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INFLUENCE OF DIFFERENT TILLAGE SYSTEMS ON ABUNDANCE AND DYNAMICS OF PESTS IN MAIZE CROP

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ABSTRACT

The abundance and dynamics of pests in maize crop are influenced by the tillage system. The research has been done at Research and Development Station for Agriculture Turda (RDSA Turda) in order to estimation the insect populations in conventional tillage (plowing) and minimum tillage system (with chisel variant). The research consisted of observations and determinations on the monitoring, abundance and dynamics of the most common species pests of maize crop: *Diabrotica virgifera virgifera* LeConte, *Autographa gamma* L. and *Agrotis segetum* Den. & Schiff. The pests monitoring, with economically importance for maize crop was evaluated using F-1 pheromone traps, with synthetic sex pheromones (atraGAM- 9, atraSEG-21 and atraVIRG). By minimizing the tillage, there has been an increase in the pest population, especially in *Diabrotica virgifera virgifera* LeConte. An almost perfect synchronization of the first generation with the optimal threshold of specific temperatures for insect biology was observed in the three monitored species. This meens even if, these mechanisms were formed over the course of evolution exist a permanent adaptations of insects to climate changes.

Keywords: pests, maize, tillage systems, pheromones, abundance and dynamics.

INTRODUCTION

Air pollution, avoiding soil compaction, conserving soil water reserves and reducing farm inputs are just some of the factors that have contributed to new studies regarding maize crop technology (Jat et al., 2011). Stopping soil degradation through erosion processes due to leaching phenomena requires a reconsideration of soil tillage systems on sloping lands (Holland, 2004; Kraut-Cohen et al., 2020).

Research on the effect of conservation tillage on corn pests began in the 1970's (Hammond and Stinner, 1987). Stinner and House (1990) point out that in a 45 scientific papers review, 28% of the pest species increased with minimum tillage, 29% were not significantly influenced by the tillage system and 43% decreased with minimum tillage.

Minimum tillage systems reduce soils erosion, dredging, carbon sequestration (Anonymous, 2001; Palm et al., 2014) and, indirectly, water contamination (Andersen, 1999). Even if the conservative tillage systems are very advantageous, tillage intensity influences pests that are more problematic in this case (Jasrotia et al., 2021). The availability of vegetation and plant residues in these systems favors increases in the populations of some pest species (Rowen et al., 2020). Different studies shows a higher pests abundance in minimum tillage than conventional tillage (Hammond and Stinner, 1987; Ivaş et al., 2013; Şimon et al., 2015).

The effects of tillage may play an important role in the management of pest species (Hammond and Funderburk, 2022). Conventional tillage has a big influence both in reducing biodiversity of soil species and in increasing levels of aerobic microorganisms (Schmidt et al., 2018; Sun et al., 2018; Xin et al., 2018). Pest pressure can be reduced by

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several cultural control options such as: crop rotation against the western corn rootworm (*Diabrotica virgifera virgifera*) (Florian et al., 2011) or the use of ploughing wich reduces populations of cutworms (*Agrotis* spp.) (Joshi et al., 2020).

Choosing the optimal moment and measures to prevent and combat pests requires knowing their population levels. Pest populations can be estimated by monitoring adults (Dent and Binks, 2020), particularly for the western corn rootworm (Meissle et al., 2010).

Pheromones are useful for detection and monitoring of pest populations but also for interruption of their mating. Pheromones studies have a great importance because of their role as mediators of insect reproduction (Islam, 2012). According to Tewari et al. (2014), the integrated pest management (IPM) uses pheromones for monitoring (Hong et al., 2021) and suppressing the population. Interruption of mating (Meissle et al., 2010), attracting and mass capture of pests are some of the most common direct control tactics that depend on the use of pheromones. The use of pheromones is a species-specific, non-toxic and ecological method of controlling insects (Vaijayanti et al., 2007).

Elimination of active males can significantly reduce pest populations (El-Sayed et al., 2006; Mfuti et al., 2016), being one of the methods of maintaining the natural balance of contemporary agrocenoses which need protection (Ivaş and Mureşanu, 2013). Malschi (2007, 2008), as well as other authors cited by Malschi et al. (2015), emphasis the importance of monitoring pest populations, in order to be able to recommend chemical treatments at warning (Nealis et al., 2010) and to be able to predict the evolution of some pests.

Both the use of pheromone traps in the natural habitat of the species and the recording of the number of catches in correlation with the evolution of climatic factors allowed to establish the trajectory of flight curves, which by their shape, number and timing of catches, lead to the appreciation of the ecological zone of Turda, where such studies have been carried out (Mureşanu et al., 1996; Roşca and Mureşanu, 1999; Mureşanu and Oprean, 2000).

In the idea that conservation soil tillage systems are expanding, being widely practiced at RDSA Turda, we tried to quantify the species of insects that have a high frequency of trapping of sex pheromone traps in the corn crop, in two tillage systems: the classical tillage system (plowing) and the minimum tillage system (chisel) (Badji et al., 2007; Şimon et al., 2015; Kraut-Cohen et al., 2020; Furlan et al., 2021). The differentiated approach of the two tillage systems was made in order to be able to appreciate the numerical evolution of the pests in the event of the existence of some population differences that would require the imposition of additional treatments in the unconventional systems.

MATERIAL AND METHODS

The research was carried out in Turda, in the period 2012-2017 and consisted of observations and determinations on the monitoring, abundance and dynamics of the most common species pests of maize crop.

