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Systems of organic farming in spring vetch I: Biological response of sucking insect pests

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SUMMARY

Four systems of organic farming and a conventional farming system were studied over the period 2012-2014. The organic system trial variants included: I – an organic farming system without any biological products used (growth under natural soil fertility) – Control; II – an organic farming system involving the use of a biological foliar fertilizer and a biological plant growth regulator (Polyversum+Biofa); III – an organic farming system in which a biological insecticide (NeemAzal T/S) was used; IV – an organic farming system including a combination of three organic products: the foliar fertilizer, the plant growth regulator and the bioinsecticide (Polyversum+Biofa+NeemAzal T/S). Variant V represented a conventional farming system in which synthetic products were used in combination (foliar fertilizer, plant growth regulator and insecticide: Masterblend+Flordimex 420+Nurelle D). Treatment of vetch plants with the biological insecticide NeemAzal in combination with Biofa and Polyversum resulted in the lowest density of sucking pests, compared to all other organic farming methods tested (i.e. without NeemAzal, with NeemAzal alone, and its combination with Biofa and Polyversum). The greatest reduction in pest numbers during the vegetation period in that variant was observed in species of the order Thysanoptera (36.0-41.4%), followed by Hemiptera, and the families Aphididae (31.6-40.3%) and Cicadellidae (27.3-28.6%). This combination showed an efficient synergistic interaction and an increase in biological efficacy as compared to individual application of NeemAzal. The highest toxic impact was found against *Thrips tabaci*, followed by *Acyrthosiphon pisum*. An analysis of variance regarding the efficacy against the species *A. pisum*, *E. pteridis* and *T. tabaci* showed that type of treatment had the most dominant influence and statistically significant impact.

Keywords: Organic farming; Spring vetch; Sucking insects; Biopesticides

INTRODUCTION

Pest control in modern agro-ecosystems is largely achieved by using pesticides, and such reliance has globally led to the development of pesticide resistance in many crop pests (Whalon et al., 2008). Conservation biological control (CBC) involves cultural practices that seek both to preserve natural enemy populations and to improve their efficacy through modification of the biotic environment and reducing pesticide usage (Landis et al., 2000).

Organic farming as an alternative to conventional practices is associated with overcoming the negative effects of synthetic products on crop production and the environment.

Biological control of pests using products based on plant extracts (botanical products) with repellent or toxic action is a step towards modern agriculture. Bioinsecticides therefore stand out for their favorable ecotoxicological traits and low initial toxicity. Their use would reduce the danger of resistance evolution (Roush & Tingey, 1994). NeemAzal T/S (azadirachtin as active substance) is such a biological product which affects the hormonal balance of insects.

Combinations of biological products have achieved considerable success in recent years. A synergist, a substance that works with a product to increase its effectiveness, may be added to a botanical compound to inhibit certain detoxification enzymes in target pests and increase pest mortality. For example, pyrethrins, such as Pyrenone, are often mixed with a synergist, such as piperonyl butoxide (PBO) (Buss & Park Brown, 2002).

Combinations of insect pathogens and botanical agents have received some attention in recent years too (Mascarin & Delalibera, 2012). Synergistic or additive effects at low doses of botanical insecticides and viruses have been demonstrated in several studies. For example, they have shown increased mortality of lepidopteran larvae under a combined use of nucleopolyhedrosis virus and azadirachtin (Nathan et al., 2005; Nathan & Kalaivani, 2006). Those laboratory and greenhouse experiments revealed the highest mite mortality under the combined use of oil + azadirachtin, compared to their individual application (Deka et al., 2011).

The aim of our present study was to determine the biological response of a complex of sucking pests to different systems of organic farming, and the efficacy of products (applied alone or in combination) against *Thrips tabaci*, *Acyrthosiphon pisum* and *Empoasca pteridis* in spring vetch.

MATERIAL AND METHODS

A trial was conducted in a spring vetch (*Vicia sativa* L) crop, variety Obrazets 666, in the experimental field of the Institute of Forage Crops, Bulgaria, over the period 2012-2014. The field experiment was located in an area complyng to a 2-year conversion requirement for organic production. Spring oat was the pre-crop. The experiment had a long-plot design, the sowing rate was 220 seeds m^{-2} , there were 4 replications and the plot size was 10 m^2. Four systems of organic farming were studied and one conventional farming system, i.e. the following variants: variant I - organic farming system without the use of biological products (growth under natural soil fertility) – Control; variant II - organic farming system involving the use of a biological foliar fertilizer and a biological plant growth regulator (Polyversum+Biofa); variant III - organic farming system involving the use of a biological insecticide (NeemAzal T/S); variant IV - organic farming system involving the use of a combination of three organic products: the foliar fertilizer, the plant growth regulator and the bioinsecticide (Polyversum+Biofa+NeemAzal T/S). Variant V represented a conventional farming system in which synthetic products were used in combination (foliar fertilizer, plant growth regulator and insecticide: Masterblend+Flordimex 420+Nurelle D). It was located at a distance from the area of organic production. Treatment was carried out at the beginning of the flowering stage. Trial variants and product characteristics are shown in Table 1.

