NARDI FUNDULEA, ROMANIA
www.incda-fundulea.ro

ROMANIAN AGRICULTURAL RESEARCH, NO. 38, 2021
Print ISSN 1222–4227; Online ISSN 2067–5720

RESEARCHES CONCERNING THE EFFECTIVENESS OF THE MAIZE FOLIAR TREATMENT COMPARED WITH SEEDS TREATMENT FOR CHEMICAL CONTROL OF THE MAIZE LEAF WEEVIL (*Tanymecus dilaticollis* Gyll) IN THE SOUTH-EAST OF ROMANIA

Emil Georgescu[1*], Maria Toader[2], Lidia Cană[1], Daniela Horhocea[1], Traian Manole[3], Roxana Zaharia[3], Luxița Rîșnoveanu[4,5]

[1]National Agricultural Research and Development Institute Fundulea, 915200 Fundulea, Călăraşi County, Romania
[2]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Mărăşti Blvd, District 1, Bucharest, Romania
[3]Research and Development Institute for Plant Protection, 8 Ion Ionescu de la Brad Blvd., District 1, Bucharest, Romania
[4]Bucharest University Economic Studies, Faculty of Agri-food & Environmental Economics, 6 Romană Square, District 1, 010374 Bucharest, Romania
[5]Agricultural Research Development Station Brăila, Viziru km. 9 str., 818008 Brăila, Brăila County, Romania
[*]Corresponding author. E-mail: emilgeorgescu@ricic.ro

ABSTRACT

Maize leaf weevil [(*Tanymecus dilaticollis* (Gyllenhal, 1834)] represents one of the most dangerous pests of the maize crops in Romania. Each year, around one million hectares cultivated with maize are attacked by this pest with different levels of attack intensities. In the case of the high weevils invasion, the maize seedlings could not survive, and the farmers have to sow their fields again, causing unexpected costs. Spring drought and higher temperatures that usually occur in Romania's south-east is even more favorable circumstances for the weevils attack. Also, maize monoculture has an increasing effect on pest density associate with a higher impact on the attack. The maize seeds' chemical treatment with systemic insecticides was the most effective method to reduce the loss. However, the use of neonicotinoid insecticides for seed treatment was banned in the European Union in 2019. As a result, no effective insecticides are available for maize seed treatment against *T. dilaticollis* in Romania.

This study aimed to evaluate possible alternatives at seed treatment to control the maize leaf weevil. The experiences were carried out at the National Agricultural Research and Development Institute Fundulea, both under the field and greenhouse conditions, with artificial infestation, between 2015 and 2018. Maize foliar treatment with deltamethrin (100 g/l), thiacloprid (480 g/l), and maize seeds treatment with imidacloprid (600 g/l) active ingredients were assessed. In all years from this trial, in the field conditions studied foliar treatments haven't assign effective protection of the maize plants in early vegetation stages against maize weevil attack. In case of high pest attack in the absence of the seeds treatment, more than 90 % of the plants can be destroyed by the weevils. Until now, no alternatives are available to replace maize seed treatments with systemic insecticides.

Keywords: maize, weevil, control, treatment, effectiveness.

INTRODUCTION

Maize is one of the most important crops in Romania. Data from the Ministry of Agriculture and Rural Development make in evidence that in the last years, the area cultivated with maize in Romania ranged from 2402.1 to 2678.5 thousand hectares, which represents the highest area in the European Union. At the same time, in 2018, the average maize yield was 7644 kg/ha (MADR data, 2020).

According to Eurostat data, in 2018, Romania occupies first place in the European Union, with a maize grain production higher than 18.6 million tones (Eurostat database, 2019). Maize leaf weevil [(*Tanymecus dilaticollis* (Gyllenhal, 1834)] is the most dangerous pest in the early vegetation stages of the maize crop in Romania (Paulian et al.,

Received 24 November 2020; accepted 16 January 2021. First Online: January, 2021. DII 2067-5720 RAR 2021-77

1969; Paulian and Popov, 1974; Voinescu, 1985; Voinescu and Bărbulescu, 1998; Bărbulescu, 2001; Bărbulescu et al., 1993; 2001a; Bărbulescu, 1995; Vasilescu et al., 2005; Popov and Bărbulescu, 2007; Georgescu et al., 2014; Trotuș et al., 2011; 2018; Toader et al., 2020). According to Meiselle et al. (2010), maize leaf weevil is considered a regional pest in the European Union, been located mainly in the south-east of the continent. Bărbulescu et al. (2001b) mentioned that this pest has a restricted distribution in Romania and neighboring countries to the east, south and west.

Data from the Romanian literature make in evidence that favorable area for maize leaf weevil is located in the south, south-east and east of the country, less favorable areas are located in the western part of Romania while unfavorable areas are placed in the northern and central part of the country (Paulian, 1972; Bărbulescu, 1995; 2001; Popov, 2002; 2003; Popov et al., 2005; Cristea et al., 2004; Roșca and Istrate, 2009). However, Antonie et al. (2012) reported high weevils attack at maize crops in Sibiu County (south of Transylvania). Until now, this area was considered unfavorable for maize leaf weevil.

T. dilaticollis is a thermo-xerophilous specie, as results, the weevils are very active at high air temperatures and low air humidity recorded in the spring (Popov et al., 2006b). Same author mentioned that in the years with reduced rainfalls registered in early vegetation stages of the maize plants (BBCH 10-BBCH 14) the pest attack was high while in the years with higher rainfalls, the attack was reduced.

Maize leaf weevil is a polyphagous pest, with 34 host plants in Romania, exhibiting preferences for maize crop which provides optimal development for the larvae and is the most preferred food by the adults (Paulian, 1972; Bărbulescu and Voinescu, 1998). The same authors mentioned that adults exhibit preferences for sunflower, sorghum, wheat, barley, or soybean, but these plants don't provide optimal larva development conditions. At the same time, pea plants are repellent for adults and larva (Paulian et al., 1979). Recent researches concluded that organic volatile compounds released from maize and sunflower young plants attract *T. dilaticollis* weevils (Toshova et al., 2010). From the weed species, creeping thistle (*Cirsium arvense*) provide optimum conditions for larva development, also are consumed by the adults (Paulian, 1972; Boguleanu et al., 1980). Maize monoculture for several consecutive years contributes to the weevils reproduction and increasing of the pest populations in the following years (Voinescu and Bărbulescu, 1998; Bărbulescu et al., 2001b). However, crop rotation has a low impact in decreasing of the weevils populations, because insects can migrate from plots sowed, the previous years, with maize (Popov and Bărbulescu, 2007). As a result of increasing area cultivated with maize and sunflower in the favorable pest area from south and south-east of Romania, and decreasing the number of economically effective crops, farmers couldn't make a proper crop rotation (Dachim, 2016; Lup et al., 2017). These facts lead to increasing of the pest maize leaf weevil populations in the south and south-east of Romania in the last decade.

