



Review Article

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# Insect Pests in Forage Crops and Integrated Plant Protection



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## Abstract

This paper describes key insect pests in common legume forage crops in Bulgaria and approaches for integrated protection system. About 10 insect species limit alfalfa production. The first four species are the most common insect pests of alfalfa in order Coleoptera - *Hypera postica* Gyllenhal, species of *Sitona genius*, *Apion seniculus* Kirby, and *Otiorrhynchus ligustici* L. The next species belong to orders Hemiptera and Thysanoptera. The leaf aphids (order Hemiptera, Sternorrhyncha: Aphidodea) occupy a special place as alfalfa pests. They appear annually in high density and can quickly cover large areas. *Therioaphis maculata* Buckt. is the main harmful species, as considerable part had *Acyrtosiphon pisum* Kalt. Ones of the most important pests belong to the order Hemiptera - Heteroptera, as serious and dominant insect pests are *Adelphocoris lineolatus* Goeze and *Lygus rugulipennis* Poppius, and subdominant species was *Piezodorus literatus*. From order Hemiptera: Fulgoromorpha and Cicadomorpha economic importance species for alfalfa are dominant species *Empoasca pteridis* Dhlb. and *Agallia ribauti* Oss., and subdominant species - *Peragallia sinuata* M.R., *Philaenus spumarius*, and *Paraphlepsius irroratus* L., while from order Thysanoptera main pests are dominant species *Thrips tabaci* L., followed by subdominant species *T. atratus* Haliday.

Insect pest with economic importance in *Pisum sativum* are *Bruchus pisorum* L., *Sitona* spp., *Acyrtosiphon pisum* and, while in *Vicia sativa* - *Bruchus rufimanus* Boh. and *Tychius quinquepunctatus* L. In the European Union, including Bulgaria, a greater emphasis on Integrated Pest Management as part of agricultural policy may lead to innovations and environment-friendly and energy efficient technologies.

**Keywords:** Forage crops; Insect pest; Species; Integrated plant protection

## Introduction

Grassland agriculture emphasizes the importance of forages in livestock production and land management. Forages consist of any high-fibre plant material, other than threshed grain, directly consumed by livestock or harvested and preserved as livestock feed [1,2]. Forages occupy over half of the arable land area of the world [2]. Cultivated forages usually comprise grass and/or legume species and have several uses and forms. Species used for cultivated hay production are primarily perennials and include season grasses and perennial legumes. A few forage crops are annuals, such as annual rye grass, silage maize, and forage peas. Forage grasses have comparatively few major permanent insect pests, and forage legumes are also relatively pest free. There are several reasons for this, one of which is the presence of comparatively high levels of compensatory ability of plants [3].

Forage species composition varies with climate and usage. The major species of legume forage crops grown in Bulgaria are annual, or perennial species. They include alfalfa (*Medicago sativa* L.), forage pea (*Pisum sativum* L.), forage vetch (*Vicia sativa* L.) and others. Alfalfa is by far the most frequently grown legume forage crop worldwide, primarily because of its high feed value. Its longevity promotes a temporal stability rarely seen in other agricultural systems and provides the opportunity for

the development of a diverse arthropod community structure [4]. Because of the environmental stability of *M. sativa*, insect communities within them also tend to be stable.



Figure 1: Map of Europe.

Insects are important components of forage production systems as direct competitors for forage resources and as pollinators essential for propagation of some forage species. This paper describes common insect pests in common legume forage crops in Bulgaria and approaches for integrated protection system. Studies were carried out in period 2001-2016 in the first

experimental field of the Institute of Forage Crops - Pleven (N 43° 23,312'; E 24° 34, 856'; altitude - 230m) (Figure 1).

**Discussion**

About 10 insect species limit alfalfa production in Bulgaria. The first four species discussed in the following case studies are the most common insect pests of alfalfa in order Coleoptera. The next species belong to orders Hemiptera and Thysanoptera. The most predominant in the total population of insect pests at the earliest and most critical stages of plant development are nodule-feeding weevils of *Sitona genus*, *Phytodecta fornicata Brugg* and *Opatrum sabulosum L.*, which attacked the alfalfa seedlings, roots, and young plants [5]. Important and permanent insect pests causing damage from Coleoptera in the next stages from alfalfa development are *Hypera postica*, species of *Sitona genus*, *Apion seniculus*, and *Otiorrhynchus ligustici L.*, which belong to family *Curculionidae* [6] (Figure 2).

yield, quality, and stand health (Figure 3A & 3B). Weevil damage is typically concentrated on the first cutting of alfalfa, but the impact of weevils on the first cutting can negatively influence vigor of the second cutting. Weevil seasonal dynamics is characterized by a high participation in spring, which coincides with the development of the first cutting of alfalfa (Figure 4).



Figure 3B: Alfalfa weevil larvae.



Figure 2: Alfalfa.

**Hypera postica gyllenhal**



Figure 3A: *Hypera postica* damage to first cutting alfalfa plant.

Dominant and most important species in lucerne is alfalfa weevil, *Hypera postica*, which occupies 69.6% on average of the total population density of species of the order Coleoptera [6]. Alfalfa weevil larvae defoliate plants and their feeding reduces

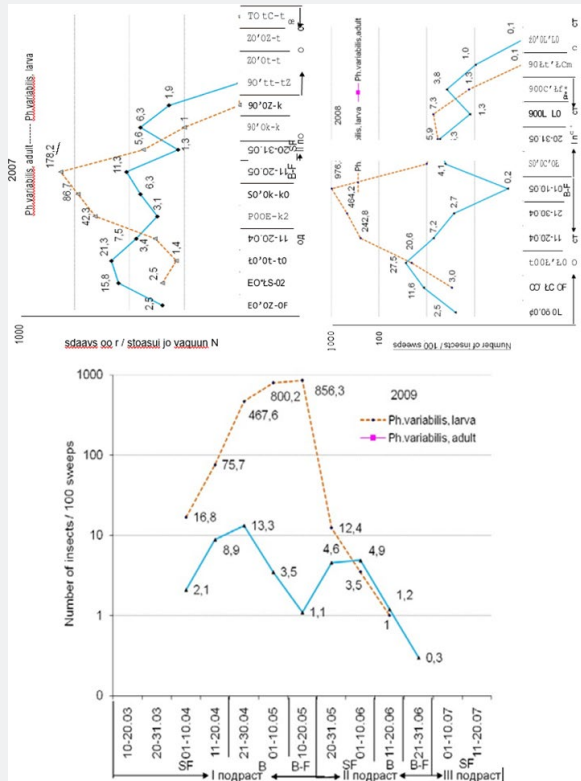


Figure 4: Seasonal dynamics of *Hypera postica* in alfalfa. SF: Stem formation; B: Button stage; B–F: Button and flower stages

Overwintering weevils appear in alfalfa in the second decade of March in to the first ten-day period of April, when the plants are in the stem development stage. The earlier occurrence of the weevil in the alfalfa stand is established in years with higher average daily temperatures during March (above 9 °C), which activates adult insects earlier, like 2008. The lower average daily temperature

in March (under 7 °C) is related to the later occurrence of insects (like 2009). The adults of *H. postica* reached the maximum of numerical dynamics in early April. Depending on the weather conditions over the years, the peak values range from 13.3 to 27.5 number adult individual/100 mowing. After harvesting the first growth, the weevil numbers suddenly decreased in the range of 0.1 - 5.9 number adult individual/100 mowing. Adults of the new generation are established in June in the stage button - beginning of flowering. The larvae appearance is observed at the end of March. Their density increases in the third ten-day period of April and the first ten-day period of May, when the alfalfa is in button stage. The maximum value of larvae is recorded at the beginning of flowering before the first harvest, which ranged from 178.2 to 976.3 number larvae individual/100 mowing over the years.

