and other forms of assistance to these countries. A given LDC may receive aid from a variety of donors, and the donors may all have different policies and procedures concerning the use of pesticides in the country.

The net result is that chemical pesticide technology is increasing and spreading much more quickly in the LDCs than is the capability to ensure its safe and effective use. Perhaps less than half of the LDCs have enacted legislation to govern the importation, domestic use, and disposal of chemical pesticides. Even with the laws, the LDCs frequently lack the infrastructures required to enforce them. Further, they seldom have the medical personnel and facilities required for diagnosing and treating cases of pesticide poisoning, and programs to train farmers on the correct use of pesticides and develop alternative methods are often inadequate.

Finally, the growing interest in the concept and application of integrated pest management is becoming a powerful international unifying force for crop protectionists and crop protection institutions. The past 5 years has seen an explosion in IPM literature and in the numbers of international meetings on the subject.

It is plain that pest problems and pest control technologies are important links in an ever-tightening chain of interdependence among nations. The potential benefits derived when different nations pool their resources and expertise and tackle the problems within the framework of a common project are also plain. Some of the more obvious benefits are: One, by pooling the resources and scientific personnel of individual nations, each nation has access to a much greater level of expertise than is otherwise possible. Sharing of expertise is especially beneficial for the very small and poor LDCs. Two, the international collaboration can make the work of individual nations more efficient and productive. A holistic effect results. International projects provide the countries with new information, ideas, and technologies and contribute in breaking down the barriers of scientific isolation so commonly found in the poor LDCs. Three, international projects generate good will important in dissolving institutional barriers that often constrain relations between countries. Four, the pooling of regional expertise and infrastructures greatly cuts the costs required by individual nations to develop their own plant quarantine programs, pesticide legislation, or pest surveillance programs. Five, it has been shown many times that various migrant pests are best managed on a large-district or regional basis. International cooperation, and sometimes legislative enforcement internationally, is integral to the success in managing some migrant pests. And finally, the donor countries also benefit -- for example, transnational projects promise in the long term to reduce the LDCs' dependency on donor input.

THE INSTITUTIONAL FRAMEWORK AND SPECIFIC PROJECTS

Transnational projects are often organized by "intergovernmental organizations" (IGOs) or "nongovernmental organizations" (NGOs). An IGO has two or more nations as members and acts under a constitution, treaty, charter, or covenant. The Organization of African Unity (OAU) is an example of an IGO. A major transnational crop protection project, the Interafrican Phytosanitary Council (IAPSC), was established as a branch of OAU in 1956 and is still functioning. An objective of IAPSC is to prevent the introduction and spread of plant insect pests and diseases in the 49 members nations of OAU.

A NGO has as members private agencies from at least two countries, a written instrument setting forth agreed purposes and procedures, some form of permanent organization, and a central office. PAN (Pesticides Action Network) International is an example of a NGO project. It is an international coalition of NGOs from 16 countries (as of May 31, 1982) with the objective of "halting the indiscriminate sale and misuse of hazardous chemical pesticides throughout the world."

Not all transnational crop projects come under the definitive IGO or NGO institutional arrangements. Our own project, the Consortium for International Crop Protection (CICP), is a nonprofit organization composed of 12 Universities in the USA, University of Puerto Rico, and United States Department of Agriculture. Our basic goal is to advance economically efficient and environmentally sound crop protection in the LDCs. CICP is partially funded by the United States Agency for International Development (AID) and works closely with the Agency in carrying out programs in training and technical assistance in the LDCs. We collaborate with LDCs having bilateral agreements with AID and various other LDCs as well.

Some transnational crop protection projects are strictly bilateral -- for instance, involving the collaboration of a developed country government agency and a LDC government. AID, Canadian International Development Agency, Overseas Development Administration of the UK, and German Agency for Technical Cooperation, for example, participate in a number of bilateral crop protection projects in the LDCs. There are also numerous multilateral crop protection projects characterized by the participation of more than two nations. The CILSS IPM research project (the English translation for CILSS is Interstate Committee for Drought Control in the Sahel) in West Africa, for example, is largely funded by AID and carried out cooperatively by the national governments of Cape Verde, Senegal, Mauritania, Upper Volta, Mali, Niger, and The Gambia and the Food and Agriculture Organization of the United Nations (FAO).

Research and training programs in crop protection organized through the Consultative Group on International Agricultural Research (CGIAR) represent another kind of institutional framework for transnational projects. The sponsors of the CGIAR are the World Bank, FAO, and United Nations Development Program, but several nations and private philanthropic foundations are also members and contribute to CGIAR activities. Under the CGIAR are 13 so-called International Agricultural Research Centers (IARCs) that, together, cover nearly all the major food commodities and ecological zones in the LDCs.

The research is organized similarly at all of the IARCs. Teams of career investigators representing several disciplines (usually including crop protection disciplines) are brought together to identify the factors that limit crop yield and to alter these factors in attempt to increase and sustain production. Each of the centers has a limited sphere of interest, confined either to a region or to a particular crop or group of related crops. The IARCs are an important centerpiece for encouraging the participation of national agricultural agencies in a given region. New technology is evaluated on farms in the participating countries. The centers also organize training for research technicians, extension officers, and others in the region. In addition, they publish newsletters and other materials that serve further to bolster participation of the national agencies.

Other international centers -- notably The Asian Vegetable Research and Development Center in Taiwan, Tropical Agricultural Research and Training Center in Costa Rica, and International Centre of Insect Physiology and Ecology (ICIPE) in Kenya -- although not members of CGIAR, have close ties to it.

Most of the CGIAR centers and collaborating international centers have programs related to crop protection. One of their roles is to maintain germ plasm preserves of major food crops grown in the LDCs. These preserves provide plant breeders with genetic stocks that they use for developing crop plants that resist insect pests and diseases. Several of the IARCs have made excellent progress in developing resistant varieties.

Through their research, training, and "outreach" programs, the international centers are ideally situated to advance the concept and application of IPM in the LDCs. The International Rice Research Institute in the Philippines has made especially outstanding contributions in IPM. The West Africa Rice Development Association in Liberia and ICIPE in Kenya have recently started to emphasize IPM in their programs.