Table 1. Characteristics of products

Trial variants	Active ingredients	Application rates, per ha
1. Control (organic production)	Treated with distilled water	300 l
2. Biofa + Polyversum (organic production)	Organic matter (9%), alginic acid (4%), natural plant hormones, total nitrogen (0.20%), total phosphorus (P_2O_5) - 8%, soluble potassium (K_2O) - 14%; *Pythium oligandrum* (strain M1), 1 x 106 oospores/g of product , natural product with a double effect: a fungicide and growth regulator	500 ml + 100g
3. NeemAzal T/S (organic production)	1% azadirachtin A + 0.5% azadirachtin B,W,G,D and 2.5% neem substance	500 ml
4. NeemAzal+Biofa+ Polyversum (organic production)	1% azadirachtin A + 0.5% azadirachtin B,W,G,D and 2.5% neem substance; Organic matter (9%), alginic acid (4%), natural plant hormones, total nitrogen (0.20%), total phosphorus (P_2O_5) - 8%, soluble potassium (K_2O) - 14%; *Pythium oligandrum* (strain M1), 1 x 106 oospores/g of product , natural product with a double effect: a fungicide and growth regulator	500 ml + 500 ml + 100g
5.NurelleD+Flordimex 420+ Masterblend (conventional system)	50 g/l a.i. cypermethrin + 500g/l a.i. chlorpyrifos-ethyl + 420 g/l ethephon; 420 g/l ethephon, a synthetic growth regulator which stimulates the formation of generative organs;	400 ml+ 50 ml+ 1600 g

Sucking pests in all 5 variants were counted immediately after treatment at the flowering stage (one day after treatment), and the counting continued until the aboveground biomass has dried (i.e. between mid-May and the end of July for approximately 75 days). Over the period, population density was recorded by sweepings with the entomological net once a week. Data in Table 2 regarding pest abundance in the studied variants were averaged for the indicated 75-day period. The efficacy of insecticides and their combinations was estimated at the flowering stage. Assessments were made 1, 3, 7 and 12 days after treatment. Insecticide efficacy was calculated by Abbott's (1925) formula and the entomological net was used for sweeping. Statistical processing of experimental data was conducted using the Statgraphics Plus software.

RESULTS AND DISCUSSION

Sucking pests that were used in the studied production systems were mainly represented by 2 orders: Hemiptera with two suborders, Sternorrhyncha and Cicadomorpha, and the order Thysanoptera. Sternorrhyncha was represented by the family Aphididae in which *Acyrthosiphon pisum* Harris was a major species, while *Cicadomorpha* included species of the family Cicadellidae. The order Thysanoptera, suborder Terebrantia, was represented mainly by species of the family Thripidae.

Weather conditions during the study years affected pest abundance and development. Particularly indicative in this regard was 2013, when weather had unfavourable impact on pest development and caused their significantly lower population density. Heavy rainfall during flowering and pod development in June reached 111.6 mm (71.3 and 57.3 mm more than in 2012 and 2014, respectively) and the average air temperature was 21.3^{0}C (2.8^{0}C lower than in 2012). This greatly restricted the reproduction and activity of sucking pests. Weather conditions in 2012 and 2014 were favourable for pest development and their numbers were relatively higher.

The organic and conventional systems of spring vetch cultivation had considerable impact on the agro-biological response of three groups of sucking pest: thrips, aphids and leafhoppers.

The average density of aphids during the growing period 2012-2014 had an amplitude variation from 7.7 to 22.0 insects/m^2 (Table 2).

