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CONTENT

1. INTEGRATED PEST MANAGEMENT (IPM)

Integrated pest management (IPM), also known as integrated pest control (IPC) is a broad-based approach that integrates practices for economic control of pests. IPM aims to suppress pest populations below the economic injury level (EIL). The UN's Food and Agriculture Organisation defines IPM as "the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms. Entomologists and ecologists have urged the adoption of IPM pest control since the 1970s. IPM allows for safer pest control.

Integrated pest management (IPM) is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. IPM programs use current, comprehensive information on the life cycles of pests and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment (Figure 1).

The IPM approach can be applied to both agricultural and non-agricultural settings, such as the home, garden, and workplace.

In agriculture, IPM is a pest control strategy that uses an array of complementary methods: natural predators and parasites, pest-resistant varieties, cultural practices, biological controls, various physical techniques, and the strategic use of pesticides. It is an ecological approach that can significantly reduce or eliminate the use of pesticides.

IPM takes advantage of all appropriate pest management options including, but not limited to, the judicious use of pesticides. In contrast, *organic* food production applies many of the same concepts as IPM but limits the use of pesticides to those that are produced from natural sources, as opposed to synthetic chemicals.

IPM is a process consisting of the balanced use of cultural, biological, and chemical procedures that are environmentally compatible, economically feasible, and socially acceptable to reduce pest populations to tolerable levels.

Integrated means that many strategies are used to avoid or solve a pest problem. These strategies come from different disciplines, such as disease information from plant pathologists, weed information from agronomists, and insect information from entomologists.

Pests are unwanted organisms that are a nuisance to man or domestic animals and can cause injury to humans, animals, plants, structures, and possessions.

Management is the process of making decisions in a systematic way to keep pests from reaching intolerable levels. Small populations of pests can often be tolerated; total eradication is often not necessary.

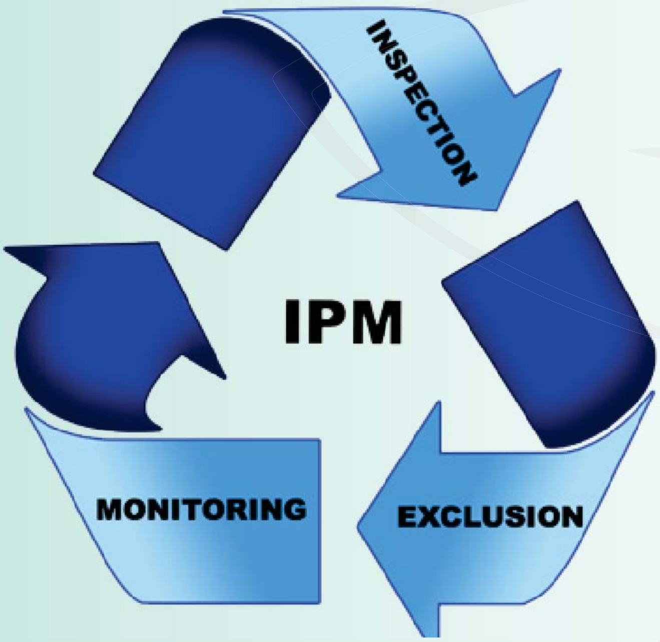

Figure 1. IPM – Inspection, exclusion, monitoring

2. THE IMPORTANCE OF IPM

When an agrocenosis is more diverse and more complex, or when one agrocenosis is richer in flora and fauna, it is more resistant, i.e. the mechanism of natural regulation of the number of harmful species acts effectively, the sanitary function is better realized, the soil fertility maintains better, as well as plants pollination and other qualities of the habitat.

In plant protection, we should not be limited to the fight against harmful organisms, and to ignore all the rest, as the meaning of pests thus is not decreasing but rather increasing. It requires a profound change in the relationship between man and nature, in the strategy of protecting crops.

One of the basic conditions for realization of this strategy is the need to preserve biodiversity, and increasing the role of beneficial elements of fauna and flora in agrocenosis. According to many studies, only 1% of insect species are included in harmful insects and other species are useful or potentially useful. So, the preservation of biodiversity on Earth is one of the most important tasks of mankind.

Analyzing the evolution of the methods used in plant protection, the International Organization for Biological control (OILB), the period after the Second World War, divides into five phases, which change with each other. The period until the beginning of the seventh decade of the 20th century can be considered as a period of domination of the chemical plant protection.

IPM, according to FAO, include control of the number of pest over the thresholds of their harmfulness, using different methods, but by giving priority to the natural regulation of pests, diseases, and weeds, meeting at this economic, environmental and toxicological conditions. Transitional period to the integral protection makes the targeted protection, which is an important step towards integrated protection, though satisfies one or fewer requirements set for integrated pest management, while integrated protection takes into account all the elements.

Stated strategy to control the number of harmful organisms means versatile use and combining different ways of monitoring the numbers of pests, making them important links in the chain of integrated management, such as using resistant varieties, quarantine, agricultural, mechanical, physical, biological and chemical measures. Orientation to one of these methods of protection is dangerous considering the practice that shows that the desired results are obtained only by the complex approach in controlling the number of harmful organisms.

Agricultural measures, along with breeding resistant or tolerant varieties and hybrids, should become the most prevalent method of controlling the number of pests (given that they are feasible in every field and the other methods are used on smaller or bigger area).

The development of an IPM system is also implemented by improving the chemical method to control the number of pests. Rationalization of the use of pesticides is achieved by reducing the dose of the preparation, optimization of the terms and manner of application, the choice of an active substance that will be least harmful to agrocenosis, reducing the volume of treatment based on the use of economic thresholds of harmfulness etc. (Figure 2)

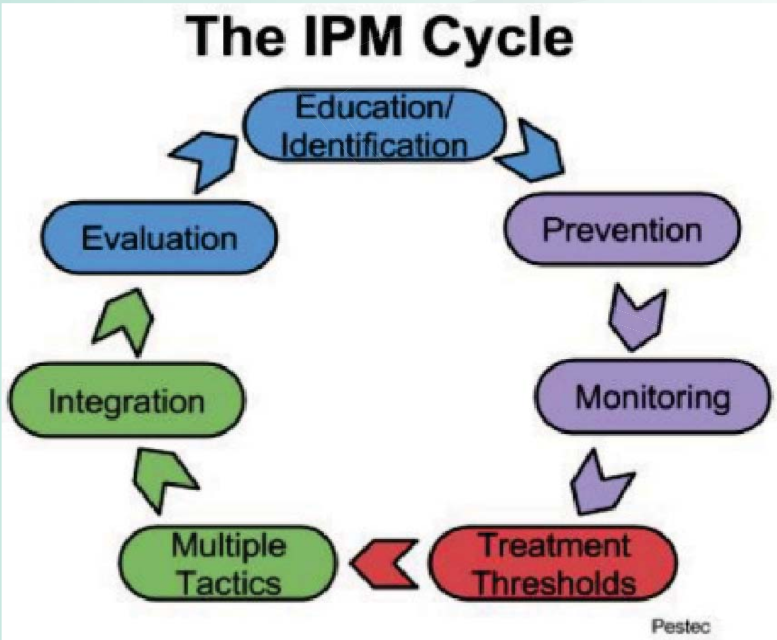

Figure 2. The development of an IPM system

The successful operation of the forecast service is especially important for the integral protection of plants against pests. Different methods of control of the number of pests (agricultural, mechanical, physical, biological, chemical, etc.) should be applied only on the basis of systematic monitoring of the distribution, abundance and development of pests (and their natural enemies), or on the use of methods of long-term and short-term forecast of the extent of occurrence and signalization of the optimal deadlines to control the number of pests. Forecasting service is an important link in the integrated plant protection.

Applying the IPM possibly reduces the use of pesticides, in some cases up to 50%, not compromising the successful control of harmful organisms. In many countries in the last 20-30 years, practicing IPM is gradually spread.

3. HISTORY OF IPM

Shortly after World War II, when synthetic insecticides became widely available, entomologists in California developed the concept of “supervised insect control.” Around the same time, entomologists in cotton-belt states such as Arkansas were advocating a similar approach. Under this scheme, insect control was “supervised” by qualified entomologists, and insecticide applications were based on conclusions reached from periodic monitoring of pest and natural-enemy populations. This was viewed as an alternative to calendar-based insecticide programs. Supervised control was based on a sound knowledge of the ecology and analysis of projected trends in pest and natural-enemy populations.

Supervised control formed much of the conceptual basis for the “integrated control” that California entomologists articulated in the 1950s. Integrated control sought to identify the best mix of chemical and biological controls for a given insect pest. Chemical insecticides were to be used in a manner least disruptive to biological control. The term “integrated” was thus synonymous with “compatible.” Chemical controls were to be applied only after regular monitoring indicated that a pest population had reached a level (the economic threshold) that required treatment to prevent the population from reaching a level (the economic injury level) at which economic losses would exceed the cost of the artificial control measures.