Various regional quasi-government and private organizations also engage in crop protection activities. In some LDCs, these organizations have a heavy hand in the pest control programs carried out in the farmers' fields. They may supply the pesticides, make all the decisions concerning the need for treating, and even carry out the treating. The Windward Islands Banana Growers Association in the Caribbean is an example of a quasi-government organization deeply involved in crop protection.

The last kind of institutional framework discussed here involves regional consortia of scientific institutions, such as universities and research centers, that have close cultural, policial, economic, and geographical links. An example is the newly formed African Regional Postgraduate Programme in Insect Science (ARPPIS). Membership in ARPPIS is presently limited to Addis Ababa (Ethiopia), Dar es Salaam (Tanzania), and Ibadan (Nigeria) Universities, University of Ghana, Legon, and University of Khartoum (Sudan), but any recognized African university from a member nation of OAU is eligible to apply for admission. Headquartered at ICIPE in Nairobi, ARPPIS offers training in insect science leading up to the Ph.D. degree. A student's training and research program is jointly coordinated by ICIPE and the ARPPIS university where the degree is earned.

Regional training consortia such as ARPPIS represent a potentially effective means for building up the LDCs' indigenous capacity in crop protection. Any one of the participating institutions may lack the scientific expertise and resources required to develop a comprehensive degree program. But collectively the institutions may offer a large and diverse technical resource. Costs for training a student in the region may be considerably less than the costs required for training him or her at a university in one of the developed countries. In-the-region training has other advantages over training carried out in the developed countries. Few universities in the developed countries have programs in crop protection that are genuinely tailored to meet the needs of LDC trainees, and the crops, pests, and pest management strategies in the developed countries often differ radically from those in the developing countries. Further, the university faculty in the developed countries may have a minimal understanding of the sociological, political, and economic factors in the foreign student's country. Regional training, if carried out by good instructors familiar with the local problems and needs, is probably the best way to ensure that the students are properly trained to develop crop protection approaches suited for their particular environment.

ROLE OF THE FAO/UNEP PANEL IN ADVANCING IPM

A meeting sponsored by FAO in 1959 to review the role of pesticides in agriculture possibly proved to be the most significant step ever taken to advance integrated pest management at the international level. The meeting's participants recommended, among other things, that "governments initiate or intensify research which will lead to the harmonizing of chemical and biological control practices."

In response to the 1959 recommendation, FAO created, in 1962, the FAO Committee of Experts on Pesticides in Agriculture. This Committee formed a series of FAO Working Parties on Pesticide Residues, Resistance to Pesticides, and Official Control of Pesticides.

In 1963, the Twelfth Session of the FAO Conference (the governing body of FAO) recommended that FAO emphasize an integrated approach to plant protection. In October 1965, the Director General of FAO convened the "Symposium on Integrated Pest Control" at FAO in Rome. The conferees endorsed the use of the term "integrated pest control" and recommended that "a panel of experts on integrated pest control be established..." In 1966, FAO's Director General established a panel of experts on integrated pest control to serve as a statutory advisory body to FAO. In 1979, the panel became an advisor to both United Nations agencies, FAO and the United Nations Environment Programme (UNEP).

The FAO/UNEP Panel advises and assists the Director General of FAO and the Executive Director of UNEP in formulating and executing policies and programs related to "integrated and environmentally sound approaches to pest control in agriculture." Initiatives started by the FAO/UNEP Panel and the earlier FAO Panel have contributed significantly in advancing IPM in the LDCs. One initiative has been the development of a series of guidelines and "how-to" manuals for the development and implementation of IPM. Guidelines have been developed for cotton, sorghum, rice, and maize IPM and are available in English and other languages. Guidelines now are being developed for IPM in soybean, groundnut (peanuts), sugar beet, and cotton (updated and expanded version). In addition, guidelines for economic evaluations of crop pest management programs are being developed.

The FAO and FAO/UNEP Panels have initiated several major IPM projects through the FAO/UNEP Cooperative Global Programme for the Development and Application of Integrated Pest Control in Agriculture. The Global Programme is coordinated by FAO, and the Panel serves as the technical advisory body. Three major projects in IPM are now operating under the Global Programme: (1) the CILSS IPM research project in basic food crops in the Sahel of Africa, (2) the South and Southeast Asia seven-country program in rice IPM, and (3) the cotton IPM program in North Africa and Near East. They were initiated, respectively, in 1979, 1980, and 1977. The projects are being funded by various donor agencies.

The three projects of the FAO/UNEP Global Programme are among the largest of coordinated international efforts to develop comprehensive IPM systems for agricultural crops. The projects are emphasizing adaptive research, carried out mostly on farmers' fields, farmers' demonstrations of promising IPM techniques, and training as required to increase the indigenous capacity in IPM in the participating countries. Although it is too early to determine the impact of these projects in advancing IPM, the research and operational advances represent a trend toward more rational management of agricultural pests in the LDCs.

EFFECTIVENESS, LIMITATIONS AND NEEDS

Some of the transnational crop protection projects have been ineffective and short-lived. Others, such as programs organized under some of the IARCs and the FAO/UNEP Cooperative Global Programme, noted above, have been fruitful and continue to alter the course of international crop protection. Some of the potentially most significant projects, ARPPIS, for example, are still very young, and it is too early to judge their success.

Experience with many transnational projects in many parts of the world has revealed certain recurring constraints that almost always limit their effectiveness. The first relates to the ideological, political, cultural, and language barriers. In theory, the transnational projects tend to dissolve these barriers; but in practice, the projects often do not. The language and cultural barriers between countries often prove to be major obstacles. The AID-financed Regional Food Crop Protection Project in West Africa, for example, includes the countries of Cape Verde, Senegal, Mauritania, Guinea Bissau, and The Gambia which together represent three official languages -- French, Portuguese, and English -- and countless numbers of local languages and dialects. Further, each country has a different political system, culture, and economy. These factors often foster an attitude of nationalism -- the antithesis of effective transnational relationships.