Table 2. Means of sucking pest numbers per 100 sweepings over the vegetation period

Trial variants	2012	2013	2014	2012-2014	2012	2013	2014	2012-2014	2012	2013	2014	2012-2014
	Hemiptera: Aphididae				Hemiptera: Cicadellidae				Thysanoptera: Thripidae			
1. Control (organic production)	20.0^{c*}	6.4^{c}	28.3^{c}	18.2^{c}	4.3^{b}	2.5^{bc}	3.0^{b}	3.3^{b}	4.5^{c}	1.8^{c}	2.3^{b}	2.9^{c}
2. Biofa + Polyversum (organic production)	21.6^{c}	6.7^{c}	30.4^{c}	19.6^{c}	4.8^{b}	2.7^{c}	3.0^{b}	3.5^{b}	5.3^{d}	2.6^{d}	2.5^{b}	3.5^{c}
3. NeemAzal T/S (organic production)	15.0^{b}	5.1^{b}	17.0^{b}	12.4^{b}	3.7^{ab}	2.2^{bc}	2.0^{ab}	2.6^{b}	3.1^{b}	1.3^{b}	1.5^{ab}	2.0^{b}
4. NeemAzal+Biofa+ Polyversum (organic production)	13.1^{ab}	4.5^{b}	15.0^{ab}	10.9^{b}	3.3^{ab}	2.0^{b}	1.8^{ab}	2.3^{ab}	2.7^{b}	1.0^{a}	1.3^{ab}	1.7^{b}
5. NurelleD+Flordimex 420+ Masterblend (conventional system)	10.8^{a}	2.3^{a}	10.0^{a}	7.7^{a}	1.8^{a}	0.9^{c}	1.0^{a}	1.2^{a}	1.7^{a}	0.6^{a}	0.8^{a}	1.0^{a}
LSD $_{0.05\%}$	4.180	1.047	5.355	3.129	2.199	0.569	1.772	1.365	0.745	0.364	1.301	0.603
Average	16.1	5.0	20.1	13.7	3.7	2.1	2.6	2.6	3.5	1.5	2.2	2.2

[a*]Means in each column marked by the same letters are not significantly different (P > 0.05)

In our organic production variants involving the biological insecticide NeemAzal, their average numbers were significantly 19.9-32.1% lower ($P>0.05$), compared to spring vetch cultivation under natural soil fertility without the use of bioproducts (Control). It is necessary to note that the minimum density values and a decrease of 31.6 to 40.3% were observed after the combined use of organic products (NeemAzal, Biofa and Polyvesum), and the differences compared to control were significant. Maximum values were found in the variants I and II (without the protection of plants and by using organic products). Insignificant differences were detected between the variants involving NeemAzal and NeemAzal+Biofa+Polyversum.

Population density of species representating the order *Thysanoptera* had a notably large range of variation – from 0.8 to 3.5 insects/m^2 on the average for the period. In organic production involving plant protection against pests (variants 3 and 4), their numbers were significantly lower and the decrease ranged from 20.0 to 40.3% relative to the control. The decrease was similar to that found in aphids.

Regarding species of the family *Cicadellidae,* their numbers varied narrowly from 1.2 to 3.7 insects/m^2. Decrease in population density in the variants with bioinsecticide application was insignificant compared to the biological cultivation of spring vetch without using those biological products (control). That reduction was smallest and had values from 17.1 to 28.6%.

Conventional production was associated with the lowest statistical number of sucking pests and a decrease of 54.3 to 68.0% (compared to control) and a more pronounced reduction was observed in species of the family *Thripidae*.

The density of sucking pests exposed to the combined use of the organic products Biofa and Polyversum exceeded their density in control. As a result of plant growth stimulated by Polyversum, and an exceptionally rich content of macro- and micronutrients in the foliar fertilizer Biofa absorbable by plants, the formulation provided a higher productivity.

The organic production systems had stronger impact on the population density of thrips and aphids than leafhoppers, and led to their more significant reduction in numbers.

Efficacy in 2012

Application of the synthetic insecticide Nurelle D in combination with Flordimex and Masterblend resulted in the lowest numbers of sucking pest (*Thrips tabaci* L., *Empoasca pteridis* Dahlb. and *Acyrthosiphon pisum* L.) and high efficacy ranging from 88.2 to 96.5% on the first day after treatment (Figure 1).

Compared to the biological insecticide, Nurelle D exhibited a quick initial action but it gradually decreased and took values similar to those of NeemAzal 12 days after treatment.

The biological product NeemAzal was characterized by relatively weaker initial effect (41.2-52.2%), which increased, and on the seventh day after treatment reached maximum values (61.7-65.0%) before decreasing again until the 12th day.

