PLANT PROTECTION PRACTISES AND THEIR IMPACT ON ENVIRONMENT

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Abstract

The world population is increasing by 81 million every year and people need more agricultural production to avoid hunger. Despite modern farming methods, where advanced technologies and new production systems such as soilless agriculture are applied, production seems far from meeting the nutritional needs of people today or in the future. Although phytopathogens, insects and weeds, which cause significant yield and quality losses in agricultural products, are struggled today, it is estimated that the total loss of crops is 36.5% in the world every year due to these pests. Plant protection practices (cultural measures, physical control, legal measures, biological control, chemical control, alternative control) are carried out against pests in order to prevent product yield and quality losses in agriculture. Among these applications, chemical control is the most effective control method against pests, the results of which can be seen in a short time. However, especially in conventional agriculture, irregular and intensive pesticide applications made to protect yield and quality with economic concerns cause environmental pollution and deterioration in soil, water resources and troposphere ecosystems. In this review, the effects of plant protection practices on non-target organisms in different ecosystems are presented.
Keywords: *plant protection, pesticides, environmental pollution, non-target organism, crop production*

Introduction

The world population, estimated at 5 million in 5000 BC, was 2,536,431,149 in 1950, 6,143,493,823 in 2000, 6,96,823,603 in 2010 and 7,794,798,739 in 2020. In the next 30 years, the world population is expected to increase by 2 billion and reach 9,735,033,990 by 2050 (www.Worldometers.info). In the world, whose human population is increasing by 81 million every year, there are 828 million empty plates according to the data of 2021, and people between 702 and 828 million estimated to faced hunger (FAO, 2022). The number of people living on the poverty line differs between countries or continents. In the world, totally 56.5 million people, less than 2.5% in Northern America and Europe, 9.1% in Asia, 424.5 million, 20.2% in Africa, 728 million, 8.6% in Latin America and Caribbean, live blow the hunger line. In order to prevent hunger in the world, which is primarily caused by income or life injustice and is expected to increase more with the increase in world population, first of all, it is necessary to increase agricultural production and ensure that everyone benefits from it equally. However, in the face of the limited areas that can be cultivated in the world and even the decrease due to unplanned urbanization, the increase in agricultural production could be possible by increasing the product to be produced in a unit area.

Indeed, with the Green Revolution that began in the 1960s, genetically improved high-yielding varieties began to be cultivated, and farmers began to use agrochemicals more to tap into the potential of new varieties. While the use of fertilizers increased by 360 percent in developing countries between 1970 and 1990, the use of pesticides have increased by 7-8 times. Thus, world agricultural production has doubled in the last 30 years (FAO, 2022).

However, considering that the world population is increasing by 81 million every year, there is a possibility that more people will face hunger in the future, despite increasing crop productivity with new genetic varieties and plant protection practices. To more people not to face hunger and to have access to a high-quality product variety, the annual losses in products due to various reasons should be controlled within the understanding of sustainable agriculture.

Pests are the most important factors causing significant yield and quality losses in products. Plants that we use as food sources are sensitive to 80.000 to 100.000 disease caused by bacteria, fungi, viruses, mycoplasma-like organisms, rickettsia, algae and parasitic higher plants, and they compete with 30,000 weed species; some species of 3.000 nematodes attack crops and more than 1000 of them cause severe damage, and 10.000 species feeding with plants of 800,000 insect species cause devastating crop damage worldwide (WARE, 1989). It is estimated that diseases, insects and weeds cause the loss of 31-42% of all crops produced in the world each year (AGRIOS, 2005). While crop losses are lower in developed countries, they are higher in countries that need more food. It is estimated that 14.1% of the total 36.5% crop loss in the world is caused by diseases, 10.2% by insects and 12.2% by weeds (AGRIOS, 2005). Despite the increase in the amount of product obtained from a unit area with new techniques and applications; diseases and pests have the potential to cause catastrophic epidemics that can result in great product losses in agricultural products, which might result in the migration of people due to hunger and mass deaths, as in the examples seen in the history of the world. As a matter of fact, in Ireland in the 1840s, early leaf blight disease (Phytophthora infestation) of potatoes caused the death of approximately 1 million people and the emigration of 1.5 million people (STRANGE, 2003); In the 1940s, 2 million people died in Bengal (Banglesh-India) due to losses caused by brown spot (*Cocliobolus miyabeanus* formerly known as *Helminthosporium oryzae*) in rice (PADMANABHAN, 1973); Chestnut cancer agent *Cryphonectria parasitica* in the first half of the 20th century It caused the death of four million chestnut trees in North America (ROANE, 1986). In Turkey, the damage of Idiocerus stali in pistachio, Phthorimaea operculella in potato and *Pieris brassicae* in cabbage can reach 100% from time to time (TOROS et al., 2001).

In order to meet the food needs of people today and in the future, it is necessary to increase the product taken from the unit area with an increase in yield, as well as to control pests. As in other developing countries, in Turkey, maximum efficiency and quality are generally aimed with the use of plant protection products (PPP) and synthetic fertilizers in the conventional production system. Consumers' preference for products with high attractiveness encourages producers to use Plant Protection Products (PPPs) more. Globally, the total pesticide use used in agriculture in 2020 was 2.7 million tons (Mt) of active substance, 1.8 kg/ha per cultivated area, 0.37 kg/person per capita (FAOSTAT, 2022). Total pesticide trade, on the other hand, reached approximately 7.2 Mt of formulated products worth $41.1 billion in 2020.

The continuous and intensive use of pesticides to protect agricultural products in the world affects the health of humans and animals, which are non-target organisms, and causes negative effects on the ecosystem by reducing the biodiversity of organisms in troposphere, soil and water. In this article, plant protection applications against pests that cause a decrease in the yield and quality of plants, and the effects of these applications on the environment in the light of previous studies will be discussed.

Material and methods

When compiling this article, an overview was planned based on the results of scientific research on the negative effects of pesticides on the environment. The data was collected during the study of the international and domestic literature in order for the readers to access the information found in the literature in the form of a collection.

