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EFFECTIVE INSECTICIDE APPLICATION TO PREVENT ECONOMIC LOSSES FOR UKRAINE CAUSED BY WESTERN CORN ROOTWORM (*Diabrotica virgifera virgifera* Le Conte) SPREADING

Svitlana HORNOVSKA, Mykola GRABOVSKYI, Yriy FEDORUK, Valerii KHAKHULA, Taras PANCHENKO, Igor POKOTYLO, Kateryna VELYKA, Oleksandr GORODETSKYI

Bila Tserkva National Agrarian University, Bila Tserkva, Kyiv Region, Ukraine, sq, Soborna 8/1, 09117, Ukraine

Corresponding author email: nikgr1977@gmail.com

Abstract

The first individuals of western corn rootworms (Diabrotica virgifera virgifera Le Conte) were noticed in the border zone of Transcarpathia region in 2001. These insect pests had inhabited only two regions of the country for a long period of time. However, the gradual spread of Diabrotica species from the places of the first detection to the South and West of Ukraine has been noticed recently. The main aim of the research is to study the spreading tendency of the western corn rootworms (WCR) in the Ukrainian forest-steppe zone and to create the preventative system for identifying insect pest localization and extermination. According to the research results, it has been determined that the population of insect pests is increasing every year. There is a plant-feeding insect adaptation due to corn cultivation increase, poor crop rotation and climate change. The research priority and relevance has been done on the basis of the interest in insect pest identification, studying of their biological spread peculiarities under the consideration of modern conditions and improving of the insect pest control preventative methods.

Key words*: Diabrotica, crop rotation, insect, effective insecticide.*

INTRODUCTION

In recent years, there has been dangerous and massive insect pest spreading of western corn rootworms (*Diabrotica virgifera* Le Conte) for corn crops in Ukraine. As a result of harmful insect pest influence, there are losses not only for corn producers in the USA but for other countries as well (Adamchuk, 2008).

D. v. virgifera species (WCR) are originally from Northern America. They are considered to be the most economically harmful insect pests for corn production. They cause approximately 1,000 million dollar losses. It includes annual expenses of preventative methods and yield losses. That is why these insect pests are called "billion dollar bugs" (Krysan & Miller,1986).

The main area of *D. v. Virgifera* inhabitancy is considered to be Mexico and central regions of Southern America. In 1909, *Diabrotica* species were discovered in the USA. The insect pests spread gradually from the East of Colorado to Southwest Nebraska. Since 1955, there has been a massive bug spreading. A bit at a time they have become one of the most dangerous insect pests of corn crops not only in the USA but in Canada as well (Hornovska & Gorodetskyi, 2023).

From 1985 to 1989 the spreading of the western corn rootworms had occurred more quickly in western, central and north-central parts of Virginia (the USA) with only 39% of the corn cultivated area than in the eastern and south-western parts with 92% of crop cultivated area being used in crop rotation from 1989 to 1992 (Andreyanova, 2010).

In 1992, the western corn rootworms were detected for the first time in Europe (close to the international airport of Belgrade, Surcin, Serbia). Based on scientists' idea, the beetles could have been brought in by accident with the help of American aviation and military equipment. At first the damage caused by insect pest was mistakenly taken by *Agrotis segetum* Schift species (Meinke et al., 2009).

The origin of these insect pests is still unknown. Having appeared in Europe, they spread quickly in the Danube basin. The previous potential spreading study, conducted by researches in Croatia, France, Germany, has shown that these species live and spread where the corn crops are cultivated in Europe (Spencer et al., 2009).

Their inhabited area was discovered in Croatia (1995), Hungary and Romania (1996), Bosnia and Herzegovina (1997), Bulgaria and Italy (1998), Slovakia and Switzerland (2000), Ukraine (2001), Austria, France, the Czech Republic (2002), Slovenia, Belgium, Holland and Great Britain (2003), Poland (2005) (Wesseler & Fall, 2010).

In 1997, the inhabited area by beetles included the territory over 5300km² in Serbia. In 1998, the beetles were identified in Bulgaria and Italy (close to the international airport of Morocco, Polo). In 2000, the western corn rootworms appeared in Slovakia, Switzerland (Lugano) and also in Italy (close to the airport on the outskirts of Milan) (Butkalyuk, 2003).