A second constraint relates to the grasp that foreign powers have on newly emerging nations. The old colonial powers often still exert considerable influence on the new LDCs, through aid, technical assistance, and other programs. Complicating the situation, a given LDC may receive aid and technical assistance from a variety of donors, and the donors may all have different policies concerning the use of pesticides and alternative methods. Regional commodity organizations may also exert influence in the individual countries. These combined forces may have a major impact on crop protection programs in a given LDC, preventing it from effectively participating in new programs being developed under a transnational project.

A third constraint is funding. Many transnational crop protection projects -- ours being no exception -- are having severe financial problems, and prospects for increased support are presently dim. The global recession is jeopardizing the future of many long-established projects in transnational crop protection. The final result cannot be predicted but it would appear to be gloomy.

A final constraint -- and in fact probably the most important constraint -- relates to the capability of personnel involved in most transnational projects. Most of these projects are funded on a very short-term basis (1-5 years), and they therefore do not offer good career opportunities. Further, many are located in LDCs that have inadequate schools for children, poor medical, transportation, housing, and recreational facilities, and undesirable climates. As a result, it is often very difficult to attract and retain outstanding persons to work on these projects.

The greatest immediate need for nearly every transnational project in crop protection is to secure funding on a long-term basis. In addition, there is a real need for a mechanism that ensures that funds are allocated to the scientists and institutions most qualified to pursue crop protection in the given environment. The international donors, especially, should immediately assess the present situation and map out a strategy that maximizes the effectiveness of future transnational crop protection projects. Perhaps the best solution is to have fewer -- not more -- projects, but projects that are enduring and highly effective.

Finally, we must recognize that good crop protection is not a guaranteed solution to the world's food problems. Social, economic, and ecological issues, problems of deforestation, human population growth, crop storage and marketing, and many other problems must be tackled. Crop protectionists need to take cognizance of the larger problem and determine how they can best cooperate with all the other disciplines working to reduce its size.

ACKNOWLEDGEMENTS

The Consortium for International Crop Protection is a nonprofit organization composed of 12 Universities in the USA, the University of Puerto

Rico, and the United States Department of Agriculture. The Consortium is partially funded by the United States Agency for International Development, advises the Agency on crop protection matters, and works closely with Agency personnel in carrying out various crop protection programs in the Third World.

THE FUTURE POTENTIAL OF CROP PROTECTION RESEARCH

J. MIYAMOTO

Takarazuka Research Centre, Sumitomo Chemical Co., Ltd.,
Takarazuka, Japan.

SUMMARY

The future potential of crop protection research will be considered under the following headings:-

INTRODUCTION

CROP PROTECTION THROUGH CHEMICAL CONTROL PROCEDURES

1. Rational approach to bioactive compounds
2. Utilization of natural products
3. Computer-assisted design of pesticides
4. Chiral synthesis of pesticides
5. Solution of resistance problems
6. Improved application techniques
7. Effective impact assessment
8. Integration of pest management

USE OF NON-CHEMICAL PROCEDURES FOR CROP PROTECTION

MODERN BIOTECHNOLOGY AS APPLIED TO IMPROVED AGRICULTURAL PRODUCTION

1. Microbial pest control
2. Regulation of plant growth
3. Breeding of new plant varieties

CONCLUSION

4P—2

REFLECTIONS ON RISK AND REGULATORY POLICY

C. F. WILKINSON

Department of Entomology and Institute for Comparative and Environmental Toxicology, Cornell University, Ithaca, NY 14853

INTRODUCTION

Despite the enormous benefits that society continues to derive from the use of pesticide chemicals, there is widespread and increasing public concern over their potentially adverse effects on human health and the environment. That pesticides are often a special focus of public concern, and continue to receive a measure of "bad press" that belies their contribution to the overall problem of environmental pollution, probably reflects the fact that they were the first materials to trigger society's awareness to the potential dangers of involuntary chemical exposure through the food chain and/or environment. Furthermore, since pesticides, unlike many other synthetic chemicals to which man is exposed, are released purposely into the environment, the public feels that there is ample opportunity for regulating the nature of the materials employed, and thereby for obviating or minimizing any public health or environmental threats they might pose. As a result, government bodies such as the Environmental Protection Agency (EPA) in the U.S.A., and responsible ministries in other countries, are under constantly mounting pressure to develop sound regulatory policies that carefully weigh the anticipated societal benefits of a given chemical against the risks that it might pose. Unfortunately, this often has to be accomplished in an antagonistic, antichemical atmosphere in which society, not yet able to come to grips with the reality that the use of any chemical is always associated with a finite level of risk, is constantly demanding assurances of the absolute "safety" of the pesticides and other chemicals to which it is involuntarily exposed. This is particularly true in the U.S.A. where, in some cases, there currently exists an emotional atmosphere verging on hysteria - a very real fear that society is being not-so-slowly poisoned by the pesticides and other products of modern chemical technology.

Many in the chemical industry, and elsewhere, believe that the public's fear of chemicals is unwarranted, that public perception of danger is exaggerated, and that the public media vastly overstate the dangers that exist; they tend to discount summarily the claims that pesticides are having an adverse impact on human health and often ridicule those who espouse such views. However, the power of public sentiment can not be underestimated or ignored and in democratic countries, where the voters ultimately have the ability to make themselves heard, strong emotions are often translated into law.

In the United States, legislation directed towards the protection of human health and/or the environment from chemicals of all types has increased enormously during the last decade or so and continues to become infinitely more complex and difficult to interpret. A burgeoning bureaucracy has been born. Legislation is often enacted too hastily in response to urgent perceived needs and is frequently based on inadequate data and incomplete scientific knowledge. In the U.S.A., the apparent absence of communication between the four major agencies given congressional authority to regulate chemicals is disturbing and leads to a lack of consistency in their approaches to developing regulatory policy. This lack of uniformity, often at both a philosophical and practical level, detracts seriously from the credibility of federal regulatory policy in the eyes of the public and frequently serves only to exacerbate their fear and confusion.

