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# Morphobioecological features and harmfulness of apple-blossom weevil (*Anthonomus pomorum* Linnaeus, 1758)

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In the course of the literature critical analysis the authors paid special attention to the morphological, biological and ecological features of the apple-blossom weevil in fruit plantations, both in Ukraine and abroad; the authors came to the conclusion that despite the considerable number of literary sources devoted to the apple-blossom weevil, there is still a number of its biological and ecological features which are in close connection with the protection measures for controlling it and these measures have not yet been completely clarified. In particular, the relationship between the phenology of the apple varieties of different time of ripening and the period of egg- laying as well as between the period of summer diapause of the pest and its concentration places during the summer diapause and during hibernation remains unclear. There is also a lack of data on the density of the hibernating beetles of the apple-blossom weevil under the dead bark on the trunks and boughs, in the surface layer of soil and plant litter of the crown projection per apple tree; the knowledge of these facts would allow to calculate the pest density in the next spring in order to protect the apple trees before blossoming. The data obtained by the entomologists from different countries regarding the harmfulness of the apple-blossom weevil and its economic importance are quite controversial and also need experimental confirmation.

**Keywords:** Apple-blossom weevil; Morphology; Biology; Ecology; Harmfulness.

## Introduction

One of the most dangerous pests of the generative organs of the apple tree before fruit formation is the apple-blossom weevil – *Anthonomus pomorum* L., belonging to a line of sheathed-winged beetles, or Coleoptera beetles of the weevil (Curculionidae) family. The apple-blossom weevil is distributed throughout the territory of Ukraine, but it causes the greatest damage in the areas of Polissia, Forest-Steppe and in the foothills of the Crimea. It is also distributed in the European part of the Russian Federation, in the north towards Leningrad, in the Caucasus, and in the Prymorskyi Krai, especially in the gardens located near the forests where wild apple- and pear-trees grow (Alekseieva, 1985; Vasiliev, 1976, 1988; Rodionov, 1932). In the Russian Federation the apple-blossom weevil is the most numerous in the middle zone (Mozgovyi, 1932). It is distributed throughout the territory of the former USSR, except Turkmenistan and Western Siberia; but it is of particular economic importance in the Moscow and Ivanovo regions, in the Gorky Krai, the Upper Volga Region, and in the valleys of the Caucasus rivers (Chugunin, 1937). As for the foreign countries, the apple-blossom weevil is found in the Eastern and Western European countries, in the greater part of Asia, in Korea, Japan, Northern China, the USA, Romania, and Greece (Batiashvili, 1959; Vasiliev, 1988; Mozgovyi, 1932; Hull, 1985; Niemczyk, 1994; Progar).

## Materials and Methods

The authors have analysed 104 literary and electronic sources from the end of the 19th up to the 21st centuries. In the course of the analysis special attention was paid to the morphological, biological and ecological features of the apple-blossom weevil in fruit plantations, both in Ukraine and abroad. The data concerning the harmfulness of the apple-blossom weevil and its economic importance have been analysed in particular.

## Results and Discussion

The total length of this beetle is 3–5 mm, the head capsule is 1,25 mm long (Diamandidi, 1923; Schreiner, 1907; Schreiner, 1915). The body is dark brown, brownish gray or fulvous brown in colour. The head capsule is long, thin and slightly bent. The elbowed-clavate antennae and legs are reddish or reddish-brown, the antennal clava and thickened part of the femura are dark brown (Ambrosov, 1976; Borisoglebskaia, 1975; Borisoglebskaia, 1977; Diamandidi, 1923; Savzdarg, 1956). The thorax of the beetle is white. Across the hind part of the elytra there is an oblique light gray stripe which forms an obtuse angle, the apex of which is directed towards the posterior part of the beetle body, and the entire strip has a dark border (Figure 1) (Vasiliev, 1924; Ginzenberg, 1912; Krikunov, 2002; Schreiner, 1915; Schreiner, 19150). The egg is elongated, watery-white, and 0.5–0.8 mm long. The larva is 5–6 mm long; it is bent and legless, narrowed to the posterior end, yellowish-white in colour and has a small dark brown head

(Figure 2). The pupa is 4–6 mm in length, pale yellow, and has two spines at the end of the abdomen (Figure 3) (Viangeliauskaite, 1992; Kolesova, 1995; Rodionov, 1932).

**Figure 1.** Imago of apple-blossom weevil (original photo).

**Figure 2.** Larva of apple-blossom weevil in a damaged button (original photo).

According to M.T. Aristov (1925) the apple-blossom weevil hibernates in the surface layer of soil, beneath the fallen leaves, and only a small proportion of the individuals can overwinter under the scales of the tree bark.

In the Forest-Steppe zone of Ukraine, especially in the young orchards, the apple-blossom weevil hibernates in the soil near the root collar or near the trunk at a depth of 2–3 cm; it also can overwinter under the fallen leaves in the orchard or near it or in the hedgerows and in the forests under the wild apple- and pear trees, or under the scales and in the bark cracks (Vasiliev, 1988; Yanovskyi, 2003).

Some authors (Drozda, 2000; Krikunov, 2002; Filippov, 1990) inform that the beetles hibernate in the surface layer of soil, beneath the fallen leaves, in the bark cracks, and in the hedgerows.

The imagoes of the apple-blossom weevil (69–88%) lie predominantly in the soil at a depth of up to 5 cm near the trunks and they are absent outside the pans (Litvinov, 2004).

Under the conditions of the middle part of Russia the adult beetle overwinters in the surface layer of soil (2–3 cm), mostly located at a distance of up to 20–30 cm from the trunk. The beetles also overwinter in the soil cracks. In the soil the beetles are placed for hibernation both under the fruit and ornamental trees located in or near the orchard. Especially many beetles hibernate under the shelter belt trees. The flight of the beetles to these trees takes place in the summer, when the juveniles are especially active after leaving the buttons. A small amount of the hibernating beetles is also found under the bark of fruit and ornamental trees (Chugunin, 1937, 1946).