In 2001, for the first time, they were detected in the region of Transcarpathia and it also was confirmed by their inhabited area in Hungary (Adamchuk, 2008; Hornovska & Gorodetskyi, 2023).

Due to their quick migration and ability to fly for a long distance, it is possible to make a conclusion that the insect pests have penetrated to the territory of Ukraine from the inhabited area of these countries (Grabovskyi et al., 2023).

On the basis of scientists' data (Sivcev, 1996; Edwards, 1999), inhabiting the area, the insect pests can be found in pheromone traps in three and more years (Edwards, 1999; Sivcev et al., 1996).

It is explained by the fact that the beetle fertilized female inhabits the area. Therefore, the monitoring and forecast are conducted due to the female pheromone traps used for male catch (Andreyanova, 2010).

Analyzing the fact that the period from the first appearance of the western corn rootworms to their identification is long enough and it is possible to draw a conclusion that they can be brought not only from the nearest countries, but these species have started their population growth on the territory of Ukraine (Rudenko, 2014).

The inhabited area by these species is constantly increasing each year. The western corn rootworms are found on corn crops in Transcarpathia, Lviv, Ivano-Frankivsk, Ternopil, Chernivtsi, Vinnytsia, Zhytomyr, Khmelnytskyi, Volyn regions. They were detected for the first time in Cherkasy region in 2017 (Stankevych & Hornovska, 2022).

In accordance with Sikura et al (2011) the attention should be paid to the rapid spreading of new corn insect pest species in Europe that have made EPPO add them to the control list of the most dangerous quarantine insect pests (A-2) that are limited in spreading in Europe.

In Ukraine, the western corn rootworms have been added to the list of controlled insect pests and to the second list of quarantine insect pests that are limited in spreading (Hornovska & Khakhula, 2020).

One of the main factors contributing to the insect pest infestation and further spreading is the presence of a host plant (corn) suitable for their development. Growing corn in monoculture conditions will provide the beetles with a permanent food base. As a result, it will lead to their significant spreading and harm in Ukraine.

Crop rotation is mentioned as the most effective preventative measure for *Diabrotica* species in all domestic and international literary sources (Hornovska & Gorodetskyi, 2023; Rudenko, 2014).

Following the crop rotation is enough to decrease the insect pest population and their damage: coming back to three or four year corn crop rotation in the field. However, using the corn crop rotation randomly can cause quick insect pest adaptation (Prymak et al., 2022). There is a reason to use three year crop rotation and rotation more than three years in the following way: corn, soybean, oat. Thus, Europe suggests using the following crop rotation: corn, soybeans, sunflower and cereals (wheat, oat, barley) (Prymak et al., 2023).

The constant international and trade-economic relation expansion contributes to the import volume increase and agricultural product export. It creates conditions for the penetration of quarantine harmful organisms into Ukraine. Their quarantine status and significant economic influence can't be always known and predictable for Ukraine (Andreyanova, 2010).

Aggressive insect pest species are dangerous for agricultural production, especially for agricultural companies that produce corn crops. The western corn rootworms have become a new problem for European famers that produce corn crops. The damage caused by (*Diabrotica virgifera virgifera* Le Conte) can be immense and alike to losses that American famers have (Adamchuk, 2008).

The amount of countries, where the phytophagous insects appear, is increasing yearly. The *Diabrotica* species inhabit broad areas and can be found in countries with subtropical or subcontinental and mild climate (mild winter and hot summer). The constant movement of all types of vehicles from other countries to Ukraine and inside the country can distribute insect pest spreading and the appearance of new infestation localizations. Also, insect pest spreading is distributed by the species ability to migrate for a long distance naturally. During the growing season they can reach distance of 40-100 km (Eben, 2022).

Since February 24, 2022, this issue has become of great importance after starting of the Russian federation a war against Ukraine. The insect pest penetration and spreading on the wheels of vehicles, tank tracks, military equipment and food supply for the army have created a dangerous situation. It will be possible to determine the infestation volume and to start preventative actions against quarantine species after de-occupation and demining of surveyed territories, farmlands of different use. It has relation to occupied regions of Donetsk, Lugansk, Kherson, Zaporizhzhia (Stankevych & Hornovska, 2022).