At the present time, the public is highly suspicious of chemical industry and mistrustful of government efforts to protect them. In the face of strong antichemical public sentiment, and runaway development costs resulting from the ever changing, ever escalating rules, regulations and guidelines promulgated by the EPA under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), the pesticide industry is justifiably concerned about its ability to continue to produce the chemicals required for pest control. All who believe that pesticide chemicals are, indeed, an absolute requirement for, and an integral component of effective pest control programs should also be concerned. It appears that we are in a very uncomfortable, uncompromising position.

No one would argue the need for some form of restrictive legislation for pesticides. But how can this be achieved in a reasonable manner that encourages industrial research and development to provide the chemicals required, that meets society's needs for a continuing supply of high quality food and fiber, and that satisfies the public that government is meeting its responsibility to protect public health and the environment?

RISK ASSESSMENT/TOXICITY TESTING

At first sight, the procedure that is followed in arriving at a regulatory decision on a pesticide entails a relatively simple benefit/risk evaluation. Since benefits can usually be assessed, at least qualitatively, from the intended use of a chemical, and since efficacy will ultimately be decided by the chemical's success in the marketplace, the regulatory process often depends heavily on an assessment of the potential risk of a chemical. Risk is a measure of the probability that an adverse effect will occur. In the case of a pesticide it is primarily a function of the intrinsic ability of the material to cause an adverse toxicological effect (acute toxicity, carcinogenicity, delayed neurotoxicity) and the intensity and duration of exposure (the dose) that relate to the circumstances under which exposure is expected to occur. Clearly, for a given material, the risk for a pesticide applicator is considerably greater than that for a consumer whose exposure is limited mainly to pesticide residues occurring in food.

The assessment of risk is the concern of the toxicologist. Indeed, the commonly accepted definition of toxicology - the science that studies the adverse effects of chemicals on living organisms and assesses the probability of their occurrence - clearly indicates risk assessment and prediction as integral components of the discipline. Toxicology has come a long way during the last two decades and has now emerged as a bona fide multidisciplinary science. It continues to attract the attention of chemists, biochemists, geneticists, pathologists, physiologists and a multitude of other specialists who focus their combined expertise and state-of-the-art research skills, methodologies and instrumentation on improving our understanding of the interactions between chemicals and living organisms. As a result, our level of understanding of many basic aspects of toxicology - pharmacokinetics, xenobiotic metabolism, chemical interactions with genetic material, etc. - has been enhanced remarkably during the last few years. But despite these advances it is somewhat disquieting to realize that, with only a few exceptions, we still have very little understanding of the mechanisms through which chemicals exert their toxic effects and little or no capacity to predict the adverse effects of a given chemical in an intact animal.

As a result, the process of evaluating the toxicological effects of a compound, often referred to erroneously as "safety evaluation," still assumes many of the mysterious characteristics of a black box. Although the types of toxicological testing required for pesticide evaluation and registration vary somewhat from country to country, most include a battery of acute and chronic tests with two or three animal species, usually rats, mice and dogs. They are directed towards obtaining data on acute oral and dermal toxicity (LD_{50}), eye and skin irritation, carcinogenicity, teratogenicity, reproductive impairment and neurotoxicity. Data from a variety of special tests, such as in vitro assays for mutagenicity, may also be required. Some of these tests can be completed in a relatively short period of time and require only a limited number of animals, whereas others, particularly the chronic oncogenicity and reproduction tests, require large numbers of animals and extend over a period of two years or several generations. From these tests emerge volumes of data and computer print-outs that provide a continual record of the well-being of each animal throughout the test period, and include a complete terminal pathology report on almost every tissue from nose to tail; it is impressive, indeed, and should satisfy even the most skeptical that toxicology testing is serious business. But obtaining the data is only the beginning; the real question is how do we evaluate and interpret the data and translate the results into a form that relates directly to human risk?

ASSESSMENT OF ACUTE TOXICITY

A few years ago, toxicology testing emphasized the importance of acute toxicity resulting from single-dose exposures. Counting dead noses is a relatively simple task and it is hard not to conclude that at a certain dose-level the animals died or suffered some overt adverse toxicological effect. Unfortunately, an acute LD_{50} value per se, no matter how good the statistical confidence level, seldom has much relevance in assessing risk, and an enormous number of animals continue to be sacrificed needlessly to provide this value. The LD_{50} tells us nothing about the slope of the dose-response curve and consequently does not aid in determining a threshold dose. In practice, the most important value that acute toxicity testing provides is the lowest dose causing an observable effect, since this immediately focuses on the next lower dose that is defined as the "no observable effect level" (NOEL). Availability of the NOEL is the key to assessing acute toxicity since it is used to calculate an "acceptable daily intake" (ADI), the amount of a material that can be ingested daily by humans over a lifetime with no adverse effect. The ADI is calculated by simply dividing the NOEL from the most conservative chronic animal test data by an arbitrary factor (often erroneously called a "safety factor") that may range anywhere from ten to several thousand depending on the degree of uncertainty inherent in the data. The magnitude of the uncertainty factor reflects the amount and types of data available, the number of species for which data are available, the nature of the toxic effect, whether it is reversible or irreversible, etc. It is designed to take into account possible differences between animal and human responses as well as individual variations within the human population. Clearly, if data are available on the effects of a given chemical on humans the uncertainty factor will be relatively low. Since the uncertainty factor reflects the quality of the data base and state of knowledge at the time it was established, this and the corresponding ADI may be modified appropriately as new data become available.

Once an ADI is established for a given material it provides regulatory agencies with a relatively firm toxicological bench-mark on which to base risk assessment, tolerances, guidelines and other policy decisions. Although there are sometimes divergent opinions on the toxicological significance of a particular adverse effect on which the NOEL is based (e.g., the depression of erythrocyte or plasma cholinesterase in the case of carbamate or organophosphorus insecticides) or on the adequacy of the uncertainty factor used to arrive at the ADI, this general approach seems to work quite well for materials causing only acute toxic effects. It also seems to be widely accepted by society at large, thus indicating that the human psyche is apparently able to accept the possibility that, under certain circumstances, a given compound will lead to a rapid demise. After all, whilst not a desirable event, the possibility of a quick, clean death is something everyone can clearly understand. What society cannot accept, is the possibility, no matter how remote, that chronic, low-level exposure to pesticides and other chemicals might ultimately lead to cancer, and effects such as mutagenesis or birth defects that are generally considered the ultimate insults to human health.

