Trans. Natl. Acad. Sci. Tech. Philippines 21: 148-154 (1999)
ISSN 0115-8848

GLOBAL PERSPECTIVE ON PESTICIDES

MANFRED KERN
Senior Scientific Communication Officer
Hoechst Schering AgrEvo GmbH
H 872, D-65926 Frankfurt/M., Germany

ABSTRACT

World food supplies will have to be doubled several times by 2025 to ensure food in sufficient quantity, due to increase in population, greater urbanization and spending power. Among the technology packages which need to be developed to increase agricultural production to during the next three decades are: germplasm, crop protection products, fertilizers, irrigation systems, technical equipment, management concepts such as integrated pest management, integrated crop management and precision farming. The annual losses due to pests especially for rice, wheat, barley, maize, potatoes, soybeans, cotton and coffee are estimated to be 50% of the total crop area worldwide. Pre-harvest losses caused by insect pests constitute 15%, pathogens – 13%, weeds – 14%, and post harvest losses, an additional 10%. Presently, pesticides are used only in about 1/3 of the total cropped area in the world, 75% of which is in North America, Europe and Japan, and 25% in the developing world. Studies show that for each US$6.5 billion in pest control save approximately US$26 billion in crops, based on direct costs and benefits. Thus, to produce more food, it is important that crops be protected against diseases, pests and weeds. It is therefore the ultimate strategy of crop protection companies to produce improved, pest-specific chemicals that are less harmful to human health and the environment and less likely to affect non-large species than earlier broad spectrum chemicals. Companies that offer farmers solutions that make use of synergies between chemical crop protection and biotechnology will have an important competitive advantage.

Keywords: crop protection, pesticides, weeds, pathogens, insect pests, biotechnology, integrated pest management

Food security is a global concern. The 1995 world food production was only 0.26% higher than the global food demand. This describes the situation of the present world food security.

It is generally agreed that world food supplies will have to be double several times by 2025 to ensure food in sufficient quantity, not only because of the increase in population but also as a result of greater urbanization and spending power. In the past, world agriculture was technically in a position to produce enough healthy food for the growing population by gradually introducing yield-increasing technologies, such as high-yield seeds, crop protection products, fertilizers and improved irrigation systems. Due to many different factors, however, more than 840 million people throughout the world are at the present time still undernourished. A prediction of the USDA (1998) shows that the number of malnourished will rise from the current level of 840 million people to 1140 million in 2008.

"Meeting the needs of the present without compromising the ability of future generations to meet their own needs" is the definition of sustainable development as written in the Brundtland commission report in 1987.

Sustainable agriculture, a paradigm that rests on the wise management and preservation of agriculture's resource base – water and land – offers us our only hope of ensuring food security as we enter the next millennium.

More land was cultivated in the last 140 years than during the last 40,000 years put together, when agriculture did begin (Dobson, 1997). Furthermore, we have to learn to accept the notion that we have to produce twice as much food within the next 30 to 40 years than in the whole of the last 10,000 years added together (Kern, 1998). One twentieth of all the people who ever lived on the earth are living today (Kaku, 1998).

What are the technology packages in agricultural production?

The key question is the following: What are the technology packages that the stakeholders in the food-production chain need to develop over the next three decades: germplasm, crop protection products, fertilizers, irrigation systems, technical equipment, management concepts such as integrated pest management, integrated crop management or precision farming?

What can we expect from different agro technologies within the next 30 years?

Full utilization of all technologies in crop production, including modern biotechnology, will play a decisive role in increasing yield for the preservation of sustainable global self-sufficiency. At the moment 1.7 billion people are "fed" by fertilizers, 1.67 billion people by irrigation, and 2.4 billion people by good agricultural practice including fertilizers, 2.4 billion by irrigation, 2.25 billion by good agricultural practice and 1.6 billion (19% of the global population) by bioengineering of crops. The quantitative impact of biotechnology on regional agricultural food production is forecasted for 2025: Africa, 6%: Latin America, 17%; Asia, 20%; developed countries, 28%.

What has happened during the last 30 and the last 60 years of agricultural production?

From 1930 up to 1995, the cotton growing area has remained unchanged, but cotton production has tripled.

Since 1950, global harvested rice area has been enlarged by 40% only, even though global rice production increased by more than 300%. This situation underlines very well the importance of agro technologies, because during the last 40 years it was possible to increase the productivity by a factor of 7.5.

Since 1980 a global reduction of cereal acreage through yield increases was possible at a level of 34%. In contrast, in Africa, an extension of cereal acreage by 24% was necessary due to insufficient yield increases.

How big are the annual crop losses from pests?

