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RESEARCH ARTICLE

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Organic cultivation of field pea by use of products with different action

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Abstract

The possibilities for increasing the productivity and control of the pea weevil (*Bruchus pisorum* L.) in field pea (*Pisum sativum* L.) organic cultivation by the use of following bioproducts NeemAzal T/S and Pyrethrum FS-EC (insecticides), applied individually and in combination with Polyversum (growth regulator and fungicide) and Biofa (foliar fertilizer), as well as to evaluate the stability of the used mixtures were studied. Synthetic products Nurelle D and Flordimex 420 (alone and in combination) were used as a standard. The products were applied once (at budding stage) or twice (at budding and flowering stages). The results showed that forage pea productivity was influenced positively by the application of all organic products. The plants treated with the organic combinations formed an average yield of 3190.2 kg/ha, which was only 4.7% lower than that for the synthetic combination of Flordimex+Nurelle D. The highest yield was produced under application of two mixtures: Biofa+Pyrethrum and Polyversum+Pyrethrum at budding and flowering stages (22.0 and 21.8% above untreated control, respectively). These combinations were also distinguished for their most pronounced protective effect against the attack of the pea weevil and decrease in its numbers of 37.0 and 38.5%, respectively. Pyrethrum was distinguished for a lower degree of damaged seeds and a toxic effect against the pea weevil in comparison with NeemAzal. Technologically the most valuable variant, which united high stability, productivity and protection against pea weevil, was the combination of Biofa+Pyrethrum applied twice. Further investigations are indispensible to expand the range of products (bioinsectides, biofertilizers and growth regulators), which provides good insect control and high productivity in pea organic farming conditions.

Additional key words: organic products; productivity; pea weevil control; stability.

Abbreviations used: F (criterion of Fisher); σ_i^2 (variance of stability); S_i^2 (variance of stability); W_i (ecovalence); Ys_i (criterion of stability).

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Introduction

Organic cultivation is an alternative way of production that protects the environment, biodiversity and provides healthy and qualitative food (Grigorova & Arabska, 2013). More and more studies have for an object not only to apply the principles of organic production, but also to search opportunities and combinations for increasing productivity and crop quality and improving pest control in the conditions of that production (Leifert *et al*., 2007; Eyre *et al*., 2009; Kristensen-Thorup *et al*., 2012).

Application of organic foliar fertilisers, growth regulators and stimulants is an important element of organic cropping system and the purpose is through them to overcome one of its main disadvantages, namely low productivity (Jones, 2003; Nenova & Atanasov, 2009). In this regard, the study and application of products from natural plant extracts, which are still less widespread, deserves attention (Dincheva, 2013), in contrast to the farmyard manure, microbial and humate fertilizers widely used in practice.

Some bioproducts of an organic and microbial origin have a complex action of biofertilizers, biostimulants and an indirect or direct effect as biopesticides (Masheva *et al*., 2013; Hristeva, 2013). In addition to the known biopesticides based on microorganisms, plant protection products on a botanical basis enter widely into practice (Hristeva, 2013). In an ecological aspect they are much safer than the synthetic pesticides. Nevertheless the natural plant products such as essential oils (Abd-El-Aziz, 2001; Upadhyay & Jaiswal, 2007) and bio-organic compounds (Konstantopoulou *et. al*., 2002) are safer and at same time toxic to phytophagous insects. They provoke very high mortality in the bruchids (Upadhyay *et al*., 2006) and control grain damages efficiently (Sabbour & Abd-Al-Aziz, 2007). Among the numerous plants having an insecticidal or insect-repellent effect, two plants, namely *Chrysanthemum cinerariaefolium* (pyrethrum) and *Azadirachta indica* (neem) have gained great importance for insect control, including seed pests (Reuben *et al*., 2006).

The pea weevil, *Bruchus pisorum* (L.), (Coleoptera: Chrysomelidae), is one of the most intractable pest problems of cultivated pea, *Pisum sativum* L., in Europe (Girsch *et al*., 1999). It causes considerable damage to pea. A number of authors (Ali & Habtewold, 1994; Damte & Dawd, 2003) found that losses as high as 50% may often be encountered in pea. Even with only a small amount of actual biological losses by seed yield per plant, economic losses can reach up to 100% (Boeke *et. al*., 2004; Somta *et al*., 2006).

