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Progress in integrated control of soybean pests worldwide.

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Soybean is a multi-purpose crop, an important source of protein in food for humans and has many industrial uses and medicinal values. In addition, it plays a very important role in maintaining the balance of the energy in human ecosystems. Therefore, many countries are involved in soybean production. The United Nations established the International Soybean Program (INTSOY) to support the research, education and development of soybeans.

1. Soybean pest populations and ecological types

Soybean production requires research on the control of soybean pests. Up until the end of the1960's, there were only eight entomologists studying soybean pests. There were at least 10 experimental stations and one United States Department of Agriculture laboratory with more than 30 entomologists committed to research and development of soybean entomology.

The University of Illinois at Urbana-Champaign and State of Illinois in USA cooperated with the International Soybean Development Planning Program from 1969 to 1974. M. Kogan presided over the research planning for soybean pest areas and species. They collected the insects and other 5000 arthropod specimens from 22 countries and 24 regions. They identified about 1700 species and analyzed the identified specimens qualitatively and quantitatively, based on their relationships with hosts, ecological environment and economic significance. Among the 1700 species, 15% of them were phytophagy (totaling 252 species including insects that ate pollen), 21% of them were predacity (352 species), 8% of them were inquilinous (134 species), 2% of them were saprozoic (34 species) and 54% of them had no fixed relation with soybean (960 species). Of course, such proportions would change with the areas.

According to the relationships between pests and host plants, soybean pests could be divided into three kinds: polyphagia, stenophagy and monophagy, each of which required certain ecological conditions such as suitable food sources, inhabiting and breeding places and ecological niches formed by the specific temperature and humidity. Thus soybean pests could be divided into five ecotypes (ecological types): (1) root-inhabiting type, namely soil pests, which included root maggots, chafer larvae and corn root leaf beetle etc.; (2) moth stalk type, namely bean fly, Melanagromyza sojae (Zehntner) de Meijere, Stalk longhorn Beetle, *coclosalis* Walker etc. that poison main stems and branches; (3) piercing sponging type, namely aphis, leafhopper, white fly, thrips and leaf acarid etc. of piercing sponging or azole phyllidium (stalk). These species are the most common (about 138 kinds) and the most poisonous, among which there are some intermediums that transmitting poison. (4) Defoliator type, which mainly consists of moth larvae and leaf beetle; Mexico beetles are the most famous pests on soybeans. (5) The moth legume (pod) pest, which mainly consists of *Maruca vitrata*, soybean pod borer, bean bug and corn earworm. The outbreak and spread of these five kinds of pests change in a pattern of obvious ecological regularity with the changes of seasons and crop reproductive periods. They sufficiently adapt to and make use of their own living spaces and damage all the different parts of soybean, from the insemination period to the harvest period. Many countries that produce soybeans have conducted in-depth research on the biology and ecology of these critical pests, which has built a solid foundation for comprehensive pest control.

2. Progress in research progress toward comprehensive pest control

The soybean pest integrated pest management system (IPM system) is being demonstrated and developed in some countries. This system results from widespread cooperation among multiple disciplines and departments. The following issues should well understood if this system is to be implemented: (1) the phenology relationships between the outbreak of the main pests and the soybean reproductive periods; (2) the biological and ecological characteristics of the pests and their natural enemies; (3) the applicable investigation and sampling techniques and economic loss threshold (EDT); (4) having economical, effective, simple, feasible and comprehensive pest control techniques, which include agricultural technology, aphid-preventing species, biological control factors and the selection and application of pesticides, then studying the dynamic patterns of pest populations and system analysis techniques. In order to control pest populations under normal economical loss levels, the integrated pest management system should be improved further. Obviously, this is a gradually developing research process that is from single to comprehensive, qualitative to quantitative and part to whole, which could both control pests and increase yields, having obvious economic impacts. Several critical problems are described as follows.

2.1 Economic loss threshold

We should research and estimate the main pest economic loss level and its lowest population density. If the level and the density are higher than the above values, it leads to economical losses, and some control measures should be taken. This parameter is called economic loss threshold, namely the common-mentioned control index. Usually, if the loss is above this level, the value of the redemptive production loss should be greater than the cost of controlling the pests. That is to say that we should pay attention to the economic impact.

The economic loss threshold changes with the regional conditions, crop species and reproductive period, pest types and habits, and the commercial values of the crop products. Under experimental conditions, it has been known that the most sensitive reproduction period of soybeans for pests is the pod formation and granule-growing period; that soybean varieties usually lose 30% of their leaves, and that 8-10% of production is lost in this period. Adapted to the local conditions, many kinds of pest control indices were established: for example, one kind of soybean bridging worm, the control indices in the State of South Carolina are 24 larvae (about 1.2cm long) /meter row length, and 15% loss of leaves; 15% Mexico beetle loss leave; corn earworms are 9 larvae/ meter row length. Dr. Kogan pointed out that the study on the economic loss thresholds of the bean fly, phyllidium pests and the moth legume (granule) pests should be enhanced and the relationships between the defoliator pests and bean leaf diseases (such as leaf rust disease) should be further understood.