In the Khabarovsk Krai the beetles overwinter under the fallen leaves and in other hidden places (Shtundiuk, 1969). K.A. Mamaiev and others (1981) also note that the beetles hibernate under the fallen leaves and in the cracks of the tree bark. In the Orel region the bulk of the beetles (55%, mainly the females) overwinters in the cracks and under the bark scales of the tree trunks at height of up to 40 cm. The males prefer to place themselves in the cracks between the trunk and the soil; the single specimens were found in the soil (Nikolaieva, 1973). S. Toepfer, H. Gu, S. And Dorn (Toepfer, 2000) indicate that dried leaves are the most attractive place for the imagoes of the apple-blossom weevil hibernation. Under the conditions of Switzerland, depending on the apple tree variety, 47–64% beetles of the apple-blossom weevil hibernate in the orchards. One beetle moves at the distance of 19 m. on the average. At the same time about one third of the beetles populate the first tree they come across; and the rest of the population moves further, mainly along the tree rows. Such distribution leads to a "marginal effect" when the greatest damage to the buttons is found in the trees located near the forest (Gamina, 1991; Kashirskaia, 1991; Toepfer, 2002).

**Figure 3.** Pupa of apple-blossom weevil in a damaged button (original photo).

In the spring the populating of the apple-blossom weevil begins from the old orchards and forest stands (Kolesova, 1996). In the spring the beetles of the apple-blossom weevil begin to show activity at a temperature of 6°C (Figure 4) (Vinokurov, 1917; Slavgorodskaia-Kurpiieva, 1993; Chugunin, 1946; Schreiner, 1915). According to the data of C. Hausman, J. Samietz, and S. Dorn (2005) the females and males of the hibernated beetles choose the warmest areas. In Belarus the migration of the apple-blossom weevil from the hibernating places coincides with the date when the maximum daily temperatures steadily exceed 5°C (Matveichik, 1998). The populating of the crown coincides with the beginning of the bud swelling in the apple tree when the average daily air temperature reaches 6°C (Aristov, 1931; Vovk, 1926; Zabrodina, 2006; Kolesova, 2005). The apple-blossom weevil populates the crown of the apple tree with the first April thaws. The beetles hibernated in the bark cracks of the trunks and in the soil near the tree trunk leave the hibernating places first. The beetles hibernated in the pan soil leave their hibernating places later when there is no snow and the soil is dry (Bezdenko, 1958).

**Figure 4.** Spring populating of crown by beetles of apple-blossom weevil (photo by the author).

From the moment the buds swelling the beetles move to the tree crown and begin their nutrition. The mass populating of the tree crown by the beetles is observed at an average daily temperature of 8–10°C (Zabrodina, 2006, 2007; Kolesova 2005; Savzdarg, 1956). In Moldova the intense beetle migration is observed at a temperature of 9,6–14,6°C (Gamina, 1991). After reactivation, when the buds begin to swell, the beetles begin their nutrition making the holes in the buds and eating away the vegetative and sexual parts of the bud, which is the germs of the leaves and buds, through these holes. Piercing the bud, the apple-blossom weevil makes a hole necessarily in the places of the scales dispersion. The bleeding sap in the form of cell sap drops shining in the sun is secreted through the holes made by the beetles. This type of damage is called "spring sap-exudation" (Aristov, 1932; Borodin, 1917; Kolesova, 1996; Korchagin, 1980; Okroshiashvili, 1996; Soshnikov, 1989; Chugunin, 1938). Under temporary lowering of temperature up to 0°C the beetles stay on the branches and withstand this period without causing damage (Kolesova, 2005).

In cold weather the activity of the beetles is reduced: they become freeze in the branching or near the fruit-bearing spurs. The imago body colour merges with the tree bark, so it is not easy to find it. After migration from the hibernating places the beetles first populate the pear tree (if available), which develops 5–7 days earlier than the apple tree (Shevchuk, 2006).

The role of meteorological factors in the apple tree blossoming and in the maturation of the sexual production of the weevil is crucial. The genital organs of the apple-blossom weevil are not yet developed after awakening in the spring and therefore the extra nutrition is required to begin the activity of the genital glands. The necessity for the extra nourishment in the spring is an unfavourable factor for the apple-blossom weevil, which puts it into a critical situation during the years of lush blossoming, when the trees vigorously undergo the preparatory stages of blossoming.

The trees begin their life cycle in the spring when the snow comes off from the ground. At the same time the weevils begin to divide into groups: the beetles hibernated under the snow cover are delayed compared with those that hibernated in the open places. Direct solar radiation quickly brings them to life; and positive phototropism leads them to the buds where they start extra nutrition (Troitskii, 1925). During early-spring nourishment and egg-laying the beetles, being very sensitive and fearful, bend their legs and fall to the ground even under little threat. The method of controlling the weevils by shaking them off on the tarpaulin is based on this fact. This feature of the beetles is not constant and changing with the fluctuation in temperature. The absolute fall of the beetles on the tarpaulins when shaking off takes place at a temperature of up to 10ºC. At a higher temperature the beetles hit the branches when falling and immediately spread their wings and fly away (Chugunin, 1935, 1938, 1954).

Usually the egg-laying does not last long because the buttons of the apple trees develop in a friendly and fast way in the warm spring. And vice versa, the cool spring delays the development of the buttons and contributes to a longer period of the egg- laying, and thus more damage is done to the orchard (Savzdarg, 1956; Samoilovich).

Depending on weather conditions the beetles can gather on the tree tops or on lower branches in large numbers. In this regard the density of the eggs differs in one or another part of the crown (Aristov, 1932).

The intensity of the weevil distribution and the population density of the pest on the plantation depend on the weather conditions, chemical treatments and close location of the orchard-protective belts in which the wild apple tree grows. The orchards that have not been treated with the pesticides are the most populated (Matviievskii, Loshchitskii, Tkachev, 1987).