IPM extended the concept of integrated control to all classes of pests and was expanded to include tactics other than just chemical and biological controls. Artificial controls such as pesticides were to be applied as in integrated control, but these now had to be compatible with control tactics for all classes of pests. Other tactics, such as host-plant resistance and cultural manipulations, became part of the IPM arsenal. IPM added the multidisciplinary element, involving entomologists, plant pathologists, nematologists, and weed scientists.

IPM – definitions

There are several definitions relating to the IPM, which actually with different words indicate the essence of the integral protection. Here are some of them:

1. **The approach that includes a combination of methods to control a large number of potential pests that could threaten crops.** It involves the maximum use of natural control of pests population, simultaneously combining methods that can contribute to the eradication, as agrotechnics, diseases that attack pests, resistant varieties, sterile insects, attractants, increasing the number of parasites and predators or chemicals (pesticides) if necessary.
2. **Strategy for pest management that is based on ecology and largely relies on the factors that determine the natural mortality, such as natural enemies and weather conditions and strives to find methods for control that disrupt those factors as much as possible.** IPM includes the use of pesticides, but only after conducting a systematic monitoring of the populations of pests and if natural factors for a control point that needs it. Ideally, the program for integrated protection of plants includes all available actions to control pests, including not taking any activity and evaluating the potential interaction between the various control methods, agrotechnics, weather conditions, other pests and the crop that is being protected.
3. **Selection, integration, and implementation of pest manage-ment, based on the expected economic, environmental and sociological implications.**
4. **All measures for plant protection where the chemical method is implemented as a "necessary evil."**
5. **"System of plant protection which means using all available methods to control the number of pests, diseases, and weeds, to prevent their numbers above the coming to economically significant damage."**

4. WHY PRACTICE IPM

You might be wondering why you should even consider IPM when chemical pesticides so often succeed at controlling pests. Here are some reasons for having a broader approach to pest management than just the use of chemicals.

- **Keep a balanced ecosystem**

Every ecosystem, made up of living things and their non-living environment, has a balance; the actions of one creature in the ecosystem usually affect other, different organisms. The introduction of chemicals into the ecosystem can change this balance, destroying certain species and allowing other species (sometimes pests themselves) to dominate. Beneficial insects such as the ladybird beetle and lacewing larvae, both of which consume pests, can be killed by pesticides, leaving few natural mechanisms of pest control.

- **Pesticides can be ineffective**

Chemical pesticides are not always effective. Pests can become resistant to pesticides. In fact, some 600 cases of pests developing pesticide resistance have been documented to date, including house flies, the Colorado potato beetle, and the greenhouse whitefly. Furthermore, pests may survive in some situations where the chemical does not reach pests, is washed off, is applied at an improper rate, or is applied at an improper life stage of the pest.

- **IPM is not difficult**

Although some of the terms and ideas may be new to you, practicing IPM is not difficult. Believe it or not, you will have done much of the "work" for an IPM approach if you've figured out the problem (the pest), determined the extent of the damage, and decided on the action to take. These steps are the same ones used in IPM.

- **Save money**

IPM can save money through avoiding crop loss (due to pests), and avoid unnecessary pesticide expense. For example, in apple orchards, direct cost for plant protection can decrease by 40%. Applicators are able to save on sprays because the calendar is not the basis for spraying; the need is.

- **Promote a healthy environment**

We have much to learn about the persistence of chemicals in the environment, and their effect on living creatures. However, more cases of contaminated groundwater appear each year, and disposal of containers and unused pesticides still pose challenges for applicators. Even though long-term documentation on the effects of all pesticides is still unavailable, it is generally agreed that fewer pesticides mean less risk to surface water and groundwater, and less hazard to wildlife and humans.

- **Maintain a good public image**

The Recent public outcry about the use of growth regulators and the presence of pesticide residues on produce has heightened pesticide applicator awareness of the level of public concern about chemicals. Consumers are pressuring food stores, which in turn are pressuring producers, for produce that has been grown with as few pesticides as possible. Growing food under integrated pest management can help allay public concerns. Structural pest control professionals can suggest improvements in housekeeping or structural modifications as substitutes for chemical control.

5. PRINCIPLES OF IPM

IPM is based on certain principles, which are:

1. **Maintenance of harmful agents to a tolerable level**. Potentially harmful species will continue to exist intolerable one, i.e. the pests are going to be eradicated only when they reach the critical number using thresholds of harmfulness;
2. **Maintenance of the ecosystem as a whole**. The ecosystem is a unit and any manipulation with it can exacerbate the problem with pests although simultaneously one or several harmful species are effectively controlled. IPM tends to manipulate ecosystem for maintaining a tolerable level of pest populations at the same time avoiding major disruptions of the system.
3. **Maximum use of biological control**. An important objective of IPM is changing the environment of the pests to enhance the action of natural enemies.
4. **Previous analysis of each applied measure**. Any measure of control can cause unexpected and undesirable effects. The use of any method may result in negative consequences and before its acceptance should be carefully reviewed from an environmental perspective.

5. **Fitting the IPM in the overall integrated production.** Interdisciplinary approach in integrated plant protection is very important because it should be an integral part of the overall management of the farm.

Populations of the pests and integrated plant protection should be considered from different perspectives, i.e. the practice of pest control includes:

– Determining the way of modification of the life cycle of the pest to reduce their numbers to a tolerable level or below the threshold of harmfulness;
– Application of biological knowledge and constant technology for achieving the desired modification i.e. applied ecology;
– Development of procedures for pest control that correspond to constant technology and are compatible with economic, social and environmental aspects, i.e. economically and socially acceptable.

5.1. The basic steps of IPM

All of the components of an IPM approach can be grouped into five major steps. The first step is a transfer of knowledge, next is taking preventative measures to prevent pest buildup, the third step is monitoring than next step is assessing the pest situation, and the fifth step is determining the best action to take (Figure 3).

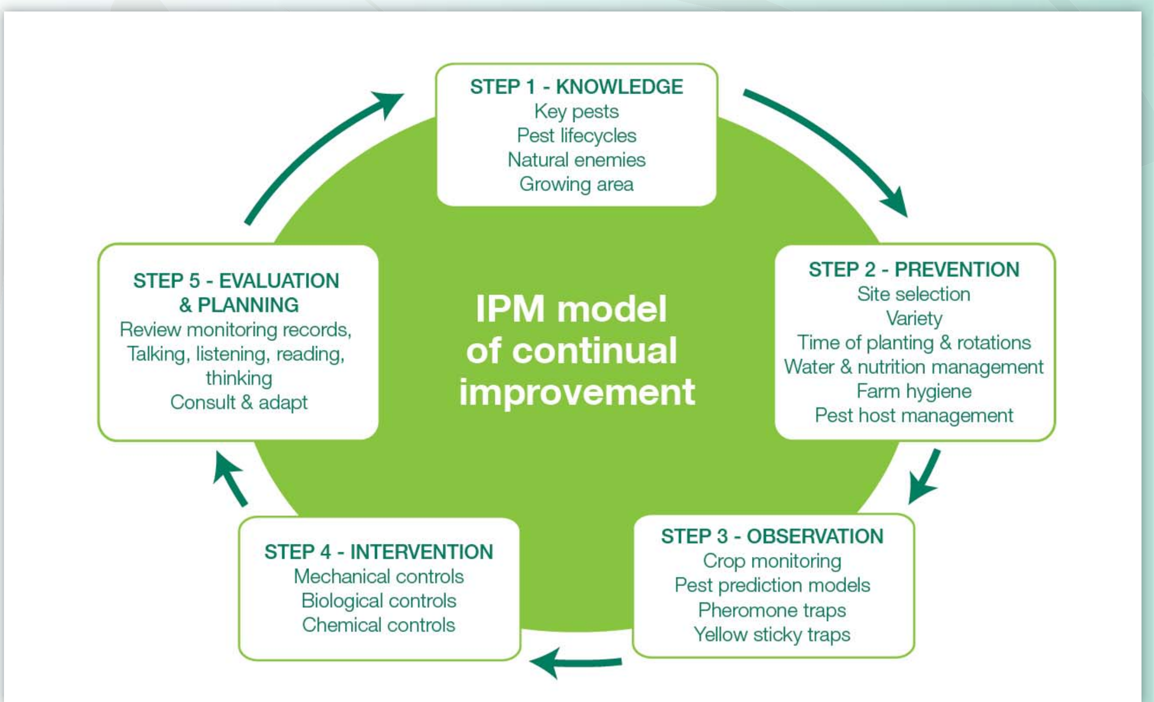

Figure 3. The basic steps of IPM

6. MEASURES FOR PLANT PROTECTION

According to the period of application, plant protective measures are divided in preventive and curative. Preventive measures are also known as prophylactic and are intended to prevent the occurrence of a disease. The rule: "To prevent is better than to cure" is mostly used against diseases or pests with great economic importance for certain crops. Curative measures are therapeutic and applied after the appearance of the disease. They aim to heal and rescue the diseased plants. The measures to treat already infected plants are few and their use is usually during the period of incubation.