Ghizdavu and Roşca (1986) pointed out the importance of evaluation of insect populations required the use of F-1 pheromone traps. In our study Romanian synthetic sex pheromones from the “Raluca Ripan” Chemical Research Institute Cluj-Napoca: atraGAM- 9, atraSEG-21 and atraVIRG were experimented.

The atraGAM pheromone bait for *Autographa gamma* L. contains Z7-dodecen-1-yl acetate; E7-dodecen-1-yl acetate.

The pheromone bait atraSEG for *Agrotis segetum* Den. & Schiff. contains Z5-decen-1-yl acetate; Z7-dodecen-1-yl acetate; Z9-dodecen-1-yl acetate; E5-dodecen-1-yl acetate; docec-1-yl acetate; Z- and E-decen-1-yl acetate; Z8-dodecen-1-yl acetate (sex attractant).

The pheromone bait atraVIRG for *Diabrotica virgifera virgifera* LeConte contains 1,7-dimethyl-nonan-1-yl (racemic) propanoate.

The traps with synthetic sex pheromones were placed, in 3 replications, at a distance of 50 m from each other, between May and September both in the classical agriculture system and in those with minimum soil tillage. Traps were fixed at heights of between 1.2 and 1.5 m. Pheromone variants were replaced every four weeks and the adhesive plate every two weeks. The number of males trapped was recorded weekly (Ivaş, 2018).

Following determination were made:

- the coefficient of variation of each insect species with the help of the relation:

$$CV (s\%) = s / x * 100$$

where:

s - the flight of insects;

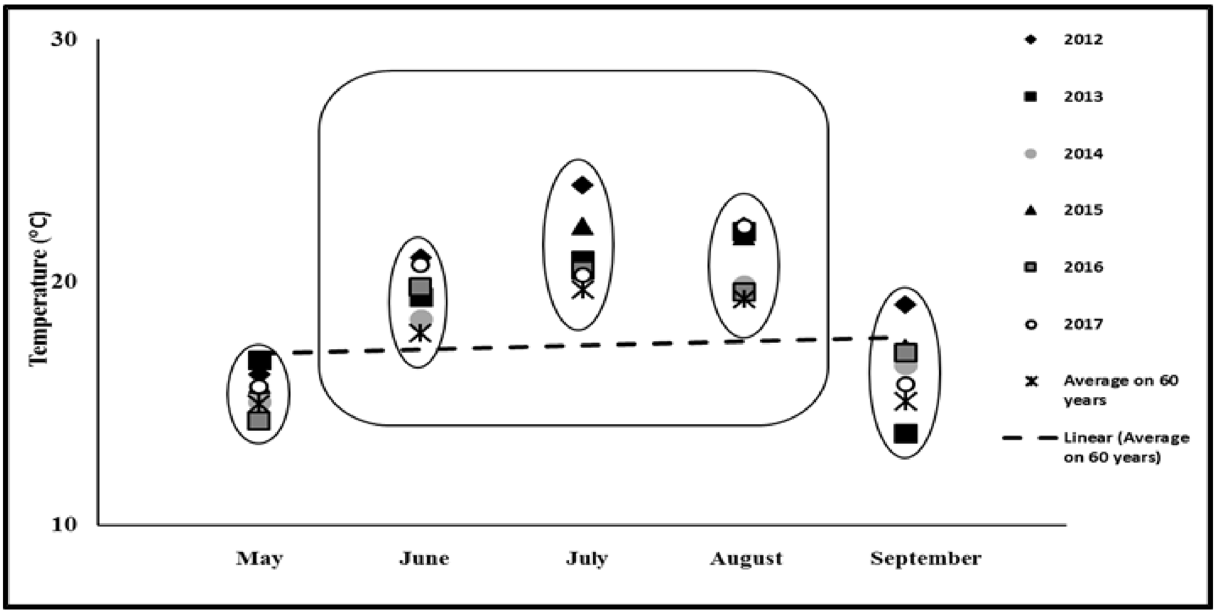
x - specific annual average capture.

- the characteristic of the flight according to the values of the coefficient of variability in:
  - high, CV≥20%;
  - medium, CV≥10%;
  - small, CV≤10%.

RESULTS AND DISCUSSION

The zonal climate is under the local influence of the slopes and exhibitions that lead to the appearance of microclimates. In general, the zonal climate is a typical continental boreal climate, the rainfall during the year having a single maximum at the beginning of summer, the winters being quite harsh and the summers hot.

The warmest year was considered 2014, with an average annual temperature of 11.1°C, with a positive deviation of 2.1°C compared to the multi-year average. The warmest month was July 2012, with an average air temperature of 24°C. The increase in average annual temperatures, especially during the months of June, July and August, favored an increase in the density of pest populations (Figure 1).