Damages are caused by weevils that feeding on maize leaves. In the case of high weevils attack, maize plants are destroyed, and farmers must sow again (Čamprag et al., 1969; Paulian, 1978; Bărbulescu et al., 2001b). The pest is dangerous when maize is in early vegetation stages, from plants emergence (BBCH 10) until four leaves stage (BBCH 14) (Roșca and Istrate, 2009). The same authors mentioned that after four leaves stage (BBCH 14), the attack is less economically important, the weevils consume only leaves margins and maize plants survive after the attack. In some extreme cases, the weevils attack can occur even before the emergence of the plants above the soil surface (Voinescu and Bărbulescu, 1998). Early data from the Romanian literature show that at a pest density between 25 and 30 weevils/m^2, maize yield losses can reach at 34% (Paulian, 1972). More recent data reveal that in the south-east of Romania, pest density ranged between 15 and 80 weevils/m^2 (Bărbulescu et al., 1994; 2001a; Bărbulescu, 1995; 1996; 1997; Popov et al., 2004). In some favorable years, there were extreme cases when it had recorded a pest density of 160 weevils/m^2, in the Dobrogea area (Voinescu, 1987 cited by Roşca and Istrate, 2009). After 2000, data from the literature show that every year more than one million hectares cultivated with maize, from south, south-east, south-west and east of Romania were attacked by this pest (Popov, 2002; Popov et al., 2004; 2005; 2006a; 2007a). Analyzing the data between 2011 and 2018 from 15 locations placed in east, south-east, south and south-west of Romania, Badiu et al. (2019) concluded that maize plant losses ranged from 25 to 50%. However, in this paper, the author refers only to density loss, not to maize yield losses because of the weevils attack. In a research made in Ialomiţa county, in the south-east of Romania, in a commercial farm, located in a favorable area of *T. dilaticollis* it has recorded high pest density (25-30 weevils/m^2) and high pest attack at maize crop, in the spring of 2018 (Georgescu et al., 2018). The same authors mentioned that the weevils destroyed untreated maize plants. Toader et al. (2020) reported a pest density between 6.4 and 10.9 weevils/m^2, in Călăraşi County, between 2016 and 2018.

A few decades ago, the main control method of maize leaf weevil was using of the organo-chlorine insecticides applied as a dust (Paulian et al., 1969; Paulian, 1972; 1978). However, as a result of the excessive and irrational use of the treatments with this type of insecticides the impact on the environment was high, resulting in pollution and the destruction of beneficial fauna (Popov and Bărbulescu, 2007). At ICCPT Fundulea (actual NARDI Fundulea) it has made researches concerning effectiveness of the chemical control of the maize leaf weevil, using different applying methods such as seeds treatment, foliar application of the insecticides when maize plants are in early vegetation stages or granules application at sowing or after plants emergence (Paulian, 1981; Voinescu, 1985; Bărbulescu et al., 1982; 2001b; Bărbulescu, 1995; 1996; Popov, 2002; Popov et al., 2007b; Vasilescu et al., 2005; Georgescu et al., 2014). Results of the researches demonstrate that seeds treatment with systemic insecticides with a high solubility degree and rapid translocation of the active ingredient to the young plants was the most efficacy method to protect maize in early vegetation stages (BBCH 10-BBCH 14) against *T. dilaticollis* weevils attack. At the end of the years ´80, maize seed treatment with carbofuran active ingredient was generalized (Bărbulescu et al., 1989). As result of the high toxicity of the carbofuran for humans, animals, or birds, this active ingredient was forbidden in Romania in 2008 and was replaced with neonicotinoids. Seeds treatment with imidacloprid, clothianidin or thiamethoxam active ingredients for protection of the maize plants, in early vegetation stages against soil pests, including *T. dilaticollis*, was generalized in Romania in the last 15 years. The effectiveness of these active ingredients was similar to carbofuran while toxicity for humans and the environment was lower (Bărbulescu et al., 2001b; Vasilescu et al., 2005; Popov et al., 2007b; Trotuş et al., 2011; 2018).

As a result of the European Commission regulations 218/783, 218/784, and 218/785, the use of the imidacloprid, clothianidin and thiamethoxam active ingredients will be totally banned in the European Union, starting from 2019 (Official Journal of the European Union, 2018a; 2018b; 2018c). After these regulations, in Romania, no active ingredients will remain available for maize seed treatment to control *T. dilaticollis* attack. This study aims to evaluate possible control alternatives of maize leaf weevil to replace seed treatments with banned neonicotinoid active ingredients, in climatic conditions from the south-east of Romania.

MATERIAL AND METHODS

The field trials were carried out at the National Agricultural Research and Development Institute (NARDI) Fundulea, Călăraşi County, Romania (latitude: 44°46’ N; longitude: 26°32’ E; alt.: 68 m a.s.l.), between 2015 and 2018. The experiments were carried out according to the standards of the European and Mediterranean Plant Protection Organization (2012a, 2012b, 2014) methods for the data analysis, efficiency evaluation trials, and phytotoxicity. The average temperatures and the rainfalls amount were daily recorded, at automatic Pessl weather station, located at 100 m from the field trial.

Table 1. Active ingredients used for controlling the maize leaf weevil (*T. dilaticollis*) in the field trial

Variant no.	Active ingredient	Rate	Rate type	Type of application	Time of application
1	—	—	—	—	—
2	imidacloprid (600 g/l)	2.20	µL/grain	seeds treatment	Before sowing (BBCH 00)
3	thiacloprid (480 g/l)	90.00	mL/ha	foliar treatment	After plants emergence (BBCH 11-12)
4	deltamethrin (100 g/l)	75.00	mL/ha	foliar treatment	After plants emergence (BBCH 11-12)

Field trial. The maize experiment was arranged according to the randomized blocks scheme; each variant has four replications. The size of the experimental plot was 42 m^2 (10x4.2 m). The time of the maize sowing, the plants emergence, and BBCH 14 stage is presented bellow:

- in 2015 maize plants were sowed on 28 April, full plants emergence was recorded on 8 May while BBCH 14 stage was recorded on 18 May;
- in 2016 maize plants were sowed on 14 May, full plants emergence was recorded on 23 May while BBCH 14 stage was recorded on 31 May;
- in 2017 maize plants were sowed on 18 May, full plants emergence was recorded on 24 May while BBCH 14 stage was recorded on 31 May;
- in 2018 maize plants were sowed on 7 May, full plants emergence was recorded on 16 May while BBCH 14 stage was recorded on 25 May. In all four years of the field trial, it has used Olt maize hybrid (FAO 450-500), with a vegetation period of 135-138 days. The field trial was carried out in the plots cropped successively over the last years with maize, thus favoring a high pest biological reserve. To avoid migration of the weevils from one plot to another, the plots were laterally isolated with a 2 m wide strip sowed with pea, a plant repellent to this insect (Paulian, 1972; Paulian et al., 1979). Distance between maize rows was 70 cm, while the distance between plants on a row was lower than normal (35 cm). The low density of the maize plants used in this experiment has a purpose for favoring the weevils movement.