Comparing *H. postica* quantitative participation over the years, a significant increase was found in pest density in the third and fourth year of alfalfa growing for forage and the alfalfa weevil occupies 80.7% of the total population density of Coleoptera species.

**Sitona spp.**

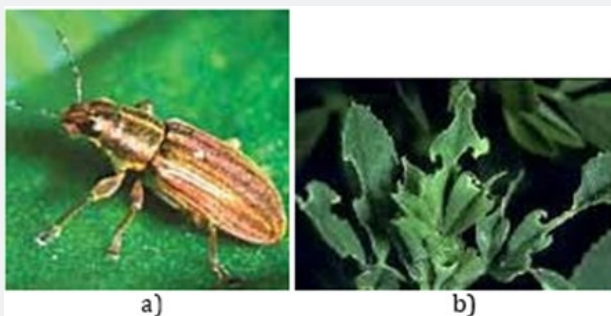


Figure 5: A: *Sitona lineatus*, adult; B: Damaged plants.

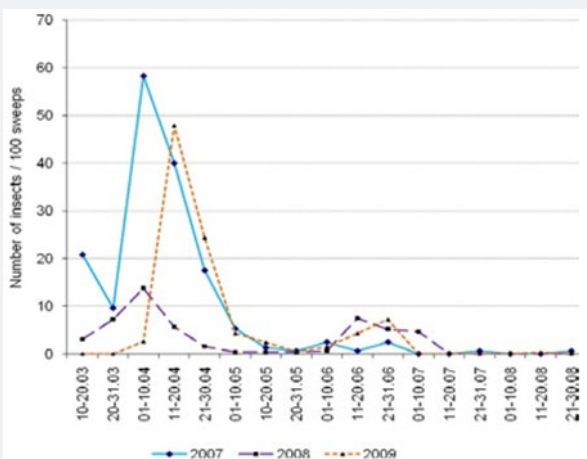


Figure 6: Seasonal dynamics of *Sitona lineatus* in alfalfa.

*Sitona spp.* is permanent subdominant insect pests in alfalfa biosynthesis (Figure 5). They occupy 5.7% of the total amount of Coleoptera order. The predominant species from of them is *Sitona lineatus*. Overwintering adult weevils beetles appear early in the spring, usually the second ten-day period of March

(Figure 6). Gradually, their number increased and peaked in the first growth in the first half of April (from 14 to 59 number adult individual/100 mowing), while in May and the beginning of June, they die. Adult weevils from new generation begin to appear in a higher density from the second half of June to the first ten-day period of July, which numbers varies in the range 2.5 - 7.5 number adult individual/100 mowing depending on weather conditions in the particular year.

**Apion seniculus kirby**



Figure 7: *Apion seniculus*, adult.

*Apion seniculus* is reported as a clover insect pest in Bulgaria by Popov and others [7], while in foreign literature species were reported as an alfalfa pest [8,9]. *Apion seniculus* is reported for the first time in our country as harmful species in alfalfa (Figure 7). The attack by the pest is found when harvesting the first cut. The species develops one generation and wintering as an adult weevil in the surface soil layer and under plant residues. Weevils damage alfalfa leaves as gnaw small holes, which have no practical importance. After copulation, female individuals lay the eggs at the base of the stem of the plants by gnawing dents in them. General damage is caused by larvae that develop and feed inside the stem by the gnawing of a thin oblong tunnel in the stem along it's length. The tunnels are clean and there are no excrements. As a result of the damage done to the plants they break and lodge. Similar picture of damage caused by this injurious insect was also reported by Roktanen [10] in clover. Overwintered weevils appear in alfalfa early in the spring in the first half of March (Figure 8).

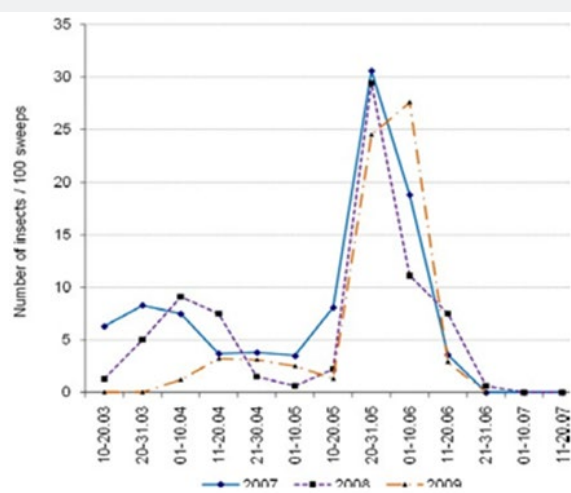


Figure 8: Seasonal dynamics of *Apion seniculus* in alfalfa.

The period of a mass do out of the pests from wintering places is in the third ten-day period of March and in the first ten-day



period of April. The beginning of the egg laying coincides with the period of stem formation in the first alfalfa growth and continues until the second or third ten-day period of June. A maximum in the number of *A. seniculus* is found in a first growth in the stages of stem and button formation (in the third ten-day period of May and the first ten-day period of June) when massively appear weevils from the new generation. The percentage of plants damaged by *A. seniculus* varied from 8.7 to 23.3% on average. The weevil density varies from 27.6 to 30.6 number adult individual/100 mowing depending on weather conditions over the years, after that, it decreases and in the second regrowth are established single adult individuals. The attack of *A. seniculus* was found primarily in the first harvesting of alfalfa. In the second harvest year of alfalfa, weevils damaged an average of 15.1% of the stems and in the third harvest year, it was 23.3%. The degree of damaged plants is gradually increasing and it is the highest in the third harvest year.