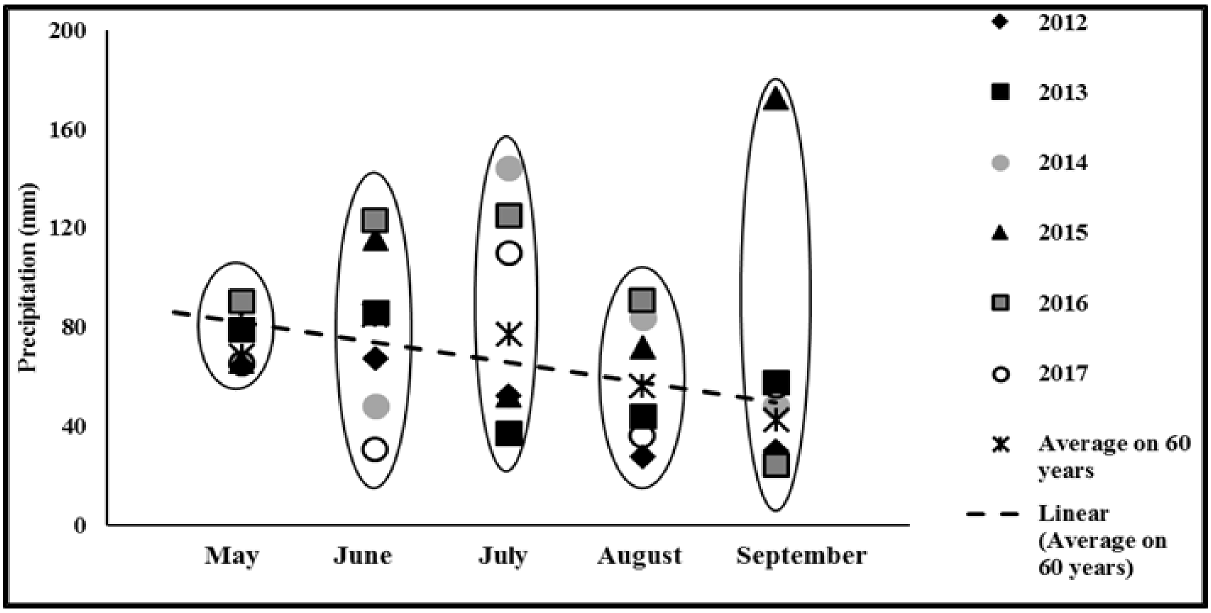


Source of primary data: Turda meteorological station (longitude: 23°4´; latitude: 46°35´; altitude: 427 m).

Figure 1. Monthly mean air temperature of each experimental year compared to the 60-year average (2012-2017)

Against the background of the increase of the average temperatures, there is also a change of the rainfall. Although the amount of annual rainfall has not decreased much, the distribution of rainfall has become much less predictable, with increasing periods of prolonged drought, alternating with torrential rains.

The analysis of the rainfall regime (Figure 2) shows much higher oscillations compared to temperatures.



Source of primary data: Turda meteorological station (longitude: 23°4´; latitude: 46°35´; altitude: 427 m).

Figure 2. Monthly rainfall of each experimental year compared to the 60-year average (2012-2017)

In the climatic conditions of 2012-2017, for the three monitored species, a major increase in the number of adults captured in the minimum tillage system (chisel) can be observed compared to the classical system (plowing). Similar results were reported by Şimon et al. (2015) in a 3 year experiment. Also, highest density of japanese beetle populations, *Popillia japonica* Newman, in reduced-tillage systems was pointed out by Hammond and Stinner (1987). As it is known, the plowing from autumn destroys some of the pests in the soil (eggs, larvae, adults) (Meissle et al., 2010) and also the vegetal remains are incorporated in the soil where they are subjected to the processes of humification, respectively, mineralization (Gill and Garg, 2014; Kraut-Cohen et al., 2020). We therefore suggest that in the case of reduced minimum tillage, more attention be paid to insect monitoring and treatment when the economic damage threshold is exceeded.

Thus, considering the period May-September, in which the species were monitored, the catch values were lower in 2016 compared to the other five years (2012, 2013, 2014, 2015 and 2017), in both tillage systems, probably due to the large amounts of rainfall that fell this year (Figure 3). Unconventional tillage systems have a positive role in the formation and development of insect populations, this is illustrated in Figure 3, the average of the three species monitored in the system with minimum soil preparation being significantly higher (384 adults) than in the classical system (285 adults).

The abundance of *Diabrotica v. virgifera* LeConte reaches higher thresholds than the other two pests monitored, in almost all the six years analysed and in both soil tillage systems for maize cultivation.