A separate set of measures that can be considered as a subset of curative measures are the eradicative measures. They are regressive and rigorous and aim to remove infected organs, completely or partially or to remove infected plants in order to reduce the pathogen inoculum and protect the remaining plant population.

According to their purpose, protective measures are divided into:

1. Direct measures and
2. Indirect measures.

Direct measures are targeted against the pests or pathogens that cause the disease, while the indirect measures are directly related to the cause.

Preventive measures can be indirect and direct but curative and eradicative measures belong only to direct measures of protection.

Preventive measures to combat plant diseases and pests include:

1. Administrative (legal) measures and
2. Agro-technical measures.

Curative measures to combat plant diseases and pests include:

1. Mechanical measures
2. Physical measures;
3. Biological measures and
4. Chemical measures
5. Integral protection

Administrative and agro-technical measures are indirect or preventive methods that aim to prevent the excessive reproduction of pests and parasites. Other methods (mechanical, physical, biological and chemical method) are curative and directly affect the destruction and control of the population in pests and parasites.

Integrated pest management is a system of all existing methods that are applied in the most compatible way with each other and aims to maintain the population of pests and parasites under the economic threshold of damage, taking care to protect the environment.

6.1 Preventive measures

6.1.1. Administrative measures

Administrative measures are legal regulations in the area of plant protection prescribed by the appropriate authorities in a country and the international community, which aim to protect plants from dangerous and important diseases and pests. Those measures are actually an indication of how important are plant diseases for the country, and how much is their importance for the international community. These measures are also called quarantine measures. The word quarantine comes from the French word “quaranta” which means 40 and it is derived from human medicine where it denoted a period of isolation of overseas travelers, which correspond to the duration of the incubation period of then significant diseases in humans.

Quarantine as a protective measure is used since the late 19th century when some dangerous plant pathogens such as *Phytophthora infenstans*, *Uncinula necator*, *Endothia parasitica*, *Ophiostoma ulmi* and *Cronartium ribicola* were introduced in Europe and America.

Quarantine measures aimed to prevent the spread of dangerous diseases and pests from one country to another are regulated by external quarantine or external quarantine measures. Quarantine measures that aim to prevent the spread of diseases and pests inside the territory of a country are regulated by internal quarantine or internal quarantine measures.

External quarantine regulates the relations between states in case of import or export of live plant material and has a great importance in preventing the occurrence of epiphytotic diseases. Internal quarantine measures regulate relations within the country.

To be able to function external quarantine, there must be an exchange of information between countries. The occurrence of any significant disease or pest should be reported in order to prevent the introduction of a dangerous pathogen or pest in a new area and prevent its spreading.

Measures of the internal quarantine are determined by each country, depending on the needs. The authorities adopt laws and acts that are mandatory for the country and aim to prevent the spread of important pathogens or pests from the region where they are present in other regions where their appearance is not observed.

Quarantine legislations in the country stipulate which pests need to be controlled when agricultural products are trade and transport. Quarantine offices (reporting - forecast services) monitor the emergence and spread of certain diseases and pests, perform signaling of possible danger and worry about the implementation of measures for its suppression.

Quarantine regulations are also related to the control of seed production and seed trading as well as production and trading of seedlings. For that purpose, experts make health control of crops and seedlings, 2-3 times during the plant vegetation. Each consignment of plant material should be provided with a phytopathological certificate issued by an authorized organization for plant protection, which guarantees that the material is not affected by any significant parasite or pest.

The plant protection act has published a list of quarantine and economically important diseases and pests that are divided into three lists (groups):

A. Quarantine diseases and pests;
B. Quarantine diseases and pests that are present in certain areas of the country;
C. Economically important diseases and pests.

The production, trade, and storage of pesticides are regulated under the separate legislation.

6.1.2. Agro-technical measures

Agro-technical measures have preventive character. They aim to reduce the negative impact of external abiotic and biotic factors on plant growth, improving their physiological condition, increases their tolerance and resistance, and create conditions unfavorable for the development of pathogens.

The basic agro-technical measures that are used in plant protection are:

- Crop rotation;
- Tilling;
- Fertilization;
- Cultivation of resistant varieties;
- Use of healthy seed and healthy planting material;
- Collecting the harvest;
- Destroying weeds, volunteer plants, and plant debris;

- Selection of suitable location;
- Optimum period for planting/seeding of plants;
- Protection of plants from mechanical damage;
- Suitable irrigation.

Crop rotation

A number of pathogens and pests maintained in the soil during the winter season. The duration of the maintained period depends on their vitality, microbiological processes occurring in soil, chemical conditions in the soil etc. It is one of the primary measures to suppress the over the reproduction of pathogens and to reduce their inoculum. It can't lead to a complete elimination of the pathogen, but it can reduce their population to the limit of tolerance.

Crop rotation includes crops that are not hosts to pathogens and pests attacking the previously planted culture, nor are closely related to them. The duration of the crop rotation is usually within one to three years, and for some pathogens up to six years.

Furthermore, crop rotation may include some attractive crops that are good hosts of the pathogens and pests and favors the germinations of spores or the germination of weed seeds (Figure 4). Then pathogens, pests, and weeds are destroyed through plowing. Such a method, for example, is applied to the destruction of broomrape in sunflower.

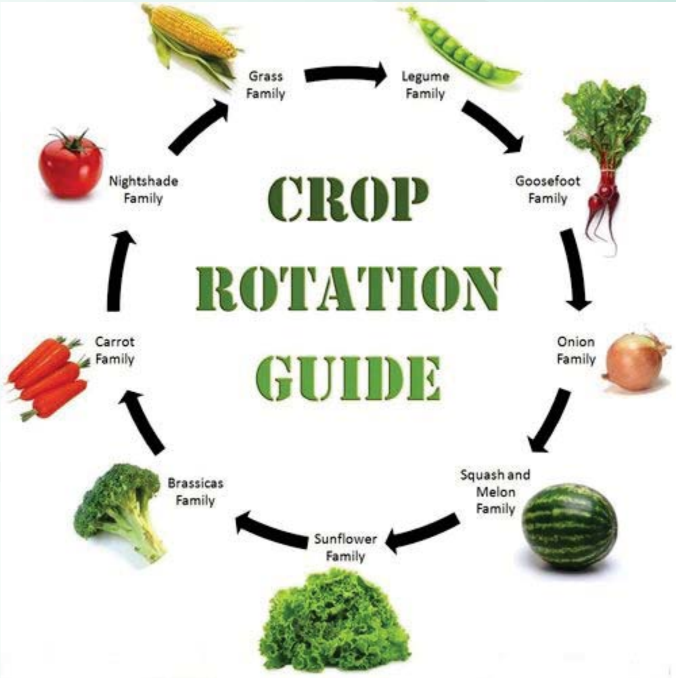

Figure 4. Principles of crop rotation

In monoculture, parasitic species related to nutrition and breeding of the crop become over populated. For example, *Zabrus tenebrioides* become over populated in wheat fields in Macedonia, after the Second World War, when the cereals were cultivated in monoculture on large areas. Crop rotation as a measure for suppression of pathogens, pests, and weeds should be applied whenever there are suitable conditions for it.

Tilling

Tilling enables mechanical disruption of soil structure changing the living conditions for insects. This measure can destroy winter shelters, nests, eggs, larva and adult insects in the soil.

Deep tilling allows many insects, their developmental stages, pathogens or seeds to be pulled into deeper soil layers, where there are no favorable conditions for life and development, and no nutrients available.

The overturning of soil layers, allow many insects to be thrown out on the soil surface, where they are exposed to unfavorable climatic conditions and often become easy prey to predators and parasites. Besides improving the soil structure, as well as improving the water and air conditions in the soil, procession of the soil affects the size of harmful insect species.

Fertilization

Soil fertilization has an indirect impact on pathogens and pests development. The use of fertilizers like potassium and phosphorus, especially trace elements improves the physiological condition of plants. Plants quickly outweigh sensitive pheno-phases of their development, which increases their level of tolerance and they become more resistant to diseases and pests. On the other hand, acidic or alkaline fertilizers can prevent the development of certain pathogens requiring certain pH-reaction in the soil.

