FAO/UNEP/USSR

International Training Course

«TRAINING ACTIVITIES ON FOOD CONTAMINATION CONTROL AND MONITORING WITH SPECIAL REFERENCE TO MYCOTOXINS»

K. L. NAZARETYAN

PLANT GROWTH REGULATORS, MINERAL FERTILIZER AND THE PROBLEM OF MYCOTOXINS

Centre of International Projects, GKNT

Moscow 1985

Plant growth regulators, mineral fertilizer and the problem of mycotoxins

Nazaretyan K.L.

The greatest danger for the health of people in our age of industrialization is pollution of the environment by chemicals. At present out of the known five million chemicals more than 60 thousand are widely used: 1500 of these are used as pesticides, 4000 -- as drugs; 5500 are used as food additives. More than 1000 new compounds are annually introduced into industry in the Soviet Union. The scale of human contact with these chemicals varies. With some of them hundreds of people come into contact, with others -- thousands and with still others -- millions of people. The latter include chemical means of plant protection.

The importance of the applied chemicals in agriculture can hardly be overestimated. One can say without exaggeration that alongside with mechanization, the introduction of chemistry is the decisive condition of increasing the harvest yield of all farm crops, the productivity of livestock breeding and the productivity of agricultural labour.

Plant growth regulators hold an important place among various representatives of chemical means of plant protection. These include natural and synthetic organic compounds which in small doses actively influence the metabolism in plants which leads to visible changes in growth and development.

The natural regulators of plant growth include primarily phytohormones. These substances which develop within the plants

and are engaged in the regulation of the metabolism on all the stages of plant life beginning with the development of the germ from the fertilized ovicell and ending with dying when the life cycle of a plant is completed.

Phytohormones develop in some organs or tissues of plants where they orient the nature of the processes therein. Thus, these substances ensure the functional integrity of a plant organism, a coordinated operation of all its components.

The peculiarity of hormonal regulation of physiological processes in plants consists in the fact that the activity of one component of a system is closely associated with the operation of others. Accordingly, each hormone has its specific functions which, however, it can fulfil only given a simultaneous (or consecutive) implementation of the activity of other endogensous regulators.

At present, we know of five groups of phytohormones: auxins, gibberellins, cytokinins, abscisinic acid and ethylene. Besides this, a large number of synthetic analogues of these natural compounds have been obtained and quite frequently they possess a high physiological activity. Strictly speaking, these substances cannot be classed with phytohormones since they are not formed in plants but many of them, judging by their activity, are not inferior to phytohormones or even surpass them.

The majority of synthetic regulators are physiological analogues of endogenous phytohormones or act by changing the hormonal status of a plant.

At present we distinguish between the growth regulators which do not have any phytotoxicity and herbicides (substances

which destroy or inhibit plants), defoliants (substances which cause the shedding of leaves) and desciccants (substances which facilitate the dehydration of plant tissues). Naturally, this classification is conditional just as the classing of many substances with one or another group. For instance, some chemical compounds (2,4-D and other haloidphenoacids) in small doses act as growth regulators but in greater doses are active herbicides. Maleic hydrazide, subject to a specific economic or physiological situation, performs the function of a herbicide or a growth regulator.

Synthetic regulators acquire increasing importance since they are capable of accelerating the transport of nutritives, activize their accumulation in useful organs of plants. These include the means which intensify the withdrawal of carbohydrates from the leaves of sugar cane or sugar beet into stalks or roots. Many other growth regulators have been developed and they modify the hormonal status of plants and therefore alter the course of physiological developments towards the wanted direction.

The share of all industrial preparational forms of growth regulators on the world market at present ranges from four to ten per cent. However, by the rate of the increase in their output, sales and application, in the sphere of "agrochemical business" outside of our country, phytoregulators surpass all other chemicals which find application in the agriculture of the world. According to preliminary estimates, the scope of world sales of growth regulators in 1980 trebled compared to 1970, the scope of application of herbicides will soon be smaller than the scope of application of growth regulators. More than that, it is ex-

pected that in the final count the application of phytoregulators will produce in agriculture just as cardinal changes as those which were produced by the application of mineral fertilizer in the past century. In any case, judging by the relative rate of the increase in the output of commercial preparations -- phytoregulators, world chemical industry is developing just as swiftly (563). It should be noted that out of the entire range of the manufactured growth regulators the lion's share belongs to retardants. In 1974 the world sale of synthetic phytoregulators (without defoliants) comprises 120-150 million dollars.