### Otiorrhynchus ligustici L.

*Otiorrhynchus ligustici* L. is widespread across Europe, including in Bulgaria. The species is a polyphag and causes serious damages on not only alfalfa, but also red clover; sainfoin, sugar beet, pea, vetch, vine [11-13]. The high population density disturbs strongly the density of alfalfa stands (occurs thinning) which impose their early plowing. Strongly attacked stands can be destroyed for one-two years and at a moderate infestation, the permanence of alfalfa reduces to two-three years [14,15]. The potential problems to host plants arising from a root attack by insects include: drought stress to the plant caused by pruning of the root system [16], loss of reproductive output [17] and an increase in the plant's susceptibility to infection by soil-borne pathogens [18]. Further, root-feeding by insects may directly reduce food reserves such as carbohydrates [19], synthesis of numerous growth hormones and plant stability, resulting in lodging [20].



Figure 9A: Damaged alfalfa roots by *Otiorrhynchus ligustici*.

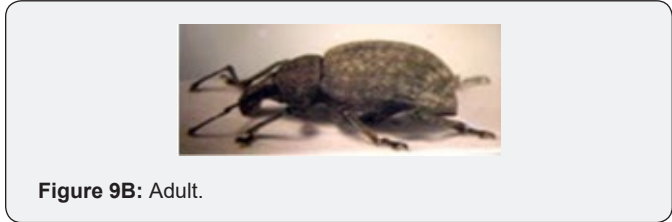


Figure 9B: Adult.

*Otiorrhynchus ligustici* (snout beetle) develops one generation per year and winters as imago and larva at depth of 30-40cm. Overwintered images gnawed leaves, buds and top parts of plants. These damages had no economic importance. The main damage was caused by the larvae, which gnawed deep longitudinal furrows on alfalfa roots and hindered it's (Figure 9A & 9B). In the year of the establishment of the stand (2006) there were no damages found on the root system of plants from O.

*ligustici*, only single furrows are established in the autumn regrowth. In the study period the percentage of damaged plants by pest increased on average from 23.9% in 2007 to 79.8% in 2009 [21]. The considered parameter was not enough precision to determine the degree of infestation by *O. ligustici*. It determined what part of plants had damaged root system but it did not reflect the degree of damage.

Table 1: The surface of damage on root system by *Otiorrhynchus ligustici* L. in alfalfa.

Varieties	Surface of Damage/10 Roots, cm2												
	2007				2008				2009				Average 2007-
	1	2	3	4	1	2	3	4	1	2	3	4	2009
Average	3.05	6.47	7.38	5.63	9.42	23.65	26.98	20.02	32.74	40.12	53.52	42.12	22.59

1- spring regrowth; 2-summer regrowth; 3-autumn regrowth; 4-average.

The main sign for determination of the degree of larva infestation by *Otiorrhynchus ligustici* on root system of plants was the surface of caused damage. The values of the studied parameter increased consistently over the years on average from 5.6 to 42.1cm<sup>2</sup> as during the last year of alfalfa growing the surface of damage increased almost eight times in compare with 2007 when the surface of damage was slightly expressed and because of low population density of pest (Table 1). Significantly, higher values were observed in 2008 as the larva damage increased nearly four times compared to the previous year. The largest surface and twofold increase of that parameter was found in the last year from the growing of stands.

During the years of study, the populations of *O. ligustici* were in the relations among themselves and were in relation to the age of alfalfa determined from the biology of culture. *Otiorrhynchus ligustici* wintered as adult and larva in the stands and with the aging of the stands, it's numbers increased respectively the surface of damage. Gnaws on the root system of plants in the spring regrowth were by overwintered larvae of *O. ligustici* which activated in the spring and feed to the moment of turning into a pupa (the second half of May and first half of June). In the next regrowths, the damages caused by the larvae were in significantly higher degree and due to the individuals from a new generation. The surface of damage increased in ascending order from the

spring regrowth to the autumn one on average by 130.6%. The most active was the feed activity of larvae in the summer regrowth when the surface of damage increased on average by 95.2% in

compare with the spring regrowth. At the autumn regrowth the value of analyzed parameter increased in less degree – average by 20.5% to summer regrowth.

**Table 2:** Density of furrows on the root system in alfalfa.

Varieties	Surface of Damage/10 Roots, cm2												Average 2007-2009
	2007				2008				2009				
	1	2	3	4	1	2	3	4	1	2	3	4	
Average	3.05	6.47	7.38	5.63	9.42	23.65	26.98	20.02	32.74	40.12	53.52	42.12	22.59

1- spring regrowth; 2-summer regrowth; 3-autumn regrowth; 4-average.

Another important parameter complementary the surface of damage was the number of gnawed furrows on the root system. In different years, it increased on average from 4.5 to 28.2 number/10 roots and during the study period, it increased six times (Table 2). The most expressed increase from the spring regrowth to the autumn one was observed in 2007 (nearly eight times) followed by two times increase in 2008 and one time in 2009. The degree of increase of the density of furrows decreased as simultaneously as the degree of increase of their length rose with the development of stands during different years. The length and number of furrows were complementaried each other parameters which influenced

complexly on the degree of damage but between them not always was observed directly proportional dependence.

**Leaf aphids**

The leaf aphids occupy a special place as alfalfa pests. They appear annually in high density and can quickly cover large areas. In addition to the direct damage that causes on plants (sucking plant juice, cause strongly deformations, drying and falling of leaves), they are infected with dangerous viral diseases. This increases their harmfulness and necessary to control them even if species are in low density [22].

**Table 3:** Species composition and abundance of the entomofauna of the order Homoptera-Aphididae in alfalfa.

Kinds	Mean Number of Individuals/100 Beats					
	2006	2007	2008	2009	Total	%
Homoptera-Aphididae						
<i>Aphis fabae</i> Scop.	21	101	0	0	122	6.3
<i>Acyrtosiphon pisum</i> Kalt.	52	80	429	2	563	29.2
<i>Therioaphis maculata</i> Buckt.	560	343	55	280	1238	64.4
<i>Macrosiphon avenae</i> F.	0	1	0	0	1	0.1
Total	633	525	484	281	1924	100



**Figure 10:** A: *Therioaphis maculate*; B: *Acyrtosiphon pisum*.

Order Hemiptera-Aphididae in alfalfa was represented by one family and four species, as spotted alfalfa aphid, *Therioaphis*

*maculata* Buckt. was with the highest participation to the total population density of aphids - 64.4% (Table 3) [23]. These are

the main harmful species. A considerable part had pea aphid, *Acyrtosiphon pisum* Kalt - 29.2%. Black aphid, *Aphis fabae* Scop. occupied a smaller proportion and belongs to the subdominant species. *Macrosiphon avenae* F was an accidental species, which participation was insignificant. *Therioaphis maculata* (Figure 10A & 10B) had the highest density in the first year (total 7918 number/100 sweeps) and second year (total 7768 number/100 sweeps) from the growing of alfalfa compared to the third year (total 990 number/100 sweeps) and fourth year (total 4128 number/100 sweeps) (Figure 11). In the population dynamics of *T. maculata* had two maximums in the density of species – during the first and second decade of June, when plants were in the flowering stage of second regrowth and the end of August to the middle of September mainly in the fourth regrowth of alfalfa. *Acyrtosiphon pisum* appeared in the highest population density from the middle of May to the middle of June and from the end of August to the middle of September depending on specific conditions of the year (Figure 12). The pest was in the highest numbers in the third (a total of 1744 number/100 sweeps) and second year (762 number/100 sweeps) of the cultivation of alfalfa compared to the first (397 number/100 sweeps) and fourth year (21 number/100 sweeps).