Yudelman et. al. (1998) have reviewed the estimated annual losses from pests, especially for rice, wheat, barley, maize, potatoes, soybeans, cotton, and coffee, i.e. 50% of the total crop area worldwide. Pre-harvest losses are caused by insects (15%), pathogens (13%), weeds (14%) and additionally 10% by post harvest losses. Without pest control the overall worldwide losses from pests were as high as 50%. A comparison of global crop loss estimates from different sources has shown that since the 1940s the pest losses today are as high as they were 50 years back (Pimentel, 1991).

Where and how much pesticides are used in the world?

At the moment pesticides are used only in about one-third of the total cropped area in the world (Oerke et al., 1995). More than 75% of pesticides are used in North America, Europe and Japan on a crop land area of only 45%, whereas in developing countries with 55% of the global cropland only 25% of global pesticides are used. The "top ten" country markets are USA, Japan, France, Brazil, Germany, China, Canada, Italy, Argentina and Australia.

The average amount of chemical crop protection products applied to arable cropland differs greatly from one country to another. Japan applies about 17.5 kg. active ingredient per hectare, but application rates in Europe and the US are below 4 and 2 kg a.i./Ha. Developing countries, e.g. Indonesia, India, and Africa, apply much less at 0.2 to 1 kg. a.i./Ha. Limited inputs for agricultural production results in generally lower yields, especially in developing countries.

Two examples describe the different trends. In Germany, the pesticides use per hectare decreased from 5.8 kg./ha to 3.0 kg./ha within the period of 1990 to 1995. In Taiwan, the overall pesticide consumption increased from 10,000 tons to nearly 50,000 tons within the period 1965 to 1995 (Chen, 1997).

Between 1960 and 1998 the world pesticide market increased by a factor of 3, from US$ 900 million to US$ 28 billion.

Ten top crops currently make up 65% of the total world market. There are important market potentials in orchards, vineyards, cereals, rice, horticulture, vegetables, rape, maize, soybeans and cotton.

Herbicides account for approximately 50% of the global crop protection market. The world insecticide market accounts for about US$ 6.8 billion, with 52% of this in the Asia-Pacific region. The most important crops in the insecticide markets are cotton, horticulture, vegetables, rice and fruits.

What are the costs/benefits from pesticides?

Pimentel (1997) made an assessment of the total estimated environmental and social costs from pesticides in the US. In general, each US$ 6.5 billion in pest control save approximately US$ 26 billion in crops, based on direct costs and benefits (Pimentel et al., 1991, 1997; USBC, 1994). With the use of IPM/ICM strategies, proper use of available pesticides as well as the development of new pesticides with improved qualities, it will be possible to optimize the benefits of crop protection products.

If mankind is forced to produce more food, feed and fibers, it is vitally important that crop plants should be protected against diseases, pests and weeds. The goal in reducing high losses is to enhance food security. It is estimated that, without crop protection, only half of what we produce would be actually available for harvesting. In other words, to achieve the same harvest volume without crop protection, it would be necessary, in theory, to double the agricultural acreage. The need for increased food production can only be met with the aid of agricultural inputs, including chemical crop protection products. The benefits of crop protection products by far outweigh their direct private and social costs, since high yields, sparing use of resources and environmentally benign technologies will not only secure our food supplies but will also maintain the biodiversity of our planet. Further conversion of forests into arable land can and must be avoided.

What is an ideal insecticide?

We focus on insecticides as an example. Today we have insecticides based on around 40 different chemical classes and more or less different modes of actions (Naumann, 1998).

The scientific challenge for a new one is described as follows:

An ideal insecticide should be highly researched, but low priced; superior to other products, but not more expensive; highly selective, but big in market size; with long life in the market, but without creating resistance problems; broadly active on pests, but does not leave crop and environmental residues; fast-acting on pests, but preferably not as a neuro-toxicant; mobile in plants, but immobile in soil.

Which are essential challenges to develop an ideal insecticide?

Combining 20 essential factors for an ideal insecticide, such as target spectrum, crop spectrum, selling price, turn over, market size, innovation, application, mode of action, mechanism of action, resistance, cross-resistance, mechanism of resistance, resurgence, selectivity, IPM/ICM-ability, acute toxicity (LD_{50}), fish toxicity, water solubility, registration costs and future perspectives, we can conclude, that there are excellent chances to improve the quality of new insecticides and to reach the level of an ideal insecticide. This is one of the research challenges for the chemical industries at the beginning of the next millennium.

How is AgrEvo realizing scientific innovations?

New chemicals

The R&D Strategy is focused on new technologies. An innovative technology in combinatorial chemistry was developed and used to rationalize the synthesis of many new molecules. Protocols and competence were developed to establish a high-through put screening in vivo Micro/Nano screening, where some milligrams of active ingredient are enough to test 100,000 to 1,000,000 compounds per year. Investments were made on new targets sites and new modes of action, leading to entirely new classes of molecules.