CARCINOGENIC RISK ASSESSMENT

During the last few years, the assessment of carcinogenic risk has emerged as the very hub of modern toxicology; it presents innumerable problems and is beset by uncertainty and controversy at every step along the way. Uncertainty begins with our current lack of understanding of what causes the disease. We do know that it occurs when for some reason the natural machinery for checking cell growth goes awry, when homeostatic mechanisms that control cellular balance break down. In part, it is a natural disease, possibly related to endogenous imbalances associated with ionizing radiation, aging or genetic make-up, but we also know that it can be triggered by a multitude of exogenous factors including diet, life style and a host of others including exposure to naturally occurring and synthetic chemicals. As a result of the complex, uncertain multifactorial etiology of cancer, there are some who even question the value of conducting tests to evaluate the carcinogenic potential of single chemicals.

Quite apart from this philosophical viewpoint, the theoretical and practical problems inherent in carcinogenic risk assessment are formidable. This is particularly true with respect to the quantitative assessment of cancer risk that requires far more than a qualitative evaluation of carcinogenic potential. Unlike the situation that exists in evaluating acute toxicity where the usual objective is to measure the severity of a specific adverse effect in individual animals, cancer risk assessment seeks to measure increases in the frequency of occurrence of an event in a population. Furthermore, whereas acute tests are concerned primarily with measuring overt adverse effects of relatively high doses of chemicals over short periods of time, the ultimate objective of cancer risk assessment is to detect the occurrence of low probability events at low doses over long periods of time. This is where the toxicologist must enter the world of probability statistics and must pause to consider the meaning and implications of such terms as significance, confidence levels and inferential adequacy that control both experimental design and data interpretation.

Statistics show that, at a 99% level of confidence, a test with ten animals might fail to detect a cancer actually affecting up to 37% of the test population; similar tests with 100 and 1,000 animals might indicate no tumors even though they may actually occur at a frequency of 4.5% and 0.46% of the respective populations. Viewed differently, a test involving 1,000 animals can be expected to detect an effect at the 99% confidence level only if more than five animals are afflicted. The implications of this are considerable since the introduction of a chemical that causes cancer at a rate of 5 in every 1,000 of the human population could lead to 1,000,000 cases of cancer in the current population of the U.S.A.

In practice, of course, it is simply not feasible to conduct the massive tests that would be required to detect cancers occurring at such low frequencies with any degree of confidence. Typical two-year oncogenicity studies involve a total of from 500 to 1,000 animals divided into groups of 50 of each sex receiving either control of treated (usually three or four dose-levels) diets. In view of the statistical and other limitations inherent in measuring effects at low doses, the actual doses employed in oncogenicity testing are usually high, often at, or approaching, a "maximum tolerable level." It is assumed that, although not measurable directly, the effects at low doses can be estimated by extrapolation from that portion of the dose-response curve observed with high doses. In deciding how this extrapolation can and should be effected we again encounter an uncertain area that continues to be the subject of considerable controversy and debate. Of chief concern are questions regarding whether or not there exists a threshold for carcinogenic effects, and the true shape of the dose-response curve in the area below which effects can be observed.

Whilst not all would agree, and no attempt will be made here to delve into detail, it is now generally accepted by the scientific community that carcinogens can exert an effect down to zero dose; in other words, it is assumed that there is no threshold below which an effect will not occur and that consequently extrapolations of observable dose-response data must pass through zero. This assumption is now firmly embedded as fact in most, if not all, agencies responsible for developing regulatory policy towards pesticides and other chemicals, since it provides a considerably more conservative approach than other methods that have been suggested. It has also served to challenge and stimulate the statisticians into a near frenzy of activity to derive with models that can be used to provide a quantitative measure of carcinogenic risk.

At the present time, probaby six or seven models, all with impressive names - one-hit, multi-hit, multistage, probit, logit and Weibull - have been proposed, and there remains considerable debate about which, if any, constitutes the most appropriate for assessing cancer risk in humans. There are some toxicologists who firmly believe that such extrapolations are impossible and that the results they provide are meaningless with respect to assessing cancer risk in humans.

The problem is further confounded by uncertainties in extrapolating cancer data from animals to man and there is continuing and active debate among pathologists regarding the nature of the cellular lesions that should be considered in the assessment. Well developed malignant tumors are relatively easy to identify, but how should the so-called benign tumors and the vast number of neoplastic nodules and foci be considered? Cancer is now clearly recognized as a multistage process and while ultimately many of these neoplastic lesions may not develop into tumors they might be indicative of carcinogenic potential. Yet, another confounding factor is the high spontaneous incidence of tumors in specific tissues of some strains of test animals; how can it be ascertained that the ability of a chemical to cause a small increase in the incidence of such naturally-occurring tumors is not due to a general effect of stress rather than to true carcinogenic potential? Is the presence of a tumor in one particular tissue of a mouse more relevant to carcinogenic potential in humans than a tumor occurring in another tissue? More often than not, the honest scientist has to answer "I do not know" to these and a host of other questions.

Our ability to assess carcinogenic potential and measure carcinogenic risk in humans continues to present serious problems in regulatory agencies. We are truly caught up in a numbers game and the numbers that emerge do little or nothing to aid a regulatory decision or to reassure a concerned public that all is well. A good example of this is provided by the report on saccharin published in 1978 by the National Academy of Sciences. The report concluded that over the next seventy years, the expected number of cases of human bladder cancer in the U.S. resulting from a daily exposure to 120 mg saccharin might range from 0.22 to 1,144,000, a risk estimate spanning a range of eight orders of magnitude.

It is clear that the quantitation of human risk based on the results of animal studies should be approached with great caution and that in most cases, we are attempting to quantify and predict responses that are beyond the realm of biological and scientific certainty. These are matters that transcend the power of science and that according to Dr. Alvin Weinberg, past Director of the Oak Ridge National Laboratory, should be termed trans-scientific rather than scientific. Toxicologists involved in risk assessment constantly come face-to-face with the world of trans-science and increasingly are placed in the uncomfortable position of having to answer questions and make recommendations in the uncertain framework it provides.