May I now turn to the toxicological-hygienic studies of plant growth regulators.

The majority of experimentally studied compounds belong to those with low toxicity, with poorly expressed cumulative properties. At the same time plant growth regulators being physiologically active compounds may actively interfere into metabolic processes of the organism of warm-blooded animals and man. According to findings by T.L. Panshina in the study of toxic properties of the group of herbicides -- halogenated anilides of carboxylic acids, it has been found that some representatives of that group of compounds when acting on the organism of warm-blooded animals, for a long time, increase the body mass of these animals and also the body mass of their progeny. The influence upon the growth of warm-blooded animals has been also found in herbicides 2,4-D etc.

The results of our experimental studies have shown that the arrival of growth regulators -- the derivatives of phosphonic acid into organism entails a disruption of the evolutionary de-

veloped mechanisms of protection of higher animals -- the activity of microsomal OSP.

A single and triple administration of kampozan, hydrel and dihydrel at a level of 1/2 and 1/5 of LD_{50} has produced an induction of OSP which is appreciated by the activity of demethylase of aminopyrine and alanine hydroxylase on the organism and subcellular levels, an increase in the activity of cytochrome C-reductase and the amount of cytochrome P-450, ultrastructural changes in mitochondrias and the proliferation of the granular endoplasmatic reticulum, an increase of the ribosome content in the latter.

When the mentioned products arrive, for a long time, at the level of 1/1000 LD_{50} the activity of OSP surpassed 44-55%.

The study of the nature of the harmful action of such preparations as TUR, HMA, alar, hydrel and others has shown that thair durable arrival into the organism of animals, at the least effective levels, may induce an embryo- and gonadotoxic effect.

The studies of Shabad (1978) and a number of other investigators revealed the blastomogenic activity of the derivatives of indole and hydrazine which indicates the necessity of appropriate studies in relation to the regulators which incorporate in their structure the mentioned groupings.

Thus, all this data indicate that the chemicalization of agriculture puts forth increased requirements to the protection of the environment since when growth regulators are applied as well as pesticides, their residues may reach food products, air and water and thus have a negative influence upon the human organism.

It is known that the distinguishing peculiarity of the Soviet science of hygiene is its prophylactic orientation, while its foundation is the hygienic regulation of the content of harmful substances in environmental objects. Therefore, when simulating intoxications with the idea of obtaining information for substantiating hygienic norms in environmental objects one should take into consideration their possible influence on the endocrynal system and the redox processes, the enzymes of detoxication and also the ability of producing remote effects. From our point of view, these studies are fundamental since the growth regulators are capable of influencing the mechanisms which accelerate the growth not only in plants but in animals also. The study of these mechanisms is the key link to decoding the peculiarities of unfavourable influences upon the organism of warm-blooded animals and man.

From the hygienic point of view it is likewise important to elucidate the actual values of residual amounts of growth regulators and of their metabolites in environmental objects. It is natural that to settle the problem as a whole one should have a range of modern quantitative methods of identifying chemical pollutants of water areas, soil, food products and air. One should take into consideration that growth regulators will be present in the environment, as it was noted earlier, in the least amounts and at the same time in a composition of an intricate combination and may be subject to transformations. Hence, the necessity of working out highly sensitive and specific techniques. This leads to the necessity of a wide application of most modern physico-chemical methods: mass-spectrometry-chromato-spectrometry, atomic absorp-

tion, neutron activation analysis etc.

The global nature of the problem of improving the environment predetermines the necessity of collaboration of specialists from different areas -- specialists in oncology, allergy, specialists in genetics, chemistry, agrochemists etc.

Summing up all aforesaid one should once again emphasise that growth regulators, as representatives of numerous chemicals, comprise one of the factors the study of which is closely intertwined with the overall task of environmental protection and environmental improvement -- protection of human health. An active settlement of this task in a strictly objective, scientific way guarantees healthy conditions of human life.

I believe that this information on the hygiene and toxicology of plant-growth regulators is adequate for a notion about them as biochemically active substances. Let us now refer to hygiene and toxicology of mineral fertilizers.