Active ingredients used in the field trial were mentioned in Table 1. It has tested two active ingredients with a different mode of actions, used for foliar treatments, when maize plants were in BBCH 11-12 stages, and a seed treatment variant, with imidacloprid active ingredient, as a standard. Evaluation of the effectiveness of the active ingredients was assessed after a methodology elaborated at NARDI Fundulea, by Paulian (1972) and improved by Bărbulescu (1995; 1996; 2001).

Attack intensity of the weevils at the maize crop was assessed when the plants were in four leaves stage (BBCH 14), according to a scale from 1 to 9, as follows:

- **note 1**: plant not attacked;
- **note 2**: plant with 2-3 simple bites on the leaf edge;
- **note 3**: plants with bites or clips on all four leaves edge;
- **note 4**: plants with leaves chafed in the proportion of 25%;
- **note 5**: plants with leaves chafed in the proportion of 50%;
- **note 6**: plants with leaves chafed in the proportion of 75%;
- **note 7**: plants with leaves chafed almost at the level of the stem;
- **note 8**: plants with leaves completely chafed and beginning of the stem destroyed;
- **note 9**: plants destroyed, with stem chafed close to the soil level.

At each experimental plot, it has assessed 20 maize plants, from four central rows (5 plants/row). Before the assessment, plants were marked with sticks in the stair system. At the same time, it has rated attack incidence (the number of attacked plants from the total number of analyzed plants per plot).

After 30 days from the plants emergence, it has assessed the percentage of the plants that escaping from the weevils attack (**saved plants percent**) by counting all the emerged plants from a plot and comparing them with the number of the sowing seeds per plot.

Greenhouse trial. The researches were carried out in a greenhouse from National Agricultural Research Development Institute (NARDI), Fundulea. Evaluation of the effectiveness of the treatments in greenhouse trial was assessed after a methodology elaborated at NARDI Fundulea, by Paulian (1972) and improved by Bărbulescu et al. (2001b). Maize was sowed in plastic pots (12x12x10 cm). Before sowing, the pots were filing ¾ with soil, harvested from the areas without any kind of chemical treatments. In each pot, it has sowed five maize seeds.

Table 2. Active ingredients used for controlling the maize leaf weevil (*T. dilaticollis*) in the greenhouse trial

Variant no.	Active ingredient	Rate	Rate type	Type of application	Time of application
1	—	—	—	—	—
2	imidacloprid (600 g/l)	2.20	µL/grain	seed treatment	Before sowing (BBCH 00)
3	thiacloprid (480 g/l)	90.00	mL/ha	foliar treatment	After plants emergence (BBCH 11) and immediately after infestation
4	deltamethrin (100 g/l)	75.00	mL/ha	foliar treatment	After plants emergence (BBCH 11) and immediately after infestation
5	thiacloprid (480 g/l)	90.00	mL/ha	foliar treatment	After plants emergence (BBCH 11) and at 24 hours after infestation
6	deltamethrin (100 g/l)	75.00	mL/ha	foliar treatment	After plants emergence (BBCH 11) and at 24 hours after infestation

For this experiment, it has used the Olt maize hybrid. After the maize's sowing, the plastic pots were complete filled with soil, then the soil surface from each pot was slightly compressed and soaking with water to ensure the uniform emergence of the plants. One variant has four replications; each pot represents one replication. For the greenhouse trial, the weevils were collected from the field at the end of April and beginning of May. The weevils collected from the field were maintained inactive in the laboratory, for a few days, at 15±2°C air temperature and 80-85% air relative humidity. Insects used in the greenhouse trial were collected from the fields without any kind of chemical treatment, located at the Centre for Organic Farming from NARDI Fundulea. After the plants emergence, the weevils collected from the field and maintained inactive at lower temperatures in the laboratory, for a few days, were added in the plastic pots. The weevils must be manipulated carefully, not to hurt them. In each pot, it has added 20 insects to have a pest density of 4 insects per plant to ensure higher pest pressure. Immediately, after the weevils were added, the pots were covered with isolators. The purpose of the high pest pressure used in this experiment is to simulate the situations that occurred in the field, in case of both, high weevils population and attack intensity.

Active ingredients used in the greenhouse trial were the same as in the field trial. It has tested deltamethrin and thiacloprid active ingredients applied as a foliar spray after the maize plants emerged. At variants 3 and 4, the two active ingredients were applied immediately after the adding of the weevils in the pots, while in case of the variants 5 and 6, the two active ingredients were applied at 24 hours after adding the weevils in the pots (Table 2). The effectiveness of the foliar treatments, in the greenhouse conditions were compared with seed treatment with imidacloprid active ingredient as a standard.

The evaluation of the weevils **attack intensity** at maize plants in the greenhouse trial are similar with assessments made in the field, using a scale from 1 (plants not attacked) to 9 (plants destroyed).

The **weevils mortality** was checked daily until maize plants from the pots arrive in four leaves stage (BBCH 14). After each assessment, dead insects from all pots were removed. Results of these assessments were evaluated as average mortality percent (%).

Statistical analysis. The results of the field and greenhouse trials were presented as the mean values for weevils attack intensity, saved plants percent, weevils mortality, the standard deviation from the average values (SD) and the coefficient of variation (CV). Data were statistically analyzed using the Student-Newman-Keuls test (Student, 1927; Neuman, 1939; Keuls, 1952).

RESULTS AND DISCUSSION

During the field trials, it has monitoring weather conditions from the experimental field located at NARDI Fundulea, in the south-east of Romania. Temperatures and rainfalls occurred in period when maize plants are in early vegetation stages (BBCH 10-BBCH 14) influenced weevils activity on the ground and attack intensity at maize plants.