RISK MANAGEMENT AND REGULATORY POLICY

Occasionally it is apparent that the potential toxicological risk associated with a given pesticide are of such magnitude that it cannot be used under any circumstances. In this case, risk alone is sufficient to deny registration or to remove it from the market. More usually, however, a quantitative estimate of a chemical's overall risk potential is just one of a host of factors that must be considered in arriving at a regulatory decision.

As previously discussed, the actual risk a chemical is likely to pose is a function of its intrinsic toxicological potential, as indicated by the toxicity testing data, and the expected level of exposure that will result from its intended use. The regulator therefore needs to consider a series of questions such as who and how many people will be exposed, to how much and by what route? Will the primary risk be through occupational exposure of factory workers, applicators, or farm workers and if so, are protective measures feasible? Or is exposure expected to involve the general public or specific ethnic groups in the form of food residues or through environmental contamination such as in groundwater.

In addition, information on the expected environmental effects is considered. Is there a possibility that the pesticide will prove injurious to nontarget species such as fish or birds? Does it show unusual environmental stability? Is it likely to leach into groundwater, etc.? Even economic factors such as possible impacts on trade and the availability of alternative chemicals are included in the decision process.

The process of reaching a final regulatory decision, of interpreting information on the risk potential of a chemical in terms of the actual risk it is likely to pose under the conditions of its proposed use, and of weighing these against expected benefits, has recently been termed risk management. Although regulators often like to clothe their decisions in pseudoscientific terms, and the process obviously requires considerable scientific input, risk management <u>per se</u> is not a science. It involves a series of value judgments on the part of the regulator and these must be made only after careful consideration of all scientific and other factors that are available.

It is extremely important that both scientists and regulators clearly recognize their quite separate but interrelated roles and responsibilities in the overall decision-making process. Scientists should realize that their only responsibility is to assess the potential risk of a chemical and in fulfilling this responsibility they must be careful not to be influenced by political, social or economic factors. For their part, regulators, politicians and lawyers must not be tempted to hide their decisions behind science or to abuse scientific objectivity. In the often heated adversarial system that currently pervades the regulatory process in the U.S., toxicologists are often impotant in the face of a good lawyer; the arguments of science, particularly the imprecise science of risk assessment, is too easily destroyed in a court of law which requires too many "yes-no" answers.

ACCEPTANCE OF RISK

The acceptance of some measure of risk is usually an inherent component of risk management. It has been said that the only safe airplane is the one that never leaves the ground, preferably one that remains in a locked hangar on a disused airfield. But the perception of risk and the level of risk that is acceptable is an extremely complex, highly subjective issue. All of us take risks of one kind or another every day. We drive automobiles, travel in airplanes, climb mountains, smoke cigarettes, and expose ourselves to a multitude of "across the center" drugs for headaches and other minor ailments. Some of these activities present quite substantial risks that can be readily estimated from actual data; and yet they are accepted as an integral part of living. Why then, are most individuals unable to accept in a similar manner a finite level of risk, often orders of magnitude smaller than those of some of the activities listed above, from the traces of pesticides and other chemicals to which they are exposed.

Probably the major problem lies in the fact that risks such as driving cars and crossing busy streets, are voluntary risks, risks where individuals have a choice and as a consequence enjoy some measure of personal control. Many people have stopped smoking in recent years because they consider the risks are too great. But in the case of pesticides in our food or water, individuals do not have the luxury of making the choice; the risk is involuntary and inescapable. Worse than that, some unknown, unseen bureaucrat in a regulatory agency is making the choice for them by registering a pesticide that according to his calculations poses a cancer risk of only "one in one million." Who is he to play God and to make the choice for me? What if I just happen to be the one? Why should I trust him?

Perhaps, this is a very simplistic view of a complicated issue but there seems little doubt that the question of who makes the choice is a critical component of risk acceptance. And society's acceptance of risk is an all important factor in the credibility of regulatory policy towards pesticides.

It is my impression that the regulatory process in Europe works for more smoothly than ours in the U.S.A., and that policy decisions are usually more readily accepted. In part, this may be due to absence in Europe of the system that dictates the establishment of an adversarial relationship between industry and the regulatory agencies and that encourages tedious legal battles that are duly reported in the public media.

COMMUNICATING WITH THE PUBLIC

One of the major reasons why society is unable to accept the fact that the use of any chemical is associated with a measure of risk is that toxicologists and other scientists have made a woefully poor effort to explain the problem in readily understandable language. At the moment, a large segment of the public seriously believes that we have a wealth of knowledge of how chemicals exert their adverse effects on humans, have precise ways of predicting these effects, and that most of the current problems arise from the profit-driven motives of big industry combined with irresponsible government regulatory policy. It does nothing to reassure an individual's suspicions when he hears on the evening news that the pesticide with which he treated his house last year has suddenly been removed from the market because of its suspected carcinogenic risk potential.

Scientists must begin to play a much more active role in educating the public in all matters pertaining to toxicology, and of clearly explaining the facts, particularly the uncertainties, associated with quantitative risk assessment. Similar efforts should be made to educate and work more closely with the public media (television, newspapers) to ensure that their thirst for sensational news on chemical threats to public health does not override their responsibility to report objective fact.

FUTURE NEEDS

The foregoing discussion has touched on a number of fundamental issues relating to the problems of weighing societal risks and benefits of pesticide chemicals and of how the results are translated into regulatory policy. Hopefully, by emphasizing some of the faults and uncertainties in the present U.S. system, it has served to illustrate the enormous task that lies ahead if we are to develop a more efficient, more effective mechanism for registering new compounds in a manner that will be acceptable to society.

In considering ways in which this task might be undertaken, several areas can be targeted for immediate attention.