Pea weevils attack peas that are grown in fields. Infestation results in seeds that may not germinate or produce weak plants. Weevils cannot persist in storage as they cannot re-infest stored seed. Females lay eggs on the outside of the pod. Larvae develop in growing seeds within the pods. After pupation within the seed, the adult chews an exit hole through the seed coat. Damage is distinctive. Both adult and larvae feed on the inside of seeds. The final effect of seeds with a beetle infestation on the germination of host legumes can be unpredictable (Fox *et al*., 2012). In some cases the larva feeding effectively kills the embryo or removes so much endosperm that the seed cannot germinate unpredictable (Fox *et al*., 2012).

Mixed use of insecticides (pesticides) with growth regulators, stimulants and foliar fertilizers, as an element of the modern technology in convential production, increases the effectiveness of the preparations (Tsibulko *et al*., 2000), allows reducing their doses (Stoeva & Shaban, 2001) and has a high economic effect saving time, energy and costs (Petroff, 2008). The investigations about effectiveness, compatibility and stability of such combinations among organic products, differing in their biological effect, are still in an initial stage in Bulgaria. The purpose of the research was to study the possibilities for increasing the productivity and control of the pea weevil in organic cultivation of field pea by the use of bioproducts (alone and combined), as well as to evaluate the stability of the used mixtures.

Material and methods

The experimental work was conducted in the Institute of Forage Crops (Pleven, Bulgaria) during the period of 2011 to 2013 on slightly leached chernozem. The object of research was spring field pea, cv. Pleven 4, sown at a rate of 120 germinable seeds/m^2 in the third decade of March (25 March in 2011 and 2012, 30 March in 2013). A treatment was performed during vegetation (once at budding state; twice at budding and flowering stages) with two growth regulators (Polyversum and Flordimex), a foliar fertilizer (Biofa) and three insecticides (NeemAzal, Pyrethrum and Nurelle D). Biofa, Polyversum, NeemAzal, and Pyrethrum are bioproducts and Flordimex and Nurelle D are synthetic products (Table 1). The three-factor field trial was carried out by the split plot method: (i) factor A, years, including the three years of the research (a_1, 2011; a_2, 2012; a_3, 2013); (ii) factor B, products and mixtures between them, including 12 levels (B_1, untreated control; B_2, Biofa 0.5%; B_3, Polyversum 100 g/ha; B_4, Flordimex 0.05%; B_5, NeemAzal 0.5%; B_6, Pyrethrum 0.05%; B_7, Nurelle D 400 mL/ha; B_8, Biofa 0.5% + NeemAzal 0.5%; B_9, Biofa 0.5% + Pyrethrum 0.05%; B_{10}, Polyversum 100 g/ha + NeemAzal 0.5%; B_{11}, Polyversum 100 g/ha + Pyrethrum 0.05%; B_{12}, Flordimex 0.05% + Nurelle D 400 mL/ha; (iii) factor C, stages of treatment, including 2 levels (c_1, at budding; c_2, at budding and at flowering. The plot size was 6.5 m^2 with four replications.

Population density of the pea weevil was recorded during the growing season by mowing with an entomological net once a week, presenting the data, and percentage of damaged seeds was recorded by bulk samples at grain harvesting.

In order to characterize representativeness and significant influence of the grain yield a statistical assessment was made by the analysis of variance and parametric criterion (F) of Fisher (Barov, 1982). The programme ANOVA123 was used for calculation in the analysis of variance. The parameters of stability for grain yield were calculated [variances of stability σ_i^2 and S_i^2 (Shukla, 1972) and ecovalence W_i (Wrickle, 1962)]. The value of each variant was presented through the criterion of stability (Ys_i) of Kang (1993), simultaneously recording the worth of the indicator and the stability of the variant. The value of this criterion consisted in the fact that through the use of nonparametric methods and statistical significance of the differences, we obtained a generalized assessment arranging the variants in a descending order according to their economic value. The programme Stable of Louisiana State University Agricultural Center, Baton Rouge, USA (1993) was used to calculate these parameters.