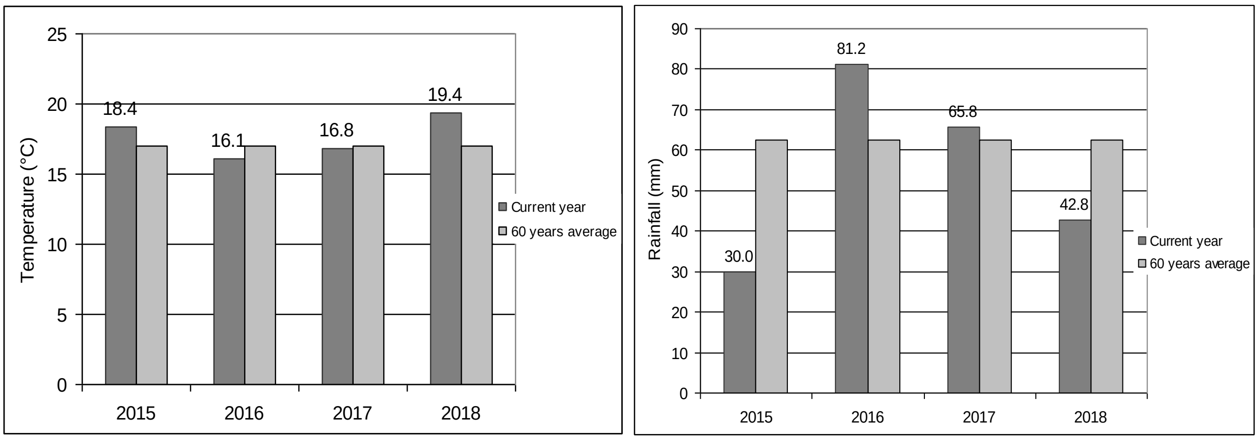

Figure 1. Average temperature and rainfall amount registered at NARDI Fundulea field trial, in May, between 2015 and 2018

The average temperature registered in May was higher than the multiyear average in 2015 and 2018, with a positive deviation of 1.4°C in 2015 and 2.4°C in 2018. In May 2016, the negative deviation of the average temperature from the multiyear average was 0.9°C, while in 2017, the average temperature was slightly lower than normal, with a negative deviation of 0.2°C. At the same time, the rainfalls amount registered in May was lower than the multiyear average in 2015 and 2018 with a negative deviation of 32.5 mm and 19.7 mm, while rainfalls from May 2016 was higher then multiyear average, with a positive deviation of 18.7 mm. Only in May, 2017, the level of the rainfalls was close to normal, only with a slight positive deviation of 3.3 mm (Figure 1). Analyzing the average values of the temperatures and rainfalls recorded in May, when maize plants from this trial were in early vegetation stages (BBCH 10-BBCH 14); it concluded that in 2015 and 2018 it was favorable weather conditions for weevils attack while less favorable weather conditions was in the spring of 2016 and 2017. According to Roșca and Istrate (2009), the maize leaf weevil is very active if the temperature recorded on the ground level is higher than 18°C and daily air temperature is higher than 20°C. At the same time, Popov et al. (2006b) refer to high weevils activity in case of lack of rainfalls. Contrarily, if the temperatures are lower and rainfalls amount are higher, the weevils activity on the ground is lower, as a result, the attack at maize is lower, and plants can survive the attack.

Analyzing the daily temperatures and rainfalls, recorded between maize plants emergence and four leaves stages it has ascertained that in 2015, the maximum temperature was higher than 20°C in all days. At the same time, the total rainfalls amount recorded was only 2.5 mm, from witch 2.4 mm was recorded on 18 May, when maize plants arrive in BBCH 14 stage. In May 2016, in the first four days after the plant's emergence, air temperature decreased. It has registered rainfalls each day, with a total amount of 13.7 mm. In the following days, until maize arrives at the BBCH 14 stages, weather conditions were favorable for the weevils attack. However, because of the rainfalls recorded after the emergence, maize plants have a good start and development. The situation from May 2017 was quite similar to those from the previous year. In the first four days after plants emergence, it has registered rainfalls each day, with a total amount of 30.2 mm, while temperatures decreasing. In the next three days, until plants arrive at BBCH 14 stage, air temperature increasing, and maximum temperature during the day was higher than 25°C without rainfalls. In the last year of the field trial, at first 24 hours after plants emergence, the temperatures decreasing and it has registered 12.6 mm of rain. Over two days it has recorded only 0.6 of rain, while on 25 May it has recorded 3.2 mm of rain. Three days after plants emergence, the temperatures increasing gradually. However, even if the temperatures were lower in the first days after plants emergence, the daily maximum temperature was higher then 20°C in all period between plants emergence and BBCH 14 stage (Figure 2). Analyzing the daily meteorological data recorded in early vegetation stages of the maize plants, that represent the most sensitive period of this crop to weevils attack it can be concluded that the most favorable conditions for weevils attack and less favorable conditions for maize plants were recorded in May 2015, followed by May 2018. On the opposite side, in May 2017 it has registered the most favorable conditions for maize plants development in the early vegetation stages and less favorable conditions for weevils activity on the ground, as a result weevils attack at maize plants, was lower.

In the field trial, in spring of 2015, the attack intensity of the weevils at maize untreated plants, on a scale from 1 to 9, was almost maximum (8.72).

At the same time, weevils attack intensity at variants with foliar treatment with thiacloprid and deltamethrin active ingredients were 8.33 and 8.15. In this case, the majority of the plants from these experimental plots were destroyed; saved plants percent was 5.00% in case of control variant and between 8.89 and 9.31% in case of variants with foliar treatment, without seed treatment. In the case of the variant with treated seeds, weevils attack intensity was 4.56, and the percentage of the escaped plants was higher than 65%. According to the Student-Newman-Keuls (SNK) test, in the field trial from NARDI Fundulea, in weather conditions of the spring of the year 2015, there weren’t significant statistical differences between weevils attack intensity at maize plants from untreated variant and attack intensity from variants with foliar treatments, without seed treatment (Table 3). Only in the case of seed treatment with imidacloprid active ingredients it has registered significant statistical differences compared with both untreated and foliar treatment variants. The situation was similar in the case of the percentage of the saved plants.