2.2 Taking full advantage of natural enemies

Among soybean field insect faunas, the entomophagous insects make up 20-30%, with the ratio of phytophagy, predation and inquilinous insects as 8:3:1. In addition, they also include the complex natural enemy community formed by spiders and pathogenic microorganisms. Their establishment and development are based on preconditions of suitable habitat and adequate nutrition for the hosts. The suitable habitat space of pests in the soybean fields is continuously enlarged with the lapse of seasons and the alternation of crop reproductive periods, and it reaches the peak in the florescence and pod formation period. The pests and natural enemies settle in the populations successively and play a role in natural control. Therefore, the utilization of the natural enemy biology in soybean fields is first based on agricultural measurements. First: enrich the plant in bean areas, provide nectar sources for the natural enemies, supply hosts and reproduce the bases. Second: introduce, reproduce and release the natural enemies, spray the microorganism insecticide, and make the natural enemies reproduce continuously. Some of these measures have been applied and effective results have been achieved in the USA, Brazil, Australia, and other countries.

2.3 The selection and breeding of the pest-resistant varieties

The study of host pest resistance in other countries involves many disciplines such as entomology, plant pathology, nematology, genetics breeding, etc.. They cooperate widely studying single-resistance to multiple-resistance and have achieved significant research progress, with many pest resistant plant varieties introduced into production systems. Research procedures include the collection and identification of pest-resistant resources, research into the mechanisms of resistance, cultivating varieties with strong pest-resistant characteristics and good agronomic characteristics through cross-breeding, and also genetic analysis of the pest-resistant characteristics and chemical and physical characteristics. Research has identified the following pest-resistant mechanisms: (1) ecological pest-resistance: that which makes pests and plants form phenological isolation by using agricultural measures that alter the ecological environment and plant nutrition conditions, making them unsuitable for pest outbreak; (2) Genetic pest-resistant characteristic: plants contain a type of inherited antibiotic substance, which influences the habit and metabolic processes of pests, which lead to pest death or a decrease in its reproductive ability, etc. (3) morphological pest-resistant characteristic: external morphological structures or colors of plants that can change behaviors such as egg-laying and predation, well-known examples being soybean varieties with leaf hair resistant to both the Mexican beetle and potato leaf pests. Soybeans varieties having upright leaf hair are seldom infested, but those without suffer more serious damage. Scientists from the University of Nebraska have been using Chinese wild hairy soybean varieties to crossbreed with the common soybeans in recent years. The leaf hair on the cultivated new variety is three times that of common soybeans, and the water required in production is about 15% less. Thus this new variety has pest-resistant, drought-resistant and stable yielding characteristics.

2.4 The application of pesticides

When pest populations reach an economic loss level, pesticides still need to be sprayed in time. In order to decrease impact on natural enemies that might also be useful, the ecological selection application method is usually used for the pesticides. In other words, the lowest dosage is used to control the pests but not kill their natural enemies. For example, when Brazil and USA controlled the defoliator pests, Carbaryl or 0.3 kilogram/hectare Methyl 1605 were first used, then 0.2-0.5 kilogram/hectare Monocrotophos were used alternatively to control the soybean bridging aphis, but it had little influence on the *Nabis sp.*,*Geocorides*, spiders etc. The physiologically selective pesticides such as one kind of Chitin synthetic depressor (*TH6040*) could disturb the molting process of the moth larvae. This new pesticide (named diflubenzuron) has been used in soybean production areas.

In addition, agronomic techniques have received greater attention and been applied to the integrated control system. For instance, early maturing soybean varieties were planted in Japan, and measures that facilitated early maturation as well as crop rotation were adopted to control insects attacking legume pods. In the USA, measures such as using early maturing soybean varieties and planting 10-15 days early were also adopted in order to lure and collect the *Cerotomat trifurcata* and *Nezara viridula* imagoes, then kill them together using insecticides. However, these measures should be used only in close collaboration with agronomists; the experiment should be carried out carefully; then some feasible agronomic techniques for controlling pests increasing yields can be formulated.

Currently, the research and implementation of soybean pest integrated control has achieved some progress in the world. Brazil adopted all of the parameters of a integrated pest management system in 1974-1978, and continuously carried out a integrated pest management demonstration in southern soybean production areas.

The insecticide spraying frequency decreased by 78%. The pests were controlled below the economic loss level. This practices has been spread throughout the whole county since 1977. The leafhopper is one type of particularly harmful pest in the central soybean production area of the United States. If slick varieties of soybean (without hair) are planted, they can be seriously damaged by the time they grow to 8-10 inch height. Therefore, the use of pest-resistant soybean varieties with a lot of hair has been popularized as a major tool in establishing agro-ecological control. For the principal soybean pest species in the Asian-Pacific area, Dr. Kogan proposed an integrated control research plan in three stages: (1) introduce modern technological research results, which deal with the phenological relationship between critical pests and soybeans, investigating their population fluctuations, studying their economic loss level, establishing an economic threshold, and ascertaining the valid period of control; (2) verify the basic research materials, namely the dynamic trends of key pest populations, changes and modifications to the economical threshold; evaluate the function of all kinds of biological prevention factors; collect the pest-resistant species resources, examine the agronomic technology control measures under different farming systems and screen out the pesticides with low dosages so as to obtain the selection effect that could both effectively control pests and protect beneficial insects; (3) develop a harmonious application. One integrated and effective pest control system should be established after integrating the biological and economic materials in the first and second stages. This system should be improved continuously with new control techniques. These schemes should be used as the reference for our future research on soybean pest control techniques.

We project the following developing trends based on the research in soybean integrated pest control in the world: (1) the pest-resistant varieties with multiple resistance characteristics would be more helpful in increasing the yields and qualities of soybeans. (2) More stress on the effects of natural control factors (namely natural enemies). (3) Agronomic techniques control and the selection of pesticides applied regularly to complement each other, based on pest population forecasts. (4) Pest control work, crop production systems and the environment treated as an integrated unit, being harmonized with one other.