POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 39(2): 79–86, Y. 2024

DOI: 10.31648/pjns.9234

COMPARATIVE HYGIENIC ASSESSMENT OF THE BEHAVIOR AND RESISTANCE OF PESTICIDES IN THE SOILS OF SOUTH-EAST EUROPE WHEN USING FORMULATIONS WITH 3RIVE 3D TREATMENT TECHNOLOGY

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Key words: hazardous pesticides, maximum allowable level, contaminated food products, human health, half-life period.

Abstract

Undoubtedly, one of the important factors that allows to reduce the pesticide load on target and non-target objects is the method of chemical plant protection products (CPPPs) application. The 3RIVE 3D pesticide application system is an innovative technology for plant treatment that allows you to reduce the rate of pesticides used and increase their effectiveness.

After the application of Brigade 3Rive 3D, SC formulation using the innovative 3Rive3D technology (soil application with simultaneous sowing of corn seeds) found that on the day of treatment, the level of bifenthrin in the soil was <0.05 mg/kg. On the 3rd day after treatment, the amount of bifenthrin in the soil slightly increased and amounted to 0.083 **±0.015** mg/kg, on the 7th day the concentration of bifenthrin was 0.06 **±0.01, which, in turn, is less than the level of the** recommended maximum allowable level (0.1 mg/kg).

It was established that when applying the Brigade 3Rive 3D, SC formulation using 3Rive3D technology, the half-life of bifenthrin was 3.6 days, which is lower than the average values obtained in other countries of the European region.

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Introduction

Numerous scientific studies (Antonenko et al. 2023, Syafrudin et al. 2021, Lamichhane 2021, Tkachenko et al. 2020, Arias-Estévez et al. 2008) have shown that the long-term pesticides application leads to their accumulation in the soil, migration into groundwater and atmospheric air. Scientific studies in different countries confirm that the soil is an important link in the migration of pesticide compounds, and its degree of contamination with xenobiotics affects the food products safety. The amount and percentage of pesticides entering agricultural crops depends on the physical and chemical properties of the soil, agro-climatic conditions, the application method and the formulations' application rates.

Undoubtedly, one of the important factors that allows to reduce the pesticide load on target and non-target objects is the method of chemical plant protection products (CPPs) application (Melnichuk et al. 2022).

According to Directive 2009/127/EC 2009 the use of machines and technologies for applying pesticides is regulated. One of the main aspects considered in this directive is the risk assessment of the machinery use for the pesticides' application. To ensure the safety of people and the environment, additional requirements have been introduced for machinery used to apply pesticides. In particular, the minimization of losses on non-target areas and the provision of maximum pesticides sedimentation on target objects are regulated. These requirements contribute to reducing the pesticides application rates, increasing the efficiency of their use, and reducing the negative impact on the environment (Borysenko et al. 2023).

The aim is comparative hygienic assessment of the behavior and resistance of pesticides in the soils of south-east Europe when using formulations with 3RIVE 3D treatment technology.

Materials and Methods

The 3RIVE 3D pesticide application system is an innovative technology for plant treatment that allows you to reduce the rate of pesticides used and increase their effectiveness. 3RIVE 3D technology converts the traditional high-volume application technology into a low-volume one thanks to the patented technology (Borysenko et al. 2023). 3RIVE 3D is an innovative insecticide delivery platform developed by FMC and Micro-Trak Systems Inc.

An experimental applicator 3D RIVE RESEARCH MACHINERY (Micro-Trak Systems, Inc.) was mounted on the "Universal dotted seeder" planter of precision seeding UPS-4 with inter-sectional placement of wheels aggregated with a tractor. Cultivators treated the soil with simultaneous sowing of corn on an area of 1 ha. The formulation was used at an application rate of 1.2 l/ha. The rate of the working solution is 2.5–3.0 l/ha. The formulation is mixed with water and air to form a voluminous foam into which the seed is placed during sowing.