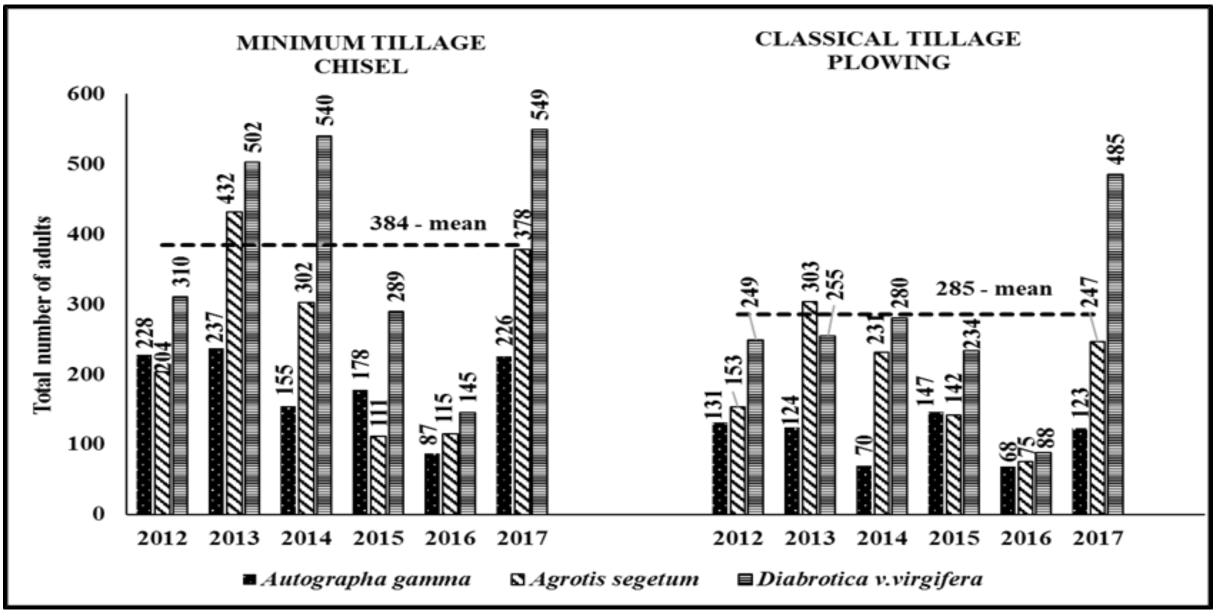


Figure 3. The abundance of pest species at maize crop, recorded at sexual pheromone traps, Turda 2012-2017

In the following we will present aspects of the flight dynamics performed by the three species, these registering the highest frequencies of occurrence in the traps with synthetic sex pheromones.

Due to the migratory nature of the Lepidoptera *A. gamma* L. it is very difficult to address the problem of forecasting actions by monitoring this species. This is illustrated in Figure 4 and reflects the large fluctuation in the number of adults captured, both from year to year and from one system to another. All this has been confirmed by Coroiu (1988), who shows that variations in the number of adults of this migratory species make it difficult to accurately highlight the number of generations and males captured.

In both systems and in all the analysed years, Silver Y appears in the traps with sex pheromones since May (Suciu et al., 2014), practically, it can be said that immediately after the emergence of the plants (Figure 4). The two generations of the noctuid evolve differently from one year to another (Roşca et al., 1990), the first maximum flight being recorded in June (2014, 2015, 2016) and July (2012, 2013 and 2017), at temperatures between 17.2-20.0°C in June, and between 20.1-22.2°C in July, respectively.

The second flight took place in July (2015 and 2016) and August (2012, 2013, 2014 and 2017). The flight dynamics performed by Silver Y highlights the existence of a third generation (partial), but with a much smaller number of males captured, in 2013, 2015, 2016 and 2017, in both soil tillage systems.

It is noteworthy that, only in 2016 and 2017, the number of males in the second generation is lower than in the first generation. This fact is confirmed by the studies conducted by Perju et al. (1998) in Satu-Mare over a period of five years, in which the authors observed situations when the level of populations in the first generation was higher than in the second generation.

Significant fluctuations in the number of individuals captured are not associated with significant captures. These observations are confirmed in other studies such as those conducted by Peiu and Popescu (1987).

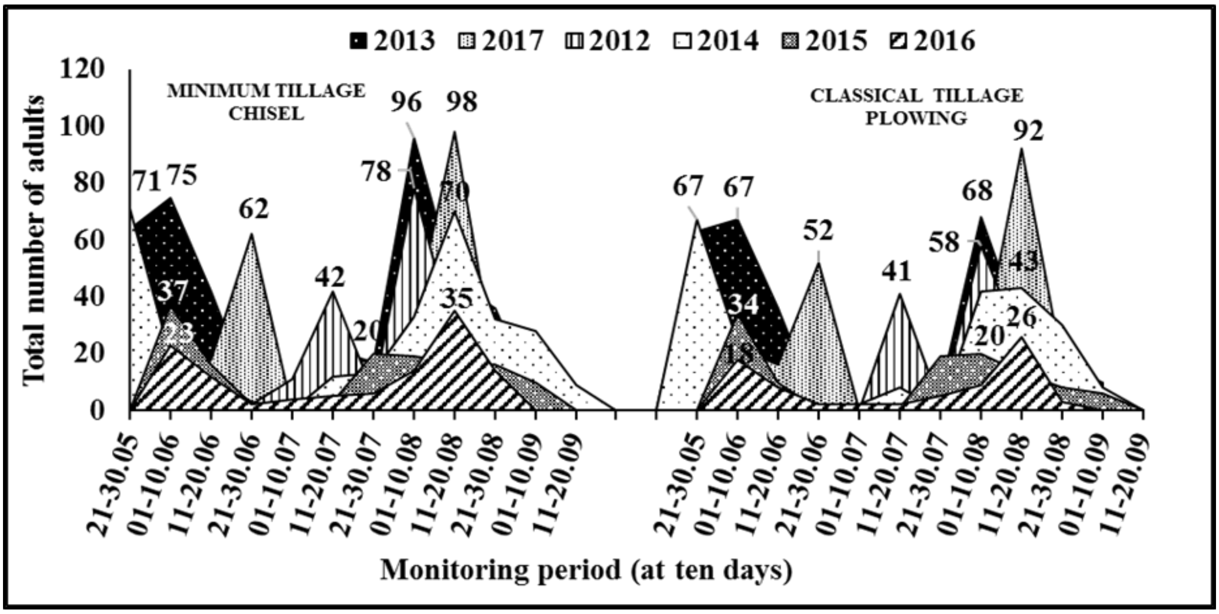


Figure 4. The dynamics of males *Autographa gamma* L. flights in maize crop, in two soil tillage systems, depending on climatic conditions, Turda 2012-2017

According to most authors cited by Perju et al. (1998) it is considered that in *A. segetum* there is a certain character of migration or, better said, of expansion. This species, it seems, has two maximum flights, which are quite close in number of individuals, and the periods in which the first maximum flight is signalled fluctuate in close connection with temperatures; it is recorded at the end of May (2014), in the first decade of June (2013, 2015 and 2016), the second decade of June (2012) and the third decade of June (2017). Studies conducted in China over a period of 11 years (2003-2013) reported, in addition to the annual fluctuations in the number of adults of *A. segetum* and a considerable variation in May-September (Guo et al., 2015), which was also observed in our study.