It is important to mention that from 2017 to 2020 phytophagous insects had been detected in new regions. They increased their spreading on the territories of 15 regions in comparison with 2015, 2016 (on the territories of 9 regions). The phytophagous have been identified in the regions of Sumy, Kyiv, Kropyvnytskyi (Kirovohrad), Vinnytsia, Cherkasy, Chernihiv (Hornovska & Gorodetskyi, 2023).

According to the 1st of January, 2018, the beetles were spread over the area of 88, 9 thousand hectares. At the beginning of October of the same year infested area increased by 20 thousand hectares. The new infestation localization was detected on the territory of 12 regions (Stankevych & Hornovska, 2022).

According to the 1st of January, 2024, the WCR spread in 16 regions of Ukraine. The regions of Mykolaiv and Chernivtsi turned out to be the most infested. They can be found on the area of 28524, 03 and 55287, 13 hectares. The region of Dnipro was less infested – 257 hectares. The dynamics of the insect pest spreading was visible in Ukraine (from 861667, 49 hectares in 2015 to 144167, 75 hectares in 2022) (Saliienko & Fedorenko, 2024).

The real threat connected with the dangerous corn insect pest spreading has appeared in Ukraine. The losses caused by them can be significant and alike to losses of the USA and other countries. The literacy resources suggest crop rotation as the most effective method against *Diabrotica* species. Though, some authors insist on combination of several methods: steady crop rotation, insecticide use, resistant corn variety cultivation (Marchioro & Krechemer et al., 2018).

The modern tendency for the insect pest prevention is focused on the biological control of population quantity as it influences the environment ecological state (Sikura, 2010).

The aim of the research is to analyze the western corn rootworm (*Diabrotica virgifera virgifera* Le Conte) spreading in 2024 on the territory of Ukrainian forest-steppe zone, to make a conclusion from the phytosanitary monitoring, to create preventative measures of insect pest spreading, localization identification and extermination in case of detection.

MATERIALS AND METHODS

The research purpose is to make a conclusion from the monitoring results of the western corn rootworm (*Diabrotica virgifera virgifera* Le Conte) phytosanitary spread control conducted in 2024 on the territory of the forest-steppe zone of Ukraine. The basis of the research is phytosanitary monitoring of various region territories of Ukraine where *Diabrotica* species are widespread. The agrocenosis phytosanitary state monitoring is a main conventional method of the research (Sikura et al.,2011; Stankevych, Zabrodina, 2016).

The corn crops had been examined three times in each month (at the beginning, in the middle and at the end) for the studied period. The monitoring was carried out by the route examination with the use of artificial sex pheromones in the corn crops.

The traps for *Diabrotica* detection were located in the corn fields with amount of 1 trap per 5 hectares. Yellow glue traps were exposed in amount of 1, 3, 6, 9, 12 samples independently from the area of corn crop during the massive imago flight. All variants of samples were used three times.

The traps were installed on the level of corncob covering their stalks. The traps were changed every week and the pheromone capsules once in two weeks. Counting and sampling of *Diabrotica* imago were carried out in the traps once in seven days. The pheromone capsules were changed in 4-5 weeks.

The constant soil digging and examination of plants were done for insect pest early detection. Since the blooming period, the beetles had been found on leaves, stalks, silk, young corncobs The *Diabrotica* species were caught by yellow, blue and transparent glue traps with and without an attractant. The traps of triangular and round shapes were used as well as traps of a panel type that turned out to be the most effective for beetle catching. Metoksifenetanol 4 was used as an attractant.

The visual root system examination for larva and egg identification was done equally by soil digging method in the fields. Basically, the edges and the middles of the fields were examined near dying, turned yellow and stunted plants.

The digging area had the form of an “envelop”. The digging in the form of a “snake” was carried out in narrow and long field areas (Baca et al., 1995).

The examination of the pheromone traps with insect pest samples on filter paper was performed. Then they were placed in a test tube with a fixed label for the further identification of their species. Insect pest species were identified using text books and pest atlases.

Phytosanitary experts mention that in recent years, pheromone monitoring has become an important and profitable method for the timely detection, spread control and assessment of the insect pest number dynamics in comparison with the method of visual crop examination (Adamchuk, 2008; Stankevych, Zabrodina, 2016).