Table 1. Characteristic of the products

Products	Composition	Producer
Biofa	Brown algae (*Ascorphyllum nodosum*) extract obtained through cold extraction, extremely rich in macro and microelements: organic matters (9%), alginic acid (4%), natural plant hormones, total nitrogen (0.20%), soluble phosphorus (P_2O_5) – 8%, soluble potassium (K_2O) – 14%, PGR enzymes (plant hormones) – 10%	Biofa, Germany
Polyversum	Spores of fungus *Pythium oligandrum*, natural product with a double effect: a fungicide and growth regulator	Biopreparaty Ltd, Czech Republic
Flordimex	420 g/L ethephon	Bayer CropSciences, Germany
NeemAzal	Product from Indian Neem tree *Azadirachta indica* A. Juss (Meliaceae); active substances: 1% azadirachtin A+0.5% azadirachtin B, W, G, D and 2.5% neem substance	Trifolio M, Germany
Pyrethrum	Natural pyrethroid, extract from *Chrysanthemum cinerariefolium*; components: 32% extract from pyrethrum (25% pyrethrin)+32% sesame oil+36% adhesives (soft potassium soap)	Andermatt Biocontrol, Switzerland
Nurelle D	50 g a.i./L cypermethrin+500g a.i./L chlorpyrifos-ethyl-pyrethroid insecticide	Dow AgroSciences-Indiana, USA

Results

The study period was characterized with different meteorological conditions. The vegetation period (March–June) of 2013 had the highest sum of vegetation rainfall (226 mm) and the highest average daily temperature (19.2°C). The experimental years 2011 and 2012 were distinguished by lower temperatures (16.5 and 18.8°C, respectively) and considerably lower sums of rainfall (141.6 and 171.8 mm, respectively) that was relatively uniform distributed during the growing season.

The bioinsecticides NeemAzal and Pyrethrum influenced the population density of the pea weevil. Under application of Pyrethrum the bruchid numbers on average for the vegetation period decreased by 22.1% when using it alone and by 28.4 to 30.4% for combined treatment (Table 2). NeemAzal showed a considerably weaker protective effect and the decrease in pest density was 13.5% on average, and for combined use it was within the limits of 16.3 to 20.9%. Compared to Pyrethrum, the density of the pea weevil was 13.8% higher on average during vegetation period, irrespective of the stage and mode of application (alone or combined).

The action of bioinsecticides was influenced to some degree when combining them with organic products Biofa and Polyversum. The population density of bruchids in the combinations with Polyversum had lower values than the corresponding values of Biofa. The most pronounced protective action among the organic products was observed for the variant of Polyversum+Pyrethrum (30.4% reduction) followed by Biofa+Pyrethrum (28.4%) and the decrease in the numbers, as compared to the corresponding combinations of NeemAzal, was 12.1 and 14.4%. Logically, the most pronounced protective action among all used products was shown by the synthetic insecticide Nurelle D and its combination of Nurelle D+Flordimex (37.9% and 41.8% reduction, respectively).

With regard to the frequency of use, the effect of two-fold application of bioinsecticides (at budding and flowering) was considerably higher and when using them alone the pest abundance decreased on average by 23.7% for Pyrethrum and by 12.5% for NeemAzal in comparison with the one-fold treatment (at the budding stage). Herein an important factor appeared to be the longer period of protection of the plants from the bruchid attack, which determined the significant difference in density in comparison with the treatment at the budding stage only. As a result of the combination of Pyrethrum with organic products Biofa and Polyversum, the bruchid numbers decreased definitely to a greater extent by 33.7 and 33.0% respectively, as compared to the relevant combinations applied once. A similar trend was observed for the relevant combinations of NeemAzal but the bruchid numbers decreased to a lower extent (by 16.9 and 25.3%, respectively). The differences in pest density when treating once and twice with bioinsecticides (alone and in combinations) on average for the period were statistically significant ($p<0.05$) as compared to the control excepting the variants: NeemAzal and Biofa+NeemAzal at the budding stage. The trend during the different years was

Table 2. Influence of some insecticides used alone and in combinations with a foliar fertilizer and growth regulators on population density of the pea weevil during vegetation period