From Figure 5, it can be seen that in 2014 and 2015 the first maximum flight is higher than the second maximum flight, the differences being small, especially in 2014 by only one individual. Our studies are also confirmed by a study conducted in Hungary over a period of 20 years, which showed that in this species the dominance of the second flight is a well-established feature, only in one year the first flight was more numerous, this being associated with climatic factors, the experiences taking place in the colder areas of the country (Meszaros et al., 1979). Another study conducted in Denmark showed that in the last decade, the second generation of the pest was higher than the first generation (Esbjerg and Sigsgaard, 2014).

The western corn rootworm, first reported in Romania in the western part of Romania in 1996, at Turda in 2002 (Mureşanu and Popov, 2005), has expanded rapidly, which can be seen in the large number of adults reported in our study. The maximum flight is recorded at the end of July - beginning of August (Figure 6). Similar results were obtained in Serbia (Tanasković et al., 2017), in 2015, when the maximum flight of this species took place in early August. The only exception is 2014, which was the warmest year of the five analysed, when the maximum flight was recorded in early September.

Of the six years studied, 2014 was considered the warmest, with more than 2°C compared to the multiannual average, and in second place in terms of rainfall, led to a delay in the maximum flight towards the beginning of September. Even against the background of slight increases in average annual temperatures in recent years, the species retains its monovoltine character. The recent increase in the number of adults should raise the alert level so that warnings are optimal so that treatments can be carried out in a timely manner.

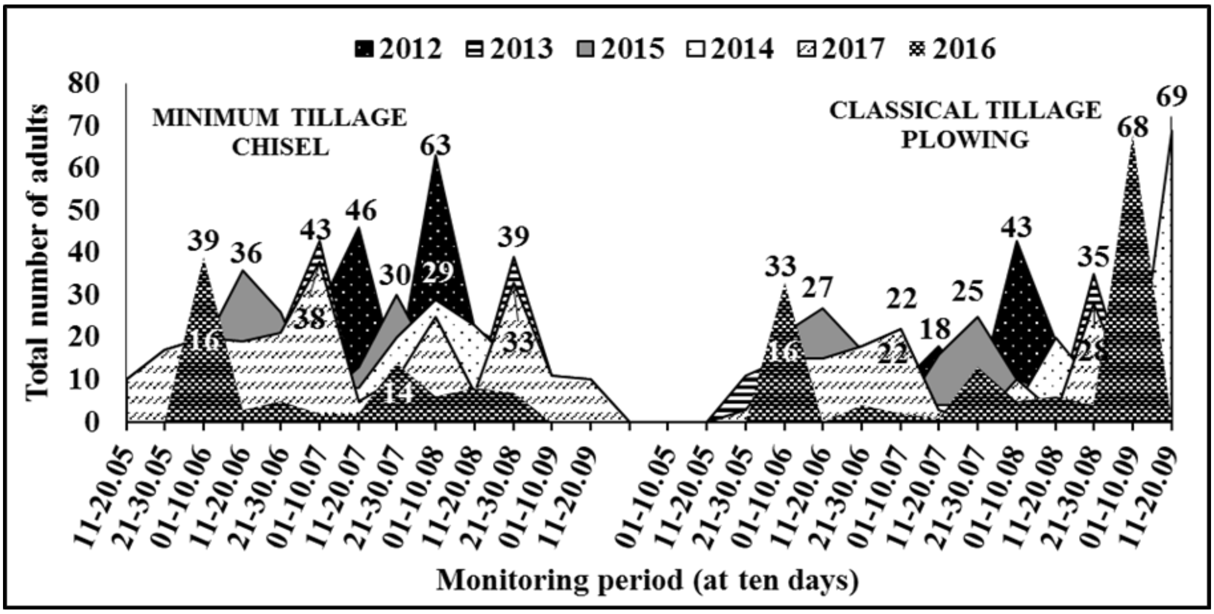


Figure 5. The dynamics of males *Agrotis segetum* Den.& Schiff. flights in maize crop, in two soil tillage systems, depending on climatic conditions, Turda 2012-2017