Optimal time of sowing

The terms of crop sowing are based on edaphic, climatic, environmental and economic needs of the crop. Optimal time of sowing can be determined on the basis of information about the time of maximum occurrence of pathogens and pests. Besides meeting the climatic needs of the culture, the optimal time of sowing should avoid overlapping of the most sensitive stage of culture development with the time when the population and activity of pests and pathogens are highest. In Macedonia, the late sowing of wheat enables the development of ergot and root rot while the early sowing favors the attack of powdery mildews, rusts and leaf spot at cereals.

When sowing and planting in an optimal period of time, favorable conditions for the emergence of disease vectors and pathogens can be avoided. For example, planting the potatoes in summer decrease the infection of potato viruses. Germinating the potato tubers before planting contributes in avoiding disease development. Defoliation before collecting potato tubers using desiccants, reduce the possibility of fire blight (*Phytophthora infestans*) and dry rot (*Fusarium ceruleum*) infection.

Early winter sowing and late spring sowing of wheat reduce rust infections while late autumn sowing increases the risk of smut infection.

Healthy seed and healthy planting material

Infected seed material, tubers, bulbs, etc. are a source of infection resulting in the development of diseased plants. Therefore fields cultivated for seed material production should undergo a health control two or three times during the period of vegetation.

On time crop disease control and destruction of diseased plants contributes to inoculum reduction, which reduces the possibility of dangerous disease expansion.

In some crops mainly cereals, seed treatment with pesticides is a regular measure for prevention of some major diseases transmitted by seed. For example, wheat, corn, and barley are regularly treated with pesticides to prevent smuts (*Ustilago nuda* f.sp. *hordei*, *Ustilago maydis* and *Ustilago nuda*).

Harvesting

Except on time planting and sowing, a major role in protecting plants from disease infection has on time harvesting. This measure directly reduces the harmful effect of diseases and pests. For example, frequent mowing of alfalfa decreases the spreading of Cuscuta and the appearance of leaf spots. Harvesting during dry weather reduces the risk of gray mold disease (Botrytis cinerea). Delayed harvesting of crops, increase the possibility of grain erosion and appearance of volunteer plants, which allow wintering of pests and pathogens like pathogenic fungi from the genera of *Puccinia*, *Erysiphe* ect., and become a source of inoculum for infection of regular crops.

Destroying weeds, volunteer plants and plant debris

Stubble plowing, destroying weeds, volunteer plants and plant debris are one of the most important agro-technical measures for reducing inoculum of pathogens and pests. Weeds alter the microclimate in crops which benefit in the development of pathogens as their hosts or host of their vectors. Volunteer plants of cereals retain the spores of rusts and other pathogens, many pathogens and pests maintained on plant debris during winter. In spring these pathogens are responsible for primary infections at plants.

Suitable locations for plant cultivation

Locations for plant breeding need to ensure optimum environmental conditions for their cultivation. Every major deviation from the optimal ones, increase the susceptibility of plants to pathogens and pests. This is especially important at perennial plants, fruits, grapes and perennial crops like alfalfa.

Choosing a suitable location, have particular importance in orchards and vineyards. If orchards or vineyards are set in inappropriate locations, they suffer from parasites that attack physiologically weak plants, such as root rot, gray mold, fruit cancer etc.

If tomato plants are grown in poorly aerated locations then he suffers from black spot disease (*Alternaria solani*), leaf mold (*Cladosporium fulvum*), as well as several bacteriosis.

Optimum sowing density

Densely sowing is one of the preconditions for the emergence of diseases. In dense crops microclimate conditions changes, atmospheric humidity is higher, and solar radiation is weaker. These conditions have a negative effect on physiological properties and plant growth. On the other hand, some conditions have a positive impact on the development of pathogens.

Dense population in cereals cause and increase susceptibility to diseases such as powdery mildews, rusts, leaf spots etc.

Planting in reduced density creates favorable conditions for the development of some viral diseases like ring necrosis in tobacco, phytoplasmas like stolbur in Solanaceae family, and mycoplasma diseases or development of pathogens transmitted by leaf hoppers and thrips.

Protection of plants from mechanical damage

Mechanical failures that occur on plants during the regular agro-technical measures, such as pruning of fruit trees and vines, as well as injuries that occur on plants become an entry for pathogens and parasites.

Therefore it is necessary to avoid major damages during pruning, wounds should be coated with suitable protection like wax, pruning of fruit trees should be performed during the summer so the wounds can recover faster.

Irrigation

Irrigation can be a vector for transmission of bacteria, spores, seeds, etc. Improper irrigation may cause a weakening in plants, so they may become more susceptible to the attack of pathogens and pests.

Improper irrigation causes the plants to suffer from powdery mildew, verticilliosis, sclerotinia and other diseases. Intensive irrigation and heavy rains can enhance the appearance of root rot, rusts, leaf spots, fire blight and some other diseases.

Selection of resistant varieties

The most reliable method of controlling pathogens and pests in plants is planting and sowing resistant varieties. This is also the most intelligent method of plant protection.

The resistance of plants on pest/pathogen attack means the ability of a particular plant variety to avoid the attack of the pathogen/pest. The plant tolerates or recovers from the attack better than other varieties of the same genus. In other words, resistance is the ability of a certain variety to give a higher and better yield than other varieties when an attack by some pathogen or pest. This characteristic of the plant has a genetic origin.

Cultivation of resistant varieties began after the introduction of Hessian fly in the United States. Today breeding resistant varieties of sunflower to *Homeosoma nebulella* (the Eurasian sunflower moth) is a very good example for the selection of resistant varieties. Another good example is grafting of the European vine variety “Vitis vinifera” on American vine variety “Vitis rupestris” or “Vitis riparia”.

However, in most cases, resistance only partially solves the problem of pathogens and pests.

Depending on the level of resistance three types of resistance are distinguished, such as immunity, high level of resistance, resistance, sensitivity and high sensitivity.

The mechanism of resistance of plants to pathogens and pests is very complex and influenced by many factors. Some of these factors are:

- preference and non-preference;
- antibiosis and
- tolerance.

Preference is an inclination of some pests to particular crops or varieties. Non-preference is a reverse process of preference and manifests when specific pathogens/pests, from some reason, do not attack some plant varieties.

Preference and non-preference are usually caused by differences in the color of the tissue, differences in the physical structure of plant surface and differences caused by chemical stimulators.

Antibiosis is the ability of certain plant varieties to manifest negative effect on the life of the pathogen/pest. Unfavorable characteristics of the plant in terms of nutrition of the pathogen/pest may result in reduced dimensions of the pest's body, lower fertility, prolonged development etc. Pathogens often show reduced virulence and extinction due to unfavorable conditions for nutrition.

The tolerance of plants to the attack of pathogens/pests is the ability of the plant to recover quickly from the attack of the pathogen/pest or to develop normally in his presence.

The selection of resistant varieties in the process of plant protection was conducted for the first time by Knight in 1815, growing resistant varieties of wheat to rusts (*Puccinia* spp.).

The disadvantage of this method is that not always the varieties with the highest degree of disease or pest resistance have the highest yield and quality. On average, it takes about 12 years of the experimental period for selection of variety with commercial properties. The resistance of variety against a particular pathogen/pest generally depends on a single gene. However, pathogens and pests constantly create new strains that disrupt the resistance. In most cases, there are strains possessing the ability to overcome the inbred resistance of the plant. For example, rusts possess the ability to create new strains that successfully overcome resistance by creating a large number of varieties.

6.2. Curative measures (prophylaxis and therapy)

The word "prophylaxis" originating from the Greek word "profylattomai" meaning prevention and the word "therapea" originating from the Greek word "therapeutic" meaning treatment.

These measures directly or indirectly remove or destroy pathogens and pests.

The therapy is a measure intended to treat a diseased plant. Its role in the process of plant protection is very limited because the doses and concentration of toxicity of pesticides for pests, pathogens, and wheat are very close to those of the plant cell. Therefore, the basis for plant protection is directed toward prophylaxis.

Prophylaxis comprises of:

- Mechanical measures;
- Physical measures;
- Biological measures;
- Chemical measures and
- Integrated measures.

6.2.1. Mechanical measures

Mechanical measures essentially are mechanical procedures conducted for destroying diseased plants or diseased plant parts in order to reduce inoculum and suppress the spreading of the pathogens. The most significant mechanical measures are:

- Cutting and destruction of infected plant parts or whole plants;
- Destroying plant organs and plant debris which serve for wintering of the pathogens;
- Destroying the sporulation bodies of the pathogens;
- Destroying of parasites;
- Destruction of intermediate hosts of the parasites;
- Coating of wounds, etc.