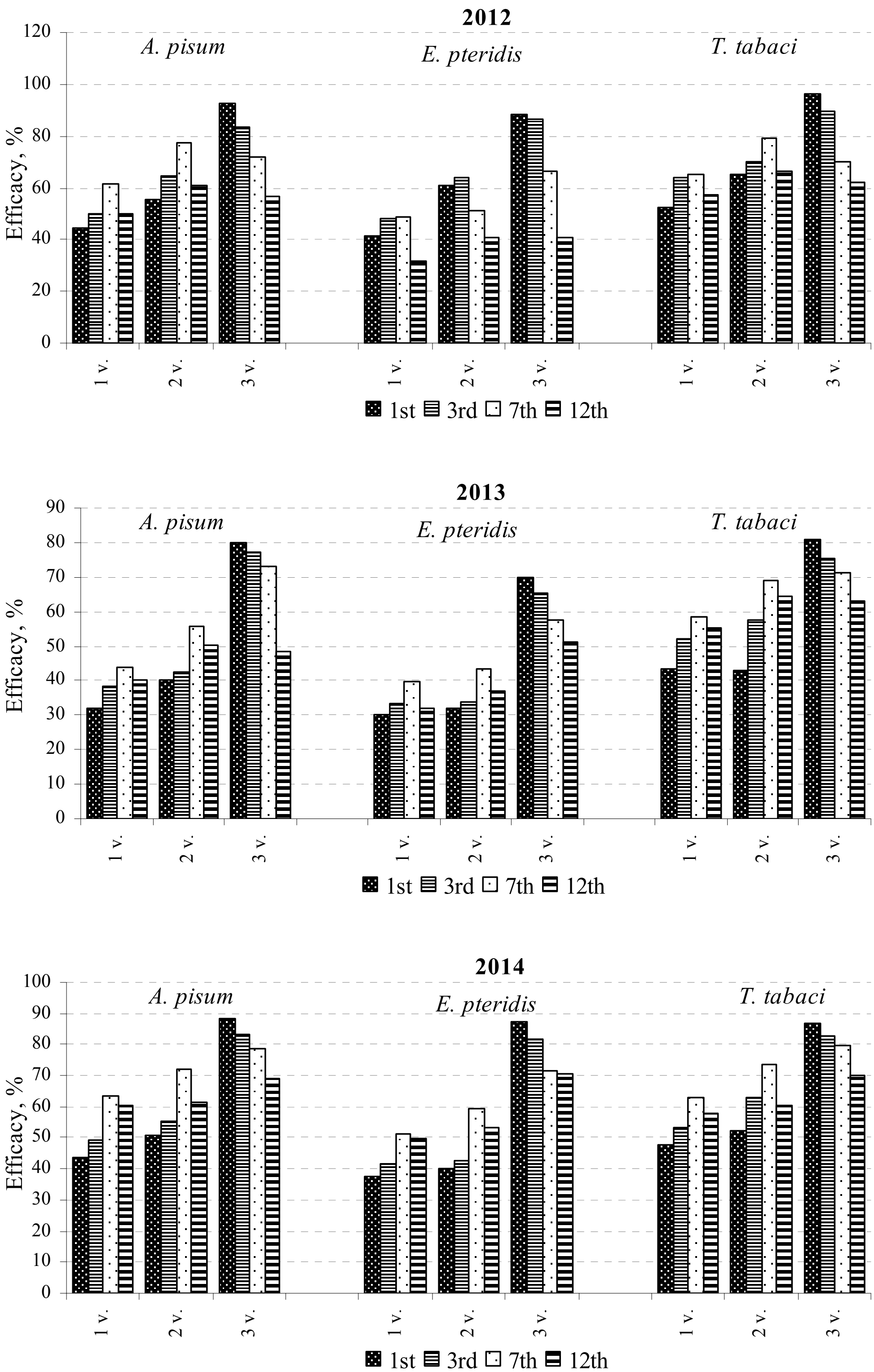
Nurelle D had the strongest toxicity to *T. tabaci*, then *A. pisum*, which mostly exceeded 60% one week after treatment and remained relatively high until the 12th day. The efficacy of NeemAzal against *E. pteridis* was relatively lower and did not exceed 50%.

A synergistic interaction of NeemAzal with the organic products Biofa and Polyversum was observed and an increase in insecticide efficacy, compared with its individual treatment against the three pest species. The efficacy of the combination increased with time, and on the 7th day exceeded 77% against *T. tabaci* and *A. pisum*, and 51.3% against *E. pteridis*. Biological activity of the combination on the last reporting day was preserved and slightly exceeded that of the synthetic insecticide Nurelle D. The increased biological efficacy of NeemAzal was due to an additional effect of Biofa, which contains algal extract. It exhibited a strong protective effect on the foliage by forming a thin coating (microfilm). The coating contributed to a better hold of the biological insecticide on leaf surface and improved its effect.