Results

Plant Protection Practices

Plant protection practices are carried out in order to prevent the destructive losses of pests on crops. Plant protection applications can be defined as applications made to reduce the quality and yields losses caused by plant diseases, pests and weeds to below the economic damage threshold. Practices against plant diseases include keeping the host away from the pathogen, destroying or reducing the inoculum of the pathogen, providing host immunity, or improving resistance, and direct protection of plants from the pathogen (AGRIOS, 2005). Among these Plant Protection Practices applied against diseases, cultural practices, physical warfare, legal warfare, biological warfare and chemical warfare are similar to the control methods applied against pests and weeds.

The cultural measures include applications like that cultivation of plants in geographical areas suitable for their genetic characteristics, balanced fertilization, and irrigation, increasing organic matter in the soil, removal of diseased plants or parts of them, applications such as growing plants healthy, increasing their resistance against pests, using trap plants. In order to purify plants from diseases, applying heat (hot water, hot dry air) to production materials such as cuttings, seeds, onions and tubers and the destruction of possible pathogens, pests and weed seeds in the soil by solarization method are physical methods. In addition, physico-mechanical methods such as collecting and destroying pests (insects), keeping pests away from the host, using false sounds, light traps, pheromones, and traps consisting of attractants, applications from radiation and changing environmental conditions (temperature, atmospheric gas composition) among the protection applications (TOROS et al. 2001).

Pests can spread to various production materials within or between countries. For example, powdery mildew and downy mildew diseases, which brought European vineyards to extinction in the 19th century, and phylloxera, a pest (insect), spread from North America to Europe (AGRIOS 2005). Another pest of East Asian and Southeast Asian origin, chestnut blight (*Cryphonectria parasitica*) spread to Europe and North America in the early 1900s and is estimated to have killed 3.5 billion trees by 2013 alone and 4 billion trees during the 20th century (ROANE et al. al. 1986). In order to prevent this spread, countries take legal measures called internal and external quarantine. In biological control, which is another method, plant resistance against pests is stimulated, antagonist microorganisms or predators and parasitic insects are used.

In general, the above plant protection practices against pests do not have adverse effects on the environment. However, many manufacturers resort to chemical control in order to achieve faster, more effective and visible results in a short time. However, residues formed by chemical pesticides on products and their presence in soil, water and atmosphere can cause significant problems.

Pesticide Practices

Pesticides are chemical compounds used to control, protect, destroy, remove or reduce pests such as insects, fungi, bacteria, nematodes, mites and weeds. They are named according to the target organism; insecticide, fungicide, bactericide, virucide, nematicide, acaricide, herbicide, algicide, and so forth.

The first early record as a pesticide is found in the Greek poet Homer, who wrote that sulfur was burned in homes for fumigation around 1000 BC. Pliny the Elder's Natural History in 70 BC contains a summary of pest control practices extracted from Greek literature 200-300 years ago, but much of the material used is superstitious and useless (WARE, 1989). In 900 AD, the Chinese used arsenic against insects. The combination of pyrethrum, lime and sulfur, arsenic, sulfur, mercuric chloride and soaps were the materials found to be effective between 1800-1825. Between 1825 and 1850, quassia, phosphorous past veretonone was used (WARE, 1989). Millardet observed in 1885 that the leaves of the vines sprayed with a mixture of bluish-white copper sulfate and lime were protected against the aggressive downy mildew disease in grapes that spread from America to Europe, while the leaves of the vines that were not treated died. Later, after several combination trials, he concluded that a mixture of sulfate and quicklime was effective against downy mildew in grapes (AGRIOS, 2005). The mixture of quicklime and copper sulfate, known as Bordeaux Mixture, has been used more than any other fungicide against downy mildew diseases, leaf spot diseases and many fungal diseases all over the world, and its use continues today. The discovery of the Bordeaux Mixture revealed that the chemicals could be used for plant diseases and encouraged the investigation of the nature and control of plant diseases (AGRIOS, 2005). The scientific pesticide applications started with arsenical Paris green and kerosene emulsion applications applied to defoliated trees in the dormant period in 1867 and 1868 (WARE, 1989).

Today, millions of kilograms of pesticides are used every year for seed spraying, soil fumigation, and spraying of plants before and after harvest because of the infections of certain diseases, insects and weeds have limited the cultivation lands and crop diversity. Pesticides are one of the most important agricultural inputs in plant production when they are used in a controlled manner against pests to maintain product yield and quality. However, the continuous and intensive use of pesticides may cause adverse environmental effects, which may affect biodiversity and sometimes result in reduced crop yield, as a result of contamination of soil, water and non-target plants and animals (FAOSTAT, 2022).

Pesticides are divided into groups such as sprays, powders, aerosols, granular pesticides and fumigants according to their physical structures and application methods. Although pesticides used by spraying have different formulation (EC, SC, WP and so forth) types, they are added for water and applied by spraying directly on the topsoil of the plants. Applications are carried out with the help of a sprayer mounted on the tractor or carried on the back. In addition, spraying applications can be made by aircraft, helicopters, and also unmanned aerial vehicles known drones in recent years.

Transport of pesticides to off-target areas (drift)

While spraying from the ground causes the plants to be crushed, more labor and cost, the possibility of pesticides being dragged out of the target by the air flow increases with the spraying made by air vehicles. Moreover, while less than 0.1% of pesticides reach the target organisms, more than 99.9% of pesticides are carried to soil, water and atmosphere living of non-target organisms, and pollute environment (PIMENTAL, 1995). On the other hand, Although very small pesticide particles directly applied as dusting formulation depend on the time of application, they can be entrained to off-target areas much more easily with air currents than pesticides applied by spraying. Besides pesticides carried in droplets and particles, most of them are volatile and in the vapor phase can be transported much further from the target, such as some pesticides were detected in ocean fog, in arctic snow, and in the Atlantic Ocean, (PIMENTEL, 1995). Pesticides applied to the soil or used as a seed coating against soil-borne pathogens and pests and weeds are more likely to be leached to the living layer, substrate, and groundwater of the soil by rain and irrigation waters. They are also easy to be carried into stagnant waters such as lakes and seas by mixing with streams. Pesticides pose a significant threat to the immediately adjacent areas as well as to the quality of the lakes, rivers and ecosystems where they are carried by surface water from the fields and orchards where they are applied (WHEELER, 2002).

