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TOXIC EFFECTS OF NEONICOTINOID INSECTICIDES ON NON-TARGET ORGANISMS*

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ABSTRACT

The aim of this review is to explain toxic effects of neonicotinoid insecticides on non-target organisms and to raise awareness in this regard. It has become more important in recent years to increase the yield in agriculture in order to meet the growing population and accordingly the increased food requirement. Accordingly, various protective substances called pesticides have begun to be utilized in agricultural areas. Insecticides are among the most commonly used pesticides. Neonicotinoid insecticides have been used against harmful insects increasingly in agriculture for the last 30 years. In addition to agricultural areas these insecticides are also used extensively against harmful pests in homes, parks and gardens. Neonicotinoid insecticides are widespread in the environment and have many adverse effects on non-target beneficial organisms. It is estimated that the harmful effects of these insecticides extend from some beneficial insects to birds and even mammals.

Key Words: *Neonicotinoid, toxic effect, pesticide, insecticide.*

NEONİKOTİNOİD İNSEKTİSİTLERİN HEDEF-DIŞI ORGANİZMALAR ÜZERİNDEKİ TOKSİK ETKİLERİ

ÖZ

Bu derleme neonikotinoid insektisitlerin hedef olmayan organizmalar üzerindeki zararlı etkilerini açıklamak ve bu konuda farkındalık yaratmak amacıyla hazırlanmıştır. Son yıllarda artan nüfus ve buna bağlı olarak artan beslenme ihtiyacını karşılamak amacıyla tarımda verimin arttırılması önem kazanmıştır. Buna bağlı olarak tarımsal alanlarda pestisit adı verilen çeşitli koruyucu maddelerden yararlanılmaya başlanmıştır. İnsektisitler en sık kullanılan pestisitler arasında sayılmaktadır. Zararlı böceklere karşı kullanılan neonikotinoid insektisitler tarımda son 30 yıldır giderek artan bir oranda kullanılmaya başlanmıştır. Bu insektisitler tarımsal alanların yanı sıra evlerde, parklarda ve bahçelerde zararlılara karşı da yaygın

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şekilde kullanılmaktadır. Neonikotinoid insektisitler çevrede geniş yayılım göstermekte ve hedef olmayan yararlı organizmalar üzerinde birçok olumsuz etki göstermektedir. Bu insektisitlerin zararlı etkilerinin bazı yararlı böceklerden, kuşlara ve hatta memelilere kadar uzandığı tahmin edilmektedir.

Anahtar Kelimeler: *Neonikotinoid, toksik etki, pestisit, insektisit.*

1. Introduction

The most important problems of the world are the increasing population and the production of foodstuffs to meet the needs of this population. But due to the lack of sufficient agricultural land, this can only be achieved by increasing the yield from the unit area. Thus, the use of preservatives known as pesticides in the production of yields has increased. Pesticides are chemicals used to control pests and they can be natural or synthetic. Due to the many advantages, pesticides are commonly used worldwide. However, it's been proved that these chemicals have harmful effects on non-target organisms. One of the most frequently used groups among pesticides are insecticides (Öztürk, 1990; Van Der Sluijs et al., 2013).

Insecticides are a type of pesticides that are produced to destroy harmful insects. Today, there are many insecticides with different active ingredients. However, there is a constant need for the development of new active insecticides, especially in the case of insect resistance against the active ingredients of certain insecticides, especially in high amounts and in extreme cases. Neonicotinoid insecticides are new generation insecticides developed in response to this need. Neonicotinoids are nicotine-derived insecticides that have been in use since the 1980s. Neonicotinoids are mostly used to control absorbent beetles and some butterflies and they are frequently preferred due to their target selective properties (Öztürk, 1990; Van Der Sluijs et al., 2013).

Neonicotinoid insecticides work as agonists of nicotinic acetylcholine receptors (nAChR), they affect the nervous system by binding to postsynaptic nicotinic acetylcholine receptors. It is known that the structure of nicotinic acetylcholine receptors in mammals is different from that of insects. It is thought that the neonicotinoids have a low relevance to the receptors in the mammals and therefore the toxicity of the neonicotinoid insecticides on the mammals is low. However, neonicotinoid insecticides have been increasingly being used instead of other insecticides in the control of pests due to their

ease of application and storage, their low costs, their destruction and their lack of lipophilic properties in contrast to other insecticides such as organophosphorus and pyrethroids. Imidacloprid, thiamethoxam, dinothifuran, clothianidine, acetamiprid, nitenpyram and thiacloprid are some of the currently active neonicotinoid insecticides (Table 1.) (Tomizawa and Casida, 2003; 2005; Casida and Quistad, 2004).

Table 1. Widely used agricultural neonicotinoids

Some of Widely Used Agricultural Neonicotinoid Insecticides
Acetamiprid
Clothianidin
Dinotefuran
Imidacloprid
Thiamethoxam
Thiacloprid
Nitenpyram

2. Distribution in the Nature

Neonicotinoid insecticides are used at high levels against pests in agricultural areas, homes, parks and gardens (Figure 1.) (Bredenberg, 2012). They are also used on pets to control parasites (Mencke and Jeschke, 2002).

Neonicotinoids are insecticides with high solubility in water. Under appropriate conditions (20°C, pH:7), solubility of neonicotinoid insecticides ranges from 184 mg/L to 590,000 mg/L and there is a continuous mixing of water sources (Wood and Goulson, 2017). For this reason, they mix with surface and ground waters in intense amounts (Figure 2.) (Gurur, 2013) and are absorbed by the applied plants. Researchers have also reported that these insecticides have been detected in some sources of drinking water (Kathryn et al., 2017). The pollution of the water resources on the earth means that the entire environment is contaminated indirectly.