Efficacy in 2013

Nurelle D, used in combination with Flordimex and Masterblend in 2013 showed fast initial activity, which ranged from 70.0 to 83.4%, and high efficacy extending until the 7th day after treatment. Biological activity of that insecticide combination was similar but provided better control of *T. tabaci* and *A. pisum* than *E. pteridis*.

Analysis of the results of biological testing of NeemAzal in 2013 showed that its activity was considerably weaker than it had been in the previous year. As biological products containing azadirachtin as their active substance are unstable under illumination, sustaining rapid photodegradation under UV radiation, and are susceptible to low temperatures and rainfall (Schmutterer, 1990; Pavela, 2009), NeemAzal was less effective due to heavy rains in June 2013 coinciding with the treatment.



1v - NeemAzal; 2v - NeemAzal+Biofa+Polyversum; 3v-Nurelle D+ Flordimex+Masterblend; 1st – first day after treatment; 3rd – third day after treatment; 7th-seventh day after treatment; 12th- twelfth day after treatment

Figure 1. Efficacy of biological and synthetic products against *Acyrthosyphon pisum*, *Empoasca pteridis* and *Thrips tabaci*

The product's initial effect was relatively low (22.2-43.4%), compared to 2012 and 2014, reaching maximum values of 34.4-58.3% on the seventh day, depending on pest species. The highest efficacy of 58.3% was reached against *T. tabaci*, and the lowest of 39.7% against *E. pteridis*. The trend in sensitivity degree of sucking pests remained the same after the combined application of NeemAzal with Biofa and Polyversum and their efficacy against thrips and aphids exceeded 66% and 50% respectively, while the efficacy against leafhoppers reached only 43%. On the last reporting day, the toxicity of the combination equalled that of the synthetic insecticide as regards *A. pisum* and *T. tabaci*.

Efficacy in 2014

The studied insecticides had the highest toxic effect on pests in 2014.

The combination containing Nurelle D had a fast initial activity of 87.1-90.1%, which extended with 65.3-76.5% into the 12th day after treatment. Protective action of that insecticide combination was similar for the three tested species.

On the 7th day after treatment, NeemAzal reached the highest efficacy that ranged 56.7-63.6% for *T. tabaci* and *A. pisum*, and was close to 50% for *E. pteridis*. Toxicity of the combination NeemAzal + Biofa + Polyversum

Table 3. Analysis of variance of product efficacy

Source of variation	Degree of freedom (df)	Sum of squares (SS)	Influence of factor, %	Mean square (MS)
		Acyrthosiphon pisum		
Total	105	17721	100.0	168.8
Variants	35	17384	98.1 *	496.7
Factor A - Year	2	2521	14.2 *	1260.6
Factor B -Insecticide	2	9110	51.4 *	4555.2
Factor C – Days after treatment	3	1178	6.6 *	392.7
A x B	4	321	1.8	80.3
A x C	6	260	1.5	43.3
B x C	6	3749	21.2 *	624.9
A x B x C	12	245	1.4	20.4
Pooled error	71	336	1.9	4.7
		Empoasca pteridis		
Total	105	20748	100.0	197.6
Variants	35	20353	98.1 *	581.5
Factor A - Year	2	2638	12.7 *	1319.0
Factor B -Insecticide	2	11546	55.6 *	5773.1
Factor C - Days after treatment	3	1175	5.7 *	391.7
A x B	4	401	1.9	100.2
A x C	6	2029	9.8 *	338.2
B x C	6	2243	10.8 *	373.8
A x B x C	12	321	1.5	26.8
Pooled error	71	394	1.9	5.5
		Thrips tabaci		
Total	105	11507	100.0	109.6
Variants	35	11176	97.1 *	319.3
Factor A - Year	2	891	7.7 *	445.5
Factor B -Insecticide	2	5700	49.5 *	2850.2
Factor C - Days after treatment	3	765	6.6 *	254.8
A x B	4	157	1.4	39.3
A x C	6	466	4.1 *	77.7
B x C	6	2998	26.1 *	499.6
A x B x C	12	199	1.7	16.6
Pooled error	71	331	2.9	4.7

Means in each column marked with an asterisk (*)are significantly different ($P > 0.05$)

was relatively higher and exceeded 70% against thrips and aphids, but did not reach 60% against leafhoppers. On the 12th day after treatment, the combination was nearly as effective as the synthetic insecticide Nurelle D and an exception was only observed in *E. pteridis*. The trend of slight differences in the toxicity of products between vetch varieties was retained.