1. There is an urgent need for improved capabilities in quantitative risk assessment, particularly in relationship to suspected carcinogens. More research effort should be placed on basic studies to understand the mechanism of action of toxicants since, ultimately, this is our only hope for predicting the probability of toxic effects with any degree of certainty. In the meantime, we should refrain from playing the "numbers game" and of becoming obsessed with the implications of statistical analyses of marginal experimental data. Cancer is a disease of the whole animal and we should not allow numbers to cause us to lose sight of the biology of the problem. In the area of carcinogenesis, we must make a real effort to assess the background incidence of cancer due to natural causes so that the significance of chemically-induced cancer can be placed in its proper perspective.

2. There is a need to establish a clear understanding of the separate roles of the scientist and the regulator in the risk assessment/risk management process. Clearly the regulators need to have

close contact with the scientists, but the credibility of the latter will soon be lost if social, economic or political factors are allowed to interfere with their scientific objectivity.

3. For the sake of both efficiency and credibility, there is a need to establish a greater degree of uniformity in the risk assessment/risk management procedures employed in the various agencies responsible for chemical regulation. In the U.S., discrepant procedures currently exist not only between different agencies, but even between different offices within the same agency. More international uniformity might also be beneficial in this area.

4. A concerted effort should be made to educate the public and to thereby raise its level of understanding of toxicology and risk assessment to a point where it can appreciate the uncertainties of the science and gain a clearer perception of risk. Only when this occurs will the public begin to develop more trust in the regulatory process.

Chemicals of all types are an essential and integral part of modern society and are certain to increase in importance in the future. To learn how to use these chemicals to maximum benefit and with minimum risk to human health and the environment is the challenge of the future. It is a challenge that dictates the unified and dedicated efforts of industrial leaders, researchers, educators, government officials, and consumers and requires the development of close associations and collaborative activities between all concerned.

4P—3

FARMING - PARTLY AN ART, PARTLY A SCIENCE

P.J. SMITH

The Bradshaws, Wrottesley, Codsall, Wolverhampton

ABSTRACT

Crop protection measures within the constraints of practical farming are considered. Progress during the lifetime of the author is reviewed and the need to adapt to change is emphasised. The importance of market forces, the role of research and the need for a realistic attitude to environmental considerations and conservation are discussed. It is the art of the farmer to achieve effective crop production in the face of this multitude of political, biological, climatic and economic factors.

Historical perspective

My views are based on a lifetime in farming; I was born some 57 years ago on a mixed Dairy Farm in the English industrial black country, so called because of the colour of the shallow pit mounds. My father milked cows, dug the drains, hoed the weeds by hand and cut the corn by binder and scythe. A man used to wear out two spades each winter draining, a feat not lightly undertaken today. All the field work was done by horses. The main enterprise of the farm was the mowing of green clover by scythe for sale to the local horse owners. The small owners collected and we delivered to the large owners, (breweries, railways, dairies) and returned home with the muck to spread on the land.

It is strange how today people seem to prefer their food grown with manure, whether it be animal or human, rather than with ground up naturally occurring minerals which have somehow acquired the name "artificial". A public relations exercise is required here by the fertilizer companies. I do not imagine many participants at this Congress were delivered to school with the milk "having helped to obtain it". The milk, of course, had priority over education. It was hard work, the men worked from 6 a.m. to 6 p.m. six days a week and milked the cows by hand on Sunday mornings and evenings. Three weeks wages equalled a ton of wheat; today one weeks wages equals a ton of wheat. The hard physical labour has disappeared. I am not sure that the men were any less happy.

The value of the "Market Place"

Everything we produced had to be sold, there were no support systems. We operated in the "market place". It is strange how everyone is afraid of the "market place" with the result that the truth which it can undoubtedly reveal to our advantage is obscured.

The "market place" is a constantly updated source of information about the supply of goods and services worldwide at any moment of time; only with this information can decision taking be valid. Where there is no "market place" there is no information on which to take decisions, which almost always results in inefficiency. In the end of course the "market place" re-asserts itself as witness today's high unemployment levels caused by distortions created by printing money or borrowing to pay for high living standards of the 1950-60-70's. Anyone who has mowed green grass with a scythe at 4 a.m. and then argued with a bargee about its value, will not need to attend any symposium "on marketing".

Technical developments

Science has reduced the real price of wheat by a factor of three in 50 years - no mean achievement. Farming then was mainly an art. Science has changed all that. I have lived through a revolution that no other generation can possibly live through. The tractor has replaced the horse. Today my staff would use a hydraulic digger to bury a dead cat. The giant combine harvester has replaced the scythe, the milking machine the hand milker. Fungicides have dramatically increased our ability to achieve regular cropping, increased yields and product storage life. Herbicides have replaced the hoe. Investment in agricultural research is producing an enormous pay-off. Wheat and rice production in India and Indonesia have each exceeded 33 million tonnes as a result of plant breeding. The big development lesson of the 1970's is that agricultural production is the best way to alleviate population pressure. Where agricultural production rose birth rates fell.

Science has indeed marched forward with seven league boots; it has not however replaced the farmers' boots which are still the best fertiliser.

A computer will not replace the farmer, although it has a place in systems management. A recent study by Leonard Scherlis, University of Maryland, U.S.A. found that where computer records were used for the diagnosis of patients' heart problems for pacemaker implants 785 were errors and only 30 were valid. He concluded the method was useless.

Last year British Telecom's computer paid out £160 million for goods not supplied. In Britain too much of our research budget is spent on electronic and computerised measuring of experiments, and not enough on evaluating the value of the experiment in the first place.

Adapting to change

During my lifetime adapting to change has been a constant challenge and the pressures are getting worse. We must aim for simpler systems. Rising living standards increase the pressure on management which will need to be the most highly rewarded sector of society in any Nation that realises that it needs to compete in the World's "market place" to maintain or increase living standards. Welfare systems have to be paid for with real money, not by borrowing or inflation. Health services, education, pensions, help to the third world, research, jobs, can only be funded by cash earned in the "market place". The rules of running a Nation are exactly the same as running a farm. Present high unemployment problems in much of the world will only be solved by using the simple rules of the farmer. To retain his capacity to produce, he is constantly ploughing back his resources into his farm. When there is no productive work to do he is draining, roadmaking, tree planting, building, investing in the future. We must all follow his example and use our spare capacity to improve our infra structure to make our countries better places to live in; living standards are not just in the paypacket.

