QUALITY CONTROL OF PLANT GROWTH, PLANT PROTECTION, AND QUARANTINE

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Contents

Summary

The development and use of many efficient and economical pesticides, since the 1940s, have permitted unprecedented crop and animal protection, and improved public health. Despite the positive effects mentioned above, many problems arose, such as the destruction of other pests in addition to target pests, destruction of natural enemies, pest resistance, and the health hazards caused by pesticide residues in foods. Trends in agriculture such as integrated pest management, sustainable agriculture, development of new and more effective pesticides, and the breeding of new and resistant plant varieties have the aim of eliminating negative effects of the use of pesticides without disrupting the positive achievements. Food regulations at the national level, and the activity of international organizations, are the tools for assurance of food safety because they establish acceptable limits of contamination and enforce food regulations and food laws.

1. Introduction

To assure a satisfactory supply for the growing world population, an increase in food production is needed. Cereal (wheat, rice, maize, rye, barley, sorghum, millet) production has to grow 2.4% annually to cope with the minimum need of world population. This food output has to be achieved by higher yields from the arable land already in use. Global land resources are about 1.4 billion hectare (ha), of which 1.2 billion ha are cultivated with major crops. Experts agree that a future substantial addition of new productive areas is unlikely. Those with a high yield potential are in use; new fields with lower outputs may possibly be obtained by cultivation of arid or cold areas. But the main way to achieve higher production is by raising crop productivity.

Raising crop productivity is not a matter of pure speculation. In the last 20 years of the twentieth century, the yield for major crops roughly doubled in Western agriculture. There is still the potential for further achievements, particularly in developing countries. In 1980 four billion people had a cultivable area of 3000 m^2 per capita; in 2020 it will be reduced to 1600 m^2, with the total population estimated at 8 billion. This is a fascinating challenge for all involved in plant production.

There is no alternative but to optimize global agriculture by continuous development and improvement through integrated plant production systems. This must be based on advanced technology, appropriate education of farmers, and efficient and economic food distribution. Technology includes mechanization of tillage and harvest, advanced seed-breeding stocks, fertilizer, and, chemical plant protection by herbicides, fungicides, and the control of weeds, fungal pathogens, and insecticides. About 50% of market share is made up by herbicides. Without chemical control of weeds, fungal pathogens, and insects, major crops would suffer losses and yield penalties up to 40% and more. Weeds compete with the crop for space, fertilizer, water, and light. Ten wild oats/m^2 in a wheat stand will reduce the yield by 10%, and 50 wild oats/m^2 by 24%. Such reductions would raise prices. The luxury of obtaining supposedly healthier food by "bio-farming" without chemicals is something prosperous people of rich nations can afford; but it cannot be the basis for meeting global needs.

The wide use of different chemicals (fertilizers, pesticides) in agricultural practice has provided numerous benefits in terms of increasing production and quality. However, in contrast to benefits, the contamination of products of plant origin, and indirectly of animal products, with the residues of pesticides, has become a safety hazard for consumers (see *Food Safety*). *Pesticide* is a term used in a broad sense for chemicals, synthetic or natural, which are used for the control of insects, fungi, bacteria, nematodes, rodents, and other pests. The era of synthetic organic pesticides began around 1940. The commonly known insecticide DDT (dichloro-diphenyl-trochloro methane), was originally synthesized in 1874, and rediscovered as an insecticide in 1939, and was soon followed by benzenehexachloride (BHC). Since then thousands of compounds have been synthesized and used.

Economical, effective, and easily available pesticides, such as 1,2,3,4,5,6-hexachlorohexane (HCH), are used by farmers for the control of insect pests. Developed countries banned DDT and HCH around 1990, as these two compounds are persistent in the environment, are lipophilic, and have the capacity to remain stored in human body fat. However, in India and some other developing countries, DDT and HCH are still being used on a large scale. The recommended dose of chlorinated pesticides ranges from 8 kg/ha to 10 kg/ha.

The limonoids present in the neem tree (margosatree, Indian lilac, or azadirachta) and its products are the base of a harmless and useful insecticide, bactericide, fungicide, and pesticide.