Variants	Stages of treatment[1]	2011	2012	2013	2011-2013	Increase/ Decrease[2] (%)
		(mean no./100 sweepings)				
Control (C)	b	22.3 f	48.0 fg	26.6 e	32.3 def	
	b+f	21.6 e	45.3 f	24.8 ef	30.6 d	
	mean	22.0	46.7	25.7	31.5	
Biofa	b	21.8 ef	50.6 g	25.1 cde	32.5 ef	0.6
	b+f	22.0 e	47.4 f	26.6 f	32.0 d	4.6
	mean	21.9	49.0	25.9	32.3	2.4
Polyversum	b	23.3 f	46.5 efg	26.9 e	32.2 def	–0.2
	b+f	21.9 e	47.1 f	24.4 def	31.1 d	1.7
	mean	22.6	46.8	25.7	31.7	0.6
Flordimex	b	22.0 ef	52.1 g	27.1 e	33.7 f	4.4
	b+f	20.0 de	48.8 f	26.1 f	31.6 d	3.4
	mean	21.0	50.5	26.6	32.7	3.8
NeemAzal	b	19.8 cd	43.5 def	23.1 cde	28.8 cde	–10.8
	b+f	17.3 c	39.0 e	20.6 cde	25.6 c	–16.2
	mean	18.6	41.3	21.9	27.2	–13.5
Pyrethrum	b	18.7 bcd	40.2 cde	22.5 bcde	27.1 c	–16.0
	b+f	14.0 a	32.0 bcd	19.8 bcd	21.9 bc	–28.3
	mean	16.4	36.1	21.2	24.6	–22.1
Nurelle D	b	16.4 a	30.6 ab	18.1 ab	21.7 ab	–32.8
	b+f	12.6 a	25.2 a	14.5 a	17.4 a	–43.0
	mean	14.5	27.9	16.3	19.6	–37.9
Biofa+NeemAzal	b	20.3 de	43.0 def	21.9 bcd	28.4 cd	–12.1
	b+f	18.0 cd	34.8 de	20.0 bcd	24.3 c	–20.7
	mean	19.2	38.9	21.0	26.4	–16.3
Biofa+Pyrethrum	b	19.0 cd	38.0 cd	20.4 abc	25.8 c	–20.1
	b+f	13.5 a	29.0 abc	15.3 ab	19.3 ab	–37.0
	mean	16.3	33.5	17.9	22.6	–28.4
Polyversum+NeemAzal	b	19.7 cd	41.8 cdef	21.5 bc	27.7 c	–14.3
	b+f	16.4 bc	33.2 cd	16.8 abc	22.1 bc	–27.7
	mean	18.1	37.5	19.2	24.9	–20.9
Polyversum+Pyrethrum	b	18.0 abc	36.4 bc	20.6 abc	25.0 bc	–22.6
	b+f	14.3 ab	26.6 ab	15.6 ab	18.8 ab	–38.5
	mean	16.2	31.5	18.1	21.9	–30.4
Nurelle D+Flordimex	b	16.8 ab	28.8 a	16.0 a	20.5 a	–36.4
	b+f	12.3 a	23.5 a	12.5 a	16.1 a	–47.4
	mean	14.6	26.2	14.3	18.3	–41.8
p=0.05	b	1.999	6.555	4.807	4.025	
p=0.05	b+f	2.220	5.788	4.750	3.902	

[1] b, stage of budding; b+f, stage of budding and flowering. [2] Respect to control. Values within a column followed by the same letters are not significantly different (p>0.05).

identical with minor exceptions. The combination of Pyrethrum and NeemAzal with organic products raised their protective action, but no significant differences were observed, as compared to their use alone irrespective of the stage and years. Pyrethrum was distinguished for a better effect on the population density of *B. pisorum:* under two-fold treatment it reduced the numbers by 29.8% on average, as compared to the treatment only once, but for NeemAzal the value was relatively lower, 15.2%.

The recording of the degree of damaged seeds showed that the trend of a better protective action of Pyrethrum persisted and the percentage of damage was 28.2% on average compared to 34.2% for NeemAzal (Fig. 1). Despite the fact that there were no significant differences between the uses of bioinsecticides alone and combined, the best results were established for the combination of Pyrethrum with Polyversum, where the highest grain yield was recorded, followed by Pyrethrum+Biofa. The organic products Biofa and Polyversum did not show a toxic effect and in 2011 to 2013 the mean bruchid density approximated or slightly exceeded the control. Compared to the bioinsecticides and their combinations the application of the synthetic insecticide Nurelle D reduced the damaged seed amount to a greater degree, by 8.9%. The two-fold use of the combination between Pyrethrum and Polyversum approximated the protective effect of Nurelle D.