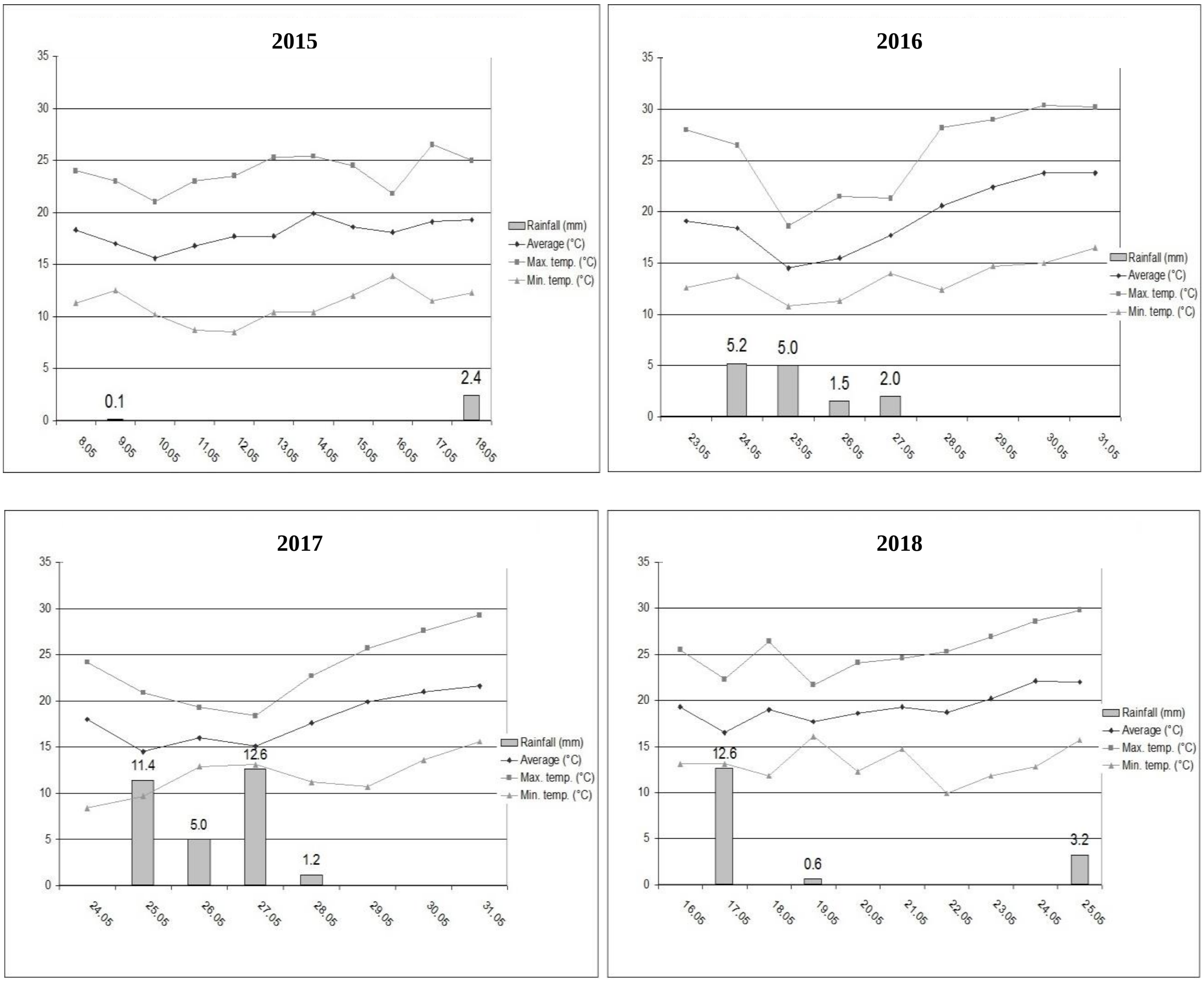

Figure 2. Daily temperature and rainfalls recorded between maize plants emergence (BBCH 10) and four leaves stage (BBCH 14) at NARDI Fundulea field trial, between 2015 and 2018

Table 3. Effectiveness of some active ingredients against maize leaf weevil (*T. dilaticollis*) in the field trial

Variant no.	Active ingredient	Attack intensity (1-9)				Saved plants (%)			
		2015	2016	2017	2018	2015	2016	2017	2018
1	—	8.72a	5.85a	5.65a	4.25a	5.00b	68.06a	80.28b	84.08a
2	imidacloprid (600 g/l)	4.56b	3.95b	3.63b	3.45b	65.69a	77.50a	86.25a	90.18a
3	thiacloprid (480 g/l)	8.33a	5.76a	5.43a	4.18a	8.89b	69.03a	80.69b	85.99a
4	deltamethrin (100 g/l)	8.15a	5.20a	5.17a	4.04a	9.31b	75.42a	81.67b	86.79a
LSD P=0.05		1.496	0.582	0.416	0.434	12.934	11.091	3.640	6.036
Standard deviation (SD)		0.045	0.364	0.260	0.271	8.086	6.934	2.276	3.774
Variation coefficient (C.V.)		4.960	7.010	5.240	6.810	36.390	9.560	2.770	4.350

Means followed by the same letter do not significantly differ (P=0.05, Student-Newman-Keuls test).

The higher intensity of the weevils attacks recorded in the spring of 2015 resulted from the favorable weather conditions for weevils feeding activity on the ground, such as daily maximum air temperature higher than 20°C and drought. The situation from spring of 2015 was similar to those reported by Bărbulescu et al. (2001b) and Popov et al. (2006b). In the next two years, the spring conditions, when maize plants were in early vegetation stages (BBCH 10-BBCH 14), were quite similar. Attack intensity of the weevils at maize untreated plants was 5.85 in 2016 and 5.65 in 2007. In these cases, most of the maize untreated plants have leaves chaffed in the proportion of 50-75%, and some plants were almost destroyed as a result of the weevils attack. Both in 2016 and 2017, the weevils attack intensity recorded at variants with foliar treatment was close to untreated variant while attack intensity recorded at variants with treated seeds was lowest. According to the Student-Newman-Keuls (SNK) test, in the field trial from NARDI Fundulea, in weather conditions of the spring of the years 2016 and 2017, there weren't significant statistical differences between weevils attack intensity at untreated variant and attack intensity at variants with foliar treatment. Significant statistical differences compared with untreated variant were recorded in the case of treated seeds variant. A similar situation was recorded in the case of saved plants percent in the spring of 2017. However, in the case of saved plants percent recorded in the spring of 2016, there weren't recorded significant statistical differences between experimental variants. A possible explication for higher percentage of the escaped plants in the spring of 2017 compared with the spring of 2016, in the conditions of the similar weevils attack intensity, is higher rainfalls amount occurred in the first four days after plants emergence in 2017 (30.2 mm). In the spring of 2018, at the control variant, the weevils attack intensity was lower than in previous years. Most of the maize untreated plants have leaves chaffed in the proportion of 25-50%, and some plants have leaves chaffed in a proportion of 75-100%. As a result of the lower weevils attack intensity, most of the plants survive the attack.