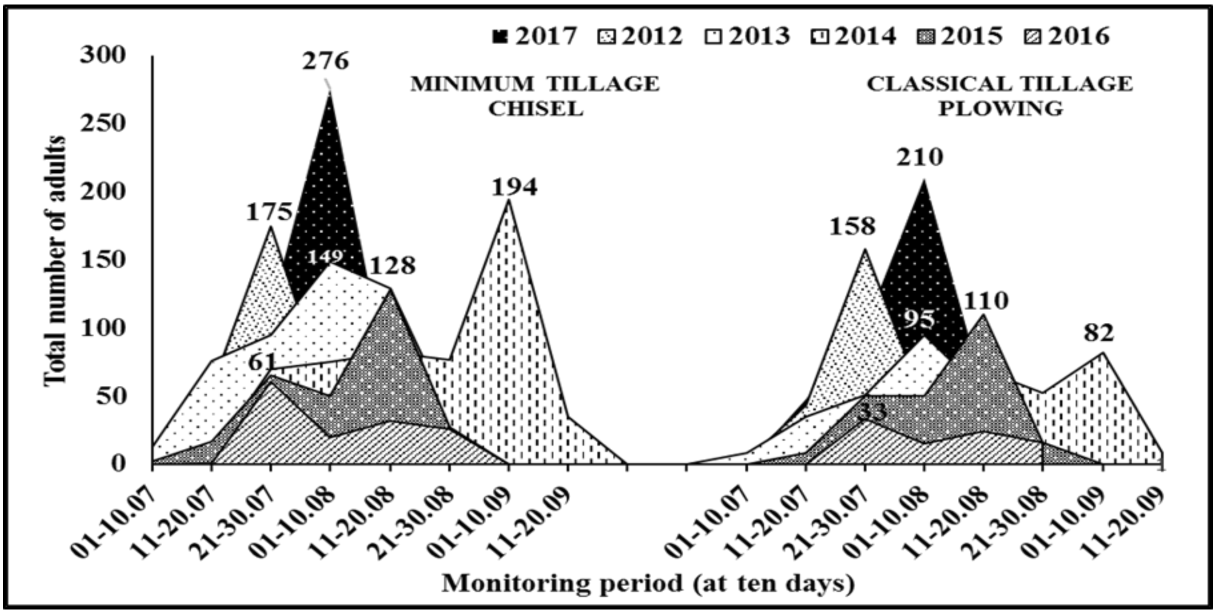


Figure 6. The dynamics of males *Diabrotica v. virgifera* LeConte flights in maize crop, in two soil tillage systems, depending on climatic conditions, Turda 2012-2017

In the three monitored species, an almost perfect synchronization of the first generation with the optimal threshold of temperatures specific to insect biology can be observed. These mechanisms have evolved over time and have required permanent insect adaptations to climate change.

Comparing the values of the *A. gamma* L. variation it can be seen from Table 1 that there are no big differences between the systems, except for 2015 when it reaches the threshold of 54% in the classic system and in the minimum tillage system, the coefficient of variability is only 39%. Although the values of the coefficient of variation show that this year the highest number of adults captured would be in the classical system, in fact, the highest number of adults is reached in the conservation system. A similar situation can be reported for 2016.

In fact, a major shortcoming of the variation coefficient is that it does not accurately reflect the small differences between populations. This is also confirmed by Ngeve and Bouwkamp (1993) who, in a study on the stability of yields at sweet potatoes, concluded that high averages lead to lower coefficients of variation and low averages to high coefficients of variation. Consequently, the following must be emphasized: the values of the coefficients of variation of the number of adults captured must be considered only by means of another flight parameter, namely abundance, which, in fact, is also included in the formula for calculating the coefficient of variability.

The abundance of adults is much higher in the system with minimal soil tillage compared to the classic system, even if the average values of the coefficient of variation regarding the flight of adults in the two soil tillage systems are practically equal. All this supports the previous statements (Table 1).

It seems that rainfall plays a very important role in reducing the number of adults. Thus, in the wettest years, out of the five analyzed, 2014, 2015 and 2016, there were higher negative differences in the coefficient of variation compared to the average. The increase in precipitation in 2016 led to a rather significant reduction, this being reflected, both in the abundance of the species and in the values of the coefficient of variation, which records the lowest values (Table 1).

Table 1. The variability coefficient of the species *Autographa gamma* L., in two soil tillage systems, Turda 2012-2017

Year	Abundance [a]		CV (s%) [b]		Diff. CV [c]		Average annual (T°C)	Annual rainfall (mm)	Flight	
	P	C	P	C	P	C			P	C
2012	131	228	48	50	7	9	10,4	504,4	H	H
2013	124	237	46	52	5	11	10,4	523,2	H	H
2014	70	155	26	34	**-15**	**-7**	11,1	741,5	H	H
2015	147	178	54	39	13	**-2**	10,6	641,2	H	H
2016	68	87	25	19	**-16**	**-22**	10,0	816,8	H	M
2017	123	226	45	50	5	9	10,5	532,3	H	H
Mean	**111**	**169**	**41**	**41**	-	-	-	-	-	-

[a] Total number of captured adults; [b] Coefficient of variability; [c] The difference from the mean; P - Plowing, C - Chisel, I - High flight, CV≥20%, M - Medium flight, CV≥10%.

And in the case of *A. segetum*, the abundance and values of coefficients of variation reach the highest thresholds in minimum tillage systems. Even if the average values of the coefficients of variation for the two systems are equal, the differences between the adults captured number are obvious.

It seems that even in the case of sowing, the significant rainfall of 2016, considered the rainiest year in the last 59 years, significantly reduces the abundance of this species, especially in the classic system, where the lowest number of captured adults (75 adults), from the six years analyzed was observed (Table 2).

The flight dynamics of this noctuid, reflected in the values of the coefficients of variation and the number of males captured in the traps with synthetic sex pheromones, is negatively affected by the association of lower annual average temperatures with high rainfall. In 2015 and 2016, when there is heavy rainfall and normal average annual temperatures, the number of adults captured in both tillage systems is small.