The substantial contribution of herbicides to farming technology started in the 1950s with auxin-type compounds, nitrophenol herbicides, and photosynthesis inhibitors such as triazines or ureas. The use rate in those days was between 2 kg and 3 kg active ingredient (a.i.)/ha and higher, which had a massive chemical impact on the environment, together with a leaching problem resulting in contamination of groundwater and tapwater. The agrochemical industry, the public, and legislators agree that reduction of the chemical load is a major objective of the development of new herbicides. At present, the use rate of modern herbicides is in the range of 100 g a.i./ha to 300 g a.i./ha, with a declining tendency. Phenoxypropanoates are in the range of 100g a.i./ha to 150 g a.i./ha; acetolactate inhibitors (such as suflonylureas or imidazolines) require an even lower amount, down to 10 g a.i./ha for some commercially active ingredients. Obviously, soils overloaded with chemicals or leaching problems are not an issue with such low application figures. This story of success is going on with the peroxidizing herbicides (peroxidizers) that are the focus of this article. Peroxidizing herbicides are inhibitors of protoporphyrogen oxidase, a key enzyme in chlorophyll biosynthesis. They show a high affinity with their target enzyme, and their radical-producing action by light activation leads to use rates down to 3 g a.i./ha, depending, of course, on application mode, crop, and peroxidizer type.

2. The Negative Effects of Chemical Plant Protection

Laboratory animal studies and accidental contamination of food, in addition to occupational and intentional exposure to pesticides, have provided evidence that those chemicals may cause serious health effects following excessive exposure. The reported effects range from acute fatal poisoning to sensitization, impaired immune function, neurobehavioral disorders, and cancer.

Concerning organophosphates (Ops), the most dangerous pesticides, it is known that these are anticholinesterases. Their action is to phosphorylate esterases, particularly the enzyme acetylcholinesterase, thus causing an accumulation of neurotransmitter acetylcholine. Inactivation of cholinesterases by Ops involves a reaction in which one substituent group, the leaving group, is lost, producing a dialkylphosphoryl enzyme. The vast majority of insecticides produce a dimethylphosphorylate enzyme or a diethylphosphorylate enzyme, and the kinetics of reactivation are the same for each derivative regardless of the structure of the leaving group of the Op. Reactivation of the enzyme dimethylphosphorylate is considerably quicker than that of the diethyl equivalent and occurs in a few hours.

Acute intoxication with Ops can cause major effects such as convulsions, respiratory failure, and cardiac arrhythmias, all of which can result in anoxia. It is hardly surprising that major intoxication is sometimes associated with long-term central nervous system changes. A number of studies of this problem have shown the occurrence of behavioral and physiological alterations, and others have failed to demonstrate any effects. Organophosphates may have other properties that are entirely independent of their anticholinesterase effects, including mutagenicity and carcinogenity, and organospecific toxicity to the heart, liver, kidney, and other organs.

The heaviest danger of pesticide intoxication is connected with direct contact. This may occur in an industrial accident during manufacture. Another type of hazard is created by those who repeatedly misuse pesticides in an agricultural setting. They may themselves become the victims of the misuse. For example, a farmer who returns to the fields too soon after spraying may face long-term health risks.Although the serious poisonings mentioned above are rare in satisfactorily organized factories and agricultural farms, the contamination of raw food materials or finished food with low quantities of pesticide residues is more frequent.

The creation of pesticide residues on cultivated crops and in the environment depends on various factors. The most important factors, which will be examined in this chapter, are the application method, environmental conditions, and molecular characteristics. Treatment with pesticides is one step in production activities that is indispensable for protecting the cultivated crops from parasites. The modalities of treatment, however, can be instrumental in limiting pesticide residues. For this reason, it seems evident that it is necessary to consider carefully the variables that most affect the optimization of the treatment itself.

The choice of sprayer machines, their adequacy, and the periodic verification of their efficiency are determining aspects of the treatment that increases the efficacy of active ingredients and consequently reduces the quantity of formulations to be used. This factor is particularly important in the treatment of fruit, because the quantity administered to the fruit is directly correlated to the residue quantity. After treatment, there are two main causes for the disappearance of the active ingredients: their degradation and their transfer into the surrounding environment. The first cause is essentially a chemical and/or biochemical process, and brings about the demolition and/or more or less complete transformation of the active ingredients, while the second is correlated to physical mechanisms such as evaporation and washing away.