312 samples consisting of 216 adult insects and 112 larvae had been collected for the period of the research. The western corn rootworms were calculated only in the fields where the corn crop had been cultivated as a monoculture for three and more years. Strong attention was paid to the fields bordering with the highways and railway lines. The insect pests were detected on all stages of their development. Stunted and turned yellow crops were the signs of insect pest inhabitancy.

RESULTS AND DISCUSSIONS

The western corn rootworm harmfulness and amount are changing in Ukraine. In 2024, 427 infestation localizations of western corn rootworms (*Diabrotica virgifera virgifera* Le Conte) were recorded in Ukraine. The quarantine regime was suggested for *Diabrotica* species in 16 regions. In 2024, the inhabited area by insect pests was 130603, 5383 hectares. Since 2015 to 2024, there had been the increasing tendency (by 1,6 times) of insect pest inhabitancy on the territory of Ukraine (Figure 1).

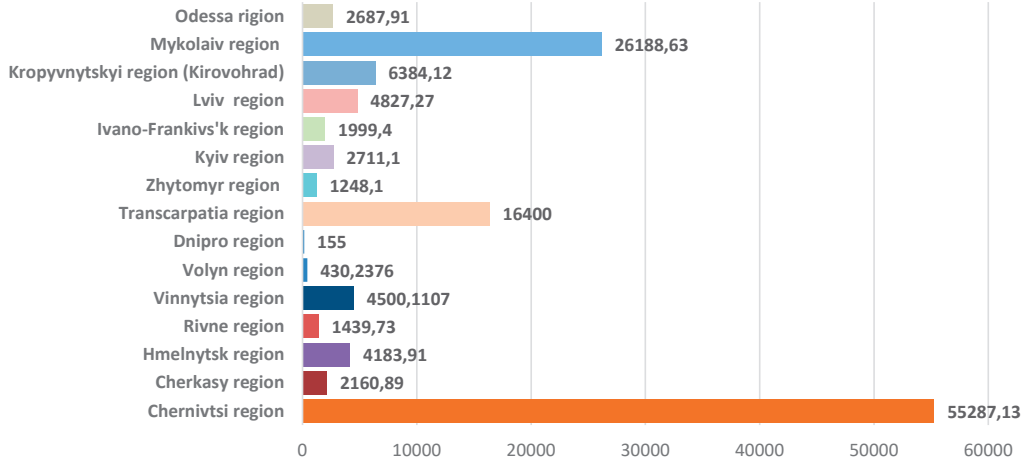

Figure 1. The inhabited area by western corn rootworms (*Diabrotica virgifera virgifera* Le Conte)

Analyzing conducted study, it is possible to make a conclusion that there is a tendency for increasing of the inhabited area by insect pests on the territory of Ukraine. The researches have a forecast that the insect pests will inhabit all corn crop agrocenosis in five years.

To analyze the seasonal flight dynamics of *Diabrotica* adult species, there was a need to conduct the observation of the flight season (at the beginning, in the middle and at the end) and to identify the general flight duration. As a result of these observations there was an opportunity to create the system for optimizing the pest control and extermination.

In 2024, the research expedition was carried out in the forest-steppe zone where the corn crops had been cultivated. The sites for studying were located at the husbandries of Kyiv region. There was a corn crop area of 5 hectares.

Starting from the last 10 days of May, the signal pheromone traps were hung on the experimented sites with corn crops. In the first 10 days of July, the first beetles of *Diabrotica* species were found in traps. When the insect pest flight was started, the pheromone traps were hung in the middle of July and yellow glue traps – in October. They were exploited to study the beetle dynamics flight using different amount of traps. In the period of massive imago flight, yellow traps in the amount of 1, 3, 6, 9, 12 were installed without dependency on the sown corn crop area. The pheromone traps in the amount of 1, 3, 5 were located for imago monitoring in the corn crops. All trap variants had three replicates.

The calculation results of the found amount of adult western corn rootworms in the traps are shown in the (Table 1).

Table 1. The number of the adult western corn rootworms (*Diabrotica virgifera virgifera* Le Conte) found in the pheromone and yellow traps.