Cutting and destruction of infected plant parts or whole plants

This mechanical measure usually includes pruning and burning of the infected plant parts such as shoots, branches, twigs, etc. or cutting (eradication) of whole plants commonly used in fruit orchards and vineyards.

This mechanical measure is very effective. It is the best to use it before sporulation of the parasites or before the appearance of viral vectors.

In nursery production, removal of diseased plants prior to planting plays important role in the mechanical protection of plants.

Destroying plant organs and plant debris which serve for wintering of the pathogens

Many plant parasites maintain during winter in falling leaves. That's why destroying them before or shortly before defoliation is an effective measure for destroying parasites that maintained on leaves.

For example, the fungus *Venturia aequalis*, causing apple scab disease, wintering and develops its fruiting bodies (pseudothecia) into the host plant tissues. Therefore the collection of defoliated leaves and their destruction will greatly reduce the inoculum of this pathogen. The leaves of apples or pears can also be treated before defoliation. Removing the infected fruits from *fruit rot* reduces the risk of developing *Monilia fructigena* in fruit species. Effective measure in vegetable production is removing and destroying the diseased fruit of Alternaria solani and Botrytis cinerea in tomato plants, particularly in greenhouse production.

Most of the pathogens in cereals maintained during winter on plant debris. Therefore stubble ploughing, removing and destroying of crop residues shortly after harvesting, is of great importance for the suppression of these pathogens.

Many parasites and pests maintained on weeds which are present in the field. Therefore disrooting and destruction of weeds is also an effective measure to suppress pathogens. This measure is especially important in vegetable, grain, and industrial crop production.

Destroying the sporulation bodies of the pathogens

Removing and destroying the sporulation bodies of fungal parasites suppress the reproduction and spreading of fungi that cause root xylem rot in fruit and forest tree species.

Destroying of parasites

This measure is commonly used for destroying weeds, such as broomrape (Orobanche), mistletoe (Viscum spp.), and dodder (Cuscuta spp.) in alfalfa. The destruction of these weeds should be done before their insemination.

Destruction of intermediate hosts of the parasites

Mechanical destruction of barberry (Berberis vulgaris), alternative host of rust (*Puccinia graminis*) on which fungus develops spermatia bearing aeciospores is a significant measure in the prevention of this disease. Also, destruction of wild juniper (Juniperus sabinae) reduces the possibility of rust attack on pear (Gymnosporangium sabinae).

Destroying volunteer hosts, for example, potato tubers left in the field, decrease the possibility of developing fire blight in potatoes. Also, destruction of volunteer plants in wheat fields reduces the occurrence of rusts in wheat. A similar situation is with onion bulbs and the appearance of fire blight in onions.

In some countries destruction of hawthorn (Cratgus spp.) contributes in the low economic importance of fire blight in apples and pears caused by the bacterium *Erwinia amylovora*, because some genera of the Rosaceae family are hosts of this pathogen.

Coating of wounds

Some fungi and bacteria cause cancer in plants, especially in fruit trees. Their cleaning and coating can greatly help in suppressing pathogens. The same is with wounds made during regular pruning of fruit trees.

Mechanical measures in combating insects

Mechanical measures to combat insects are one of the oldest measures used in plant protection and mainly consist in collecting pests and their mechanical destruction.

These measures are very expensive because they demand engagement and participation of living labor, and can be implemented only on small parcels. They consist mainly of manually cleaning the old bark in fruit trees and vines from the beds of insects, tossing insects etc.

Mechanical measures include the use of adhesive tapes, bands of corrugated paper, use of hunting stems, hunting baits on the basis of olfactory substances and hunting vessels. For these methods, we can say that they have great significance in determining and prognosis of periods for pesticide applications against pests.

Burning crop residues directly destroys many harmful insects that remain after harvesting, it also destroys organic mass such as straw and grain that serves as food for insects.

The burning of crop residues have many negative consequences like disturbance of biocenosis balance of wheat fields, therefore this mechanical measure is not recommended.

6.2.2. Physical measures

Although the use of physical measures in plant protection was familiar for a long time, we can say that its use is intensified in the last decade. Because of its advantages, this measure replaces chemical protection measures, particularly in fighting against the storage diseases and pests. The danger of pesticide residues is greatly restricted by the use of this chemical method.

Physical measures can be direct and indirect measures, particularly in determining prognosis and the deadlines for spraying. Most physical methods are based on the use of temperature, sound, humidity, light, color, smell, ionization etc.

The most important and most frequently used physical measure is based on the temperature and the use of high and low temperatures, a method known as thermotherapy.

Thermotherapy was known among the ancient people who lived along the river of Nile, and who have used this method for seed disinfection. Similar procedure is used today in organic production. The seeds need to be without mechanical damages, and after immersion in hot water it should be immediately cooled in cold water and dried at a low temperature to prevent germination.

For seed from different cultures are set different temperatures. For example, dipping the seedlings of cereals in hot water at a temperature of 51 to 52 ^{0}C for 10 minutes is used to destroy spores of rust (Ustilago nuda). This temperature destroys spores of this fungus, but it doesn’t destroy the germ of the seed that remains vital. Thermotherapy of onion attacked by fire blight (*Peronospora destructor*) is carried heating the seed material at 40 ^{0}C for a period of 16 hours or at a temperature of 43 ^{0}C for 8 hours.

In the Republic of Macedonia, thermotherapy is most frequently used for soil disinfection. It can be done dry or wet disinfection of the soil. Dry soil disinfection can be done in several different ways using different types of ovens. Wet disinfection can be done using steam or boiling water. The use of aqueous steam is a very effective in soil disinfection, especially in horticulture and gardening.

Disinfection of soil using aqueous steam is carried out using devices that release steam into the soil at a depth of 30 to 40 cm, with a temperature of 95 ^{0}C, for at least 5 minutes. This destroyed all economically important pathogens, their permanent stages, seeds, vegetative debris, weeds, and insects. Using surface sterilization in slightly affected soils satisfactory results can be achieved using steam temperature of 70 ^{0}C, for 30 minutes. Thermotherapy using hot water is carried out so that the soil is sealed with hot water heated to a temperature of 80 ^{0}C, covered with appropriate frames and hold for 30-60 minutes.

The advantage of this method is that the treated soil can be used immediately after disinfection, and plants can better utilize nitrogen and manganese from the soil. Mostly, soil sterilization is done in the summer when greenhouses are empty.

The most significant disadvantage of this method is possible to damage of the salad which is especially sensitive. Heavy and poor soils with humus may undergo changes in the structure, which can be enhanced using soil calcification. If sterilization isn't done successfully (not fully covered surface, not sufficiently high temperature or short exposure), it may lead to overpopulation of some pests in this soils.

A special type of soil sterilization is soil solarization. This method uses solar energy as a heat source. The first data on the use of this method dating back to 1939 when Glosshevoy explored the impact of solar energy on the development of some pathogenic fungi in the soil. A number of studies around the world confirm the effectiveness of solarization in the eradication of harmful fungi in the soil. The method of soil solarization consists of covering the soil with a transparent PE or PVC-foil over 1 - 2 months during the hottest time of the year. The foil should be as thinner as possible (0,015 - 0,050 mm) for better heat transfer and for allowing better heating of the soil. Before starting the process of solarization, the soil should be properly prepared. Soil particles should have fine structure and it should be moist (relative humidity is about 60%) because the wet soil easily transmits heat. Thus, in a depth of 10 cm is achieved a temperature of 10-20^{0}C higher than in uncovered soil. In this way, if the temperature reached 37^{0}C during 18-33 days or a temperature of 50^{0}C during 23-68 days, the fungi from the genus *Verticillium* and *Pythium* can be successfully destroyed.

The phytopathogenic fungus *Armillaria mellea* can be successfully destroyed by heating the soil to a temperature of 41 ^{0}C during 4 to 7 hours. Some studies worldwide have shown that soil solarization can destroy the weed flora in 76-98%.

A research conducted in Croatia showed that using soil solarization, phytopathogens and nematodes can be destroyed in 97 to 100% at the open to 89 to 100% in a covered field. Soil solarization is a simple and effective method, economically most effective but it must be applied in warm climates, both in the open and protected fields.

Low temperatures are also commonly used in plant protection, to protect fruit berries, potatoes and some vegetable fruits from storage pests and pathogens that attack plant fruit during the storage period.

Another physical measure which is used is ionizing radiation. This measure is commonly used in combating pests or insects. One unit of ionizing radiation is one rad (rad - radiation absorbed dose). One rad radiation corresponding to the absorbed dose of 1 gram of matter when it transfers power from 100 erg.