As it has been said, the increase in the size of the population puts before all countries one and the same task -- knowledgeable control of the ability of nature to reproduce vital resources and, first of all, food and we require not a simple but an extended reproduction of those resources. Governing the processes of extended reproduction of food resources may be most effectively implemented by applying mineral fertilizers in agriculture. It is not accidental therefore that scientific forecasts and plans are providing for further increase of the world output of mineral fertilizer at the highest rate compared to the forecast growth of the size of the world's population.

Taking into consideration the essential influence of mineral

fertilizers on farming output it is important to study and identify the main trends of the development of the output of mineral, and specifically of nitric fertilizers. As for the nitrogen industry, its main link which determines the progress of this branch is the technology of ammonium production which is the main raw material for the output of all types of nitric fertilizers. Besides this, ammonium as such in its liquid form is the most concentrated nitric fertilizer.

Table 1 and 2 show total world capacities for the production of ammonium, forecast data for their development up to 1990 and also the input of individual countries into the overall production.

The transformation of the industry of fertilizers has found reflection in the improvement of the quality of output. The improvement of the quality of fertilizer is not reduced merely to the improvement of their physico-chemical properties but encompasses a range of indicators -- broader assortment, an increase in the concentration of nutritives, an improvement of the ratio of nutritives etc.

Soviet mineral fertilizer industry is manifacturing practically all fertilizers known in world practice.

Mineral fertilizers constitute a powerful factor of the growth of harvest yields of all farm crops.

Alongside with high effectiveness of the application of mineral fertilizer in agriculture it has been found that a surplus or an erroneous application of fertilizer can lead to soil pollution, to the pollution of water or air and also to the accumulation of high levels of mineral fertilizers, specifically of

Table 1

Total capacities for ammonium production (thousand t)

Area	Years				
	1970/72	1975/76	1980/81	1981/82	1985/86
Western Europe	14363	15171	15809	16693	17148
Eastern Europe	13779	21711	32148	34487	39910
Including USSR	8420	13397	22187	23610	27300
Africa	780	1247	2228	2826	4201
North America	13766	15229	17813	17837	18433
Including USA	12491	13926	15723	15723	15750
Central America	962	1357	2814	3904	4724
South America	348	1144	1679	1842	3559
Asia	9069	14609	23732	25114	32627
Oceania	480	452	452	452	536
World capacity	53547	70793	96675	102186	121138

Table 2

Share of some countries in the world capacity of ammonium production (%%)

Countries	Years				
	1970/71	1975/76	1980/81	1981/82	1985/86
USSR	15.7	18.9	22.9	23.1	22.5
USA	23.3	19.7	16.3	15.4	13.0
France	5.0	3.7	2.9	2.7	2.3
FRG	5.2	3.9	2.6	2.5	2.3
Romania	2.2	2.7	3.5	3.7	3.2
China	4.0	5.5	8.1	7.7	7.4
India	2.8	4.0	5.5	5.6	7.0
Japan	5.7	5.1	2.5	2.4	2.0

nitrates in food products, specifically of food products of plant origin. Nitrogen containing fertilizers are of the greatest hygienic importance.

Recent studies have shown that the application of mineral fertiliers influences considerably the quality of food products of plant origin.

The branch of the Research Centre for Hygiene and Toxicology conducted a study into the influence of various doses and combinations of mineral fertilizers on the organoleptic properties and some other indicators of the chemical composition of a range of farm products (cucumbers, sweet pepper, grapes, tomatoes etc.) . It has been identified that different doses and combinations of mineral fertilizers, in a number of instances, have a definite influence on the organoleptic property and some other indicators of the chemical composition of the studied products. The changes which have been identified are different and are in close dependence upon the dose and the combination of fertilizers and also upon the grown products.

Besides nitric fertilizers, phosphorous fertilizers are also widely used.

From the point of view of hygiene, fluorine compounds are of special interest in the chemical composition of phosphorus fertilizers.

The content of fluorine in phosphorous raw materials, according to different authors, varies from 1.5 to 6%.

The content of fluorine in phosphorous mineral fertilizers depends upon the type of the fluorine containing raw material and comprises approximately the same values as is the case in the

production of mineral fertilizers where approximately 90-95% of fluorine passes from the raw material into the finished product.