Agricultural support policies

The farmers are the gardeners and guardians of the countryside and are, after all, only life tenants. In Europe the Common Agricultural Policy (C.A.P.) has had as one of its objectives, a reduction in the number of farmers working the land. To the extent that it has succeeded it may have contributed to unemployment numbers and urban crowding. The C.A.P. is also producing a fiscally supported surplus that is being dumped on the world markets, causing a trade war with the U.S.A. and tension within Europe over its costs. A new approach to agricultural support is required (see separate paper "A new strategy for the C.A.P." available from the author).

It is at last becoming accepted that to give food to the third world as aid is misguided. A recent study has shown that less than 1% of American post war aid reached its target. The development of agriculture in developing countries in order to meet local needs is a pre-requisite to true development. Their current annual deficit of 14 billion dollars to buy food cannot continue. No increase in agricultural productivity can occur until there are prosperous local farmers. If increased production is desired the producers must be paid more to produce it. This must be backed by research and development and technical support at the production centre. A research/advisory system must be developed in each local situation. Local pride, local markets, local production, local knowledge provide the only means available or necessary to allow the third world to advance by its own endeavours. Food aid should be used to support these developments and in local disaster situations, not to supplant them.

Farming and conservation

In Britain, we have one of the World's most beautiful and varied court-yards which has been the subject of much emotive debate and now legislation. The countryside has always reflected the pressures of population and farming upon it. A code of practice where each farmer keeps say 2% of his land in hedges or woodland would produce a sensible impact and remove the need for unenforcable legislation. The farmer could be forgiven for suggesting that town dwellers do not show the same level of responsibility.

On our family's farms we have, I believe, demonstrated that scientific agriculture and the environment can go hand in hand. We are proud that my farm, "The Bradshaws", was runner-up in the Country Life Farming and Wildlife competition in 1983. Fungicides, herbicides and irrigation are used in the early stages of woodland copse and hedgerow planting followed by elimination of briars and nettle. This encourages natural areas of woodland scattered in highly intensive agricultural and horticultural situations.

Fungicides and preservatives have considerably extended the shelf life and quality of most perishable foods and there has been a substantial increase in the availability of processed foods; these trends have tended to favour the supermarket chains at the expense of the small individual shopkeeper. However, we are witnessing a swing away from standardised processed food back towards fresh produce. The fresh chicken commands twice the price of the similar frozen article.

At "The Bradshaws" we are building on this situation with our farm shops selling fresh local produce, where fruit and vegetables harvested on the same day are available to the public with supermarket self-selection in good environmental surroundings and with good parking facilities. We have gone the full circle from when the fruit and vegetables were grown within transport distance for a horse and cart to the city market in pre-motor car days back to the same situation today. Access of the public is another feature of our farming where a wide range of fruit and vegetables is available for self harvest and self selection.

Developments in production systems

In our cereal crops simple innovations have had large impacts on our ability to manage the crop. Tram lines and wide profile tyres have given us access to the crop throughout its growing period with spin off benefits to the game birds nesting in the crop.

These two simple developments have removed the need for aerial spraying with its attendant risk of drift. The production of vegetable oil from rape has enabled us to maximise the use of our existing grain sowing and harvesting equipment.

The chemical industry and agricultural research centres are constantly producing more potent and more specific new products which are rapidly biodegradable. Integrated control with such environmentally safe materials must be the long-term approach. Policing of all the spraying on all the farms in the world is impossible. Efforts to improve the safety of agrochemicals and to develop safer working practices must continue. For example, drivers will simply not tolerate heavy protective clothing in hot climates; many of them smoke and management is already overloaded in many situations. The emphasis must be on the production of safe materials which remove the need for policing. The safety record is already impressive: it is interesting that in a recent survey in U.S.A. where records are available on the causes of death, food colouring, food preservatives, pesticides and starvation, produced no deaths. Smoking, alcoholic beverages and motor vehicles caused 300,000 and an unspecified number from overeating. A reader of the media might be forgiven for thinking that the figures were the other way round.

Three simple problems that occur on our own farms suggest that we should not be complacent in any way about protection against pests and diseases:-

1. The ability of powdery mildew to overcome inbred resistance in barley.
2. The ability of red spider mites to acquire resistance to acaricides.
3. The emergence of weeds resistant to herbicides that are in common use, for example, groundsel, atriplex and mayweed.

These simple observations together with the facts that we only have a few months' supply of grain in the world at any one time and that the main aim is to reduce the cost of food production, thereby providing a better variety and quantity of food to the world's population, suggest that we must continue in our quest for knowledge. Feeding the world is technically easy, it is only the price that causes problems. While the cost of production is declining the cost of distribution is increasing. The objective must be to provide a wider variety of better quality food to a larger percentage of the population.

The art of the farmer: practical problems in using crop protection chemicals

Farmers say that the weather does not come with the can of pesticide. Consider the following list of conditions under which pesticides should not be applied:-

1. it is raining
2. leaf is wet with dew

3. plant is dry under moisture stress
4. under windy conditions
5. temperature is over 65^{o}F
6. temperature is below 50^{o}F
7. in intense sunlight
8. mixed with non-compatible materials
9. on open blossom
10. to resistant pathogen or pest
11. to plants to be consumed within 14 days
12. to untested varieties
13. to uncleared minor crops
14. when water supply is hard
15. without adding cationic or non-ionic wetter
16. before reading instructions on can
17. after material has been exposed to frost
18. to rapid growing lush foliage
19. if unable to convert pints per acre to litres per hectare
20. if unable to calibrate sprayer
21. if unable to identify the target
22. when ground is too wet to carry machine
23. when unsure of effectiveness of material
24. if you have no field experience
25. when customers are looking
26. if unable to afford the cost.

Apart from these situations you may apply when you wish. Agriculture with high inputs and high technology is bound to cause pressure on both the farmer and the environment.

And so the evolution of farming will continue with the increased pressure of the "market place" being a challenge to the art of the farmer, whose constant struggle with the climate has made him one of the most stable and philosophical members of modern society. His art is an essential part of the science of feeding the world; the art of running a farm will be a better model on which to base our future path than any computer model.