Forty percent of the R&D budget accounted for approximately 12% of sales invested in research and development of new chemicals, 30% in the maintenance of existing products, new formulations, re-registration and new indications, and 30% held in reserve for biotechnology.

Our goal is to launch two to three new active ingredients per year.

Nevertheless, as mentioned earlier, the new technology – biotechnology genetic engineering – will significantly contribute to crop protection and/or crop production in the future. Therefore, it is essential to reflect and to analyze the potential of both technologies, what is technically possible, in which time, at what price as well as what is socially acceptable.

Rice as an example (of low and high potential zone) will show some parameters, which are important for setting research targets to support sustainable agriculture, sustainable development, and finally sustainable socio-economy. Five areas are included: seeds, water irrigation, fertilizer, crop protection products and biotechnology.

Which plant production problem can be solved by using which technology?

Seeds: for higher yields, higher conversion rate of sun energy, better defense system of rice against pathogens; for rice plant/ insect pest interaction, plant herbivore interaction, better utilization of nutrients; for rainfed rice, better plant "architecture", tolerance of greenhouse gases (CO_2, CH_4, etc.), tolerance to temperature, and increase of feed value of secondary products.

Water irrigation: to avoid salinity and contamination, optimized use.

Fertilizer: to avoid methane production, optimized use.

Crop protection products: for improved pesticides, broad spectrum fungicide, broad but selective insecticide, combat-resistant baiting insects, systemic activity of insecticides, highly flexible "one shot" herbicides, development and implementation of IPM/ICM.

Biotechnology/Genetic engineering: for new qualities or properties, resistance against hoppers, stem borers and weevils, resistance against virus diseases, resistance against fungus diseases, minimizing use of nutrients, gene mapping, gene discovery -- useful for rice plants, rice plants with low CH4 transport potential, improved level of vitamins, improved level of iron, temperature tolerant or insentive rice plants, increase of the feed value of secondary products.

At the moment a wide spectrum of genetically optimized crops are grown in the world, especially in North and South America. It is forecasted that in the year 2003 nearly 60% of all grown crops are GMO-crops in North America (corn, soybean, cotton, potato, rape, sugar beet). Most of them are pest resistant or herbicide tolerant. The final result is a reduction in the number of pesticide applications and last but not least a significant reduction of chemicals.

Pesticides: Future trends

Nevertheless, a changing crop spectrum and a changing pest spectrum will need new pesticides. Therefore, continuous development will be important and essential. Pest control methodologies are expected to change substantially in developed and in developing countries, but pesticides will remain a major tool in the future.

A very good summary is given by Yudelman et al. (1998):

In developing countries, however, if current trends persist, chemical pesticides will continue to grow over the next 25 years. There will have to be substantial growth in food production to provide food security for their population. Production of pesticides within developing countries is also increasing, with both multinational and local manufacturers (India's and China's export will be more than US$ 500 million).

In developed countries the major manufacturers of pesticides are investing heavily in research to produce improved, pest-specific chemicals that are less harmful to human health and the environment and less likely to affect non-target species than the earlier broad spectrum pesticides.

Rates of pesticides use have dropped from 2 to 5 kilograms per hectare to 0.01 to 0.2 kilogram per hectare. The same is true for the number of applications using ICM. The industry is also moving towards improved delivery and application systems. Most companies are also diversifying to other pest management solutions, including IPM/ICM, precision farming and biotechnology.

It is the ultimate strategy of crop production companies to develop and implement new technologies down to farmer level. Companies such as AgrEvo, which offer farmers new solutions that make use of synergies between chemical crop protection and biotechnology, will have an important competitive advantage. Companies providing all tools of integrated crop production systems will be in the pull position.

Yardstick for agricultural progress

At the end let's take a look at the yardstick of agricultural progress and AgrEvo's contributions. In recent history, let us begin with the discovery of photosynthesis by Jungenholz in 1779. From then on until the invention of the first photosynthetically active herbicide, Atrazine, in 1957, 178 years have passed. Between the first discovery of the cell nucleus by Brown in 1833 and the establishment of the first seed company in 1926, 93 years have passed. The innovation concerning fertilizers made by Liebig in 1840 was intensively used after World War II. Between the first report on chemical pest control of the Colorado Potato Beetle in 1877 and the synthesis of the first insecticide in the year 1939 by Muller, there was a span of 62 years, The time span between the genetically engineered organism in 1980 and the first commercial introduction of a genetically modified plant, the insect resistant Bt-cotton, was a mere 46 years.

These simple examples suggest that changes are not progressing in a linear way, but in a positive, non-linear acceleration. Fortunately, the increasing speed of implementing agro technologies is in line with the exponential growth of the world food demand and safeguards world food security, today and in the future. Within this context we have an optimistic vision of what the future can be.