The most intense flight of the beetles takes place during the button exposure period, when the females lay eggs in bulk. Depending on the temperature, the egg- laying by the females of the apple-blossom weevil may last up to 30 days in the cold and prolonged spring or reduce to 10–15 days in the warm and friendly spring. The fertility of the apple-blossom weevil is 52–82 eggs per female on the average, and the potential fertility of the females is up to 100 eggs. In some years, characterised by a very short period from the beginning of the inflorescence formation to the apple-tree blossoming, the females lay only 57,3% of eggs. In such years the egg-laying occurred when the air temperature lowed to 3,6°C, whereas the species development threshold was within the limits of 6°C. The population in the fruit trees in the orchard was different. In the central part of the orchard it did not exceed 2–10 beetles, whereas in the trees of the same orchard near the forest- and orchard-protective belts the population density was up to 30–40 specimens per tree (Matviievskii, Loshchitskii, Tkachev, 1987).

According to the observations of A.M. Sokolov and R.A. Sokolova (1974) the apple-blossom weevil damages that part of the crown where the buttons are suitable for the egg-laying; so in the years when the egg-laying process took place early the weevils mostly damaged the buttons from the south side of the crown, and in the years when the egg-laying process took place late the weevils damaged the crown from the north side.

The beetles lay the eggs into the buttons of a certain stage of development; so the egg-laying period lasts from 10 to 20 days. The optimum temperature for the egg- laying ranges from 12 to 15°C. During this interval the females realise the potential stock of the eggs as much as possible. The egg production of the females ranges from several to 80–100 pieces (Batiashvili, 1959; Drozda, 2000; Slavgorodskaia-Kurpiieva, 1993; Tertyshnyi, 1988).

According to the data of V.F. Drozda (2000) the lower pest fertility at high temperature is caused by a shorter egg laying period even if in the trees there are enough buttons in the corresponding phase of development. At high temperature the apple-blossom weevil lays fewer eggs not only because the females do not have time to lay off their entire stock due to the rapid opening of the buttons, but also because at high temperatures the normal course of the females' ovogenesis is disturbed. This was shown by the results of the preparation of the females in their lifetime while keeping them at different temperatures. The functional disorder of the female sexual system is observed already at a temperature of 20°C. It is also important that the female lay the most part of the eggs within the first 3–5 days. Too low temperatures during the egg-laying period also have a negative influence on the fertility of the apple-blossom weevil. Not only the maximum fertility but also an increase in the total pest number is revealed within the limits of the optimal temperatures (12–15°C). Under natural conditions the reproduction rate (the population growth rate) was 18,4 at a temperature of 12°C; at a temperature of 15°C it was 20,6, whereas at too low and too high temperatures this index was 7,3–9,1. This indicates that even under the extreme conditions the natural regulatory mechanisms do not significantly affect the number of the apple-blossom weevil.

According to the data of O.F. Nikolaieva (1973) the egg-laying into the green buttons begins in the phenophase of the apple tree flower-bud bursting at an average daily temperature of 10–11°C. The females prefer the early blossoming apple varieties such as White Transparent and Moscow Grushevka, in which the damage of the buttons reaches 50–80%. During this period they cause less damage to the pear trees (up to 2% of the buttons).

Before the phase of button separation some beetles may be ready to lay eggs even under the most unfavorable conditions. But the number of the eggs that they have laid depends on the external conditions, mainly on the course of blossoming. The experiments carried out at the Applied Entomology experimental station (Troitskii, 1925) showed that the daily maximum number was 5 eggs, and for the period of 28 days there were 36 eggs.

In Georgia the fertility rate of the apple-blossom weevil females reaches 30–100 eggs, but the entire stock of the eggs is realised during the prolonged spring, when the buttons of the apple trees open slowly (Okroshiashvili, 1996). According to the data of Ya.V. Chugunin (1935) each female lays from 50 to 100 eggs.

The experiments carried out by M.M. Tretiakov (1982) showed that the highest fertility of the apple-blossom weevil (40,5 eggs per female) was observed at a temperature of 15°C, and the lowest fertility (22,5 eggs per female) was observed at a temperature of 25°C; there was no egg-laying at a temperature less than 10°C.

Juveniles go to hibernation early (July – August) after feeding on the leaves of fruit trees. The fat body of the beetles is well developed, and the genitals are in a juvenile state and heavily entangled in the trachea. In the spring they need extra nutrition in order the ovaries become mature. The ovaries of the females became mature in 7–10 days when feeding in the chambers at a temperature of 10–11°C, but at a temperature of 5–6°C the maturation was delayed. During the experiments in the laboratory the egg-laying of one female was artificially interrupted after laying 20 eggs, and the female went to the second hibernation. The following year it continued the sexual activity and laid another 19 eggs. During the preparation of another female whose egg-laying was artificially interrupted but it continued to feed for another month, a highly developed fat body and "juvenile" ovaries were found. Thus, the ability of the apple-blossom weevil to have two hibernations and to the renewing of the interrupted sexual activity was experimentally demonstrated (Troitskii, 1925). M.M. Tretiakov (1982) also indicates the possible recurring hibernation.

So, in the absence of the appropriate buttons for laying eggs by the females of the apple-blossom weevil at the right time they go to hibernation and wait for the next spring, when they can lay eggs again. In such a way the preservation of the species is secured. The appearance of the weevils on a mass scale after a year of poor blossoming of the apple tree is explained by the fact of double hibernation (Triapitsyn, 1982).

V.A. Vasiliu (1998, 1999) observed the behaviuor of the apple-blossom weevil imago during the day and noted that in the morning and early in the afternoon they were on the peripheral part of the crown, and late in the afternoon, when the air temperature reached more then 20°C, they migrated to the shadow central part of the crown. At the same time the ability of the apple-blossom weevil female to lay eggs was reduced as the result of the insignificant damage of the buttons in the central part of the crown in comparison with its peripheral part both under the thickened and thinned crowns (Vasiliu, 1998, 1999).