The study of the bifenthrin behavior was carried out using a specific hygienic method of a natural experiment, and the plant and soil sampling was carried out according to applied rules, starting from the first day of treatment, and subsequently at regular intervals during the crop vegetation period until harvesting. The last sampling was carried out at the harvest. In parallel, the selection of crops control samples, plants' green mass and soil was carried out in order to compare them with the results of the treated target objects.

Table 1 presents data on the conditions and place of the studied formulation application and its active ingredient using modern plant protection technologies.

The xenobiotic persistence index (XPI) was calculated according to the formula given in (Li 2022):

$$\mathrm{XPI} = \tau_{95} \cdot \ln \frac{\mathrm{P}_m}{\mathrm{MAL}}$$

where:
XPI – is the xenobiotic (pesticide) persistence index,
τ_{95} – pesticide half-life period (average or for specific conditions) [months];
MAL – maximum allowable level of pesticide in soil [mg/kg],
P_m – the maximum recommended dose of pesticide [kg of active substance/ha].

We used a scale of values for the XPI values evaluation, according to which the XPI is less than 5 – the level of soil pollution is assessed as safe, from 5–20 – moderately dangerous, 20–60 – dangerous, with values greater than 60 – very dangerous (Li 2022).

Table 1
Characterization of the soils of the regions, where agricultural land was treated with the use of innovative pesticide application technologies (PANAGOS et al. 2011)

Place of treatment	Province, climatic zone	Soil type
Kyiv region	Right Bank Province, forest steppe	chernozems are podzolized mainly on loess rocks
Zhytomyr region		meadow and chernozem-meadow soils + turf-medium and slightly podzolic sandy and loamy soils
Vinnytsia region		typical chernozems are moderately highly humus-accumulative
Kyiv region	Left Bank Lowland Province, forest steppe	dark gray podzolized, moderately weakly humus-accumulative + chernozems, moderately humus-accumulative, podzolized

Results and Discussion

Bifenthrin practically does not migrate along the profile, both in sandy and soils rich in organic compounds (RAMASUBRAMANIAN et al. 2021). The compound is relatively poorly soluble in water; therefore, the substance does not concentrate in aquifers. The half-life period in the soil ranges from 7 days to 8 months, depending on the type of soil (RAMASUBRAMANIAN et al. 2021).

Laboratory studies in the EU: τ_{50} range 54.2–173.7 days, τ_{90} range 223–577 days, field studies: τ_{50} range 5.4–267 days, τ_{90} range 135.3–965.2 days. Other studies: τ_{50} range from 65 to 125 days or range from 2 to 6 months depending on the type of soil (RAMASUBRAMANIAN et al. 2021).

We conducted field studies in different agro-climatic zones of south-east region of Europe with different types of soil, for a more detailed study of the behavior of the Brigade 3Rive 3D, SC active ingredients in environmental objects when it is applied using 3RIVE 3D technology.

The results of determining the level of residual amounts of the studied active substances are shown in Table 2.

Table 2

The content of bifenthrin in soil samples when using the Brigade 3Rive 3D, SC formulation

Standard, MAL	Content [mg/kg] in the soil in the treatment zone due to:			Re-entry intervals [days]	
	1 hour	3 days	7 days	mechanized works	manual works
0.1	<0.05	0.083 ±0.015	0.06 ±0.01	does not require	does not require

Explanations: MAL – maximum allowable level of pesticide in soil [mg/kg]

After the application of Brigade 3Rive 3D, SC formulation using the innovative 3Rive3D technology (soil application with simultaneous sowing of corn seeds) found that on the day of treatment, the level of bifenthrin in the soil was <0.05 mg/kg. On the 3rd day after treatment, the amount of bifenthrin in the soil slightly increased and amounted to 0.083 ±0.015 mg/kg, on the 7th day the concentration of bifenthrin was 0.06 ±0.01, which, in turn, is less than the level of the recommended MAL (0.1 mg/kg).