Table 2. The variability coefficient of the species *Agrotis segetum* Den. & Schiff., in two soil tillage systems, Turda 2012-2017

Year	Abundance [a]		CV (s%) [b]		Diff. CV [c]		Average annual (T°C)	Annual rainfall (mm)	Flight	
	P	C	P	C	P	C			P	C
2012	153	204	33	35	**-8**	**-6**	10,4	504,4	H	H
2013	303	432	64	73	23	32	10,4	523,2	H	H
2014	231	302	49	51	8	10	11,1	741,5	H	H
2015	142	111	30	19	**-11**	**-22**	10,6	641,2	H	M
2016	75	115	16	20	**-25**	**-21**	10,0	816,8	M	H
2017	247	278	53	47	12	6	10,5	532,3	H	H
Mean	**192**	**240**	**41**	**41**	-	-	-	-	-	-

[a] Total number of captured adults; [b] Coefficient of variability; [c] The difference from the mean; P - Plowing, C - Chisel, I - High flight, CV≥20%, M - Medium flight, CV≥10%.

The highest values of the coefficient of variation in the case of the western worm of maize roots were recorded in 2017. In the minimum tillage systems, as shown by the values presented in Table 3, there is a higher number of captured adults. The lowest values of the coefficient of variation, which indicate an average flight (CV≥10%), are in 2016, an excessively rainy year, in the other years the chrysomelid achieves an intense flight (CV≥20%).

Table 3. The variability coefficient of the species *Diabrotica v. virgifera* LeConte, in two soil tillage systems, Turda 2012-2017

Year	Abundance [a]		CV (s%) [b]		Diff. CV [c]		Average annual (T°C)	Annual rainfall (mm)	Flight	
	P	C	P	C	P	C			P	C
2012	249	310	38	33	**-3**	**-8**	10,4	504,4	H	H
2013	255	502	39	53	**-2**	12	10,4	523,2	H	H
2014	280	540	43	57	2	16	11,1	741,5	H	H
2015	234	289	36	30	**-5**	**-11**	10,6	641,2	H	H
2016	88	145	14	15	**-27**	**-26**	10,0	816,8	M	M
2017	485	549	75	58	34	17	10,5	532,3	H	H
Mean	**265**	**389**	**41**	**41**	-	-	-	-	-	-

[a] Total number of captured adults; [b] Coefficient of variability; [c] The difference from the mean; P - Plowing, C - Chisel, I - High flight, CV≥20%, M - Medium flight, CV≥10%.

In order to deepen the influence of temperatures and precipitation on the evolution of pest populations, an attempt was made to establish interference between these climatic factors. However, the influence of climatic conditions on the flight of these pests requires a much longer study in order to be able to formulate some clear clarifications on the dynamics of the populations in a certain area.

The climatic characterization of the Turda area shows that the maximum precipitation is recorded in June and July and it can be said that they correspond to the period of appearance of adults of *Diabrotica v. virgifera*, namely the end of June and continues over the following months. By correlating the precipitations from July, August and the first two decades of September, with the number of adults of the species *Diabrotica v. virgifera*, a reduction of individuals is observed in accordance with the increase of precipitations. According to these and as can be seen from Figure 7, there is an indirect, statistically uncertain link between the two variables. Similar results were obtained in western Romania - Timiş (Grozea et al., 2010) and in Serbia (Tanasković et al., 2017). These studies have shown that excessive rainfall has led to a decrease in the number of adults of this species.

By comparing the curves in Figure 7, we can see a significant degree of similarity of the flight curves and the number of males of *Diabrotica v. virgifera* captured in 2012, 2013, 2014, 2015 and 2017, in both soil systems. A significant deviation from the frequency distribution of this pest can be reported for 2016, when a drastic reduction in the number of adults captured can be observed compared to other years.

The highest number of pests is recorded in both cropping systems in 2012, 2013 and 2017, dry years for the maximum flight months. An interesting development, which confirms all these statements, is in 2014, considered an excessive rainy year, which led to a shift in the flight curve to September. As can be seen from the data shown in the figure, the highest number of adults was during the first decade of September, when only 10.4 l/m^2 were recorded. Therefore, the monitoring of the western worm of maize roots must be done with special care, especially in the dry years (June and July).