In Turkey, cockspur grass (*Echinochloa* spp.), rice sedge (*Cyperus difformis*), saltmarsh bulrush (*Scirpus maritimus* l.), common cattail (*Typha latifolia* L.), saltmeadow cordgrass (*Leptocloa fusca*), and moist bank pimpernel (*Lindernia dubia*) are important weeds in paddy fields and quinclorac, clomazone, bentazone and oxadiazone are usually herbicides used against those weeds. In the districts of Çanakkale Kumkale (Troia) and Bursa Karacabey, farmers observed abnormal development in their tomatoes that are close to paddy fields and irrigated from the drainage or stream where the irrigation water used from the paddy is discharged. They have reported the situation to the authorized agricultural organization. In the water samples taken, 21.79 ppb bentazone in 1 sample and quinclorac between 1.90 and 34.47 ppb in 4 samples taken from the water drainages in Çanakkale, 0.76 ppm in the water sample taken from the drainage (Midilli drainage) in Bursa, and 3.02 ppb in the water sample taken from the creek (Karadere). quinclorac was detected (YILMAZ et al. 2020).

Pesticides carried into water sources can accumulate inside aquatic organisms and remain unchanged for long periods of time. However, pesticides that adhere to the particles on the soil surface are carried to untreated areas by wind erosion or by passing into the vapor phase, horizontally and vertically in the soil or moving out of the soil by air currents (TIRYAKI et al. 2010). Pesticides are absorbed by organic matter and decomposed by microorganisms during their vertical movement in the soil, but the remaining part is desorbed again due to the evaporation pressure in the soil and moves towards the soil surface (CONWAY and PRETTY, 2009). Upward transport from the soil to the soil-atmosphere interface occurs either by gas diffusion through the air-filled volume of the soil or by the upward flow of the soil solution induced by the evaporation of water (SUNTIO et al. 1988). In both cases, the rate at which pesticide volatilizes from the soil is governed by the soil-air and soil-water-air balance at the surface, according to Henry's Law.

Pesticide applications with wheeled vehicles are limited by the height of the crop and irrigated areas, ruts damage the crop and can cause a decrease in productivity by compacting the soil. While aerial spraying by plane, helicopter or unmanned aerial vehicles is an alternative to ground spraying, the most important problem is environmental pollution resulting from the drift of pesticides to non-target areas in aerial spraying (KIRK, 200; OLIVEIRA et al., 2013).

Effects of pesticides on non-target organisms

Plant diseases, pests and weeds interfere with crop production and destroy 31-40% of the world's total crop crops required to feed humans and animals each year (AGRIOS, 2005). Considering that 14% of the total crop in the world is destroyed only due to plant diseases, the annual total economic loss due to diseases in the world is 220 billion dollars. When the pesticide costs applied to prevent product, losses are added to this economic loss, the cost increases even more. However, the loss resulting from pesticides' negative effects on pets, natural enemies, honey and wasps, fish, beneficial microorganisms, non-target plants and crops, birds and wild mammals, as well as polluting surface and groundwater where living things meet their drinking water needs should be much higher than the economic loss caused by pests (PIMENTEL, 1995).

Effects of pesticides on soil organisms

Microbial and faunal activities in the soil are indispensable for a healthy and high quality soil. Soil organisms include earthworms, nematodes, protozoa, actinomycetes, fungi, bacteria and different arthropods (SRIVASTAVA et al. 2020). While these organisms help plants to take these minerals with the mineralization, they provide by decomposing the organic materials in the soil, they help to preserve the soil structure by releasing some organic materials.

However, earthworms feed on sediments in the soil, providing vital bioturbation for soil vitality. After feeding on organic matter such as worms, plant residues and other biological waste, they produce worm casting, a humus-like substance. Vermicast passing through the worm's digestive tract becomes clean, odorless and enriched with many micronutrients such as nitrogen (2–3%), phosphorus (1.55–2.25%), and potassium (1.85–2.25%). Vermicompost improves soil health and plant productivity by converting organic waste into nutrient-rich compost. Vermicompost improves soil microbial activity and soil porosity and water infiltration rate. At the same time, it increases the oxygen availability in the soil and maintains the soil temperature (ARORA et al. 2011).

While rhizobacteria participate in the nutrient cycle through mineralization, nitrification, nitrogen fixation, denitrification, and soil enrichment processes, soil microorganisms such as mycorrhizal fungi play an important role in delivering nutrients to the plant. While rhizobacteria benefit from significant amounts of root secretions released into the rhizosphere, microorganisms in the rhizosphere provide nutrients to plants by competing for inorganic nutrients and mediating the turnover and mineralization of organic matter (BRIMECOMBE et al. 2007). Thus the accumulation of organic matter stimulates microbial growth and activity in the rhizosphere, which then controls the conversion of C, N and other nutrients. This is very important for nutrient mineralization and soil structure improvement in the soil.

Besides plants in the soil, microorganisms secrete siderophores, which are iron chelating agents, and these compounds function in the ecology of microorganisms in the plant rhizosphere as well as iron nutrition (CROWLEY and CRAEMER, 2007). Siderophores mediate competition for iron nutrition and help suppress plant diseases. In addition, siderophores and phytosiderophores facilitate heavy metal uptake and food chain transfer of metals. Streptomyces spp., Pseudomonas aeruginosa, *Alcaligenes denitrificans*, *Mycobacterium tuberculosis*, *Staphylococcus* spp., *Bacillus anthrasis* are some of the siderophore-producing microorganisms found in soil ecology (SAHA et al. 2012).

Most of the pesticides that are used irregularly and repeatedly in agriculture and other areas, especially in developing countries, accumulate not only in the area where they are used, but also in the soil where they are transported non-target. Many studies have been conducted on the presence of pesticides in the soil. Among them, in a study conducted in the agricultural areas located in the Troi (Troy) National Park, which is a secondary bird migration corridor in the northwest of Turkey and accepted as a world cultural heritage by UNESCO in 1998 due to its archaeological riches; HCH, ethion, endosulfan, captan, trifluralin, mancozeb and α-endosulfan residues were detected in soil samples taken from 0-20 cm depths of the soil at different times (YILDIRIM and ÖZCAN, 2007).

In soil samples collected from different regions of China, an average of 286 μg/kg of pesticide per sample was detected due to indiscriminate use of pesticides (DHANANJAYAN et al. 2020). While 76 pesticide residues were detected in 317 top surface soil samples collected from agricultural areas of European Union countries, high amounts of pesticide residues were detected in soil samples collected in the post-harvest period from the southern regions of Jordan (DHANANJAYAN et al. 2020).