Calculation date	The average number of the found adult beetles by the pheromone traps			The average number of the found adult beetles by the yellow glue traps				
	1	3	5	1	3	6	9	12
15.07	86±8	77±10	98±4	-	-	-		-
22.07	169±13	185±7	183±11	8±3	7±6	16±5	10±4	7±3
29.07	180±9	194±15	186±17	40±6	45±8	69±5	46±7	43±5
05.08	68±6	73±5	78±9	30±5	34±7	40±6	36±8	35±10
12.08	162±27	140±14	148±12	36±8	43±6	57±7	40±5	44±8
19.08	110±23	125±21	109±5	35±7	38±12	52±12	38±9	36±6
26.08	105±34	98±17	95±14	29±5	32±8	40±7	35±8	32±5
02.09	85±12	78±8	81±6	-	-	-	-	-
07.09	64±10	70±7	69±6	-	-	-	-	-
14.09	45±8	48±7	52±9	-	-	-	-	-
21.09	18±4	21±3	25±3	-	-	-	-	-
28.09	0,5	0,9	0,6	-	-	-	-	-
Adults detected on average, specimens/traps	91.0±14	92.5±10.4	93.7±8.1	14.8±2.8	16.6±3.9	22.8±3.5	17.1±3.4	16.4±3.1

It was established during the research that all pheromone trap variants in different quantities showed almost the same beginning and duration of the *Diabrotica* species flight period.
All pheromone traps were used in different amounts in the experiment. Analyzing the data in the table 1, it was possible to come to conclusion that almost the same number of beetles was found in the pheromone traps on the date of registration.

The beginning of the *Diabrotica* imago flight was observed on the 15th of July in 2024 when the massive amount of the male beetles started coming out from the soil to search the females for mating.
The massive flight of beetles lasted from the third decade of July to the end of August. It was that period that indicated active feeding, mating and the female egg laying of *Diabrotica* species (Figures 2, 3).

Figure 2. Feeding of *Diabrotica* imago (*Diabrotica virgifera virgifera* Le Conte)

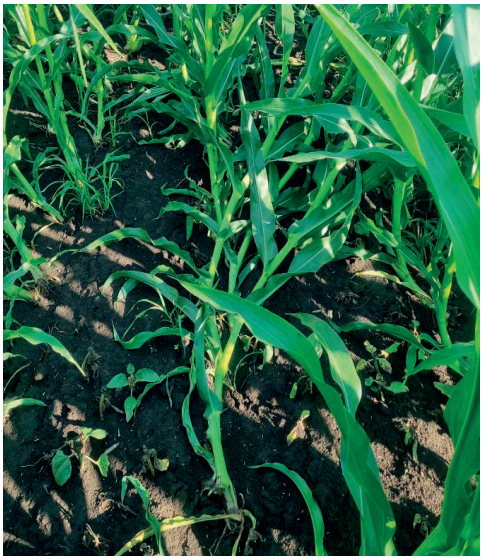

Figure 3. Corn crop laying caused by the larvae of *Diabrotica* species

As stated by this observation the leap of the imago flight was in the first decade of September. The end of the flight was in the last decade of September.
The leap of the Diabrotica flight had been recorded from 22.07.2024 to 12.08.2024.
The biggest amount of imago beetle was found in pheromone traps (29.07.2024: 194 samples per trap). That is why it was suggested using insecticides exactly in this period. 5 insecticides for western corn rootworms were used for the experiment.
The experiment was carried out randomly four times with repetition in accordance with the scheme:
1. Insect pest control of the site;
2. Coragen CS (chlorantraniliprole, 200 g/l), 0.15 l/ha;
3. Karate Zeon 050 CS (lambda-cyhalothrin, 50 g/l), 0.3 l/ha;
4. Engio 247 CS (thiamethoxam, 141 g/l + lambda-cyhalothrin, 106 g/l), 0.18 l/ha;
5. Avaunt EC (indoxacarb, 150 g/l), 0.17 l/ha;
6. Danadym stable, EC (dimethoate, 400 g/l), 1.0 l/ha.
The insecticides were applied in the stage of early corn maturity, which corresponds to the international scale of growth and development of grain crops (BBCH). A portable selective sprayer Pulverexper was used to apply chemicals. The effective dose of solution was 200 l/ha.
To compare the insecticide effectiveness, statistically reliable indices (the number of pests in traps) were used for each calculation.
The effectiveness of the chemicals was measured in 1-5 days.