The productivity of spring forage pea cv. Pleven 4 was influenced positively by the application of all organic products, which are the object of this study (Table 3). When applied alone, the organic products Biofa and Polyversum, which directly stimulated the plant growth and development, led to a yield increase of 8.2% on average for the three-year period as against the control. The foliar fertilizer Biofa, whose rich content of macro and microelements determined a more significant increment of the productivity compared to that of the organic product Polyversum, was distinguished for a more pronounced action. The application of the synthetic growth regulator Flordimex was related to the realization of higher productivity (by 13.6% on average), but in comparison with the productivity after treatment with Biofa and Polyversum in all three experimental years the differences were insignificant.

When using alone the organic products NeemAzal and Pyrethrum having an insecticidal action, the productivity also trended to an increase (of a mean value of 7.1%) which was conditioned by the control of bruchid and its decreased density during the vegetation period. Despite the considerably greater efficacy of the synthetic insecticide Nurelle D, the differences in the yield compared to the bioinsecticides NeemAzal and Pyrethrum were not significant (an exception was observed for the treatment with Pyrethrum in 2011).

The weather conditions during the study had some influence on the number and harmful activity of the pea weevil. Earlier appearance and development of weevils in 2012 and higher activity and fertility of the adults were determined by favorable air temperature and sum of rainfall during the growing season of 2012. In terms of applied insecticides, their efficacy was similar in 2011 and 2012, while in 2013 it was lower (due to considerable rainfalls). In the earlier study was found that NeemAzal and Pyrethrum not had a harmful influence on beneficial species *Aeolothrips intermedius* Bagnall (Thysanoptera: Aeolothripidae) and *Coccinella septempunctata* L. (Coleoptera: Coccinellidae) (Nikolova & Georgieva, 2015).

The combined use of organic products having an insecticidal action and those having no insecticidal action led to synergetic manifestations. The synergetic manifestations of Polyversum were much more pronounced than those of Biofa and the yield increased by 10.9% on average for the combinations with Polyversum, compared to its use alone (the value was 6.9% for Biofa irrespective of the fact that the foliar fertilizer used alone was more effective than the growth regulator). The plants treated with the four organic combinations formed an average yield of 3190.2 kg/ha, which was only 4.7% lower compared to that formed for the synthetic combination of Flordimex+Nurelle D. The differences between organic combinations and synthetic combination were not significant during the separate years except for the treatment with Biofa+NeemAzal in the second experimental year. A particular emphasis should be placed on the combined use of Biofa+Pyrethrum and Polyversum+Pyrethrum at the budding and flowering stages: these combinations were distinguished not only for high productivity, but also for the most pronounced protective effect against the pea weevil attack.

In the conditions of this study the grain yield was influenced also by the stages and frequency of treatment. Despite the obtained higher absolute values of the parameter under two-fold treatment at budding and flowering, there was no significance compared to the treatment at the budding stage in all three experimental years. On average for the period of 2011 to 2013 under application at budding and flowering, the formed yield was 3169.4 kg/ha grain, which was 5% higher than that under application at the budding stage. The effect of the two-fold treatment (as against the treatment only once) was more pronounced under combined application of the products compared to their use alone.

Figure 1. Influence of some insectides used alone and in combinations with a foliar fertilizer and growth regulators on degree of damaged seeds by *Bruchus pisorum.* 1, Control; 2, Biofa; 3, Polyversum; 4, Flordimex; 5, NeemAzal; 6, Pyrethrum; 7, Nurelle D; 8, Biofa+NeemAzal; 9, Biofa+Pyrethrum; 10, Polyversum + NeemAzal; 11, Polyversum + Pyrethrum; 12, Flordimex + Nurelle D. b, stage of budding; b+f, stage of budding and flowering.