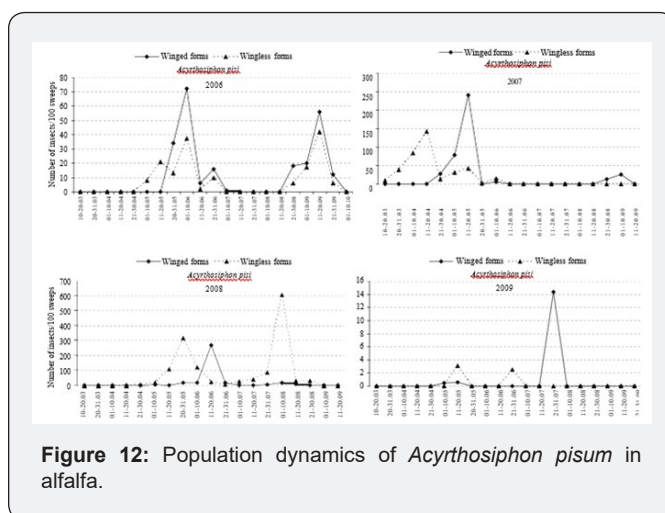


Figure 12: Population dynamics of *Acyrtosiphon pisum* in alfalfa.

The species of the order Heteroptera in Bulgaria in alfalfa crops were represented by 39 species of bugs, including 28 phytophagous and 11 predatory. Phytophagous species belong to 8 families and 21 genera, and predators - to 5 families and 6 genera. Serious and dominant pests were *Adelphocoris lineolatus* (29.7%) and *Lygus rugulipennis* (19.1%), and subdominant species was *Piezodorus literatus* (5.2%) [26].

**Adelphocoris lineolatus:** Goeze (Figure 13A) is a main pest of alfalfa. Imago individuals were found in alfalfa in the beginning of May at the beginning of the flowering stage of first regrowth (Figure 14). Their number increased significantly in the second half of the month and sharply reduced by harvesting. The first generation of alfalfa bug was in the highest density in the second decade of June in the second regrowth before decimation (from 10.6 to 36.3 number individual/100 mowing). The second generation of the bug developed in the third and fourth regrowth and reached maximum numbers in the third decade of July in the flowering stage of third regrowth, reaching 178.8 number individual/100 mowing (2006). The development of the second generation was long and large compared to the first generation, due to favorable climatic conditions and migratory individuals from neighboring areas.

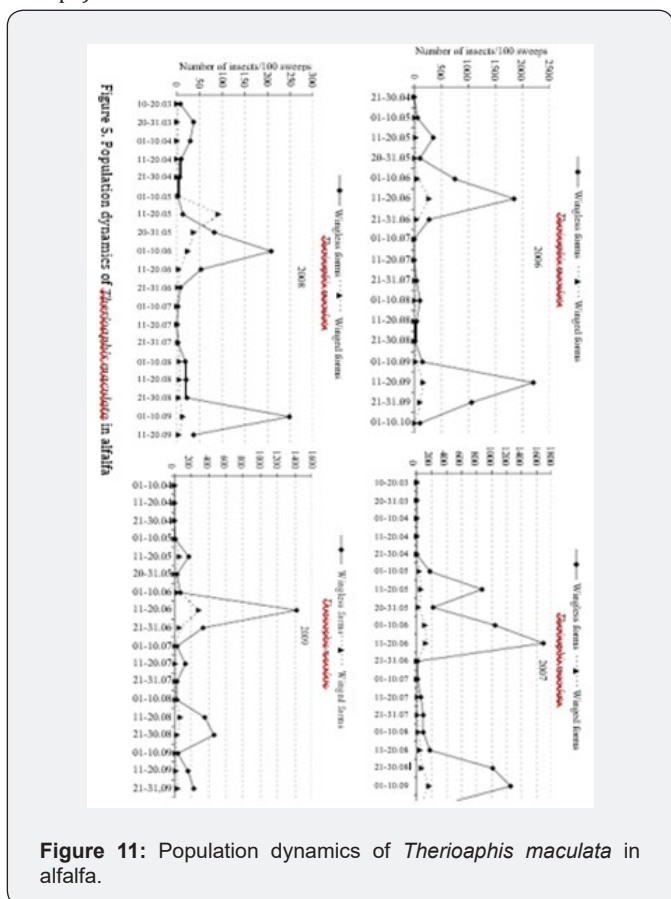


Figure 11: Population dynamics of *Therioaphis maculata* in alfalfa.

One of the most important pests belong to the order Homoptera - Heteroptera. Adult and larvae of plant bugs feed on the reproductive parts, resulting in premature abortion of the buttons and flowers, deformation of the seeds, and the decrease in their viability [24]. Adult individuals and larvae of the fourth and fifth age cause the most serious damage [25].



Figure 13: *Adelphocoris lineolatus*



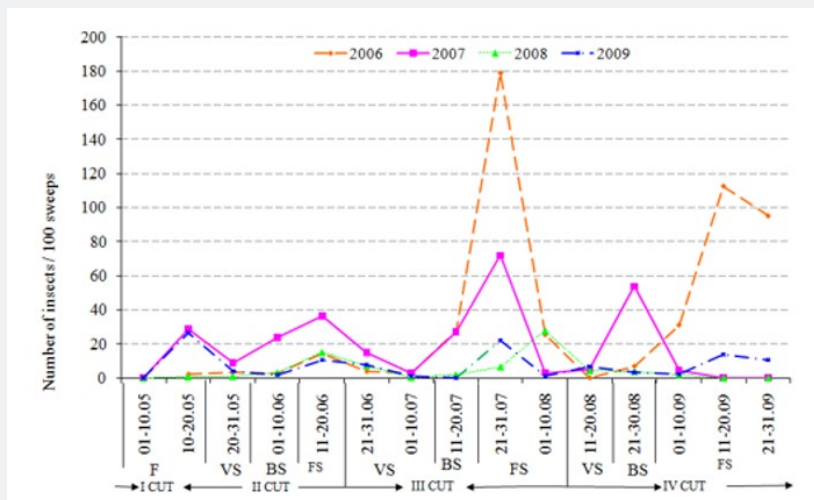


Figure 14A: *Adelphocoris lineolatus* Goeze.