For example, it was determined that for sterilization of rice ionizing radiation from 7000 to 8000 rad should be used. A dose of 25 000 rad kills all development stages of rice weevil (*Calandra oryzae*). In contrast, neither dose of 100,000 rad is not sufficient to sterilize Angoumois grain moth (*Sitotroga cerealela*) and Indian mealmoth (*Plodia interpunctella*). For fruit fly (Dacus spp.), sterilizing dose is from 8000 to 12 000 rad, and for apple worm (*Laspeyrresia pomonella*) from 10 000 to 25 000 rad in certain stages.

In some countries, this method is extensively used to suppress the storage of pests. Using ionizing radiation, some countries have achieved major successes in combating the onion, brassica and fruit fly.

The use of color as a physical method is also very often used in plant protection. This method is based on the attractiveness of a certain color to certain insects.

6.2.3. Biological measures

Biological control can be defined as the use of natural enemies to reduce the damage caused by a pest population. Biological control is an approach that fits into an overall pest management program, and represents an alternative to continued reliance on pesticides. For the purpose of pest and disease control, beneficial organisms are specifically preserved and fostered, released in large numbers or introduced into habitats where they have not been found hitherto. Biological control of weeds has to date primarily involved introducing beneficial organisms into new habitats. The fungi *Trichoderma* and *Gliocladium* are used to control soil-borne pathogens like *Rhizoctonia*, *Sclerotium*, *Sclerotinia*, and *Fusarium*. Similarly, some saprophytic bacteria like *Bacillus turingensis* are used to control pests, fungal or bacterial disease.

Several types of pheromones are used in the biological control like sex hormones, aggregation pheromones, alarm pheromones and repellent pheromones. The use of sex hormones is very effective measure used in biological control of insects. Males locate and subsequently mate with females by following the trail or pheromone emitted by virgin females. The indiscriminate application of high levels of sex pheromone in traps and dispensers interferes with this natural process since a constant exposure to high levels of pheromone makes trail following impossible (habituation/adaptation phenomenon). The use of discrete source of sex pheromone released over time presents the male a false trail to follow (sexual confusion/ mating disruption). Control is subsequently achieved through the prevention of mating and consequently the laying of fertile eggs. Sex pheromone are species-specific.

Aggregation pheromone can be also used in monitoring. Males and females locate host trees by following a plume of air enriched with a mixture of the odour of the host tree and the aggregation pheromone. Evaporation of pheromone vapours from dispensers attached to host trees attract both males and females of the insect pest to the baited trees and establiches conditions for mass attack of baited trees by the insect pests. The baiting of selected areas and trees reduces the number of attacks in the main orchard or forest areas. The baited trees and those trees closed to them should be felled before the progeny emerges from the infested trees. They are effective in the case of beetles (Coleoptera). Attractants are used in traps for monitoring and time management decisions of pesticides applications (Figure 5).

Alarm pheromones are released under natural conditions when the population in threatened or being attacked by a predator. The result of this release in an increase in the activity of phytophagous insects with the subsequent higher exposure to a co-applied pesticide. Alarm pheromones are often mixed with conventional pesticides (especially acaricide) and show an increase in the mortality of pests (mites). The alarmed pests (e.g. spider mites) feed less than undisturbed ones.

Reppelent pheromones are emitted naturally by some insect pests (e.g. beetles) when they reach a critical density in order to repel additional insects and, thereby to protect the food supply needed by these insects and their offspring. A slight chemical alteration can change an attractant to a reppelent (e.g., Seudenol which is an attractant of douglas fir and spruce beetles was transformed into 3-methyl-cyclohex-2-en-1-one which is a reppelent of the same species). The use of reppelent pheromone on healthy trees can be combined with the use of aggregation pheromone on dead or dying trees.

A long time ago, the man noticed the beneficial influence of some biotic factors in maintaining balance in biocenosis. In past, the knowledge of biology and the laws of nature were not satisfactory so the biological method couldn't be used satisfactorily. Future development of these sciences contributes to the development of biological measures in plant protection.

Generally, it can be said that biological measures are based on:

- parasitism
- antagonism
- competitive relationships between organisms

Parasitism

Interpretation of insect parasitism and the development of insect pathology were dependent upon the invention of microscopy. Parasitic insects (also known as parasites and parasitoids) are insects whose immature stages (larvae) develop by feeding on or in the bodies of their host arthropods, which are usually other insects. Host is the organism attacked and used as a food source by the parasite. The recipient of the protagonist's action. Equivalent to a prey used by a predator. Unlike true zoological parasites, parasitic insects kill their hosts, they are unique, because it is the immature stages that kill the host. Nearly all parasite immatures develop on or in a single host. Parasites are holometabolous, having complete development (egg, larval, pupal and adult stages). Adult parasites are free living; some species will feed on hosts (predators), in addition to ovipositing in or on the hosts.

In the world of parasites, only females are significant players, as they are the ones that find and attack hosts. For some species, males are not known to exist. The number of species of parasites is unknown and speculative, ranging from an estimate of 800,000 to as many as 25% of all insects. According to where the eggs are laid parasitoids are usually defined like endoparasite (the egg is laid inside the host and the parasite larva develops inside the host's body) or ectoparasite (the eggs are laid outside the host and the parasite develops externally on the host with its mouthparts inserted into the host's body). According to the feeding habits of the immature stage, parasitoides are defined as egg, larval, pupal parasite, etc. Egg parasite: Parasite adult attacks the host egg, and the parasite progeny emerge from the egg. Egg-larval parasite: Parasite adult attacks the host egg, but the parasite progeny emerge from the larva. Larval parasite: Parasite adult attacks the host larva, and the parasite progeny emerge from the larva. Larval-pupal parasite: Parasite adult attacks the host larva, but the parasite progeny emerge from the pupa. Pupal parasite: Parasite adult attacks the host pupa, and the parasite progeny emerge from the pupa.

Although parasitism is found in several insects orders, primary orders of parasites are Hymenoptera and Diptera. The most important parasitic families within *Hymenoptera* order are: Dryinidae, Bethylidae, Chrysididae and wasps. Several Diptera families have members that are parasitic: Acroceridae, Bombylidae, Cecidomyiidae, Cryptochetidae, Phoridae, Pipincluidae, Tachinidae, and Sarcophagidae. Rare representative taxa are also found in the Coleoptera, Lepidoptera and Neuroptera.

Predation can be defined as a trophic level interaction in which one species derives energy from the consumption of individuals of another species (Figure 6). A predator is considered an entomophagous species that generally consumes more than one prey individual to complete its development. Some parasitoids host-feed as adults which could be considered a type of predation. Over 16 orders of insects contain predaceous members, in approximately 200 families. Including spiders and mites, there are probably in excess of 200,000 species of arthropod predators. Many crops contain a rich assemblage of predators, and it is not uncommon to find 300-500 species of predators in a given crop. Among the non-insect arthropods, spiders (Araneae) represent the largest, most diverse group. Spiders have been little utilized in biological control.

Generally speaking the most common features of insect predators are:

– kill and consume more than one prey organism to reach maturity;
– relatively large size compared to prey;
– predaceous as both larvae and adults;
– larvae are active with sensory and locomotory organs;
– except for predatory wasps that store prey for immature stages, prey are generally consumed immediately.

The major groups of predaceous insects belong to the following orders: *Coleoptera, Dermaptera, Diptera, Hemiptera, Hymenoptera, Mantodea, Neuroptera, Orthoptera* and *Thysanoptera*. The most important *Coleoptera* predaceous families are the following: *Carabidae* (ground beetles); *Cicindelidae* (tiger beetles), *Staphylinidae* (rove beetles); *Lampyridae* (fireflies); *Cantharidae* (soldier beetles) and *Coccinellidae* (ladybird beetles). Members of the order *Dermaptera* are recognized by pincers at the tip of the abdomen. These structures are used to hold prey while it is being consumed. The predaceous species feed on soft bodied insects (e.g. aphids, leaf hoppers, larvae of *Coleoptera* and *Lepidoptera*). The most important *Dermaptera* predatory families are: *Forficulidae* (spine tailed earwigs); *Labiduridae* (striped earwigs) and *Labiidae* (little earwigs). Some flies (*Diptera*) are predators of other arthropods (e.g., robber flies), but most of them are external parasites (e.g., mosquitoes and deer flies). Families that contain predaceous species are: *Asilidae* (robber flies), *Empidae, Dolichopodidae* (longlegged flies), *Rhagionidae, Tabanidae, Tipulidae, Chamaemyiidae, Cecidomyiidae* (midges), and *Syrphidae* (hover flies). Species in the later three families have been used in biological control. The most relevant *Hemiptera* predatory families are: *Miridae* (plant bugs); *Nabidae* (damsel bugs), *Anthocoridae* (insidious flower bugs), *Reduviidae* (assassin bugs), *Phymatidae* (ambush bugs), *Lygaeidae* and *Pentatomidae* (stink bugs). Hymenoptera is one of the larger orders of insects, comprising sawflies, wasps, bees, and ants. Females of Hymenoptera typically have a special ovipositor for inserting eggs into hosts or otherwise inaccessible places, often modified into a stinger. The most important Hymenoptera predaceous groups are: Sphecidae (sphecid wasps); Vespidae (paper wasps, yellow jackets); Eumenidae (mason and potter wasps) and Formicidae (ants).