In the Netherlands, since 2004, the concentration of imidacloprid, a neonicotinoid insecticide, in surface waters has been found to be 25,000 times higher than the ecotoxicological limit (13

ng/L) (Van Dijk et al., 2013). Imidacloprid was detected in 89% of samples taken from surface waters near agricultural areas in California in 2010 and 2011, and 19% of these samples exceeded the USEPA limit of 1.05 µg/L (Starner and Goh, 2012; Van Dijk et al., 2013). In a study conducted in Canada in 2014, neonicotinoid insecticide concentration was found to be maximum 256 ng/L (mean: 15.9 ng/L) for imidacloprid, 1,490 ng/L (mean: 40.3 ng/L) for thiamethoxam, maximum 3,110 ng/L (mean: 142 ng/L) for clothianidin and 54.4 ng/L (mean: 1.1 ng/L) for acetamiprid in the analysis of samples taken at different times from water sources and sediments (Main et al., 2014; Bonmatin et al., 2015). In the underground waters in Spain, the concentrations of neonicotinoids were found to be more than 20 times the limit amount (Gonzalez-Pradas et al., 2002). In Australia, five different neonicotinoid insecticides were found in 27-93% of the samples taken after rainfall from rivers drained from farmland and the concentrations of imidacloprid and thiacloprid from these insecticides were reported to be 4.6 µg/L and 1.4 µg/L, respectively (Sanchez-Bayo and Hyne, 2014; Morrissey et al., 2015).

It is known that insecticides are absorbed by plants and accumulate especially in their pollen. In addition to leaf residues of plants, the presence of these group of insecticides has been detected, especially in nectars and pollen. Insecticides are known to reach beneficial insects, bees, frogs, birds and even mammalians in this way (Goulson, 2013).

Figure 1. Agricultural areas

Figure 2. Water sources

3. Toxic Effects

The harmful effects of neonicotinoid insecticides, which were initially thought not to cause harmful effects on non-target

organisms, have begun to attract attention in recent years (Figure 3.) (Smitley, 2016). Neonicotinoids cause many adverse effects such as growth retardation, behavioral and reproductive disorders, teratogenic effects and even death in useful organisms in the ecosystem.

2008 May: The use of clothianidin and imidacloprid in Germany has been determined to eliminate 50% of the honey bee (*Apis mellifera L.*) population (EPA, 2008; Hopwood et al., 2012).

2013 June: 50,000 wasps died after the treatment of linden trees with dinotefuran in the state of Oregon, USA (Black and Vaughn, 2013). Studies conducted under laboratory conditions also show that neonicotinoid insecticides have significant toxic effects on honey bees. These effects have been reported to result in loss of learning and remembering abilities of the bees, communication disorders within the hive, predisposition to immune system impairment, decreased fertility and increased mortality (Maini et al., 2010; Uçkun, 2013).

It is known that butterfly species and ladybugs, which are necessary for pollination such as bees, are highly sensitive to these group insecticides. Neurotoxic symptoms were detected in 72% of the ladybug larvae (*Hippodamia undecimnotata)* found in the corn crops which medicated with neonicotinoid insecticides. In addition, it has been determined that neonicotinoid insecticides cause reproductive disorders, cytotoxic, genotoxic effects, growth and development problems and immun system disorders in fishes, non-target insects, amphibians and some sensitive bird species (Tegowska et al., 2004; Moser and Obrycki, 2009).

Lethal concentration (LC50) is the concentration of toxic substance required to kill 50% of test animal populations under controlled conditions. For many neonicotinoid insecticides, LC50 values were determined in different living organisms. The LC50 of thiacloprid to zebrafish *Danio rerio* was 19.7 mg/L after 96h. (Osterauer ve Köhler, 2008). According to a study conducted in 2004, the 96 hour LC50 value of imidacloprid, which is a neonicotinoid insecticide, on *Rana nigromaculata* was 129 mg/L and the 96 hour LC50 value on *Rana limnocharis* was 82 mg/L (Feng et al., 2004).

When the neonicotine group insecticides are applied to the seeds, they also kill the seed-consuming bird species. In particular, it has been observed that insectivorous birds are severely damaged and their mortality rate is increased by the use of this group of pesticides. At the same time it is estimated that the application of

neonicotinoid pesticides to soil can have negative impacts on earthworms (Seagraves and Lundgren, 2012). The use of three insecticides (clothianidin, imidacloprid and thiamethoxam) belonging to this group has been restricted on a continental basis as of 1 January 2013 (EFSA, 2013; Goulson, 2013).

Figure 3. Examples of non-target organisms in the world

4. Conclucions

Every organism in the ecosystem has an important role in ensuring ecological balance in the nature. The decline or increase in the number of any living organism in the ecosystem causes the degradation of this ecological balance. Pesticides can have serious

negative impacts on the environment. Neonicotinoid insecticides are increasingly used in agriculture and they are actively marketed worldwide for the last 30 years (Tomizawa and Casida, 2003).

It's estimated that neonicotinoid insecticides have significant toxic effects on many non-target beneficial organisms in the nature. Although neonicotinoids are frequently used, studies on the environmental effects of these pesticides are very limited. More ecotoxicological studies are needed to demonstrate the risks associated with the use of neonicotinoid insecticides.

Further investigations of the acute, chronic, genotoxic and carcinogenic effects of these insecticides are ecologically important. As well as the results of these studies use of pesticides should be restricted and controlled worldwide. This rewiev aimed to assess the adverse affects of neonicotinoid insecticides on non-target beneficial organisms and to raise awareness about unconsciously usage of these insecticides.

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