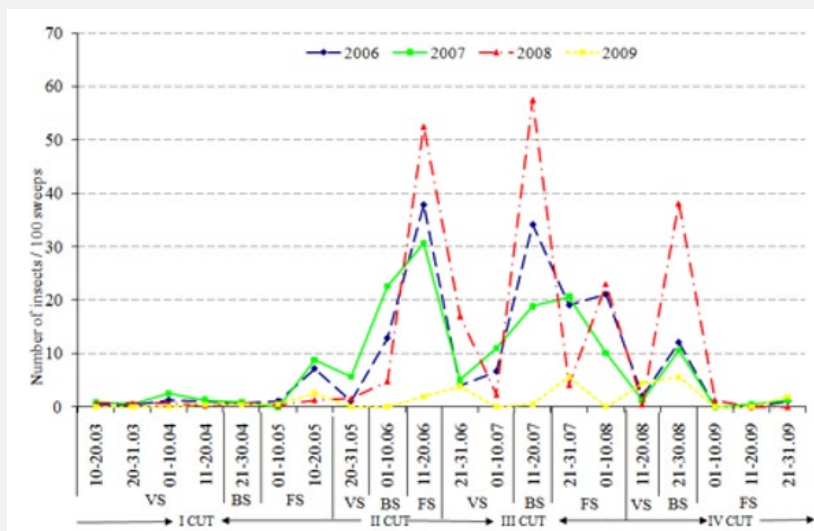


Figure 14B: *Lygus rugulipennis* Poppius.

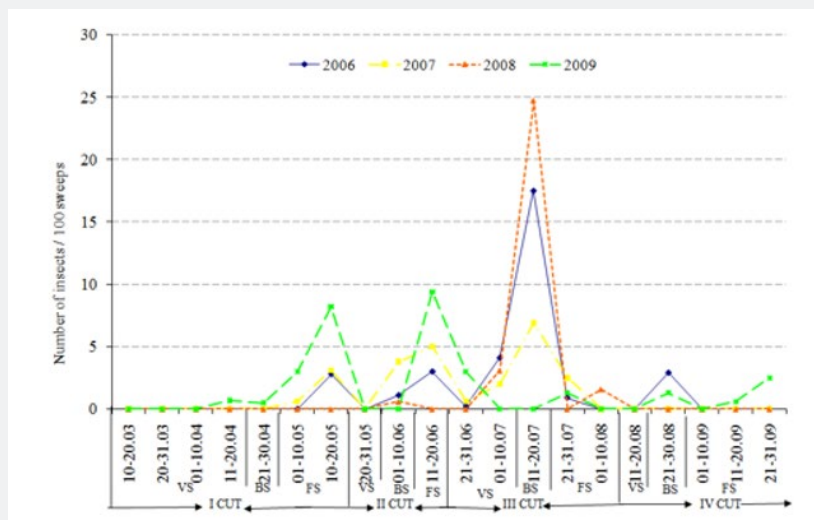


Figure 14C: *Piezodorus literatus* Fabricius.

VS: Vegetative stem; BS: Bud stage; F: Flowering stage.

Figure 14: Population dynamics of some harmful bugs in alfalfa forage.

***Lygus rugulipennis*:** Poppius (Figure 15A) is much broader polyphagous than *A. lineolatus* and is one of the most common and widespread pests. The species was found in crops in the second half of March, much earlier than alfalfa bug. His numbers were negligible from March to May in the first regrowth and at the stage of the vegetative stem of the second regrowth. The maximum density of the first generation was observed during the second decade of June in the flowering stage of second regrowth (from 1.9 to 52.5 number individual/100 mowing). The second peak in numbers was found in the second generation in the second decade of July in the third regrowth (from 0.5 to 57.5/100 mowing) and the values were similar to those of the first maximum. The bugs were detected in higher numbers in the fourth regrowth at the end of button stage and in the beginning of flowering in 2008.

*Piezodorus lituratus* (Figure 15B) appeared in alfalfa in the start of buttoning stage in the second half of April. The bug was observed in higher numbers in the second decade of May and June in flowering stage respectively of the first and second regrowth. The pronounced maximum was found in the second half of July, in the stage of the end of a button and in the beginning of flowering in third regrowth (from 3.0 to 9.4 number individual/100 mowing). Then the density remained insignificant. For the environmental conditions of Bulgaria, the most important harmful bugs in alfalfa belong to the family Miridae and Pentatomidae as in general harmful bugs were found in the highest number in the flowering stage of second and third regrowth respectively in the second decade of June and the second half of July.



Figure 15A: *Lygus rugulipennis*.



Figure 15B: *Piezodorus lituratus*.

**Cicadas (Order Hemiptera, Auchenorrhyncha):** Cicadas are pests that can cause serious damage and losses in the cultivation of crops, including alfalfa. Direct damages are related to eating by which cicadas suck juices from the tissues. That slows of plants. The pest causes mechanical damage by laying eggs. Some phytophagous are vectors of plant viruses and mycoplasmas and cause direct and indirect damages.

Order Hemiptera, Auchenorrhyncha was represented by 26 species that belong to 9 families and 22 genera [27]. The most diverse composition was family Cicadellidae, containing 14 species

and 12 genera. It had the highest part of the total population density of cicadas - 76.3%. Economic importance species for alfalfa were dominant and subdominant cicadas. Dominant species were *Empoasca pteridis* Dhlb. (22.0%) and *Agallia ribauti* Oss. (19.4%), subdominant species were *Peragallia sinuata* M. R. (13.6%), *Philaenus spumarius* L. (11.2%) and *Paraphlepsius irroratus* Groton (10.4%).

Image of *Empoasca pteridis* (Figure 16) in alfalfa appeared in the second half of March at the beginning of the vegetation period. Considerable increase in density was observed in the second



regrowth from button stage to flowering stage. Maximum density was observed in the second ten-day period of August at the stage of stem formation and the beginning of the button in the fourth regrowth. It reached 40.6 number individual/100 mowing, and

then sharply decreased. Larvae of the species were found in the second half of May to mid-June in buttoning and flowering stages of the second regrowth (Figure 17).



Figure 16: *Empoasca pteridis*.

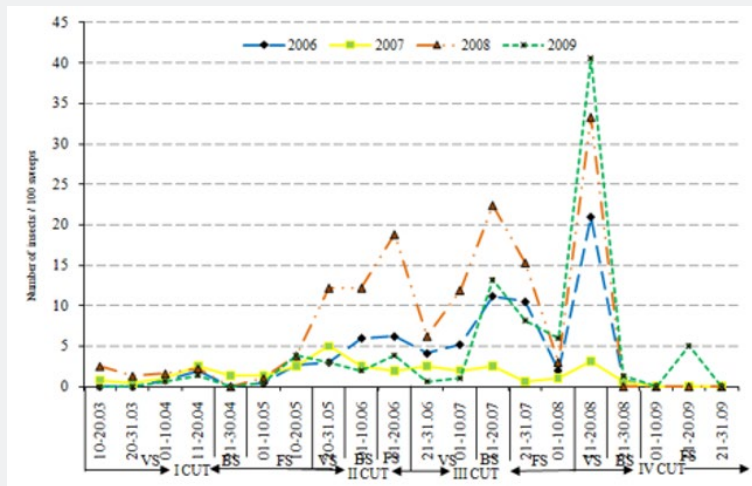


Figure 17A: *Empoasca pteridis*.