Table 3. Grain productivity under influence of organic and synthetic products

Variants	Stages of treatment [1]	2011	2012	2013	2011-2013	Increase [2] (%)
		(kg grain/ha)				
Control (C)	b	2618.7	3020.8	2519.7	2719.7	
	b+f	2645.1	3035.5	2511.7	2730.8	
	mean	2631.9	3028.1	2515.7	2725.2	
Biofa	b	2832.0	3209.6	2774.7	2938.8	108.1
	b+f	2950.9	3331.5	2848.8	3043.7	111.5
	mean	2891.5	3270.5	2811.7	2991.2	109.8
Polyversum	b	2813.3	3132.5	2649.6	2865.2	105.3
	b+f	2901.6	3174.7	2753.1	2943.1	107.8
	mean	2857.5	3153.6	2701.3	2904.1	106.6
Flordimex	b	2972.5	3257.1	2815.5	3015.0	110.9
	b+f	3152.3	3440.3	2932.5	3175.0	116.3
	mean	3062.4	3348.7	2874.0	3095.0	113.6
NeemAzal	b	2749.1	3137.1	2641.1	2842.4	104.5
	b+f	2938.7	3213.3	2689.6	2947.2	107.9
	mean	2843.9	3175.2	2665.3	2894.8	106.2
Pyrethrum	b	2749.1	3219.7	2710.9	2893.2	106.4
	b+f	2801.1	3371.7	2811.5	2994.8	109.7
	mean	2775.1	3295.7	2761.2	2944.0	108.0
Nurelle D	b	2992.3	3235.5	2860.3	3029.3	111.4
	b+f	3113.1	3483.2	2941.6	3179.3	116.4
	mean	3052.7	3359.3	2900.9	3104.3	113.9
Biofa+NeemAzal	b	3021.9	3274.1	2860.5	3052.2	112.2
	b+f	3175.7	3427.7	2960.4	3188.0	116.7
	mean	3098.8	3350.9	2910.5	3120.1	114.5
Biofa+Pyrethrum	b	3072.8	3394.4	2987.5	3151.6	115.9
	b+f	3329.1	3501.9	3163.7	3331.6	122.0
	mean	3200.9	3448.1	3075.6	3241.6	118.9
Polyversum+NeemAzal	b	3038.9	3286.4	2908.3	3077.9	113.2
	b+f	3182.4	3485.1	3060.0	3242.5	118.7
	mean	3110.7	3385.7	2984.1	3160.2	116.0
Polyversum+Pyrethrum	b	3046.4	3478.1	2930.4	3151.6	115.9
	b+f	3199.5	3641.6	3138.9	3326.7	121.8
	mean	3122.9	3559.9	3034.7	3239.2	118.9
Flordimex+Nurelle D	b	3137.9	3528.3	2953.9	3206.7	117.9
	b+f	3392.5	3722.9	3358.1	3491.2	127.8
	mean	3265.2	3625.6	3156.0	3348.9	122.9

[1] b, stage of budding; b+f, stage of budding and flowering. [2] Respect to control. LSD $p \leq 0.5$: F.A = 129.2; F.B = 258.4; F.C = 105.5; A×B = 347.6; A×C = 182.7; B×C = 365.4; A×B×C = 633.0.

By the analysis of variance with regard to the grain yield (Table 4) it was established that the years had a strong influence on the parameter, 23.0% of the total variation of the variants. The large differences in the meteorological conditions during the three years of the trial were the reason for that. The influence of years and products had very high significance at a level of probability $p \leq 0.01$ and that of the treatment stages had high significance at a level of probability $p \leq 0.1\%$. There was a significant interaction of products and their tank mixtures with the conditions of the years (A×B), 2.4%, which was significant at a level of probability $p \leq 0.5$.

Table 4. Analysis of variance for grain yield

Source of variation	Degrees of freedom	Sum of squares	Influence of factor,%	Mean square
Total	215	412198	100	–
Tract of land	2	7060	1.7	320.9
Variants	71	183638	45.4	2586.6**
Factor A – Years	2	96132	23.0	48066.0***
Factor B - Products	11	57040	13.8	5185.5***
Factor C – Stages of treatment	1	11240	2.7	11240.0**
A×B	22	10150	2.4	5075.0*
A×C	2	24	0.5	120.0
B×C	11	5260	1.3	478.2
A×B×C	22	6882	1.7	312.8
Pooled error	142	218410	52.9	1538.1

*$p \leq 0.5$, **$p \leq 0.1$, ***$p \leq 0.01$.