Irregularly used pesticides and their degradation products can affect the flora and fauna including soil microflora, disrupt the soil environment and cause serious ecological consequences (ARORA and SAHNI, 2016). The effects of pesticides on microorganisms vary according to the dose of the chemical, physical and chemical properties of the soil, and environmental factors (ECOBICHON, 1991). As with phytopathogens, pesticides have direct toxic effects on non-target soil microorganisms by changing their intracellular pH, as well as inhibit physiological events such as mitochondrial respiration, nucleic acid synthesis and nuclear division by forming biochemical complexes with enzymes and proteins or disrupting their structures (DELEN, 2016).

In studies on the effects of herbicides on phytopathogens, chlorsulfuron increased root disease caused by Rhizoctonia solani, while it had no effect on take-all disease caused by *Gaeumannomyces tritici* (ROVIRA and MCDONALD, 1986), glyphosate and chlorosulfurone in barley *Pythium* root rot (BLOWES, 1987) and promotes take-all diseases (MEKWATANAKARN and SIVASITHAMPARAM, 1987).

Soil microflora has an important place in the nutrient cycle and plays an important role in the soil ecosystem. In a field where glyphosate was applied, it was determined that microbial biomass carbon increased up to 17% and microbial biomass nitrogen up to 76% in the soil 14 days after the application (ARORA and SAHNI, 2016). In the same study, it was reported that microbial biomass C increased up to 30 days in soils treated with cartap hydrochloride as well as chlorpyrifos, and then decreased gradually.

The chemical and physical structure and microbial richness of the soil may affect the degradation and adsorption of pesticides or their transport to other regions (HUSSAIN et al., 2009). Degradation products of pesticides disrupt the diversity of microorganisms in the soil, as well as their enzyme production and the function of many enzymes (hydrolysis, nitrate reductases, urease, oxidoreductase, nitrogenase, dehydrogenase) (HUSSAIN et al., 2009; MUNOZ-LEOZ et al., 2011; MEEHA et al. 2020; SEBIOMO et al. 2011; SRINIVASULU et al. 2012).

HUSSAIN et al. (2009) presented the effects of pesticides compiled from studies on the enzymes of microorganisms. According to this; of carbendazim, imazethapyr, and thiram in *Rhizobium leguminosarum* bv. *trifolii*, *Sinorhizobium meliloti*, and *Bradyrhizobium* sp., while carbofuran negatively affected the nitrogenase enzyme activity of *Anabaena doliolum*, captan nitrogenase activity decreased in soil under aerobic conditions, while terbutryn, simazine and prometryn (herbicides) decreased total nitrogenase activity. In addition, they inhibited nitrogenase and hydrogen photoproduction activities of 2,4-D, quinalphos, monocrotophos, captan, carbendazim purple nonsulfur bacteria. In another study, it was found that acetamiprid adversely affected soil respiration and phosphatase activity at normal field doses (0.5 mg/kg dry soil) and increased dehydrogenase activity 2 weeks after the application (YAO et al. 2006), while in another study bromoxinil + prosulfuron (herbicide) has been reported to cause significant changes in the soil microbial population by affecting the dehydrogenase activity (PAMPULHA and OLIVEIRA, 2006). On the other hand, while ý-HCH stimulated rhizosphere-associated nitrogenase activity, butachlor, benthiocarb, cinmethylin, 2,4-D and anilofos stimulated nitrogenase activity have been reported (PATNAIK et al. 1995, 1996).

Along with biological nitrogen fixation, biotransformation is affected by pesticide residues in the soil. The functional diversity of the non-target microbial fauna in the soil affected by pesticides is negatively affected by decreasing carbon biomass (MONKIEDJE and SPITELLER, 2005). It is known that pesticide residues impair the growth and metabolic activities of arbuscular mycorrhizae, root colonizing microorganisms and a small number of algae and fungi species (DHANANJAYAN et al. 2020). It has been determined that carbendazim and mancozeb, which are fungicides, negatively affect the number of mycorrhizal spores and mycorrhizal root colonization on the face and reduce the growth of sunflowers (AGGARWAL, 2005). Similarly, studies on the effect of herbicides on mycorrhizae have reported that oxyfluorfen and oxadiazon promote the microbial population and can increase the presence of phosphorus (P) in rice. However, the systemic herbicide glyphosate inhibits spore, vesicle, propagules, root colonization, indirectly intra-radical mycelial growth and arbuscular formation of mycorrhizal fungus *Glomus mosseae*; it has been reported that the herbicides oryzaline, trifluralin and oxadiazon adversely affect spore germination and propagation of mycorrhizal species (MEENA et al. 2020).

Earthworms, which feed on soil organic matter and sediments and have important functions for soil health, are constantly exposed to soil pollutants through their outer epidermis and feeding surfaces (RODRIGUES-CASTELLIANA and SANCHEZ-HERNANDEZ, 2007). Pesticides can have a direct effect on worms as well as have an indirect effect on their growth and reproduction (PAOLETTI, 1999). SOLAIMALA, et al. (2004) reported detrimental effects such as body swelling, rupture of the cuticle, discoloration and softening of the skin, leakage of coelomic fluid, etc., in worms exposed to different types of pesticides. Worms contaminated with pesticides are a source of contamination for higher members of the food chain such as gulls and birds that feed on them. Pesticides accumulate as a mixture, especially in orchards, and these mixtures show high effectiveness of worm species *Lumbricus rubellus* and *L. castaneus* feeding on the soil surface (PAOLETTI, 1999). It has been reported that especially copper sulfate and carbamate fungicides, copper and zinc compounds, diclopropane and diclopropene (D-D mixture), soil fumigants such as metamsodium and methylbromide, nematicides and fungicides have high toxicity for worms (EDWARDS and BOHLEN, 1992).