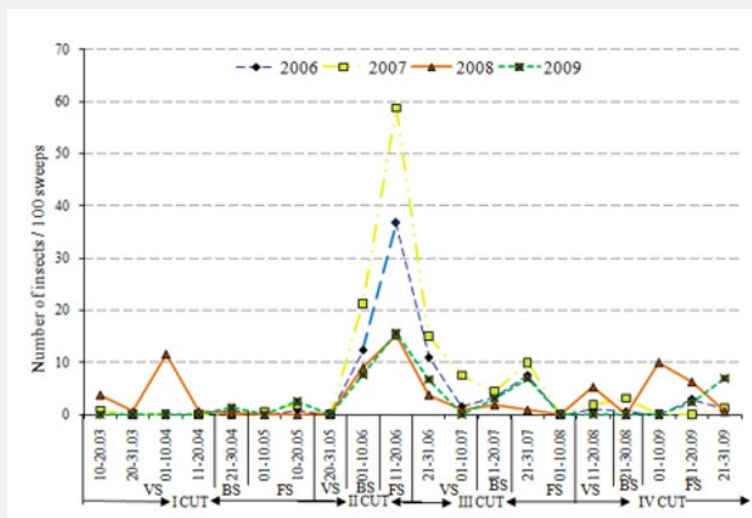


Figure 17B: *Agallia ribauti*.

VS: Vegetative stem; BS: Bud stage; F: Flowering stage

Figure 17: Population dynamics of some harmful cicadas in alfalfa forage.

*Agallia ribauti* (Figure 18) was found in all regrowth at the vegetation period of alfalfa with a pronounced maximum in the second decade of June in the flowering stage of a second regrowth. The numbers of cicada in this stage depending on weather conditions over the years ranged from 15.3 to 58.8 number individual/100 mowing. Relatively high numbers were observed in the buttoning stage. The density of cicada in other re-growths had been substantially lower and relatively high values were established at the end of June at the stage of stem formation in the third regrowth (3.8-15.0 number individual/100 mowing). In conclusion, common cicada fauna of alfalfa was significantly high participation in April, June, July and August, which was determined by the number of dominant and subdominant species when alfalfa grown for forage was most vulnerable to damage. *Paraphlepsius irroratus* was reported as a new harmful species, which cause damage in alfalfa.



Figure 18: *Agallia ribauti*.

### Thysanoptera

Thrips have piercing-sucking mouthparts through which they inject enzymes in plant parts and generate biochemical changes. Following thrips suck plant juices. Result of damage inflicted is deformation and wrinkling of the leaves, due to irregular growth around the area of damage. When nutrition is especially close to the central node, leaves turned and looked like a half open funnel [28]. Thrips damage induces not only reduce productivity, but they are vectors of virus diseases in plants.



Figure 19: Image of *Thrips tabaci*.

Order Thysanoptera was presented by 13 species from 3 families and 9 genera [29]. The harmful species occupied 54.0% of the total number of species, and predatory species – 44.0%. Main pests were dominant species L. with 37.4% participation, followed by subdominant species *T. atratus* Haliday - 9.7%. The highest percentage participation had the harmful species, *T. tabaci* (Figure 19) and depending on weather conditions during the study, it appeared in alfalfa crops in the second half of March to the end of September (during the entire growing season) - Figure 20.

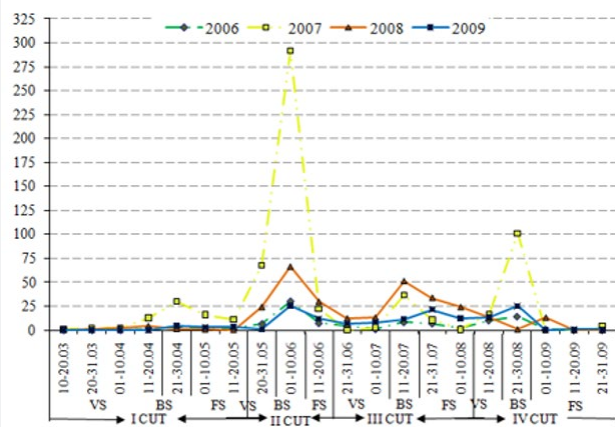


Figure 20: *Thrips tabaci*.

VS: Vegetative stem; BS: Bud stage; F: Flowering stage

Figure 20: Population dynamics of some harmful thrips in alfalfa forage.

The highest density was found in second regrowth from the second half of May to the second half of June. A maximum value was recorded in the first ten-day period of June at the budding and the beginning of flowering stages (from 25.5 to 291.4 number of individuals per 100 sweepings), which was related to favourable weather conditions. In the third and fourth regrowth species occurred in considerably lower number. The high temperature in July and August, combined with small rainfall amount suppressed the development and abundance of onion thrips. It was observed slight density increase in the second half of July and the second half of August at the budding stage and the beginning of flowering. Tobacco trips had a minor participation at the end of September. The population dynamics of species showed that the treatment against *T. tabaci* need to do at the end of May - the beginning of June at the budding stage in the second regrowth of the alfalfa (when the density exceeded the economic threshold level of pest populations).

### Lepidoptera

Important pests of the order Lepidoptera are *Agrotis segetum*, *Euxoa temera*, *Autographa gamma*, *Heliothis maritima*, and *Loxostege sticticalis*. Depending on the species, their caterpillars cause substantial damage, gnaw the foliage and plant generative parts. The presence of *Heliothis maritima* is more frequent in alfalfa grown for forage. Given that the caterpillars from the fourth age onwards feed on the generating parts of plants and seeds, and alfalfa is cutting for hay, the species do not endanger the plants.

### Insect pest in *Pisum sativum*

*Bruchus pisorum* L. is one of the economically most dangerous pea pests in the environmental conditions of Bulgaria. The pea weevil is distributed widely across Europe and all countries where field pea is grown [30]. It spread from one country to another mainly through weevil-infested seed materials, export trade, germplasm exchange, etc. Biology of *B. pisorum* and its harmful activity has been studied by many Bulgarian and foreign authors [31-39]. Many authors found that pea weevil could cause enormous damages, reducing the grain yield by 40% or more [40-42]. Everywhere in the world, the insect pest has one generation per year and hibernates like an adult insect inside the seeds in storage or in the field, under dead leaves or under the bark of trees. The larva that destroys most of the grain during its full development, whereupon it also affects the embryo, causes injury. Damaged seeds have a low germination percentage and are not suitable for sowing.