Therefore the effectiveness of some products or some of their combinations was strongly influenced by the meteorological conditions during the different years. The interaction between treatment stages and year conditions (A×C) was 0.5%, that between products and treatment stages (B×C) was 1.3% and that between the three factors of the trial (A×B×C) was 1.7% and they were not significant. The lack of a significant interaction showed that the conditions during the years had a weak influence on their action with regard to the pea grain yield.

On the basis of the significant interactions of product × year (A×B), the stability of manifestations of each variant, consisting of product and treatment stage, was evaluated with respect to the years (Table 5). The variances of stability, σ_i^2 and S_i^2, which take account of the linear and nonlinear interactions, respectively, evaluate unidirectionally the stability of the variants. Those variants, which showed lower values, were estimated as more stable, because they interacted more weakly with the environmental conditions. The negative values of the indicators σ_i^2 and S_i^2 were taken for 0. At significantly high values of anyone of the two parameters (σ_i^2 or S_i^2) the variants were considered as unstable. At the ecovalence W_i, the higher the values of the parameter, the more unstable the corresponding variant. On that basis, using these three parameters of stability, it was found that the combinations of organic fertiliser Biofa with bioinsecticide Neemazal applied at budding+flowering stages and the combination of growth regulator Polyversum with bioinsecticide NeemAzal applied at budding stage were most unstable. For these variants the values of the variances of stability σ_i^2 and S_i^2 and ecovalence W_i were highest and mathematically significant. For the abovementioned tank mixtures there was instability of a linear and nonlinear type. The instability was mainly due to the significant differences in the grain yield of these mixtures during the different experimental years, especially in 2013 compared to 2011 and 2012. The meteorological conditions influenced these variants most strongly.

In order to make a complete evaluation of the effectiveness of each variant, both its influence on the grain yield of forage pea and its stability, the reaction of the crop in the different years should be taken into account. Very valuable information about the technological value of the variants was given by the indicator YS_i for a simultaneous evaluation of yield and stability, based on the significance of the differences in the yield and the variance of interaction with the environment. The generalizing criterion of stability YS_i, which considered both stability and value of grain yield, gave a negative evaluation only for the untreated control, characterizing it as the most unstable and low-yielding variant. According to this criterion, the variants with twofold application of combinations of the studied products were technologically most valuable. These variants united high values of grain yield and high stability of this indicator during the different years. The highest evaluation was obtained by two-fold treatment with organic mixture of Biofa+Pyrethrum (24+), followed by Polyversum+NeemAzal (22+). These evaluations were very similar to that of synthetic mixture of Flordimex+Nurelle D (26+). The variants with products used alone obtained low evaluations, mainly due to the lower yields, although they were characterized by high stability of the indicator during the different years. In terms of the technology of forage pea cultivation, a

Table 5. Stability parameters of the variants for grain yield in regard to the years

Variants	Stages of treatment[1]	σ_i^2	S_i^2	W_i	Ys_i
Control (C)	b	31.7	77.9	83.3	–1
	b+f	7.1	19.2	38.3	0
Biofa	b	86.5	140.9	183.9	5
	b+f	20.4	54.4	62.8	12
Polyversum	b	–8.1	–11.1	10.4	3
	b+f	52.4	–9.6	121.3	6
Flordimex	b	27.1	–8.6	75.0	10
	b+f	17.0	47.8	56.4	19+
NeemAzal	b	17.5	50.9	57.4	2
	b+f	49.0	113.9	115.1	7
Pyrethrum	b	167.8	335.8	332.9	4
	b+f	460.3	778.9	869.2	9
Nurelle D	b	139.0	–10.0	280.1	11
	b+f	–2.3	–10.1	21.0	20+
Biofa+NeemAzal	b	76.4	2.2	165.4	15+
	b+f	1419.8*	1839.7*	2628.2	16+
Biofa+Pyrethrum	b	78.3	36.8	168.9	18+
	b+f	295.2	50.6	566.5	24+
Polyversum+NeemAzal	b	130,9	–10.7	265.2	17+
	b+f	41.0	–5.7	100.5	22+
Polyversum+Pyrethrum	b	3851.6*	2359.6*	7086.6	8
	b+f	103.3	216.5	214.7	23+
Flordimex+Nurelle D	b	26.3	–11.3	73.5	21+
	b+f	191.6	140.7	376.6	26+

[1] b, stage of budding; b+f, stage of budding and flowering. σ_i^2 and S_i^2, variances of stability, W_i, ecovalence, Ys_i, criterion of stability of Kang.

high evaluation was also obtained by the variants with application of the mixtures among products only once at the budding stage. They united good grain yields with high stability in the different years of study.