Effects of pesticides on organisms living in water

Earth has a wide variety of aquatic habitats, from temporary ponds, ponds, lakes, swamps, swamps, streams, rivers, estuaries, inland salt lakes, melting ice, and hot springs to the seas and oceans. Pesticides applied in agricultural areas can be carried to non-target environments such as rivers, lakes, or seas with the movement of air currents, surface or subsoil waters, and they have an impact on the development and functions of organisms (ecological niche) in water resources. While irrigation and rainwater in agricultural areas bolster pesticide pollution in water resources, water pollution is increased by the fact that producers discharge the increased pesticide into water resources after spraying and wash the spraying equipment they use in these resources (KILINÇ et al. 2007).

YILDIRIM and ÖZCAN (2007) collected samples from water sources within the area of Troi (Try) Natonal Park (declared as a world cultural heritage by UESCO in 1998) in Çanakkale. Methoxychlor, α-endosulfan, β-endosulfan, α-HCH and β-HCH residues were detected. In a study conducted to monitor the diversity of PPP and biocide in five river basins scattered over the Swiss plateau, more than 100 parent compounds and 40 degradation products were detected, with 30 to 50 compounds in each of the samples taken from the rivers (MOSCHET, 2014).

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Both fish and aquatic flora and fauna during swim on pesticide-contaminated surfaces and substrates of flowing and stagnant waters are exposed to pesticides directly or indirectly by absorption through the skin, by respiration through the gills, by drinking the contaminated water and by feeding on contaminated preys (MAURYA et al. 2019). Aquatic organisms contaminated with pesticides constitute the beginning of toxicity in the food chain. The toxic residue passes directly to animals and humans that feed on them, and from insects that feed on contaminated aquatic organisms to their predators.

Different types of pesticides such as organophosphoruses, carbamates, organochlorines, pyrethroids and nicotonoids used in agriculture cause the disruption of ecological relations between aquatic organisms and the permanent deterioration of large ecosystems with the loss of biodiversity. Growth rate decreases in organisms exposed to insecticides, metabolic and reproductive disorders occur. Especially in fish species, it can cause genetic disorders when exposed to insecticides, and neurological and behavioral disorders in hematopoietic tissues such as gill, liver, spleen, kidney, kidney tubules, endocrine tissues, brain (MAURYA and SARMA, 2019).

Effects of pesticides on organisms living in the troposphere

Pesticides, which accumulate in the ecosystem at high concentrations, interfere with the food chain of animals and cause significant damage to them. The widespread use of organic phosphates poses a risk to future generations by causing thinning of the eggshells of various raptors such as the bald eagle, brown pelican, and golden falcon (ROLLINS, 1994). While endosulfan has no toxic effects on beneficial insects, it is highly toxic to fish, birds, poultry, and bees, such as parasitic wasps, ladybugs, and some mites (PANAP, 1996). It is also reported that endosulfan has moderate-to-high toxicity on mallards (KIDD, 1991; HUDSON, 1994). In addition to abnormal development in the skin, central nervous system, eyes, ears and musculoskeletal of pregnant rats, decreased fertility and bone deficiencies in Mancozeb fed rats are among the most important findings (EXTOXNET, 1996).

Birds are very important in the ecosystem due to their role in the food chain and are also valuable indicators for chemical pollution in the environment, accumulation of their residues and magnification in the environment (DHANANJAYAN et al. 2020). Birds act as insect-eating predators, aid in pollination and provide many ecosystem services. However, chemical residues accumulate in the tissues of birds exposed to pesticides and their cholinesterase activities decrease (DHANANJAYAN, 2012; DHANANJAYAN et al. 2012). Ingestion of granular pesticides in various ways, medicated seeds, feeding with contaminated food and water, or direct exposure to pesticide sprays cause their death (FISHEL, 2013). Birds exposed to pesticide residues show behavioral and reproductive changes (DHANANJAYAN et al. 2020).

One of the most important elements of the food chain living in the troposphere ecological system are pollinator animals. Pollinators consist of honeybees, fruit flies such as the fig fly, insects, and birds, which aid in flower pollination through their foraging behavior. According to the report of the United Nations Food and Agriculture Organization; of the nearly 100 crop species that provide 90% of the food consumed worldwide, 71 are pollinated by bees. In addition, according to the report, 84% of 264 different crops in Europe are pollinated by pollinators (KLUSER, 2010). Pollinators are responsible for approximately 9.5% of the world's food production (GALLAI et al. 2009). For this reason, the role of pollinators in the ecosystem is so important that it cannot be ignored. However, pesticides, especially insecticides applied in agriculture, and their degradation products threaten pollinators as well as other non-target organisms. Especially pollinator insects that meet contaminated flowers are damaged by pesticides. For example, neonicotinoid group insecticides with systemic effects such as acetamiprid, clothianiadin, imidacloprid, thiacloprid and thiametoxam can be transported to all parts of plants, including flowers and pollen. Pollinating insects are exposed to these insecticides and even if they do not die, they have important effects on their behavioral physiology, which will affect the colony life later (GILL et al. 2012; BRYDEN et al. 2013; GILL and RAINE, 2014; MOFFAT, 2015)

SAMUELSON et al. (2016) investigated the effect of acute thiamethoxam exposure on the spatial working memory of the wasp *Bombus terrestris* and found that the spatial working memory of the insecticide-applied wasps was adversely affected. Indeed, HENRY et. Al (2012) reported that, as a result of their research under field conditions, collapses with high mortality rates occur in the colony due to the target search failures of honeybees exposed to non-lethal doses of thiamethoxam (neonicotinoid systemic pesticide).

Conclusions

The world population is constantly increasing and more agricultural production is needed to feed people. However, the land areas to be cultivated in the world are limited and soilless agriculture practices are not yet at a level to meet the nutritional needs of people. Moreover, diseases, insects and weeds become partners in agricultural products that people and their animals need every year, reducing crop yield and quality.

To minimize the damage of these pests to the crops, various plant protection and protection practices (PPPs) are carried out in both conventional agriculture, integrated production, good agricultural practices or organic farming production systems. Cultural measures within Plant Protection Practices include growing plants in conditions suitable for their genetic structures, increasing their resistance with balanced nutrition, growing plants resistant to pests, reducing phytopathogens, insects or weed populations, supporting antagonist microorganisms and beneficial insects, and similar practices. Cultural measures, control method using biological factors, physical control method in which heat is applied, and legal regulations that prevent the spread and dominance of pathogens are plant protection practices that have the least negative impact on ecological systems or positively support them.