Fluorine containing compounds may reach human organism with food and water.

The influence of fluorine upon human organism has been studied rather well in industrial conditions associated with the processing of fluorine containing raw materials.

Besides complete or macrofertilizers, the production and application of microfertilizers (molybdenum, zinc etc), is also of considerable importance since their proper application greatly increases the harvest yield and the quality of many farm crops.

The agrochemical and physiological role of microelements is quite versatile. They improve the metabolism in plants, facilitate the normal course of physiological - biological processes, etc. It is known that microelements enter the composition of many enzymes. Plans are made to develop new fertilizers making use of such chemical substances which selectively act on nitrifying microorganisms, i.e. such which could control microbiological soil processes -- inhibitors (stabilizers) of nitric fertilizers.

The results of field trials have shown that inhibitors yield an addition to the harvest of various farm crops. The influence of inhibitors of nitrification is not confined to an increase in the harvest yield. Even in the case when inhibitors are not increasing the harvest yield, they prevent the accumulation of toxic amounts of nitrates in farm products, the pollution of air and water. At the same time, one should bear in mind that inhibitors of nitrification are biologically active chemicals. Therefore, the industrial application of stabilizers of nitric fertilizers

should be preceded by a comprehensive analysis of all possible consequences of their action upon the physico-chemical and biological properties of soil, which in their turn, may have an unfavourable action on the quality of the harvest with all ensuing consequences for man.

In recent years, industrial waste is being widely applied in agriculture where it is used as mineral fertilizer. The basis of this waste, as a rule, is comprised of one or two macrofertilizer (ammonium nitrate, ammonium sulphate etc.) with different chemical admixtures which are not standardized in many cases.

The results of field studies show that their effectiveness is not inferior to standard fertilizers. Considering the great prospect of production and application of industrial waste designed for use in agriculture as mineral fertilizer and also the absence of methodological approaches to their hygienic appreciation (makes) the settlement of this question most timely and urgent.

Prophylaxis of mycotoxicoses

One of the properties of fungal toxins is their high stability to different physical and chemical factors. High temperature (more than 200°C), an increase in acidity or alkalinity, exposure to ultraviolet or gamma rays -- are not effective. Therefore the removal or destruction of a toxin in food products is a very difficult task.

Toxic or not toxic, grain cannot be distinguished just by the way it looks, by its smell, colour or taste. Therefore, with the idea of prevention of food mycotoxicoses, food products which are suspected of being contaminated are subjected to a laboratory in-

vestigation which includes: 1) the determination of the toxicity by biological methods, 2) a mycological analysis, when besides determining the general mycobackground, the species composition of fungi is also determined.

The maximum allowable concentration of aflatoxins in food products ranges from 5 to 50 mkg/kg, and in feeds -- 50 mkg/kg. Appropriate state bodies like the Ministry of Health and the Ministry of Agriculture stringently enforce the observance of these standards since they are responsible for the safety of food products.

In 1979 a UNEP subunit, known as the Global Environmental Monitoring, acting in cooperation with FAO and WHO, developed recommendations for the organization and consolidation of national programs of monitoring of the contamination of food products. The final objective in prevention consist in complete
food products from mycotoxins, though the requirements which provide for absolute removal of aflatoxin contamination of basic food products is impracticable at present. Nevertheless, we should strive to lower the level of contamination by broadening the study for the identification of the sources of contamination with mycotoxins, improving the quality of farm crops and the techniques of their conservation, and control of the presence of aflatoxins in food products and feeds, application of appropriate technology of food processing to remove contaminated parts from those which are not contaminated, improvement of analytical techniques of the analysis of mycotoxins in tissues and biological media with the idea of identifying mycotoxins. A number of recommendations is oriented to develop a system of measures towards the prevention

of alimentary mycotoxicosis of man and farm animals.

Many countries have enforced stringent limitations of the level of contamination of food products with aflatoxins. The maximum allowable concentration of aflatoxin B_1 content in oil-bearing crops, ground nuts and their products is 30 mkg per 1 kg of raw product, it is 10 mkg/kg for wheat, rice, soya beans and other grains. The allowable concentration in feeds is not more than 50 mkg/kg.

The settlement of the mycotoxin problem is closely associated with the training of personnel and the creation of conditions in developing countries for conducting research in mycotoxicology.