The effectiveness of insecticides against diabrotic adults depends on the seasonal dynamics of their flight - at the beginning and during the mass flight of beetles, when their number is the highest. Therefore, the effectiveness of chemicals against adults was determined during their mass flight.

The studies showed high technical efficiency of the studied chemical insecticides against the western corn borer.

The most effective insecticide was Avaunt, EC. (indoxacarb, 150 g/l) with an application dose of 0.17 l/ha. This chemical showed 96.97% decrease of the amount of *Diabrotica* species in comparison with the control samples, Coragen, CS - 94.36%, Karate Zeon 050, CS with. - 96.78%, Engio 247, CS - 94.01%, Danadym stable, EC - 93.32% (Table 2).

The highest efficacy of the products was observed on the 3rd day after their application. This is due to the fact that the pest is in direct contact with the insecticide.

Table 2. Effectiveness of insecticides when used against imago of *Diabrotica virgifera virgifera*

Variant	Consumption rate l, kg/ha	Number of imago on ... day of accounting, units/100 plants			Technical efficiency, %.
		before processing	on the 3rd day	on the 5rd day	
		2024			
Control		39.5	49.0	42.0	-
Coragen CS (chlorantraniliprole, 200 g/l)	0.15	47.00	8.8	2.65	94.36
Karate Zeon 050 CS (lambda-cyhalothrin, 50 g/l)	0.3	47.27	2.25	1.52	96.78
Engio 247 CS (thiamethoxam, 141 g/l + lambda-cyhalothrin, 106 g/l)	0.18	46.25	6.6	2.77	94.01
Avaunt EC (indoxacarb, 150 g/l)	0.17	48.90	2.28	1.48	96.97
Danadym stable, EC (dimethoate, 400 g/l)	1.0	49.22	6.54	3.29	93.32

The decrease of *Diabroticia* amount in the comparison with the control samples was established in the range of 50-75% in 6-8 days after the application of insecticides.

It was found out that the larvae, being obligate monophages and feeding only on the roots of corn, were especially harmful for corn crops. It was observed during the research that first of all, the larvae ate root hairs, then thin roots and later

– large and tap roots. At the same time, they introduced root rot pathogens.

As a result, damaged plants turned yellow, stunted, withered and young plants died quite often.

It was noticed that mature plants had laid out easily during strong wind and rainfall. The plant stems became in the form of a “duck neck”. At the same time mechanized harvesting was impossible. But for beetle feeding on the generative organs, the seed amount decreased in the corncob. That was the reason of yield declining (Figure 4).

Figure. 4 Damaged roots by western corn rootworms (*Diabrotica virgifera virgifera* Le Conte)

The biggest damage caused by the western corn rootworms was observed in the fields without crop rotation. But for steady corn cultivation, the population of beetles increased.

That is why the crop rotation, including cereals, perennial grasses, clover, alfalfa, is an effective agricultural measure against the western corn rootworms.

Thus, in case of their overcoming the economic damages (in the amount of 2 larvae per plant), the soil insecticide use is effective to control larvae of the western corn rootworms. The insecticides can be used before and during sowing or during the growing season.

CONCLUSIONS

It has been found out during the chemical use and the seasonal imago flight determination that the application of 1 pheromone trap per 5 hectares of corn crops is enough to monitor the inhabited forest-steppe zone by imago of the western corn rootworms.

In order to decline the probable appearance of the WCR in the corn crops, an important action is to carry out the control by detecting larvae and examining the root system, leaf surface, silk. To determine the early stages of beetle development there is a need to dig the soil.

The main preventative measure against imago and larvae is the insecticide use.

It is highly recommended to use insecticides that have shown great effectiveness: Avaunt, k.e. and Karate Zeon 050 CS, hp, with technical efficiency of 96.97% and 96.78%, respectively.

They are mentioned in the list of approved pesticides and agrochemicals of Ukraine (2023).

The declined amount of Diabrotica is observed (in the rate of 50-75% and lower than on control sites) in 6-8 days after pesticide using. This is the evidence of a long-lasting protection effect of the insecticide.

The most effective and approved insecticides by the research are recommended to corn crop production regions with *Diabrotica* species spreading.

The use of the recommended insecticides at the first appearance of diabrotica will allow farmers to maintain corn yields, thereby increasing the economic efficiency of growing the crop.

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