During the egg laying the female makes a hole in the button, eats away its sepals and petals, then turns around and lays one egg in the middle of the button, and then closes the hole with its excrement and bites as if a plug (Chugunin, 1935). M. Shcherbynovskyi (1925) notes that the female always carefully examines the young buttons; and if the egg has already been laid into the button, the other female never lays another egg into the same button.

The egg is usually placed between the stamens and the pistils and sometimes between the anthers. The egg-laying continues until the phenophase of the buttons staining. The embryonic development of the egg lasts from 3 to 10 days, depending on the temperature (Chugunin, 1935), but it can be delayed up to 20 days (Borisoglebskaia, 1977; Vasiliev, 1984; Savzdarg, 1956; Tertyshnyi, 1988).

In Georgia the beginning of the egg-laying period was observed at the beginning of the button separation in the pear trees of the Beurre Bosc variety. The egg-laying lasts until the beginning of the apple tree late-ripening varieties blossoming. The beetles that came out of the hibernation places later lay the eggs into the buttons of the quince-tree which blooms later than the other fodder plants. In general the egg-laying by the apple-blossom weevil is noted into the buttons of the apple, pear, quince, cherry, sweet cherry and some other species (Batiashvili, 1959).

After leaving the egg the larva feeds first on the anthers and only after casting the coat it begins to destroy the stamens and pistils completely. From this time the larva becomes very voracious and secretes a large number of excrement which glues the petals of the button and thus does not allow them to open. If the egg is laid late, namely in the phenophase of the button opening, then the larva does not have time to glue the petals with its excrement, and the button is opening. In this case the larva is killed by the direct sunbeams. After the larva has glued the petals, it eats away the contents of the buttons causing the petals to deprive of nourishment; they become brown, dry and form the caps. The damaged buttons do not open; they become well visible against the background of the apple tree blossoming (Borisoglebskaia, 1975, Chugunin, 1938).

V.V. Vassiliu (1999) and B.M. Litvinov (2004) noted in their works that the ovary can be formed from the buttons damaged by the larvae. The share of such ovaries reached 2–3% of the total number of the damaged buttons. But after a while such ovaries fell off.

In the early and hot spring, when the air temperature reaches 20°C during a week period, the buttons simultaneously and relatively quickly open, and the larvae do not have time to glue the petals and fall off to the ground, but due to the lack of legs they are not able to get back to the tree; as a result they die and in such a way reduce the number of the pests (Batiashvili, 1959).

Light frosts do not influence the apple-blossom weevil larvae and they successfully complete the development even in the buttons of the apple trees damaged by the frost.

The larva of the apple-blossom weevil casts the coat twice, i.e., it has three ages. The total life expectancy of the larvae from the egg stage to the pupal transformation varies from 15 to 20 days. Before pupation the larva frees oneself from the excrement and glues the button even more tightly (Figure 5). The mass pupation of larvae takes place during the end of the apple tree blossoming. The pupal stage usually lasts from 7 to 12 days (Zabrodina, 2006, 2007; Vasiliev, Degtiarova, Shestopalova, 1976; Chugunin, 1935).

**Figure 5.** Larva of apple-blossom weevil in a damaged button (photo by the author).

As V.P. Vasiliev (1961, 1984, 1988) notes the pupal stage at a temperature of 14–18°C lasts 9–11 days, and at a temperature of 22°C it lasts 6 days.

It takes 10–18 days on the average to develop the larvae in Belarus. The mass pupation of the larvae is dated to the end of the apple-tree blossoming. The beginning of pupation under the climate of Belarus takes place 4–6 days after the end of the Antonivka apple variety blossoming. The pupal stage of the apple-blossom weevil larva lasts up to 12 days (Bezdenko, 1958).

If the cap is removed from the damaged button, then the larvae or pupa could be seen on the receptacle; when touching, they start to move vigorously demonstrating their viability (Borisoglebskaia, 1977).

Unlike the larvae the pupa of the apple-blossom weevil has all the organs of an adult insect, but they are in the embryonic state. Before the juvenile leaves the pupa its proboscis and head become dark in colour (Kolesova, 1996; Savkovskii, 1990; Chugunin, 1935). When leaving the pupa the juvenile has a yellow colour for 2–3 days. By the time the coverings become dark and hard, the beetle stays in the button and then bites a round hole with a diameter of its body width and goes out (Bezdenko, 1958).

In the Forest-Steppe zone the beetles' coming out begins in the third decade of May and ends in the first decade of June (Vasiliev, 1961; Savkovskii, 1990).

Each stage of the apple-blossom weevil development needs a certain sum of effective temperatures (SET). Thus, the egg laying begins at SET of 38–50°C, larval revival – at 80–85°C, and pupation – at 194–206°C; the complete cycle of development ends at 373–382°C (Nikolaieva, 1973).

The biological cycle of development from the egg to imago lasts 25–35 days, and in the years with cold and rainy spring it lasts 35–50 days. If we add the period of 10–15 days, which precedes the egg-laying, then the complete cycle of development lasts up to 35–50 days, and under the unfavourable conditions it lasts up to 65 days (Sevesku, 1966).

The revival of the beetles new generation takes place during the phenophase of throwing down of redundant ovary of the apple tree (Bezdenko, 1958; Sorochinskyi, 1998).

In some years the coming out of the apple-blossom weevils coincides with the revival of the larvae of the oyster-shell bark louse and the beginning of the first butterflies of the codling moth revival, and this fact should be taken into account when organizing the protective measures to control the adult beetles of the apple-blossom weevil (Bezdenko, 1958).