The situation recorded in the spring of 2018 was in opposition to the situation from spring of 2015 when most of the untreated plants were destroyed. According to the Student-Newman-Keuls (SNK) test, in the field trial from NARDI Fundulea, in the spring of 2018, there weren't recorded significant statistical differences between weevils attack intensity at untreated variant and attack intensity at variants with foliar treatment. Significant statistical differences compared with untreated variant were recorded in the case of treated seeds variant. However, in the case of saved plants percent, there weren't significant statistical differences between experimental variants. As a result of the lower weevils attack, in the case of treated seeds, the percentage of the escaped plants was higher than 90%. Possible explication for lower weevils attack intensity in spring of the 2018 has rainfalls occurred in the first 24 hours after plants emergence. Analyzing the weather data during this field trial it has observed that between 2016 and 2018, the total rainfalls amount recorded in the first four days after maize emergence ranged from 13.2 to 30.2 mm, while in a similar period from 2015, the total rainfall amount recorded in the first four days after maize emergence was only 0.1 mm. Paulian (1972) mentioned that in case of higher rainfalls amount recorded in the first days after the emergence, maize plants have higher recovery capacity after the weevils attack.

In all years from this study, weevils attack incidence was 100 % at all experimental variants. At the same time, there weren't recorded any phytotoxic effects as a result of the maize seeds treatment or foliar spraying.

Table 4. Effectiveness of some active ingredients against maize leaf weevil (*T. dilaticollis*) in the greenhouse trial

Variant no.	Active ingredient	Weevils mortality (%)	Attack intensity (1-9)
1	—	1.25c	8.65a
2	imidacloprid (600 g/l)	65.00a	4.73d
3	*thiacloprid (480 g/l)	50.00b	6.45c
4	*deltamethrin (100 g/l)	57.50ab	4.75d
5	**thiacloprid (480 g/l)	7.50c	7.40b
6	**deltamethrin (100 g/l)	11.25c	6.68c
LSD P=0.05		9.983	0.643
Standard deviation (SD)		6.625	0.427
Variation coefficient (C.V.)		20.650	6.630

Means followed by the same letter do not significantly differ (P=0.05, Student-Newman-Keuls test).
*Foliar spraying immediately after pots infestation; **Foliar spraying immediately at 24 hours after pots infestation

Data from Table 4 demonstrate that in greenhouse trial, in conditions of high pest pressure (4 weevils/plant) the mortality of the insects was higher in the case of the variant with seeds treated with imidacloprid active ingredient, a systemic insecticide with rapid translocation in the plant tissues. Higher weevils mortality it has recorded in case of foliar spraying with both deltamethrin and thiacloprid active ingredients, immediately after the insects were added to the pots. However, if the foliar spray were made at 24 hours after the insects were added in the pots, weevils mortality was lower, at the same statistical level with the untreated variant. This is a more realistic scenario and could explain the lowest effectiveness of the maize foliar treatments in field conditions, when not all weevils are on the ground or the maize plants during the spraying time. Data from this experiment show that in greenhouse conditions, the weevils attack intensity was almost maximum (8.65) and quite similar to the attack intensity recorded in the field trial in the spring of the year 2015. As a result of high weevils attack, all untreated plants from the pots were destroyed by the weevils. The lowest attack intensity was recorded in case of the variant with treated seeds and variant with plants sprayed with deltamethrin immediately after the insects were added to the pots. In case of treatment with deltamethrin active ingredient, at 24 hours after the insects were added in the pots, the attack intensity was higher.

The treatment with thiacloprid active ingredient, immediately after the insects were added in the pots, have the consequence in a lower attack intensity compared with untreated variant but higher attack intensity compared with variants with seeds treatment or deltamethrin spray, immediately after the insects were added to the pots.

The results from the field and greenhouse trials make in evidence that single foliar treatment of the maize plants, without seed treatment wasn't effective for controlling the maize leaf weevil attack. According to Bărbulescu et al. (2001b) for *T. dilaticollis* control is needed for a high soluble insecticide with a rapid translocation of the active ingredient in the young plants so that the lethal dose for the weevils occurs at the time of the attack. These requirements were achieved in the case of the maize seeds treatment with systemic insecticides such as imidacloprid active ingredient. On the other hand, deltamethrin active ingredient can kill the insects through direct contact or feeding. Deltamethrin has rapid action on the target insects by disrupting their nervous system activity (Mesters and Mesters, 1992). This fact can be a possible explication for higher efficacy of this active ingredient in the greenhouse trial, in case of spraying immediately after the insects were added in the pots and lower efficacy in the field trial. Even if the thiacloprid active ingredient belongs to the same chemical class as imidacloprid, however, foliar spray with thiacloprid is less effective in protecting the maize plants against weevils attack. A possible explication for this is due to the different chemical structures of the two active ingredients. It's likely to be differences in a mode of action and effects on chewing pests (Matsuda et al., 2001; Thany et al., 2007).

Further studies are necessary to elucidate all these aspects.

CONCLUSIONS

Weather conditions during early vegetation stages of the maize crop (BBCH 10-BBCH 14) were the most favorable for *T. dilaticolis* attack in the spring of the year 2015 and less favorable in the spring of the year 2017.

In the field trial, high weevils attack intensity at maize plants it has recorded in the spring of 2015, while in the spring of 2016, 2017, and 2018 the attack intensity was lower.

In 2015, almost all untreated plants from the field trial were destroyed as a result of the high weevils attack intensity. A similar situation was in the case of the greenhouse trial, in conditions of high pest pressure.

Both in the field and greenhouse trials, seeds treatment with imidacloprid active ingredient has high efficacy in protecting of the maize young plants against weevils attack.

In the absence of the seeds treatment, foliar spraying with deltamethrin and thiacloprid, active ingredients didn't protect maize young plants against weevils attack.

ACKNOWLEDGEMENTS

This research work was carried out with the support of National Agricultural Research and Development Institute, Fundulea, Plants and Environment Collective.

REFERENCES

Antonie, I., Stanciu, M., Sand, C., Blaj, R., 2012. *The researches regarding the biodiversity of the entomologic of the corn cultures in the Sibiu County*. Scientific Papers, Series Management, Economy. Engineering in Agriculture and Rural Development, 12(1): 5-10.

Badiu, A.F., Iamandei, M., Trotuș, E., Georgescu, E.I.V., 2019. *Study concerning Tanymecus sp. populations behavior in some locations from Romania in period 2010-2018*. Acta Agricola Romanica, 1(1): 108-136.

Bărbulescu, A., Baniță, E., Brudea, V., Ciurdărescu, G., Csep, N., Enică, D., Ignătescu, I., Iliescu, H., Mateiaș, M., Munteanu, I., Mustea, D., Nagy, E., Paulian, F., Petcu, L., Peteanu, S., Popov, C., Romașcanu, O., Roșca, I., Sandru, I., Săpunaru, T., Stoica, V., Tușa, C., Voicu, M., Voinescu, I., 1982. *25 years of research on protection of cereal and industrial crops against diseases and pests*. Problems of Plant Protection, 10(4): 230-255.