The earliest recorded observations in western Europe of insect parasitism occurred during the 1600s. In 1602 Aldrovandi recorded observations of parasitic larvae of *Apanteles (Cotesia) glomeratus* exiting from cabbage butterfly (*Pieris rapae*) and spinning external cocoons. In 1670 Martin Lister correctly interpreted insect parasitism in a letter published in the Philosophical Transactions of the Royal Society of London.

Parasites are organisms that parasitize and cause disease in plant pathogen organisms, pests, and weeds. They can be found in all species: insects, bacteria, fungi and parasitic flowering plants. Perparasites can parasitize organisms from the same kingdom, such as insects parasitising other insects which are a pest of a plant or to parasitize organisms belonging to different kingdoms, such as a type of fungus parasitise some sort of insect and so on. Ladybug is a predator for larvae of many aphids, fleas, thrips, cicadas and others. Ladybirds are an important element in biocenosis, especially in agro biocoenoses because they play an important role in the population decrease of many pests. Larvae of a ladybug can eat 300-400 larvae of aphids during their live and 600 to 1000 imagoes. Because of their extremely important role in the process of crop protection their population should be protected in agro biocoenoses. Both, native or introduced species of ladybirds can be used in biocontrol of pests.

The importation of the ladybirds from species *Novius cardinalis* Muls. (Sin. *Rodolia cardinalis*) in 1924c Australia and used against citrus (Australian) bug *Icerya purchasi* Mask. is considered as the beginning of the modern era of biological control. In Western Europe, the problems with the appearance of San Jose scale (*Quadraspidiotus perniciosus*) are solved with the introduction of a predator wasp, *Prospatella perniciosi* Bulk. Commercialized production of eggs parasite *Trichodermae vanescens* has been massively used as a biocontrol agent.

Very actual pest in Macedonia is a white fly (*Trialeurodes vaporariorum*) which can be efficaciously suppressed by the parasite *Encarsia formosa*, which affects the early stages of the white fly's life cycle.

Only one individual of the predator *Anthocoris nemorum* on 50 leafs per apple or plum is able to completely exclude the use of acaricides, regardless of population density of red spiders (*Panonychus ulmi*).

For some microorganisms, the presence of pathogenic and non-pathogenic strains which are in competitive relations for existence has been discovered. Kerr and his colleagues in 1972 isolated several non-pathogenic strains of bacterial cancer (*Agrobacterium tumefaciens*), and selected the non-pathogenic strain *Agrobacterium radiobacter* 84, known as Agrocin 84. The presence of this non-pathogenic strain prevents the development of pathogenic strains of the bacterium Agrobacterium tumefaciens, in many plant species.

The fungus *Darluca filum* develops and parasitizes the uredospores and teleutospores of Uredinales spp., preventing their development. The fungus Cicinobolus cesatise develops and parasitize fungi that cause powdery mildew and prevent the formation of asci and ascospores.

The use of bacteria in biological control due to the endotoxins that are products of their metabolism. For example, the bacterium *Bacillus thuringensis* is used for the preparation of biopesticides for suppression of larvae from the family *Lepidopterae* and has important commercial value.

Until now, about 300 different viruses are known pathogenic to insects. Unlike bacterial toxins which use products of metabolism, viruses are used as living organisms. Therefore their use is limited and requires very strong criteria.

Figure 6. Predators

Antagonism

Antagonistic relations is the most prevalent between soil microorganisms. The essence of the antagonistic relations lies in the ability of many soil bacteria and fungi like *Aspergillus* spp., *Penicillium* spp., *Trichoderma* spp., *Bacillus* spp. etc. to synthesize antibiotics that inhibit the development of other microorganisms.

Antagonistic relationships between microorganisms have theoretical and practical significance. In vitro breeding of antagonistic microorganisms and their release in nature can influence the competitive relations between pathogens, allowing indirect protection of plants, which from a practical point of view is very useful.

For example, the fungus *Trichoderma lingorum* inhibits the development of fungus *Pythium* spp. The fungus *Trichoderma viridae* inhibit the development of fungi *Fomes radiciperda* and *Armillaria mellea*, causing root rot of certain fruit and forest species.

Competitive relationships between organisms

If two different organisms inhabit the same substrate, wherein the organism not harmful to the plant suppresses the plant pathogen in the process of food competition, we are talking about competitive relationships between organisms. The development and growth of microorganisms are dependent primarily on the type and amount of organic matter in the soil. For example, cereals much less suffer from *Gaeumannomyces graminis* if they are fertilized with livestock manure. Organic fertilizers enhance the development of saprophytic microflora that competes with pathogenic microorganisms so that eventually the parasites lagbehind in their development.

Breakdown of plant residues in soil suppresses the development of parasites reducing their food. In soils reach in microorganisms the germination of spores and sclerotia is reduced. In such soils, the germination tubes or infectious hypha are decomposed rapidly. Thus, entering the organic fertilizer into the soil contributes to low disease development. Saprophytic microflora in such soils decompose the organic nutrients into inorganic chemical compounds which are available to plants, but not for microorganisms. Thus, due to the lack of organic nitrogenous substances, pathogens lag in growth and development, become less aggressive and the infections are reduced.

One of the modern concepts in suppressing harmful insects due to the genetics, which offers great opportunities and solutions. Thus, the use of sterile males who will copulate with females at the critical period is very simple and environmentally acceptable technique that offers a simple and secure solution for reducing the population of harmful insects.

The use of artificial hormones that attract males for their suppression results in synthesizing substances that have the ability to stimulate or destimulate feeding of the insects. These substances are called fagostimulators and fagodestimulators. They are selective and non-toxic for many organisms.

6.2.4. Chemical measures

Chemical measures to combat pests and pathogens involve the use of certain chemical compounds, called pesticides. Despite the wide range of measures that we have mentioned previously and its negative ecological effect, the chemical method is still the mostly used in practice. The use of pesticides is accepted as the fastest, simplest and most effective measure in plant protection. Without chemical protection, crops will be ravaged by diseases, pests, and weeds, which will result in significant yield reduction. For example, without treating the seed with pesticides against rusts and smuts (Ustilago spp.), the yield would be reduced to 400 kg/ha. So, the chemical measure is still the most effective method in fighting pests, pathogens and weeds, despite intensive studies of other alternative methods. Based on detailed analysis, it was determined that the exclusion of pesticides on the production technology would lead to a reduction in the total world production by 30%, which would increase the price of products for 50-70% (FAO, 1973).

The use of chemical method has its advantages:

– Effective suppression of many pathogens;
– Possibility to combat several different harmful biological agents using only one pesticide;
– Results are achieved quickly before or during the attack;
– Easy to use and low cost compared to physical methods;
– Lower cost per unit area and high ROI.

Disadvantages of the chemical method are:

– Disruption of the natural balance;
– Toxic effects on non-target organisms;

- Pesticides promote pests, microorganisms, and weeds evolution. Individual pests/microorganisms/weeds may develop resistance to that particular chemical so it can no longer be used in their controlling. If this resistance is genetic-based, the future generation could not be controlled using that chemical.

A significant disadvantage of the chemical method is the need of several pesticide applications in the soil during the vegetation period. The success of pesticide use depends mainly on their proper use. So the basic rule is first to detect and identify the cause of the disease, to determine properly the method of application and to determine the right time for application. Also of great importance, it is to properly prepare the pesticide and used in the most suitable weather conditions.

Using pesticides is not always economically justified, calculation the cost-effective factor (ROI factor) will answer the question whether it is economically justified to spray or not.

$$\textbf{ROI factor} = \frac{\text{value of prevented loss}}{\text{(cost of the measure + environmental damage)}}$$

Environmental damage = (cost of the measure x environmental factor) - cost of the measure

Based on the numerous studies it is estimated that the average environmental damage from the application of pesticides to protect vegetable crops ranges from 30 to 80% of the cost that is made from the used measure, and according to the formula the ecological factor will vary from 1.3 to 1.8.

7. MONITORING (SCOUTING)

Monitoring pests involve:

- regular checking of the area;
- early detection of pests;
- proper identification of pests;
- identification of the effects of biological control agents.