After the revival the beetles feed on the leaves. They skeletonise the leaf parenchyma, and as a result the leaves become dry. The beetles also feed on the fruits making numerous pricks in them. The weevils partially fly to the borders of the orchard or populate in the orchard trees, and even in those trees that have not blossomed this year. At an average daily air temperature of 23–25°C they fall into a state of summer diapause (temporary rest). The period of such rest for the apple-blossom weevil lasts till the end of the summer. At this time it sits almost motionless under the bark and only with the beginning of the leaf fall, when the temperature lows significantly, migrates to the hibernating places (Bezdenko, 1958; Vassiliu, 1999; Vasiliev, 1984; Yevtushenko, 2008; Zabrodina, 2008; Chugunin, 1950; 1954).

The repopulation of the apple-blossom weevil takes place during the nourishment period of the juveniles. At the end of the nourishment the apple-blossom weevil leaves for the diapause and hibernation and temporarily places under the old dead bark. In the autumn, when the weather is cold, the beetles already crawl out of the bark to hibernate in the soil or in the litter; and at this time the beetles no longer fly, but crawl along the trunk moving into the soil. This indicates that the movement of the beetle into the soil from the trunk and boughs is a secondary fact which was formed under the conditions of the severe north climate. The data of the experiments carried out by Ya.V. Chuginin (1950) at the state farm "Novinki" of the Gorky region for the period of 1925–1926 indicate that the beetle leaves the crown before the middle of July; and the analysis of the materials when using the trapping bands put on the trunks indicates that the beetles appear in the bands only in the first days of October. Thus, the author faced the problem concerning the location of the beetles during July, August and September. For this purpose the bark from the trunks and boughs was removed and then analysed. From the obtained materials it is seen that all stock of the beetle migrates under the tree bark at the end of the nourishment and remains there till the moment of passing on to hibernation. In the middle part of Russia the apple-blossom weevil migrates under the dead bark of the branches and trunk at the end of the nourishment and stays there for some time waiting for the cold weather, and then moves to the soil.

Ya.V. Chugunin (1950) carried out the similar experiments in the Crimea in 1938. The beetles moved from the crown under the bark of the trees where they stayed for hibernation but did not migrate into the soil. The soil and bark analysis conducted during the winter of 1938 did not confirm this data. The number of the beetles did not correspond to the stock of the apple-blossom weevil which was determined during the spring shaking off. The author did not notice the phenomenon of the beetles' movement from the tree trunk and boughs into the soil. In the Crimea the beetles stay in the places where they were after the end of the nourishment throughout the winter and only in the spring, with the beginning of the fruit trees development, the weevils begin to move from the hibernating places to the buds.

The same experiments were carried out by M.D. Yevtushenko and I.V. Zabrodina (2008, 2009) in the orchards of the Kharkiv region and as a result of these experiments the location of the beetles of the apple-blossom weevil under the bark during the summer diapause and hibernation and their ratio on the tree trunk, on the main boughs, in the soil and in the litter have been determined.

The question regarding the connection of the insect population cycles with the long-term dynamics of the solar activity is being discussed in domestic and foreign literature. The theory of the population dynamics cyclic character explains the regularities of the population autowave cyclic processes of development, functioning and change of the population structure in synchrony with the cyclic character of the external environment. The regularity in the solar activity changes and the cyclic character of mass reproduction of the main pests of the apple trees in space and time, as well as the availability of the historical materials on the population number outbreaks make it possible to predict the beginning of their next population cycles in a given region (Beletskii, 2008; Dovhan, 2009; Yevtushenko, 2005).

The mass reproduction outbreaks are known for many insect species. These outbreaks often develop synchronously in different regions of the globe testifying to the global cause of this phenomenon.

The mass reproductions of the apple-blossom weevil in Ukraine were noted in 1910–1913, 1922–1924, 1937–1939, 1956–1957, 1966–1968, 1986–1988, 1990–1993, and in 2002–2009 (Beletskii, 1987, 2008).

The apple-blossom weevil has always been considered one of the most dangerous pests of the apple trees. Its harmfulness increases especially during the years of poor yield, when the fruit buds are killed by the frost; and nowadays it increases especially in the orchards with no protective measures or where the application of the insecticides is limited. According to the scientific sources the damage caused by the apple-blossom weevil is significant if 70–80% of buttons are damaged during the normal blossoming and the damage of up to 50% of flowers is not economically noticeable. The most noticeable damage of the buttons is observed in the years with poor blossoming of the apple trees, as well as in the years with cool spring when the trees are budding slowly (Borisoglebskaia, 1975; Volodichev, 1974; Kudas, 2002; Shevchuk, 2006; Sevesku, 1966).

A.N. Kazanskyi (1915) calls the apple-blossom weevil a pest of the first-class. The apple-blossom weevil is undoubtedly one of the main causes of fruit-bearing periodicity, if it is not the single cause of it. If one female lays only 20 eggs during the egg laying period, then it will be sufficient to have even 50 females per tree in order they could cause 100% damage to the tree in the presence of 1000 buttons per tree. Considering that the number of the males and females of the apple-blossom weevil is approximately the same, so the population of 100 specimens per tree will be enough to destroy 1000 buttons. Usually the spring stock of the apple-blossom weevil in the orchard accounts to 200–300 specimens, and sometimes it reaches up to 500–600 specimens per tree. In the latter case the weevil can destroy the crop of the trees with moderate blossoming even in the fruitful years (Kazanskyi, 1915; Chugunin, 1954).

According to the literary data (Boldyrev, 1989; Vynnychenko, 1988; Volodichev, 1974; Matviievskii, Loshchitskii, Tkachev, 1987) the yield losses caused by the apple-blossom weevil often reach 100%, and this situation can be recurred from year to year.

The main harm to the apple plantations is caused by the larva of the apple-blossom weevil which feeds inside the buttons.

The question concerning the attitude of the apple-blossom weevil to the apples variety is of great importance from the point of view of the varieties characteristics and selection. It is well known that a tree produces many times more flowers than it can further hold the fruits (Grossheim, 1925).