However, although the chemical control method, in which pesticides are used unconsciously and continuously, protects plants from pests for a short time and with high effectiveness, it can also lead to irreversible consequences on the environmental ecosystem.

References

AGGARWAL, A. – SHARMA, D. – PARKASH, V. – SHARMA, S. – GUPTA, A. (2005): Effect of Bavistin and Dithane m-45 on the mycorrhizae and rhizosphere microbes of sunflower. Helia, 28(42): 75–88. https://doi.org/10.2298/hel0542075a

ARORA, S. – SAHNI, D. (2016): Pesticides effect on soil microbial ecology and enzyme activity- An overview. Journal of Applied and Natural Science 8 (2): 1126–1132.

ARORA, V. K. – SINGH, C. B. – SIDHU, A. S. – THIND, S. S. (2011): Irrigation, tillage and mulching effects on soybean yield and water productivity in relation to soil texture. *Agric Water Manag*, 98(4): 563–568.

BLOWES, W. M. (1987): Effect of ryegrass root residues, knock-down herbicides, and fungicides on the emergence of barley in sandy soils. *Australian Journal of Experimental Agriculture*, 27: 785–790. https://doi.org/10.1071/EA9870785

BRIMECOMBE, M. J. – DE LEIJ, F. A. A. M. – LYNCH, J. M. (2007): Rhizodeposition and Microbial Populations. Chapter 3 in The Rhizosphere: Biochemistry and Organic Substances at the Soil-Plant Interface, second edition, edid by R. Pinton, Z. Varanini, P. Nannipieri, CRC Press. https://doi.org/10.1093/aob/mcp166

BRYDEN, J. – GILL, R. J. – MITTON, R. A. – RAINE, N. E. – JANSEN, V. A. (2013): Chronic sublethal stress causes bee colony failure. *Ecology Letters*, 16: 1463–1469. https://doi.org/10.1111/ele.12188

CONWAY, G. R. – PRETTY, J. N. (2009): Unwellcome Harvest: Agriculture and pollution. Earthscan Publications Ltd, London, pp 645.

CROWLEY, D. E. – KRAEMER, S. M. (2007): Function of Siderophores in the Plant Rhizosphere. Chapter 7 in The Rhizosphere: Biochemistry and Organic Substances at the Soil-Plant Interface, second edition, edid by R. Pinton, Z. Varanini, P. Nannipieri, CRC Press. https://doi.org/10.1093/aob/mcp166

DELEN, N. (2016): Fungisitler. Nobel Akademik Yayıncılık Eğitim Danışmanlık Tic. Ltd., 2. Baskı, Ankara, pp. 534.

DHANANJAYAN, V. – JAYANTHI, P. – JAYAKUMAR, S. – RAVICHANDRAN, B. (2020): 11 Agrochemicals Impact on Ecosystem and Bio-monitoring. in: Resources Use

Efficiency in Agriculture, Eds: S. Kumar, R. S. Meena, M. K. Jhariya, Springer Nature Singapore Pte Ltd. https://doi.org/10.1007/978-981-15-6953-1_11349
DHANANJAYAN, V. – RAVICHANDRAN, B. – RAJMOHAN, H. R. (2012) Organochlorine pesticide residues in blood samples of agriculture and sheep wool workers in Bangalore (rural), India. *Bull Environ Contam Toxicol* 88(4): 497–500. https://doi.org/10.1007/s00128-012-0546-6
DHANANJAYAN, V. (2012): Acetylcholinesterase and butyrylcholinesterase activity in brain and plasma of several species of birds from India. *Res Rev J Toxicol*, 2(1): 1–9. https://doi.org/10.1016/s1096-4959(03)00048-4
DIX, N. J. – WEBSTER, J. (1995): Aquatic Fungi. Fungal Ecology, 225–283. https://doi.org/10.1007/978-94-011-0693-1_9
ECOBICHON, D. J. (1991): Toxic effects of pesticides. In: Amdur MO, Donl J, Klassen CD, editors. Casarett and Doull's toxicology. 4th edition. New York: Pergamon Press. p. 2–18.
EDWARDS, C. A. – BOHLEN, P. J. (1996): Biology and Ecology of Earthworms. Chapman & Hall, London, 426 pp.
EXTOXNET (1996): Pesticid İnformation Profile; Mancozeb. Extoxnet, Itaca N.Y., USA. September, 3.
FISHEL, F. M. (2013): Pesticides effects on non-target organisms. PI-85. Pesticide information office, Florida Cooperative Extension Service, IFAS, University of Florida, Gainesville, FL, USA; 2011. http://edis.ifas.ufl.edu/pi122.
GALLAI, N. – SALLES, J. M. – SETTELE, J. – VAISSIÈRE, B. E. (2009): Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. Ecological Economics, 68: 810–821. https://doi.org/10.1016/j.ecolecon.2008.06.014
GILL, R. J. – RAINE, N. E. (2014): Chronic impairment of bumblebee natural foraging behaviour induced by sublethal pesticide exposure. Functional Ecology, 28, 1459–1471.
GİLL, R. J. – RAMOS-RODRİGUEZ, O. – RAİNE, N. E. (2012): Combined pesticide exposure severely affects individual-and colony-level traits in bees. Nature, 491: 105–108. https://doi.org/10.1038/nature11585
HENRY, M. – BÉGUIN, M. – REQUIER, F. – ROLLIN, O. – ODOUX, J. F. – AUPINEL, P. – APTEL, J. – TCHAMITCHIAN, S. – DECOURTYE, A. (2012): A Common Pesticide Decreases Foraging Success and Survival in Honey Bees. Science, 336: 348. https://doi.org/10.1126/science.1215039
Pesticides use, pesticides trade and pesticides indicators. https://www.fao.org/3/cc0918en/cc0918en.pdf FAOSTAT Pesticides,erişim (06.11.2022)
HUDSON, R. H. – TUCKER, R. K. – HAEGELE, M. A. (1984): Handbook of Acute Toxicity of Pesticides to Wildlife, Resource Publication 153. U.S. Department of Interior, Fish and Wildlife Service, Washington, DC., 6–54.
HUSSAIN, S. – SIDDIQUE, T. – SALEEM, M. – ARSHAD, M. – KHALID, A. (2009): Chapter 5 Impact of Pesticides on Soil Microbial Diversity, Enzymes, and Biochemical Reactions. Advances in Agronomy, 102: 159-200. https://doi.org/10.1016/S0065-2113(09)01005-0
HUSSAIN, S. – SİDDİQUE, T. – SALEEM, M. – ARSHAD, M. – KHALİD, A. (2009): Impact of pesticides on soil microbial diversity, enzymes, and biochemical reactions. Adv Agron 102: 159–200.
KIDD, H. – JAMES, D. R. (1991): The Agrochemicals Handbook, 3rd edn. Royal Society of Chemistry Information Services, Cambridge, UK, 6–10.
KILINÇ, K. – KÖSEDAĞ, O. – DİRİK, g. – VURALIN, A. – YILDIRIM, C. – YILDIRIM, İ. (2007): Çanakkale Tarım Alanlarında Kimyasal Kullanımdan Kaynaklanan Sorunlar. Ziraat Mühendisleri Odası III. Öğrenci Kurultayı, Bildiriler Kitabı, 91-94.
KIRK, I. W. (2000): Aerial spray drift from different formulations of glyphosate. Transactions of the ASAE, 43(3): 555.
KLUSER, S. – NEUMANN, P. – CHAUZAT, M. P. et al. (2010): UNEP Emerging Issues: Global honey bee Colony disorders and other threats to insect pollinators. Unige: 32251.
MAURYA, P. K. – MALIK, D. S. – SHARMA, A. (2019): Chapter 9 Impacts of pesticide application on aquatic environments and fish diversity. In: Contaminants in Agriculture and Environment: Health Risks and Remediation, Vol. 1, eds by V. Kumar, R. Kumar, J Singh, P. Kumar, ISBN: 978-81-942017-0-0. https://doi.org/10.26832/AESA-2019-CAE-0162-09