The pest is established at the highest density in the stage of flowering and pod formation [43]. Result of damage by *B. pisorum* in seeds with parasitized larva was significant decrease of the germination by 16.4% percentage points, the length and weight of primary radicle by 17 and 25%, the length and weight of plumule by 12 and 14%, the vigor index of primary radicle and plumule by 33 and 32% as well as the germination index by 17% [44]. The inhibitory effect was on average 18%. Essential significant changes in regard to the studied parameters were found for damaged seeds with bruchid emergence hole. In these seeds, the germination, the length, and weight of primary radicle, the length and weight of plumule, the vigor index of primary radicle and plumule, as well as the germination index, decreased considerably. The inhibitory effect was on average 58%. It was found that the damaged seeds with parasitoid emergence hole provided the better possibility for of plants whereas the damaged seeds with bruchid emergence hole had significantly low germination, vigor and sowing characteristics. These seeds could not provide the establishment of a well-garnished stand and stable yields. The result of the harmful effect by pea weevil was increased quantity of crude protein, crude fiber, and phosphorus in the seeds [45]. *Tychius quinquepunctatus* L., nodule weevils of genus *Sitona*; pea aphid, *Acyrtosiphon pisum* Harris and Tobacco thrips L. are others insect pest with economic importance (Figure 21) [43].



Figure 21: *Bruchus pisorum*.

### Insect pest in *Vicia sativa* L.

*Bruchus rufimanus* Boh. and *Tychius quinquepunctatus* L. in common vetch are the main species of order Coleoptera, which damaged seeds and represent 15.4 and 9.1% respectively of the total population of the found harmful coleopterous species [46]. The population density of *Bruchus rufimanus* (Figure 22A) was the highest in the second ten-day period of June at the stage of full pod formation. Depending on the weather conditions, the abundance of the insect pest during the growing season varied from 6.2 to 120.0 individuals/20m<sup>2</sup>, the degree of damaged seeds from 1.3 to 24.6% and the decrease of 1000-seed weight from 3.8 to 29.6%. *Tychius quinquepunctatus* (Figure 22B) had the greatest abundance in the second and third ten-day period of June with the beginning of milky ripeness of lower pods. The weevil density during the growing season varied from 10.2 to 199.4 individuals/20m<sup>2</sup>, the degree of damaged seeds from 0.6 to 16.0% and the decrease of 1000-seed weight from 4.8 to 35.9%. The larvae of *B. rufimanus* caused greater damages to the seeds of common vetch.



Figure 22A: *Bruchus rufimanus*.



Figure 22B: *Tychius quinquepunctatus*.

*Sitona lineatus* L. (Coleoptera: Curculionidae) is an important pest of field vetch in Bulgaria. Defoliation by adult weevils can account for losses of up to 50% of photosynthetic tissues, limiting the ability of plants to reproduce and support root nodules [47]. Yield losses of up to 28% were attributed to decreased pod production [48]. Larval damage to root nodules can range from



40 to 98% of nodules [49]. These weevils cause damage and major loss of seedlings, reduce stand vigor and vetch plant longevity [50].

The biological cycle and food activity of *S. lineatus* were closely related to the phenological development of vetch plants. Pea weevil migration and density variations directly depend on weather conditions as a high density of overwintering weevils are mainly observed in the early spring [51]. The activity of the weevil was much higher and sustained in June. In this month, the low relative humidity and rainfall (about 70% and 14.0mm) and combined with higher temperature had a positive effect on the weevil activity and sexual maturation [52]. The highest numbers were observed in the first and second ten days of June, averaging from seven to sixteen individuals 10m-2.

**The sucking pests in common vetch were represented mainly by two orders:** Hemiptera with two suborders: Sternorrhyncha and Cicadomorpha and order Thysanoptera. The family Aphididae with a major species *Acyrtosiphon pisum* Harris represented Sternorrhyncha, while Cicadomorpha included species of the family Cicadellidae. Order Thysanoptera, suborder Terebrantia was represented mainly by species belonging to the family Thripidae. Under favorable conditions, insect pests of these orders may exceed the economic threshold of harmfulness and cause serious damage to vetch plants.

### Integrated insect pest control in forage crops

Searching for new active factors having an effect on the plant productivity is a major trend in world agriculture [53]. Promising direction to increase the plant production is the use of pesticides in combination with growth regulators, leaf fertilizers, and biostimulants [54]. Often under simultaneous application of growth regulators with nutrient elements and pesticides, the positive effect on the yield was higher [55,56]. For example, the used biologically active substances Atonic (growth stimulant) - 0.06 l/da, Masterblend (combined leaf fertilizer) - 160g/da and Confidor 70WG (700g/kg imidacloprid) - 15g/da (an insecticide, used alone and in combination, had a positive effect on the grain formation in spring forage pea [57]. The yield increase varied from 3.8 to 26.3% and was the highest for treatment with the combination of Confidor and Masterblend. The combined use of products was more efficient than their application alone. The Confidor efficacy (applied alone and combined) against *Acyrtosiphon pisum* was the highest for the combination of Confidor with Atonic and Confidor with Masterblend. The most pronounced decrease in pea aphid density was found for the use of Confidor with Masterblend (55.4% decrease) and Confidor with Atonic (50.5% decrease), which determined the highest plant productivity.

A similar effect is given by the products of common vetch against a complex of sucking pests (Hemiptera, suborder Aphidodea and Auchenorrhyncha and Thysanoptera order) [58]. The use of Atonic, Masterblend and Confidor alone and in combination increased the dry mass productivity of spring vetch by 6 to 33%. The application of the combinations of Confidor with

Atonic and Confidor with Masterblend had the highest efficiency, for which the lowest abundance of the pests was also found irrespective of their order belonging (the decrease was by 41-46% to 36-40% for Homoptera and Thysanoptera respectively, as against the control).

Against pea weevil, *Bruchus pisorum* in spring forage pea necessary double treatment of suitable insecticide as Regent 800 WG (active substance fipronil 800g/kg) at doses of 15 and 20g/da in the stages of buttoning and beginning of flowering. By treating, grain yield compared to the control is increased from 23 (2577.4kg/ha) to 29% (2716.8kg/ha), the number of seeds of a plant - from 21 to 25% and the weight of the seeds of a plant - from 37 to 43% [59].

Reduced use of pesticides and their combinations with different products in order to decrease their negative impact on the environment is an environmentally friendly approach to a conventional production. This provides as good protection of the plants and the realization of a considerably higher productivity. For example, treatment with a synthetic insecticide Eforia at reduced doses with a mineral oil Akarzin (a.s. thiamethoxam + lambda-cyhalothrin) has a positive effect against important alfalfa pest as *Tychius flavus*; *Adelphocoris lineolatus* and *Acyrtosiphon pisum*. The application of Eforia in reduced by 1/5 and 2/5 dosages in combination with Akarzin is associated with significant increasing the efficiency of the active substance and providing the most long-term protection. Forage productivity increases by 31-33% (unpublished data).