An analysis of variance for the species *A. pisum*, *E. pteridis* and *T. tabaci* in terms of product efficacy (Table 3) showed that the type of plant protection product and mode of application (individual product or combination) had the most dominant influence and significant effect - 51.4, 55.6 and 49.5% respectively, considering the total variance (factor B).

Trial year (A) and days after treatment (C) were factors with significant impact on the variation of efficiency, and factor A had the stronger influence of the two (ranging from 7.7 to 14.2%). Interaction between the factors B and C was the strongest influence, compared to the other combined interactions, and its differences were significant for all three pest species (10.8-26.1%). The strength of the influence A x C was considerably lower and significant differences were found for *Empoasca pteridis* (9.8%) and *Thrips tabaci* (4.1%).

CONCLUSIONS

Under the organic farming systems tested, the lowest density of sucking pests was found in the variant involving the bioinsecticide NeemAzal in combination with the biological regulators Biofa and Polyversum. Compared with cultivation of spring vetch in naturally fertile soil free of any pesticides, this variant achieved the greatest reduction regarding the number of pests of the orders Thysanoptera (36.0-41.4%) and Hemiptera, and families Aphididae (31.6-40.3%) and Cicadellidae (27.3-28.6%).

Combination of NeemAzal with Biofa and Polyversum showed an efficient synergistic interaction and an increase in biological efficacy compared to the individual application of NeemAzal. The highest biological activity was achieved on the 7th day after treatment, when toxic impact was the most pronounced against *Thrips tabaci*, followed by *Acyrthosiphon pisum*.

The analysis of variance for the species *A. pisum*, *E. pteridis* and *T. tabaci* in terms of product efficacy showed that the type of treatment (application of insecticide alone or in combination) had the most dominant influence and significant impact on this indicator - 51.4, 55.6 and 49.5% respectively, compared to total variance.

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Sistemi organske proizvodnje obične grahorice I: Biološki odgovor insekata koji se hrane biljnim sokom

REZIME

Proučavana su četiri sistema organske proizvodnje i jedan klasičan sistem u periodu od 2012 do 2014. Varijante organske proizvodnje su bile: I – sistem organske proizvodnje bez upotrebe bioloških proizvoda (uslovi prirodne plodnosti zemljišta) – kontrola; II – sistem organske proizvodnje sa upotrebom folijarnog biološkog đubriva i biološkog regulatora rasta (Polyversum+Biofa); III – sistem organske proizvodnje sa upotrebom biološkog insekticida (NeemAzal T/S); IV – sistem organske proizvodnje sa upotrebom kombinacije tri organska proizvoda: folijarnog đubriva, regulatora rasta i bioinsekticida (Polyversum+Biofa+NeemAzal T/S). Varijanta V predstavljala je konvencionalni sistem proizvodnje u kom je korišćena kombinacija sintetičkih proizvoda (folijaro đubrivo, regulator rasta i insekticid: Masterblend+Flordimex 420+Nurelle D). Tretman grahorice biološkim insekticidom NeemAzal u kombinaciji sa preparatima Biofa i Polyversum dao je najmanju gustinu štetočina koje se hrane isisavanjem biljnog soka u poređenju sa ostalim ispitivanim metodama (bez NeemAzal, samo sa NeemAzal i u kombinaciji sa Biofa i Polyversum). Najizrazitije smanjenje brojnosti štetočina tokom vegetacije u toj varijanti zabeležen je kod vrsta iz redova Thysanoptera (36,0-41,4%) i Hemiptera, kao i familija Aphididae (31,6-40,3%) i Cicadellidae (27,3-28,6%). Ta kombinacija je pokazala efikasno sinergično delovanje i povišenu biološku efikasnost u poređenju sa primenom bioinsekticida pojedinačno. Najsnažniji toksični uticaj zabeležen je kod *Thrips tabaci*, kao i kod *Acyrthosiphon pisum*. Analiza varijanse za efikasnost protiv vrsta *A. pisum*, *E. pteridis* i *T. tabaci* pokazala je da je tip tretmana imao dominant i statistički značajan uticaj.

Ključne reči: Organska proizvodnja; Obična grahorica; Insekti koji se hrane biljnim sokom; Biopesticidi