MEENA, R. S. – KUMAR, S. – DATTA, R. – LAL, R. – VIJAYAKUMAR, V. – BRTNICKY, M. – SHARMA, M. P. – YADAV, G. S. et al. (2020): Impact of Agrochemicals on Soil. Microbiota and Management: A Review. Land, MDIP, 9: 34. https://doi.org/10.3390/land9020034

MEKWATANAKARN, P. – SİVASİTHAMPARAM, K. (1987): Effect of certain herbicides on saprophytic survival and biological suppression of the take-all fungus. New Phytology, 106: 153-159. https://doi.org/10.1111/j.1469-8137.1987.tb04799.x

MOFFAT, C. – PACHECO, J. G. – SHARP, S. – SAMSON, A. J. – BOLLAN, K. A. – HUANG, J. – BUCKLAND, S. T. – CONNOLLY, C. N. (2015): Chronic exposure to neonicotinoids increases neuronal vulnerability to mitochondrial dysfunction in the bumblebee (Bombus terrestris). *The FASEB Journal*, 29: 2112–2119. https://doi.org/10.1096/fj.14-267179

MONKIEDJE, A. – SPITELLER, M. (2005): Degradation of Metalaxyl and Mefenoxam and Efects on the Microbiological Properties of Tropical and Temperate Soils. Int. J. Environ. Res. Public. Health, 2: 272–285. https://doi.org/10.3390/ijerph2005020011

MOSCHET, C. – WITTMER, I. – SIMOVIC, J. – JUNGHANS, M. – PIAZZOLI, A. – SINGER, H. – STAMM, C. – LEU, C. – HOLLENDER, J. (2014): How a complete pesticide screening changes the assessment of surface water quality. *Environ. Sci*.. Tech., 48: 5423−5432. https://doi.org/10.1021/es500371t

MUNOZ-LEOZ, B. – RUİZ-ROMERA, E. – ANTIGUEDAD, I. – TEBUCONAZOLE, G. C. (2011): Application decreases soilmicrobial biomass and activity. *Soil Biol Biochem*, 43: 2176–2183. https://doi.org/10.1016/j.soilbio.2011.07.001

OLIVEIRA, R. B. D., – ANTUNIASSI, U. R. – MOTA, A. A. – CHECHETTO, R. G. (2013): Potential of adjuvants to reduce drift in agricultural spraying. *Engenharia Agricola*, 33(5): 986–992. https://doi.org/10.1590/S0100-69162013000500010

PADMANABHAN, S.Y. (1973): The Great Bengal Famine. *Annual Review of Phytopathology*. 11: 11–24. https://doi.org/10.1146/annurev.py.11.090173.000303

PAMPULHA, M. E. – OLIVEIRA, A. (2006): Impact of an herbicide combination of bromoxynil and prosulfuron on soil microorganisms. *Curr Microbiol*. 53: 238–243. https://doi.org/10.1007/s00284-006-0116-4

PANAP (1996): Endosulfan Datasheet. Pesticide Action Network Asia and the Pacific, Penang, Malaysia, June, 6.

PAOLETTI, M. G. (1999): The role of earthworms for assessment of sustainability and as bioindicators. Agric. *Ecosyst. Environ*. 74: 137–155. https://doi.org/10.1016/S0167-8809(99)00034-1

PATNAIK, G. K. – KANUNGO, P. K. – ADHYA, T. K. – RAO, V. R. (1996): Effect of repeated applications of gamma-hexachlorocyclohexane (gamma-HCH) on nitrogenase activity and nitrogen-fixing bacteria associated with rhizosphere of tropical rice. Microbiol. Res. 151, 375–378. https://doi.org/10.1016/S0944-5013(96)80006-1

PATNAIK, G. K. – KANUNGO, P. K. – MOORTHY, B. T. S. – MAHANA, P. K. – ADHYA, T. K. – RAO, V. R. (1995): Effect of herbicides on nitrogen-fixation (C2H2 reduction) associated with rice rhizosphere. Chemosphere 30, 339–343. https://doi.org/10.1016/0045-6535(94)00401-F

PİMENTAL, D. (1995). Amounts of pesticides reaching target pests: Environmental impacts and ethics. Journal of Agricultural and Environmental Ethics, 8: 17–29.

PİMENTEL, D. – LEVİTAN, L. (1986): Pesticides: amounts applied and amounts reaching pests. Bioscience, 36: 86–91.