Organic farming is part from integrated insect pest control. Organic farming is an important priority in the thematic priorities of the European Research Programs, policy development of agriculture in Bulgaria and one of the highlights of the Common Agricultural Policy. The main direction for the development of Bulgarian biological agriculture as a priority sector for the economics is sustainable development of the agricultural production. The application of the principles of sustainable biological agriculture in agricultural production is based on the application of traditional as well as new, environment-friendly and energy efficient technologies, which had proven advantages. They will provide maintenance of soil fertility, biodiversity, and an environment.

Legumes crop cultivation in terms of organic farming helps improve the biodiversity of natural habitats, which help to create a more diverse living conditions, better conditions for the reproduction and distribution of individual species, increasing the supply of nutrients, etc. This is a system that is more focused on problems related to the environment and landscape. Organic farming is a challenge for the scientific community which has to provide safer methods of pest control so that farm produce is safe to consume.

In Bulgaria, organic agriculture is also experiencing growing interest by producers and consumers. Organic production unlike other agricultural sectors grows not in percentage and is growing

many times. The number of organic operators increased more than 9 times and the area of certified land has increased almost 7 times for the period from 2006 (the year before the accession of Bulgaria to the EU) to the end of 2012 [60].

Controlled pests in modern agroecosystems are essential for the environment and biodiversity, but the management is difficult and is mainly conducted through chemical means [29,61]. Biopesticides may be excellent alternatives to chemical pesticides which are included in effective and flexible pest management programs [58,61,62].

Biological insecticides, Madex (0.5%) and Agricol (0.05%) (a natural polysaccharide of plant origin) can be used for the control of pea aphid, *Acyrtosiphon pisum* in spring forage pea. When bioproducts combined with bio-fertilizer products as Nagro, the efficacy, and duration of toxic effects is increased. The forage yield increases from 25 to 36%, and the grain yield - up to 34%. In addition, the organic fertilizer, Nagro exhibits insecticidal properties and the toxic effect is in the range of 41-69%.

The development of resistant or tolerant cultivars is a part from integrated insect pest control in forage crops too. In addition, in terms of the modern organic farming, the use of tolerant cultivars against phytophagous insects is very important to environmental protection because of decrease the application of insecticides, increase the activity of entomophagy, and reduce the negative effect of the anthropogenic factor on the agroecosystems. In this regard, to find and use different markers for resistance as a genetic material in the creation of new cultivars is one of the most effective methods for defense and control against main insect pests. The introduction of resistant (tolerant) cultivars would help farmers reduce losses due to pests and provide a greatly contribute to practical crop improvement programs. Global trends, including Europe and Bulgaria in the selection of legumes such as alfalfa, peas, vetch, lupine and others are mainly related to an increase in productive potential, increase the protein content and improve the amino acid composition, reducing the content of antinutrients, increase resilience and the tolerance of economically important diseases and pests.

An effective and environmentally important method of controlling insect pests for different leguminous plants is setting up germplasm that is resistant or tolerant of main pests for the improvement of the genetic resistance of the host plant [52]. The find of sources of valuable breeding value and exhibited resistance (tolerance) to the economically important pests is very important in creating of new cultivars and it is one of the ecological approaches to solving of essential problems related to the development of sustainable forms among insect pest and creating conditions for their rapid multiplication [39]. *Sitona spp.*, leaf aphids, and weevils are important pests in pea, spring and winter vetch, and alfalfa [43,57, 59,63-65]. They are oligophagous and often react to varietal differences and this fact could be useful in the development of varieties with resistance to these pests.

In the earlier Bulgarian studies was found that in order to reduce insect attack, plants developed different defense mechanisms,

including morphological, chemical and others barriers. Yankova et al. [66] suggested that varieties with low trypsin inhibitor activity had a relatively low percentage of damage seeds. Nikolova et al. [64] were found that cultivars with lower protein and phosphorus content had a lower level of damage and the phosphorus content had the highest significant influence on pea weevil infestation. The degree of attack Poryazov [67] associated with plant height while Nikolova & Pachev [63] – seed size and duration of the flowering and pod formation period. In relation to tolerance, were found less sensitive varieties of spring forage pea against *Bruchus pisorum* and common and winter vetch varieties (*V. sativa* L., *V. villosa* Roth), tolerant to leaf aphids and species of the *Sitona* genus. Various resistance markers have been identified in the creation of new varieties. The most promising are recommended for inclusion in the sustainability selection process.

The application of agrotechnical methods of pest control is environmentally friendly approach too. The sowing dates of wintering forage pea is a factor that affects the population density of *Acyrtosiphon pisum* and *Bruchus pisorum* by reducing the numbers of pests and the degree of weevil damaged seeds [68,69]. The number of the pests is also affected by the system of cultivation of wintering forage pea as insect density is lower in a triticale mixture, compared to the independent growing of the wintering forage pea [70]. An alternative to the chemical method of controlling the *Sitona* species and leaf aphids in winter vetch is a later sowing period (October 5-10 and October 20-25) [65,71].

In the European Union, including Bulgaria, a greater emphasis on Integrated Pest Management (IPM) as part of agricultural policy may lead to innovations and environment-friendly and energy efficient technologies. There is an urgent requirement for alternative tactics to help make crop protection more sustainable and environmentally friendly.

### Conclusion

- The most common insect pests of alfalfa in order Coleoptera are *Hypera postica* Gyllenhal, species of *Sitona* genus, *Apion seniculus* Kirby, and *Otiorrhynchus ligustici* L.
- From order Hemiptera, Sternorrhyncha: Aphidodea *Therioaphis maculata* Buckt. is the main harmful species, as considerable part had *Acyrtosiphon pisum* Kalt.
- Ones of the most important pests belong to the order Hemiptera – Heteroptera, as serious and dominant insect pests are *Adelphocoris lineolatus* Goeze and *Lygus rugulipennis* Poppius, and subdominant species was *Piezodorus literatus*.
- From order Hemiptera: Fulgorormorpha и Cicadomorpha economic importance species for alfalfa are dominant species *Empoasca pteridis* Dhlb. and *Agallia ribauti* Oss., and subdominant species - *Peragallia sinuata* M.R., *Philaenus spumarius*, and *Paraphlepsius irroratus* L., while from order Thysanoptera main pests are dominant species L., followed by subdominant species *T. atratus* Haliday.
- Insect pest with economic importance in *Pisum sativum*

are *Bruchus pisorum* L., *Sitona* spp., *Acyrtosiphon pisum* and, while in *Vicia sativa* - *Bruchus rufimanus* Boh. and *Tychius quinquepunctatus* L.

f. In the European Union, including Bulgaria, a greater emphasis on Integrated Pest Management as part of agricultural policy may lead to innovations and environment-friendly and energy efficient technologies.

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