The damage caused by the apple-blossom weevil cannot be determined by the proportion of the buttons damaged by it, because the apple tree yields no more than 20% of the useful ovary and throws down the remaining 80% as the excess which cannot be grown. In the Crimea the apple-blossom weevil causes especially significant damage in the valleys of the rivers Belbek, Kachi, and Karas. The damage to the buttons caused by it in the valleys of these rivers often reaches 90% and even 100% (Chugunin, 1938).

The shortage of nutrition as a factor affecting the size of the beetle is especially clearly revealed in the work of M.N. Nikolska (1926); from this work it is seen that the oppression of the buttons with *Psylla mali* Schm. leads to insufficient size of the beetles which has been found biometrically.

According to the data of Ya.V. Chugunin (1932) the apple-blossom weevil becomes a pest when the damage caused by it to the buttons reaches 70% and only if the damage reaches 85–95% then the yield will be lost completely. The apple-blossom weevil can be considered a pest only in some cases where the ratio of the flower stock and the number of the beetles lead to the complete destruction of flowers.

The strength of the button development is definitely closely related to the blossoming time and the duration period of this stage of buttons: the stronger the button, the earlier it begins to blossom and the shorter is the period of the button stage because the buttons are exposed from the buds almost simultaneously; but due to the fact that stronger buttons grow more intensive and quickly they begin blossoming earlier than the other buttons. It can be concluded that the weaker the button is, the longer it is in the button stage, and thus there is a risk of attack by the female of the apple-blossom weevil. Therefore, the weaker buttons are damaged more than the strong ones and the longer the blossoming period, the more damage is caused (Chugunin, 1932).

Yu. H. Mozhovyi (1932) came to the same conclusion. Since, regardless of the inflorescence structure, the largest proportion of damage falls on one of the lateral groups of the buttons, so the female does not “choose” the strongest buttons when laying the eggs; the female needs to place the entire stock of the eggs and its activity is limited by the short blossoming period. In this situation it is important only to have the buttons in the desired state. Therefore, the female uses the first button she can find among the slowly vegetating lateral buttons (Mozhovyi, 1932).

M.M. Troitskii (1925) informs that under any average damage to the buttons in the tree there are both severely damaged inflorescences, including the inflorescences with totally damaged buttons, and slightly damaged ones; and even there are absolutely undamaged buttons. To determine the degree of damage caused by the pest it is necessary to know the nature of the damaged buttons distribution according to the inflorescences. In fact the number of the undamaged inflorescences is much larger than that of the damaged buttons because the females quite often lay the eggs into two adjacent buttons at the same time which leads to an increase in the proportion of the completely damaged inflorescences and this happens in 25% of cases (Troitskii, 1925).

Having considered the materials about the importance of the apple-blossom weevil in the periodicity of fruit-bearing and having analysed these materials from the point of view of the fruit tree biology, in particular the apple trees, Ya.V. Chugunin (1950) came to the conclusion that the apple-blossom weevil should be considered as one of the most harmful insects in horticulture. Causing damage to the buttons by 50–100% during the years of poor yield, the weevil destroys the potential crop yield completely. During the productive years it either destroys the yield completely when the trees are heavily populated (500–600 specimens/tree) or reduces it to scanty sizes. In the years of weak blossoming the proportion of the populated buttons can be taken as the rate of harmfulness of the apple-blossom weevil; thus the decline in the yield level caused by the apple-blossom weevil under these conditions is equal to the proportion of the buttons populated by it. Thus in the presence of a small number of flowers the proportion of the useful ovaries often reaches 70–80%. It means that 3–4 fruits could be produced from each of the five flowers damaged by the weevil; and these fruits could ensure the rich yield at the expense of increasing their size (Chugunin, 1950).

In nature there are the appropriate adaptations of the development stages of *Anthonomus pomorum* L. to the time of the apple-tree blossoming and their study is of practical interest. One of the task of the researches carried out by T.M. Ritus-Potapova (1928) in the orchard of the A.K. Timiriazev Agricultural Academy was to clarify the question of how different varieties of the apple trees respond to the damage caused by the apple-blossom weevil and to determine the role of the meteorological factors in the rate of the apple-blossom weevil development and in the time of the apple trees blossoming. The author found out that all varieties of the apple trees exposed the buttons much later than the eggs of the beetle females had matured and that the exposed buttons of all varieties required more heat than it was needed for the sexual maturation of the weevils. Early- and late-ripening varieties can not avoid the damage even in the case when an interval in the time of the buttons exposure of some varieties would be significant. Usually the egg-laying by the apple-blossom weevil is extended depending on the meteorological conditions (Ritus-Potapova, 1928).

The harmfulness of the weevil changes depending on the condition of the fruit trees and the strength of their growth. More stable trees can produce bumper yield under the same amount of the preserved ovary, and the feeble trees will produce poor yield (Chugunin, 1954).

Most researchers consider the apple-blossom weevil as one of the dangerous pests of the apple trees. However, some authors (Chizh, Filiov, Havryliuk, Chukhil, 2008, Troitskii, 1925) believe that under the abundant blossoming this species may be useful normalizing the blossoming and fruit-bearing.

Other authors (Litvinov, 2004) consider such a statement to be false. According to their studies (absolute calculations) the yield capacity of the trees treated with the insecticides when controlling the apple-blossom weevil was higher by 50% than the yield capacity under the control even under the abundant blossoming of the apple trees. At the same time under the control the undamaged buttons prevailed over the fruits obtained from the yield about six times more. In this regard the researchers suggest that the apple-blossom weevil may have selectivity: the females prefer to lay eggs in the productive buttons. Therefore, it is impossible to rely on the apple-blossom weevil as a regulator of "blossoming and fruit-bearing" even in the case of the abundant blossoming of the apple tree. In addition the apple-blossom weevil greatly reduces the yield of fruits from the peripheral part of the crown. According to the experiments carried out by V.V. Vassiliu (1998) in this case the apple fruits harvested from the peripheral part of the crown significantly surpass the fruits harvested from the central part of the crown by the content of micro- and macroelements, vitamins and sugar and therefore they are more valuable.