ROANE, M. K. – GRIFFIN, G. J. – ELKINS, J. R. (1986): Chestnut Blight, Other Endothia Diseases, and the Genus Endothia. APS monograph series. APS Press, American Phytopathological Society. pp. 53. ISBN 978-0-89054-073-2.

RODRI´GUEZ-CASTELLANOS, L. – SANCHEZ-HERNANDEZ, J. C. (2007): Earthworm biomarkers of pesticide contamination: Current status and perspectives. J. Pestic. Sci., 32(4), 360–371. http://dx.doi.org/10.1584/jpestics.R07-14

ROLLİNS, D. – FUCHS, T. W. – HANSELKA, C. W. – WİNN, J. (1994): Reducing Pesticide Risks to Wildlife in Sorgum and Small Grains. Texas Cooperative Extension, The Texas A and M University System, B–5095.

SAHA, R. – SAHA, N. – DONOFRIO, R. S. – BESTERVELT, L. L. (2012): Microbial siderophores: a mini review. Journal of Basic Microbiology 52: 1–15. https://doi.org/10.1002/jobm.201100552
SAMUELSON, E. E. W. – CHEN-WISHART, Z. P. – GILL, R. J. – LEADBEATER, E. (2016): Effect of acute pesticide exposure on bee spatial working memory using an analogue of the radial-arm maze. *Scintific Reports*, 6:38957. https://doi.org/10.1038/srep38957
SEBİOMO, A. – OGUNDERO, V. W. – BANKOLE, S. A. (2011): Effect of four herbicides on microbial population, soil organic matter and dehydrogenase activity. *Afr J Biotechnol* 10(31), 770-778. https://doi.org/10.4314/AJB.V10I5
SOLAIMALAI, A. – RAMESH, R. T. – BASKAR, M. (2004): Pesticides and environment. In: Environ Contam Bioreclam, pp 345–382.
SRINIVASULU, M. – MOHIDDIN, G. J. – MADAKKA, M. – RANGASWAMY, V. (2012): Effect of pesticides on the population of Azospirillum sp. and on ammonification rate in two soils planted to groundnut (*Arachis hypogaea* L.). *Tropi Ecol* 53: 93–104.
SRIVASTAVA, P. – BALHARA, M. – GIRI, B. (2020): Soil Health in India: Past History and Future Perspective. In: Soil Health, Soil Biology 59, eds. by B. Giri, A. Varma, Springer Nature Switzerland.
STRANGE, R. N. (2003): Introduction to Plant Pathology. John Wiley & Sons Ltd, England, pp. 439.
SUNTIO, L. R. – SHİU, W. Y. – MACKAY, D. – SEİBER, J. N. – GLOTFELTY, D. (1988): Critical Review of Henry's Law Constants fro Pesticides. *Reviews of Environmental Contamination and Toxicology*, 103: 1–59.
TİRYAKİ, O. – CANHİLAL, R. – HORUZ, S. (2010): Tarım ilaçları kullanımı ve riskleri. *Erciyes Üniversitesi Fen Bilimleri Enstitüsü Dergisi* 26(2): 154–169.
TOROS, S. – MADEN, S. – SÖZERİ, S. (2001): Tarımsal Savaş Yöntem ve İlaçları. AÜ Ziraat Fak. Ders Kitabı, Ankara, pp. 417.
TOROS, S. – MADEN, S. – SÖZERİ, S. (2001): Tarımsal Savaşım Yöntem ve İlaçları. Ankara Ün. Ziraat Fak. Ders Kitabı, Yayın no: 1520, Ders Kitabı: 473.
WANG, H. – HE, X. – SONG, J. – WANG, Z. – WANG, C. – WANG, S. – WU, R. – MENG, Y. (2018): Drift potential of UAV with adjuvants in aerial applications. Int J Agric & Biol Eng, 11(5): 54–58.
WARE, G. W. (1989): The Pesticide Book. Thomson Publlication, USA, pp 336.
WHEELER, W. B. (2002): Pesticides in Agriculture and the Environment. CRC Press, pp. 360. https://doi.org/10.1201/9780203909430
XU, N. – QU, Q. – ZHANG, Z. – YUAN, W. – CUİ, H. – SHEN, Y. – LİN, W. – LU, T. – QİAN, H. (2020): Effects of residual S-metolachlor in soil on the phyllosphere microbial communities of wheat (Triticum aestivum L.). Science of the Total Environment 748: 141342 https://doi.org/10.1016/j.scitotenv.2020.141342
YAO, X. – MIN, H. – LU, Z. – YUAN, H. (2006): Influence of acetamiprid on soil enzymatic activities and respiration. Eur J Soil Biol. 42(2): 120–126. http://dx.doi.org/10.1016/j.ejsobi.2005.12.001
YATES, W. E. – AKESSON, N. B. (1973): Reducing pesticide chemical drift. In Pesticide Formulations, edited by J.W. Van Valkenburg, pp. 275-341. New York: Marcel Dekker.
YILDIRIM, İ. – ÖZCAN, H. (2007): Determination of pesticide residues in water and soil resources of Troia (Troy). *Fresenius Environ. Bull.*, 16 (1): 63–70.
YILDIZ, M. – GÜRKAN, O. – TURGUT, C. – KAYA, Ü. – ÜNAL, G. (2005): Tarımsal Savaşımda Kullanılan Pestisitlerin Yol Açtığı Çevre Sorunları VI. Türkiye Ziraat Mühendisliği Teknik Kongresi, TMMOB Ziraat Mühendisleri Odası, Ankara, 3–7 Ocak 2005
YILMAZ, A. – TAKKABULAN, A. – BUDAK, İ. (2020): T.C. Tarım ve Orman Bakanlığı Zirai Mücadele Merkez Araştırma Enstitüsü Müdürlüğü, Teknik Rapor, Rapor no: 2020/143, Anakara.
ZHANG, B. – BAI, Z. – HOEFEL, D. – TANG, L. – WANG, X. – LI, B. – LI, Z. – ZHUANG, G. (2009): The impacts of cypermethrin pesticide application on thenon-target microbial community of the pepperplant phyllosphere. *Sci Total Environ*, 407: 1915–1922. https://doi.org/10.1016/j.scitotenv.2008.11.049

The lecture was delivered at the 6th International Scientific Conference on the Development of Rural Environment on 17th November 2022 in the plenary session in Szarvas, Hungary.

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