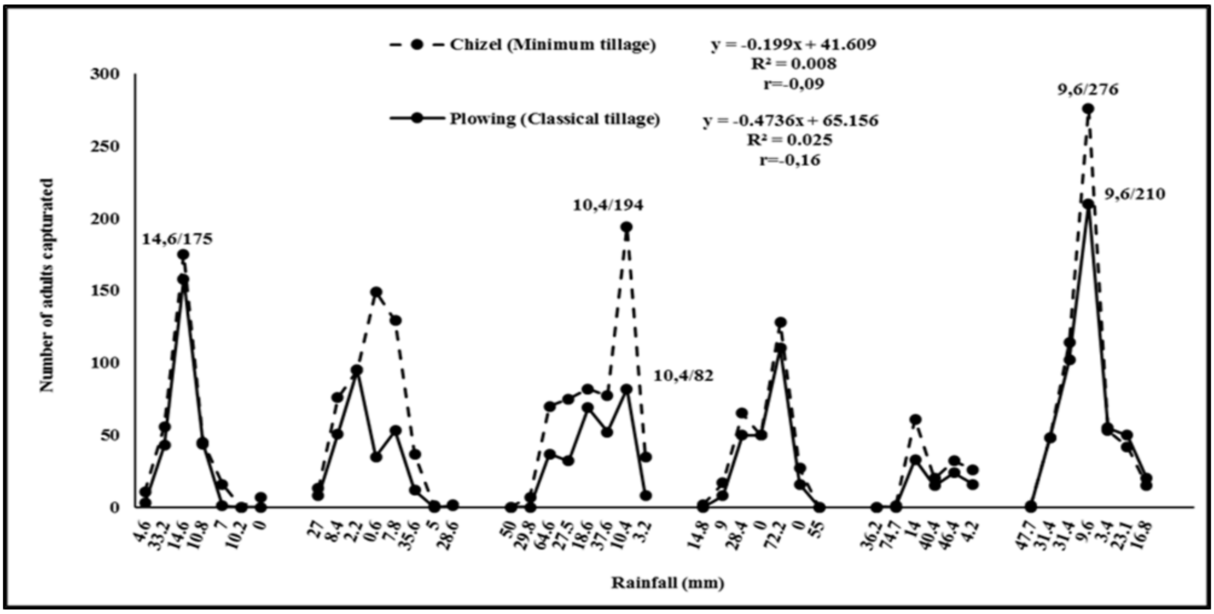


Figure 7. The relationship between rainfall and the captured males of *Diabrotica v. virgifera* LeConte, in two soil tillage systems, Turda 2012-2017

The graphical representation of the influence of temperatures and precipitation on the abundance of the species was made separately only for a clearer picture, otherwise the role of the influence of the two climatic elements in insect biology could not be seen separately. Thus, in 2012, 2013 and 2017, the highest number of captured adults is recorded against the background of lower amounts of precipitation and temperatures of 23-25°C. Moreover, recent studies (Grozea et al., 2010; Tanasković et al., 2017) suggest that, in general, high temperatures and drought lead to an increase in the number of adults of *Diabrotica v. virgifera*. Earlier I was talking about the special situation of 2014, when, probably, the heavier rainfall in July and August led to the extension of the maximum flight period, which took place even in the case of lower temperatures (19.5°C). Even though 2016 was a warm year, it can be seen from Figure 8 that the number of adults captured in the two systems was probably lower due to more significant rainfall, 2016 being considered one of the rainiest years in the last 59 years.

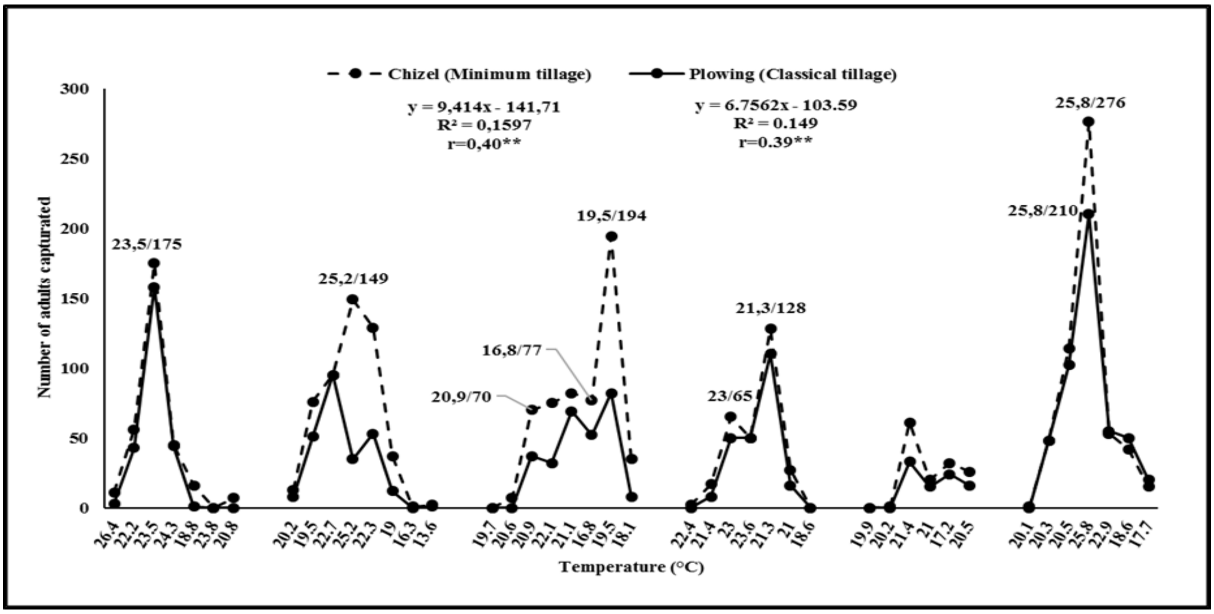


Figure 8. The relationship between temperature and the captured males of *Diabrotica v. virgifera* LeConte, in two soil tillage systems, Turda 2012-2017

CONCLUSIONS

Conservative tillage systems play a positive role in the formation and development of insect populations, the average of the three monitored species, in the system with minimum tillage being clearly superior to the one in the classical system.

The abundance of *Diabrotica v. virgifera* LeConte reaches higher thresholds than the other two monitored pests (*A. gamma* and *A. segetum*), in almost all the five years analyzed and in both soil tillage systems, in maize crop.

In the three monitored species, an almost perfect synchronization of the first generation with the optimal threshold of temperatures specific to insect biology can be observed. These mechanisms have evolved over time and have required permanent insect adaptations to climate change.

The values of the coefficients of variation for the captured adults number should be considered only by means of another flight parameter, namely abundance.

Experimental data reveals that the thermal regime, as expected, has a more important influence on the dynamics of these pests.

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