Bărbulescu, A., Voinescu, I., Gheorghe, M., Mateiaș, M.C., Bratu, R., Bucureanu, E., Săpunaru, T., 1989. *Seed chemical treatment, important tools for fight against some pests of the field crops*. Annals of NARDI Fundulea, 57: 367-376.

Bărbulescu, A., Popov, C., Voinescu, I., Mateiaș, M.C., 1993. *The impact of chemical control of pests and diseases in cereals and some industrial and forage plants, on the environment*. Problems of Plant Protection, 21(1): 67-98.

Bărbulescu, A., Mustea, D., Săpunaru, T., Sendru, T., Burdea, T., Emilia, B., Ignătescu, I., Mateiaș, M.C., Popov, C., Roșca, I., Elena, B., Csep, N., Goga, N., Valeria, I., Dana, M., Felicia, M., Elena, N., Lucica, P., Emilia, P., Marta, R., Stoica, V., Elena, T., Angela, U., Florina, V., Voicu, M., Voinescu, I., Emilia, L., Laura, M., Maria, O., 1994. *Results obtained in 1993 in the research on diseases and pests of cereals and some industrial and forage crops*. Problems of Plant Protection, 22(2): 143-216.

Bărbulescu, A., 1995. *Results obtained in 1994 in the research on diseases and pests of cereals and some industrial and forage crops*. Problems of Plant Protection, 23(2): 125-170.

Bărbulescu, A., 1996. *Results obtained in 1995 in the research on diseases and pests of cereals and some industrial and forage crops*. Problems of Plant Protection, 24(2): 87-142.

Bărbulescu, A., 1997. *Results obtained in 1996 in the research on diseases and pests of cereals and some industrial and forage crops*. Problems of Plant Protection, 25(2): 99-164.

Bărbulescu, A., and Voinescu, I., 1998. *Influence of the crop rotation on the evolution of Tanymecus dilaticollis*. Annals of NARDI Fundulea, 65: 321-326.

Bărbulescu, A., 2001. *Results obtained in 2000, regarding the diseases and pests of cereals and some industrial and forage crops*. Problems of Plant Protection, 29(2): 123-178.

Bărbulescu, A., Popov, C., Mateiaș, M.C., Voinescu, I., Guran, M., Raranciuc, S., Spiridon, C., Vasilescu, S., Vâlsan, D., 2001a. *Evolution of some diseases and pests of grains, industrial and forage crops in our country during 2000*. Problems of Plant Protection, 29(1): 1-16.

Bărbulescu, A., Voinescu, I., Sadagorschi, D., Penescu A., Popov, C., Vasilescu, S., 2001b. *Cruieser 350 FS-A new product for maize and sunflower seed treatment against Tanymecus dilaticollis Gyll*. Romanian Agricultural Research, 15: 77-87.

Boguleanu, G., Bobîrnac, B., Costescu, C., Duvlea, I., Filipescu, C., Pașol, P., Peiu, M., Perju, T., 1980. *Agricultural Entomology*. Didactic and Pedagogic Publishing house, Bucharest: 184-186.

Čamprag, D., Jasnic, S., Sekulik, R., Matic, R., 1969. *Harmfulness and control of Tanymecus dilaticollis Gyll. in corn*. Contemporary Agriculture, 17(5/6): 261-268.

Cristea, M., Căbulea, I., Sarca, T., 2004. *Maize - Monographic study*. Romanian Academy Publishing House, Chapter 1: 589-626.

Dachin, A., 2016. *Structure of production costs for field crops in Romania - a regional analysis*. Competitiveness of Agro-Food and Environmental Economy: 101-109.

Georgescu, E., Cană, L., Popov, C., Gărgăriță, R., Râșnoveanu, L., Voinea, L., 2014. *Maize leaf weevil (Tanymecus dilaticollis Gyll) in the context of neonicotinoid seed treatment restriction*. Annals of NARDI Fundulea, 82: 251-277.

Georgescu, E., Crețu, A., Zob, C., Cană, L., 2018. *Preliminary results concerning maize leaf weevil (Tanymecus dilaticollis Gyll) control, in commercial farm conditions, from south-east of the Romania*. Scientific Papers, Series Agronomy, 61(1): 221-226.

Keuls, M., 1952. *The use of the "studentized range" in connection with an analysis of variance*. Euphytica, (1): 112-122.

Lup, A., Miron, L., Alim, I.D., 2017. *Studies and strategies regarding the evolution of crop yields per unit of land area in Romania, studies*. Scientific Papers, Series Management, Economic Engineering in Agriculture and Rural Development, 17(2): 227-233.

Matsuda, K., Buckingham, S.D., Kleier, D., Rauh, J.J., Grauso, M., Sattelle, D.B., 2001. *Neonicotinoids: insecticides acting on insect nicotinic acetylcholine receptors*. Trends in Pharmacological Sciences, 22(11): 573-580.

Meissle, M., Mouron, P., Musa, T., Bigler, F., Pons, X., Vasileiadis, V.P., Otto, S., Antichi, D., Kiss, J., Pálinkás, Z., Dorner, Z., Van Der Weide, R., Groten, J., Czembor, E., Adamczyk, J., Thibord, J.B., Melander, B., Cordsen Nielsen, G., Poulsen, R.T., Zimmermann, O., Verschwele, A., Oldenburg, E., 2010. *Pests, pesticide use and alternative options in European maize production: current status and future prospects*. Journal of Applied Entomology, 134(5): 357-375.

Mestres, R., and Mestres, G., 1992. *Deltamethrin: uses and environmental safety*. Reviews of environmental contamination and toxicology, Springer, New York: 1-18.

Newman, D., 1939. *The distribution of range in samples from a normal population, expressed in terms of an independent estimate of standard deviation*. Biometrika, 31(1): 20-30.

Paulian, F., Popov, C., Marcela, D.P., 1969. *The corn leaf weevil (Tanymecus dillaticolis Gyll.) in Romania and its control*. Contemporary Agriculture, 5-6: 643-652.

Paulian, F., 1972. *Contribution at knowledge of the development, ecology and control of the Tanymecus dilaticollis specie*. Doctoral thesis, IANB Bucharest, chapter IV: 49-57; 193-200; 209-225.

Paulian, F., and Popov, C., 1974. *Observation on some anomalies of the female genitalia in Tanymecus dilaticollis Gyll (Coleoptera - Curculionidae)*. Problems of Plant Protection, 2(1): 208-224.

Paulian, F., 1978. *Maize pests and their control*. Academy of Agricultural Sciences, Agricultural Library, Bucharest: 1-32.