Regular checking of a warehouse, bakery, restaurant, field, greenhouse, golf course, or other areas and early detection of pests can function together like an early warning system for pests, helping to avoid or prevent a pest problem.

Proper identification of pests is an extremely important prerequisite to handling problems effectively. For example, the brown banded and German cockroach can be easily confused with each other. Identification is important because certain management practices may control only one species and not the other. Correct identification enables you to manage the real source of the problem and avoid merely treating the symptoms (or controlling non-pests). Some pests cause similar evidence. Unless the pest is identified, the control program may have the wrong pest as its target. Identification enables you to cure the pest problem and avoid injury to non-target organisms, particularly if you:

- use a pesticide that is specific to the pest;
- control the pest effectively during the most susceptible stage of its life cycle;
- consider the use of a non-chemical control.

Identifying the effects of the biological control means knowing which creatures are helpful and determining if pests have been affected by the beneficial organisms. Sometimes pests are kept in check naturally, and at other times the pest populations increase sharply.

8. ASSESSMENT

Assessment is the process of determining the potential for pest populations to reach an economic threshold or an intolerable level. Is a grower likely to suffer financially? Is the pest likely to transmit a disease? How can you tell? There are important differences between the assessment of crop pests and urban pests.

Forecasting can help you determine if weather conditions will be favorable for the development of diseases and insect pests. For example, by “plugging in” values (such as the number of rainy days and the temperatures for those days), growers can predict outbreaks and spray only when conditions are favorable for diseases. Growers who have kept good records of pests in previous years can use these records to help determine if problems such as weeds, insects, and diseases will reoccur. They might be able, for example, to apply the most effective herbicides at the proper time for early control of a problem.

IPM means control of the number of the pest population, using various methods, over the thresholds of their harmfulness or when they reach a critical number. The critical number is the density of the pest population when is accessed to measures to control their number. So, in the IPM we must know:

- How to recognize the pest population which has reached a critical number to use treatment;
- What pest population density will reduce yields and to what extent;
- Assessment of pest population density that can be tolerated, without reducing yields and thus to prevent the excessive use of pesticides or unacceptable reduction in yields.

Economic threshold of harmfulness is a number of the harmful agent in any stage of development, which, when comes in harmful stage (larva, imago, emerging, infestation) can cause damage to the crop greater than the cost of measures for destruction.

There are several thresholds of harmfulness:

- **Pheromone threshold catch** - Minimum of overall numbers adult insects caught in pheromone trap during the week, that when come into damaging stage will cause damage greater than the cost of measures for destruction.
- **Treatment threshold** - Minimum number of the pest in the optimal stage for the destruction that, when come in the damaging stage will cause damage greater than the cost of measures for destruction.
- **The economic injury level** - Loss of yield caused by a pest that worth more than the cost of measures for destruction.
- **The threshold of tolerance** - loss of yield caused by a pest that worth less than the cost of measures for destruction.
- **The threshold of activity of predators** - Average number of the host when predator activity starts.
- **The threshold of predator reproduction** - Average numbers of the host when copulation and egg laying of the predator starts.

In the IPM we take into account many factors before making a decision on the choice of tactics, strategy and so on. So, we need to ask a few questions so we develop and implement the most effective strategy. We should take into account the scientific assessment: how we can achieve control of the pest? We should take into account the social assessment: how to achieve control of the pest? Theoretically, we can tell the breeder what he should do, but he makes the final decision on what is the best to do. We need to make a comparison of the theoretical aspects of the economic harmful level to the practical aspects that are important in the decision process.

There are certain risks in decision-making in the field of plant protection: we must intelligently, not emotionally, determine the weight of all the factors before making a decision. In the IPM we try to adhere to the philosophy of "Treat when it is necessary" and to avoid the preventive treatment, as it is impossible to do always.

Thresholds, or more specifically economic thresholds, are levels that mark the highest point a pest population can reach without risk of economic loss. Populations above these thresholds can reach the economic injury level, where they cause enough damage for the grower to lose money. At the economic injury level, the cost of control is equal to the loss of yield or quality that would result otherwise.

Thresholds for many pests and crops have been scientifically determined. The advantage of thresholds is that if a pest has not reached the threshold, there is no risk of economic loss. Therefore, there is no need to spray. Once the pest density (number of pests per unit area) has reached the threshold, the action is justified. The costs of control will be less than equal to the estimated losses that the pests would cause if left uncontrolled.

Urban pest thresholds are often related to aesthetics rather than economic considerations. Where health concerns or individual sensitivities exist, the tolerable level of the pest may be zero. A zero threshold forces action, even if only one pest has been detected. Zero thresholds exist in hospitals, food production, warehousing, and retail facilities.

9. ACTION (CONTROL MEASURES)

Once a pest has reached the economic threshold or intolerable level, action should be taken. In some situations, cultural controls can destroy pests. One example is early harvesting to avoid pest problems, which prevents crop loss and can sometimes be more economical than a pesticide application.

Chemical pesticides are used as a control measure when no other strategies will bring the pest population under the threshold. In fact, the success of waiting until a pest reaches threshold usually hinges on the availability of a pesticide that will bring the pest populations down quickly.

Everywhere in the world as well as in our country, during the second half of XX century, there was a tendency of increased crop production and use of chemicals for plant protection. For example, in 1945 it was produced 100 000 tons of pesticides in the world, in 1980 two million tons, and in the nineties almost three million tons of pesticides.

Pest reduction most often and very effectively is carried out by applying pesticides, and at the same time, two or more types of pest insects are destroyed at once. Therefore chemical measures represent the dominant and most commonly used method to combat various pests in all countries. Intensive crop production today can't be imagined without the use of pesticides. Application of pesticides during the second half of the XX century, worldwide, contributed to the increase in crop production.

In recent decades, the protection of vegetable crops in our country is characterized by the dominance of the chemical method (other methods of repression are used very little), then with a low level of knowledge on how to care, lack of efficiency in the application pesticides that unnecessary, uncontrolled and unprofessionally are used, and low level of responsibility of farmers to preserve the environment.

The possible adverse impact of the application of pesticides includes:

– the risk of acute or chronic poisoning in humans;
– in the form of eco-toxicological effects in the poultry, fish and bees microflora and microfauna of the waters and in soil;
– in disorders of the biocenosis (destruction of natural enemies or suppression of a harmful species, and the emergence of others);
– the occurrence of phytotoxicity on cultivated crops;
– the development of resistance in pests, pathogens or weeds;
– as well as environmental pollution - some pesticides are very persistent and very long, even years, linger in the environment.

Multi-annual results and the agricultural practice shows that more intensive use of pesticides does not prevent or reduce the frequency of mass outbreak of pests, pathogens, and weeds, but on the contrary, it leads to expanding the application of pesticides. With the application of pesticides, besides the pests, many beneficial insects are destroyed. As a result of the application of pesticides comes to the emergence of resistance in populations of pests, against which chemical measures are performed. With the advent of synthetic pesticides, an increase in the number of resistant strains of harmful insects and spiders is occurring.

But of course, there are opportunities for reduced pesticide application, consisting of the following:

- Application of pesticides at a very high professional level - selection of the optimal pesticides for each case, application of pesticides in an environmentally most acceptable way, application of pesticides with a shorter residual effect, using differentiated doses of active substance depending on the level of pest population in certain areas, treating when you establish a critical number of harmful organisms perform timely treatment, changing the pesticides because of slowing the emergence of resistance in populations of harmful organisms;
- Application of seed treated with insecticides and fungicides;
- Treatment of end-infested parts of the crops which sufficiently contribute to reducing the number of treatments in each area;
- Extending the curative application of herbicides;
- Choosing the time of treatment and usage of selective pesticides that reduce the number of natural enemies of pests;
- Avoiding the use of airplane spraying, but using nozzles and other machinery;
- Using mechanical - chemical measures in protecting crops from migrating pests;
- Application of poisoned baits.

At the end of XX century, reduced use of pesticides began, thanks to the propagation of the IPM. This is achieved by using the newly synthesized or formulated pesticides (effective in minimal doses per hectare), with the development of techniques for their application, and by introducing the practice of integrated measures to protect the plants.

Finally, it should be said that full replacement of pesticides with other methods of eradication, nowadays in the intensive agricultural production, would be very risky, as in human medicine would be full dumps of chemical preparations and practicing alternative medicine. In intensive vegetable production for a long time, we can't deny the advantages of using pesticides. To reduce the use of pesticides is necessary, to spread the application of methods of the integrated plant protection.

In summary**,** an IPM approach means that pest managers use multiple tactics to prevent pest buildups, monitor pest populations, assess the damage, and make informed management decisions, keeping in mind that pesticides should be used judiciously.

10. LITERATURE

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