Many differences among pesticides concerning the speed of their disappearance from matrices are due to their chemical-physical properties, which are responsible for the capability of their molecules to penetrate into and be transported within the plant. Coverage product residues can be eliminated, for the most part, in a physical way (meteorological washing away). The primary chemical mode of elimination is photodegradation.

Temperature constitutes an external agent that is able to reduce pesticide residue concentration; high temperatures help the degradation and volatilization of most active principles. Partly systemic products are absorbed by plant tissues and, although they remain in the area surrounding the site of application, they are subject to chemical and/or biochemical transformation. The destination of the systemic fungicides is even more difficult to specify because, having the capability of penetrating the plant tissues and of being transported within them, they undergo various transformations according to the biochemical properties of each vegetable tissue.

It must also be kept in mind that some treatments against fungi are carried out even after harvest, with the aim of avoiding numerous physiological alterations in the vegetable product. The pesticides normally used for this purpose are systemic fungicides with broad-spectrum action belonging to the chemical class of benzimidazole fungicides (MBC, TBZ, and tiophanate methyl). Such preventive interventions are the last to be carried out before the storage of the vegetable, and residues of these active ingredients are frequently present in products coming from preservative refrigeration.In conclusion, we briefly consider some of the most common industrial operations that foodstuffs undergo that affect the quantity of the possible residue.

Vegetable washing is an operation that no doubt has a positive effect on the removal of superficial residues, whereas the scalding treatment normally used in industry has various effects according to the modalities: If it is carried out with steam, it is ineffectual in removing residues; if, instead, the scalding is carried out in water, it causes the elimination of a good quantity of residues through washing away. Similar results can be obtained by peeling, when applicable.

Cooking, more or less completely, is considered the best way to demolish pesticide residues, even those of a systemic nature, especially if followed by mashing of the food materials. Pesticides are applied directly to the parts of plants above ground, or they may enter plants via the soil and roots, or by seed treatment. Once in contact with the plant, the fungicide will be subject to natural processes, which may alter its chemical structure. Knowledge of the metabolic fate of pesticides in crops is necessary to assess the nature of any residue of the compound. Such assessment is part of the toxicological evaluation of the pesticide because the products of metabolic degradation processes also may be toxic.

A large amount of the pesticide escapes the natural degradation process and persists, not only in agricultural products but also in natural water resources and the soil. Whereas surface water is subject to naturally occurring environmental processes that help to chemically transform or degrade pollutants, processes such as heating and cooling cycles, exposure to sunlight, microbial transformation, and oxidation, groundwater is not subject to these processes. Therefore, once contaminated, this important resource recovers slowly, if ever. A national survey organized by the US Environmental Protection Agency (EPA) in 1990 found that about 10% of the community water systems and 4% of the rural domestic wells contained detectable concentrations of pesticides. Less than 1% of all the wells surveyed had concentrations slightly above levels considered safe for human health.

Soil is the main nutrient source for growing plants, but farmers have for thousands of years added growth-enhancing nutrient substances to the soil or rotated their crops in a certain order to replenish nutrients. Until this century, most of the fertilizers used were naturally occurring compounds. However, the development and widespread use of industrially synthesized crop-protecting pesticides have made agriculture much more chemical-intensive than ever before. Consequently, depending on the conditions, smaller or greater parts of the pesticide used may be incorporated into the soil. Keeping in mind that many pesticides are not biodegradable, an increase of contamination may occur if the pesticides are not fully absorbed by plants. The pesticides remaining in the soil may negatively influence soil microorganisms and are a potential danger for surface water and groundwater.

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Biographical Sketch

Demeter Lásztity is assistant professor at the Department of Plant Physiology at Eötvös Lorand University in Budapest. He obtained his M.Sc. Degree in biology at Budapest University in 1964, and his Ph.D. Degree in molecular biology in 1971 at the same university.

His research work is connected with plant physiology, particularly with photosynthesis and the mechanism of the action of herbicides. He has published more than 100 scientific papers in domestic and international scientific journals.