Paulian, F., Popov, C., Grigorescu, R., 1979. *The role of the feeding regime in the life of Tanymecus dilaticollis Gyll. adults (Curculionidae: Coleoptera)*. Problems of Plant Protection, 7(4): 363-374.

Paulian, F., 1981. *Insecticides and other granules pesticides*. Ceres Publishing House, Bucharest, chapter 4: 92-137; chapter 5: 151-154.

Popov, C., 2002. *Researches concerning the protection of the cereals, leguminous for grains, technical and forage plants against pathogen agents and pests, year 2001*. Problems of Plant Protection, 30(2): 109-190.

Popov, C., 2003. *Researches regarding the protection of cereals, leguminous for grains, industrial and fodder crops to pathogens and pests performed in year 2002*. Problems of Plant Protection, 31(2): 7-84.

Popov, C., Guran, M., Raranciuc, S., Rotărescu, M., Spiridon, C., Vasilescu, S., Gogu, F., 2004. *Phytosanitary state of cereals, leguminous for grain, industrial and fodder crops in Romania in 2003*. Problems of Plant Protection, 32(1): 1-23.

Popov, C., Guran, M., Raranciuc, S., Rotărescu, M., Spiridon, C., Vasilescu, S., Gogu, F., 2005. *Phytosanitary state of the cereals, leguminous for grains, forage and technical crops from Romania, year 2004*. Problems of Plant Protection, 34(1-2): 15-37.

Popov, C., Guran, M., Raranciuc, S., Rotărescu, M., Spiridon, C., Vasilescu, S., Gogu, F., 2006a. *Phytosanitary state of the cereals, leguminous for grains, forage and technical crops from Romania, year 2005*. Problems of Plant Protection, 33(1-2): 7-30.

Popov, C., Trotuș, E., Vasilescu, S., Bărbulescu, A., Rîșnoveanu, L., 2006b. *Drought effect on pest attack in field crops*. Romanian Agricultural Research, 23: 43-52.

Popov, C., Raranciuc, S., Spiridon, C., Vasilescu, S., Cană, L., 2007a. *Phytosanitary state of the cereals, leguminous for grains, forage and technical crops from Romania, year 2006*. Problems of Plant Protection, 35(1): 1-24.

Popov, C., Bărbulescu, A., Raranciuc, S., 2007b. *Seed treatment a modern, efficient and less pollutant method for field crops protection*. Annals of NARDI Fundulea, 74: 133-139.

Popov, C., and Bărbulescu, A., 2007. *50 years of scientific activity in field protection domain against diseases and pests*. Annals of NARDI Fundulea, 75: 371-404.

Roșca, I., and Istrate, R., 2009. *Entomology (Agriculture, Horticulture, Forest)*. Alpha Mdn Publishing House, Bucharest: 119-124.

Thany, S.H., Lenaers, G., Raymond-Delpech, V., Sattelle, D.B., Lapied, B., 2007. *Exploring the pharmacological properties of insect nicotinic acetylcholine receptors*. Trends in Pharmacological Sciences, 28(1): 14-22.

Toader, M., Georgescu, E., Ionescu, A.M., Șonea, C., 2020. *Test of some insecticides for Tanymecus dilaticollis Gyll. control, in organic agriculture conditions*. Romanian Biotechnological Letters, 25(6): 2070-2078.

Toshova, T.B., Velchev, D.I., Subchev, M.A., Toth, M., Vuts, J., Pickett, J.A., Dewhirst, S.A., 2010. *Electrophysiological responses and field attraction of the greycorn weevil, Tanymecus (Episomecus) dilaticollis Gyllenhal (Coleoptera: Curculionidae) to synthetic plant volatiles*. Chemoecology, 20(3): 199-206.

Trotuș, E., Buburuz A.A., Zaharia, P., 2011. *Researches on the protection of maize crops* *against soil pests*. Agronomical Researches in Moldavia, 4: 45-51.

Trotuș, E., Mincea, C., Dudoiu, R., Pintilie, P.L., Georgescu, E.I., 2018. *The preliminary results regarding the impact of the neonicotinoids insecticides, applied at rape, sunflower and maize seed treatment, on the harmful entomofauna and honey bees*. Annals of NARDI Fundulea, 87: 251-260.

Student, 1927. *Errors of Routine Analysis*. Biometrika, 19(1/2): 151-164.

Vasilescu, V.S., Popov, C., Stoica, V., Negrilă, M., Procopovici, E., 2005. *Results regarding control of maize leaf weevil (Tanymecus dilaticollis Gyll) by chemical seed treatment during 2000-2004*. Scientific Papers, USAMV Bucharest, 48: 343-350.

Voinescu, I., 1985. *Maize seed treatment with carbamic insecticides, effective method for controlling of the weevil T. dilaticollis Gyll*. Problems of Plant Protection, 13(2): 151-156.

Voinescu I., and Bărbulescu, A., 1998. *Evolution of maize leaf weevil (Tanymecus dilaticollis Gyll.) in various crops depending on the preceding crop*. Proceedings of International Symposium on Integrated Protection of Filed Crops, Vrnjaka Banja: 157-164.

*** Eurostat Statistics Explained, 2019. https://ec.europa.eu/eurostat/statistics-explained/index.php/Agricultural_production_-_crops (accessed on 16.11.2020).

*** EPPO Standards, 2012a. *Design and analysis of efficacy evaluation trials, PP 1/152(4)*. European and Mediterranean Plant Protection Organization, 44: 367-381.

*** EPPO Standards, 2012b. *Conduct and reporting of efficacy evaluation trials including good experimental practice, PP 1/181(4)*. European and Mediterranean Plant Protection Organization, 44: 382-393.

*** EPPO Standards, 2014. *Phytotoxicity assessment, PP 1/135(4)*. European and Mediterranean Plant Protection Organization, 44: 265-273.

*** MADR data, 2020. https://www.madr.ro/culturi-de-camp/cereale/porumb.html (accessed on 18.11.2020).

*** Official Journal of the European Union, 2018a. Commission implementing regulation (EU) 2018/783 of 29 May 2018 amending Implementing Regulation (EU) No 540/2011 as regards the conditions of approval of the active substance imidacloprid. 61(L132): 31-34, ISSN 1977-0677.

*** Official Journal of the European Union, 2018b. Commission implementing regulation (EU) 2018/784 of 29 May 2018 amending Implementing Regulation (EU) No 540/2011 as regards the conditions of approval of the active substance clothianidin. 61(L132): 35-39, ISSN 1977-0677.

*** Official Journal of the European Union, 2018c. Commission implementing regulation (EU) 2018/785 of 29 May 2018 amending Implementing Regulation (EU) No 540/2011 as regards the conditions of approval of the active substance thiamethoxam. 61(L132): 40-44, ISSN 1977-0677.