The selective ability of the apple-blossom weevil regarding the buttons for the egg-laying is not directed towards the strong and most rapidly blossoming flowers but vice versa, it is directed towards the weak outer flowers of the cyme which surround the strong central flower and lag behind in development.

In addition in each cyme the apple tree has 5–6 flowers that do not open at the same time. At first the central flower opens and in 2–3 days other 2 and more flowers will join it.

There are also differences in the time of blossoming between the separate cymes. On the tops of the branches the cymes open earlier and they open much later at the base. This biological feature prevents from the slight lowering of temperature that is very common in spring.

In the regions where the early spring is changed by summer rapidly and abruptly the button stage of the apple tree is limited to 7–10 days while in the northern and highlands regions the stage of the buttons exposure extends to 3 weeks or more. Thus, the egg-laying period in these areas is 3 times longer (Aristov, 1932).

These conclusions are supported by M.T. Aristov (1926), who showed that the biological minimum of temperatures of the apple-blossom weevil and the apple tree coincides and reaches 6ºC. But regarding the apple-blossom weevil it corresponds to the curve of the maximum daily temperature course and regarding the apple tree it corresponds to the curve of the minimum daily temperature course. The maximum daily temperature reaches 6ºC for the period of 2–3 weeks before the minimum temperature reaches this degree. This fact gives the apple-blossom weevil an advantage because it can always be ready to lay the eggs.

In some orchards of the northern regions of Ukraine the density of the apple-blossom weevil population in the fruit trees was 50–70 specimens per tree and it was equal to 100% population. The uneven population of the orchards by the apple-blossom weevil caused a different degree of damage to the buttons, it constituted 0,18–42,5%. The lowest damage to the buttons (0,18–0,2%) was found in the young orchards treated with the pesticides and in which there were the trees with the thin-story crown shape under the turf covering and without it. There were not much more damaged buttons in the young orchards shaped as palmate. In the old orchards the share of the damaged buttons was much higher (2,4–5,4%) and only in some parts it reached 10%. The maximum damage to the buttons was noted in the orchards which did not undergo the chemical treatment; and it reached 42,5% in the first three rows located near the forest. The population of the buttons in the eighth-tenth rows was 2%. The reason for the intensive population of the first rows is the migration of the beetles from the hibernating places (Matviievskii, Loshchitskii, Tkachev, 1987).

A.M. Sokolov and R.M. Sokolova (1974) note that when determining the resistance of the variety to the apple-blossom weevil, the degree of the generative organs development should be taken into account not only in the crown of the tree, but also in the inflorescence cyme and it should be compared with the course of egg laying by the weevil under given meteorological conditions. The morphological features of the inflorescence, namely the density of the cyme and buttons and the pubescence of the sepals are also important (Sokolov, Sokolova, 1974).

In the years of mass reproduction of the apple-blossom weevil the losses can reach up to 80–90% of the crop yield in the centres of damage unless the protection measures from this pest are carried out. The proportion of flowers damaged by the weevil can reach up to 95% as for the apple trees and it can reach up to 4–5% as for the pear trees depending on the intensity of the damage. The apple plantations located near the forests are damaged most often (Lanak, 1972).

Damaging the buds, buttons and leaves of the apple and pear trees the apple-blossom weevil has caused great damage in Kirov, Bilohorsk and Simferopol districts of the Crimea, especially in the orchards adjacent to the forest where there were wild-growing apple and pear trees (Livshits, 1961).

During the unproductive years for the apple tree, the apple-blossom weevil partly places its offspring in the pear and cherry trees. But the cherry tree is not a favourable substrate for the larvae feeding, and the beetles turn out much smaller in size (Vitkovskii, 1926).

The harmfulness of the apple-blossom weevil in the Kiev region is manifested when 60% of the Jonathan variety buttons and 80% of the Snowy Calville variety buttons are damaged. Comparing the maximum fertility of the apple-blossom weevil (80 eggs per female) and the number of buttons, that is 2–3 thousand per the Jonathan apple tree variety which begins to bear fruit, 3–5 thousand buttons of 10 year-old tree of Snowy Calville variety and 5–10 thousand flowers of 12–25 year-old tree, the authors come to the conclusion that 17–30 females cause damage to 60% of buttons of the Jonathan variety, 30–50 females cause damage to 80% of buttons of 10 year old tree of Snowy Calville variety, and 50–100 females damage the 15 year old tree of the same variety. If to add that the sexual index of the apple-blossom weevil reaches 1,0:0,8 (10 females per 8 males) then the number of the beetles that could cause the above-mentioned damage would be even greater (Matviyevskii, Loshchitskii, Tkachev, 1987).

The researches of V.V. Volkodav and V.P. Konverska (2002) carried out under the conditions of the Research Centre "Variety" (town of Berezan of the Kyiv region) testify to the high number and harmfulness of the apple-blossom weevil. The pest development at low temperatures (7–8°C), the absence of the specialised entomophages and intensive migration contributed to its considerable abundance. Thus, during the phenophases of a "green cone" and "buttons exposure" the imago number was 35–47 specimens per 2 linear metres of branches. The damage rate of the trees caused by the apple-blossom weevil depended on the variety. The varieties "Tsyhanochka", "Fialka", "Vohnyk", and "Slava Peremozhtsiam" were the most resistant to the damage; their rate of damage was 5–7%. The varieties "King David", "Novosilkivske Zymove", "Ornament", "Radohost" and "Svitlytsia" (40–50%) were the most attractive to the pest. The damage rate of other varieties was 15–35% (Volkodav, Konverska, 2002).

According to Yu.P. Yanovskyi (2003) the apple-blossom weevil also reduces the yield capacity of the nursery-seed orchards by 24–40% and the seed yield by 24–70%. The beetle of the apple-blossom weevil destroys all the vegetative buds on the seedling in one day.