The obtained levels of the content of pesticide active ingredient residual quantities in the soil allowed us to calculate the destruction rate constants (k) and quantitative parameters of stability in environmental objects by the method of least squares: periods of decay for 50, 95 and 99% (τ_{50}, τ_{95} and τ_{99}) – Table 3.

Table 3

The bifenthrin degradation rate in soil (BORYSENKO et al. 2023)

Indices of degradation rate in soil [days]				
k^{-1}	τ_{50}	τ_{95}	τ_{99}	τ_{50}*
0.194 ±0.031	3.55 ±0.965	15.38 ±2.134	26.66 ±4.64	26.0–86.8

Explanations: k^{-1} – the destruction rate constant; τ_{50} – the period of 50% of the substance initial amount decomposition; τ_{95} – the period of 95% of the substance initial amount decomposition; τ_{99} – the period of 99% of the substance initial amount decomposition; * – according to the literature

When applying Brigade 3Rive 3D, SC formulation using 3Rive3D technology, the bifenthrin's τ_{50} was 3.6 days, τ_{95} – 15.4 days and τ_{99} – 26.7 days, the destruction rate constant was equal to 0.19, which is lower than the average values obtained in other countries of the European region. In our opinion, this is explained, first, by the feature of the 3Rive3D technology, which allows to reduce the pesticide consumption rate as much as possible and ensures its accurate introduction into the furrow simultaneously with the sowing of corn seeds. Also, climate and weather conditions, type of soils, their pH value, air humidity and temperature, intensity of ultraviolet radiation, and others are important.

According to State Standard (*Pesticides. Classification…* 8.8.1.002-98), by to the stability indices in the soil, bifenthrin can be classified as a low-hazard compound (hazard class 4).

The results of field studies using the innovative technology of pesticide application with 3Rive3D technology in the agro-climatic conditions of south-east Europe indicate its lower persistence under the conditions of these treatments compared to the values established in the soils of other countries.

We also calculated the Xenobiotic Persistence Index (XPI) in the soil, since the τ_{95} of bifenthrin applied by us in an innovative way differs from the values established in other countries. The calculation and evaluation of the xenobiotic persistence index in the soil will allow establishing the risk of cumulation and the degree of soil contamination with pesticides.

According to the results obtained during field studies when applying the Brigade 3Rive 3D, SC formulation in the innovative application technology (3Rive3D technology) in different soil and climatic conditions of south-east Europe, the average values of bifenthrin τ_{95} was (15.4 days) 0.51 months. Tentatively allowable concentration in soil of bifenthrin is 0.1 mg/kg. The maximum recommended consumption rate for the pesticide application recalculated for bifenthrin is 0.23 kg/ha. Hence,

$$\mathrm{XPI}_{\mathrm{bifentrin}} = 0.51 \cdot \ln\frac{0.23}{0.1} = 0.43.$$

The obtained XPI value of bifenthrin (0.43) made it possible to classify the studied active ingredient as a pesticide with a safe potential level of soil contamination (XPI <5) and characterizes it as a short-lived compound in the studied soil and climatic of conditions of south-east Europe when applying formulations based on it using 3Rive3D technology. The assessment of the XPI value in the soil allowed us to predict a relatively low expected level of accumulation and soil contamination with pesticides (BORYSENKO et al. 2022).

Conclusions

1. It was established that when applying the Brigade 3Rive 3D, SC formulation using 3Rive3D technology, the half-life of bifenthrin was 3.6 days, which is lower than the average values obtained in other countries of the European region. According to State Standard (*Pesticides. Classification…* 8.8.1.002-98), the compound can be pertained to the 4^{th} class of danger (low-dangerous compounds) based on stability indices in the soil.

2. The obtained value of the persistence index (XPI) of bifenthrin (0.43) made it possible to attribute the studied active ingredient to pesticides with a safe potential level of soil contamination and characterizes it as a short-lived compound in the studied conditions when applying formulations based on it using 3Rive3D technology.

Accepted for print 20.07.2024

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