According to the researches carried out by V.F. Drozda (2001) the apple- blossom weevil causes considerable damage to the seedlings and rootstocks in the nursery fields, to the pistil of the vegetative propagated rootstocks, nursery-graft and especially to the nursery-seed plantations of the apple trees. In the absence of protection in the nursery one female destroys 97,9–100% of the

buds of the 2 year-old seedling a day; in the nursery orchards it causes damage to the buds and lays the eggs into the buttons of the apple tree, thus reducing the yield by 16,1–29,7%.
In the orchards of the Kharkiv region the apple-blossom weevil has destroyed the flowers of the apple trees in Ohultsi by 26,4%, in Krasnokutsk – by 23,0%, in Kupiansk – by 15–22%, and in Izium – by 9%, and it destroyed the flowers of the pear trees by 3,3% in Ohultsi and by 16% in Krasnokutsk. The apple varieties were not damaged equally. Pepinka Lithuanian was damaged by 8% and White Transparent was damaged by 11,5% (Kamyshnyi, Soloviova, 1927).
For the last nine years the apple-blossom weevil has caused significant damage to the apple trees buttons in the orchards of the Scientific and Research Farm of Kharkiv national agrarian university named after V.V. Dokuchaiev. The greatest damaged was done to the Jonathan (81%), Boiken (77,5%), Titovka (81%) and Common Antonivka (62%) varieties (Zabrodina, 2002, 2007).
According to the data of Ye.Sh. Gamina (1991) this pest can damage up to 60–90% of buttons of the apple tree.
In the last two decades the harmfulness of the apple-blossom weevil has increased in several European countries (Hausmann, Samietz, Dorn, 2004). The maximum damage to the buttons is observed along the perimeter of the orchard, that is, in the rows that are closer to the forest belt (Gamina, 1991; Kashirskaia, 1991).
In Belarus (Bezdenko, 1958) the economic losses caused by the apple-blossom weevil are enormous. In some years it damages the buttons so much that during blossoming the trees seem to be burnt. However, these damages are not the same. It has been found out that the weevil causes the greatest damage during the years of the long spring development of the orchards.
The flowers in the apple trees of summer varieties are more damaged than those in the trees of winter varieties. In 1954 on the farm named after the Red Army in Belarus the summer varieties were damaged by 72%, and winter varieties were damaged only by 45%; on the farm named after Lenin the summer varieties were damaged by 80% and winter varieties – by 12%. When estimating the damage caused by the apple-blossom weevil it was found out that the share of the buds damaged by the beetles after their migration from the hibernating places reached up to 36,4% regarding the quickly-ripening varieties of the State Fruit Nursery and it reached 29,6% regarding the late-ripening Antonivka variety.
After the buds opening the leaves were eaten away along the edges by 50% or they had the holes. The damaged leaves developed significantly worse than the healthy ones (Bezdenko, 1958).
In the Orel region (Kryzhanovskii, 1974) during the extra nourishment period the beetles can damage up to 60–80% of the apple fruit buds and up to 80–90% of the pear buds, causing the death of more than half of the buttons; at the same time they greatly damage the apple varieties which have larger buds, namely the Brown striped, Borovynka and Common Antonivka varieties.
In the apple orchards of Moldova (Vynnychenko, 1988) the apple-blossom weevil also reaches a very large number and causes the considerable damage.
According to A.P. Yakymchuk and M.M. Muten (2008) the decrease in the number of chemical treatments in the apple orchards of Moldova in recent years has led to an increase in the number of the apple-blossom weevil, previously considered a minor pest. For example, in 2003 the apple-blossom weevil which number was above the threshold was found in the area constituted 53,3% of the inspected 11,9 thousand hectares. In some foci the apple-blossom weevil damaged 60–80% of the buds.
Under the conditions of Dagestan (Batiashvili, 1959) the apple-blossom weevil also damaged the apple tree most severely, it damaged the pear tree to a less extent. The zone of the greatest damage covered two natural zones: the Northern and Southern Mountain ones. In some areas of this zone the damage caused by the apple-blossom weevil reached up to 90% (the Khunzakh district).
In the Transcaucasus in general and in Georgia in particular the apple-blossom weevil is a common pest. In some years, especially in the unproductive ones, it caused great losses of the apple and pear crops (60–80% on the average), usually in the places where no effective measures of protection have been carried out (Batiashvili, 1959).
In Lithuania in 1968–1969 the larvae of the apple-blossom weevil damaged 20–25% of the apple flowers and 33% of pear flowers (Livshits, Petrushova, 1979).
The weevil caused the greatest damage in the northern regions of the apple cultivation in the cold spring when the blossoming was delayed and the females had time to lay off their entire stock of the eggs. In such years the apple-blossom weevil can destroy more than 70% of buttons. The damage caused by it is especially dangerous in the years with poor blossoming of the apple trees (Zhemchuzhyna, Stepina, Tarasova, 1985; Rilishkene, Zayanchauskas, 1985).
In Bosnia and Herzegovina the apple-blossom weevil damaged up to 100% of the apple buttons (Batinica, 1958).

## Conclusion

The analysis of the literary data indicates that despite the considerable number of the literary sources devoted to the apple-blossom weevil, there are still a number of its biological and ecological features which are in close connection with the protection measures for controlling it and these measures have not yet been completely clarified. In particular the relationship between the phenology of the apple varieties of different periods of ripening and the period of egg-laying, as well as between the period of summer diapause of the pest and its concentration places during both the summer diapause and the hibernation remains unclear. There is no data on the density of the hibernating beetles of the apple-blossom weevil under the dead bark on the trunks and boughs, in the surface layer of soil and plant litter of the crown projection per apple tree; the knowledge of these facts would allow to calculate the pest density in the next spring in order to protect the apple trees before blossoming.

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