Discussion

Different biopesticides, such as botanical pesticides can contribute to pea weevil control. Biopesticides used to control pests include animals, plants, bacteria, and minerals (Bonsignore & Vacante, 2012). A number of merits can be mentioned in favour of biological insecticides, including neem and pyrethrum, in this respect: 1) the proved efficacy of the neem products under field conditions; 2) its environmentally friendly characteristics coupled with its harmless or minimal side-effects on the main natural enemies; 3) the great enthusiasm of the farmers for available inexpensive pesticide and their willingness to use it in their crop fields (El Shafie, 2001).

Many studies confirmed that neem compounds act in different ways on insects, disrupting the developmental processes, inducing adult sterility, disturbing adult behavior, or by repelling adults and larvae (Schmutterer, 1990; Mordue & Blackwell, 1993). Pyrethrum products were effective and had high lethal activity toward insects, low mammalian toxicity, and short environmental lifetimes (Henry *et al*., 1999).

The present study demonstrates that the biopesticides NeemAzal and Pyrethrum reduced pea weevil adult numbers and had high effect, as a better protective action showed Pyrethrum Similar results were found by many authors. Weaving (1970) and Yankova (2010) reported about a high toxic effect and good protection of Pyrethrum against different bruchid species. The botanical insecticides Neem Azal T/S (azadirachtin) and Pyretrum FS-EC (pyrethrum) showed an excellent effectiveness against rosy apple aphid (*Dysaphis plantaginea* Pass.) (Andreev *et al*., 2012). Schmutterer (1990) reported observable effect of neem products in the jassid [*Amrasca biguttula biguttula* Ishida (Hemiptera: Cicadellidae)] adult stage as a reduction of fecundity or reduced fitness reported. According to Pavela (2009) biological efficiency of neem oil was high against *Tetranychus urticae* Koch and *Spodoptera littoralis* Boisduvala.

Neem products may exhibit systemic effect and could affect on larval bruchids. Maheshkumar *et al.* (2000) studied the systemic effect of eight neem formulations including neemAzal-T/S on the green leafhopper (*Nephotettis virescens* Distant.) on rice seedlings as they demonstrated a downward translocation of azadirachtin. In another experiment, their results showed that only six hours are enough for the seedling roots dipped in neemAzal-T/S to prove the upward translocation and efficiency against the green leafhopper nymphs. Larew (1988) demonstrated the movement of a neem extract ingredient from a sprayed bean leaf to an unsprayed leaf on the opposite side of the plant.

Liu *et al*. (2014) recommended that azadirachtin and Pyrethrum should be combined with plant oils in order to be more effective. In this study as a result of the combination of Pyrethrum and NeemAzal with organic products Biofa and Polyversum, the bruchid numbers decreased definitely to a greater extent as compared to the relevant combinations applied once.

The recording of the degree of damaged seeds showed that the trend of a better protective action of Pyrethrum compared to NeemAzal was persisted. Similar results were established by Mulungu *et al.* (2007), according to which Pyrethrum, compared to other organic insecticides against bean bruchid, was distinguished for a low percentage of damaged seeds.

It should be noted that many field tests reported that neem's field performance in many pest control uses has failed to equal that of standard synthetic insecticides, perhaps because of its limited persistence and limited effectiveness in the presence of sunlight and rainfall (Rechcigl & Rechcigl, 2000). Pavela (2009) reported that biological products containing azadirachtin are unstable under illumination, have rapid photodegradation under UV radiation, and are susceptible to low temperatures and rainfall. NeemAzal was less effective in 2013 due to heavy rains in June coinciding with the treatment. The use of botanical insecticides could reduce insect pest resistance, resurgence, environmental pollution, ecological imbalance and harmful residues in market production (White & Leesch, 1995).

Based on our results in terms of productivity, field pea showed a relatively well-pronounced responsiveness to alone application of organic products with growth-stimulating effect or insect protective action (Table 3). The obtained results are of great importance, because the data of the use of Biofa are insufficient (Cholakov & Boteva, 2012) and those of Polyversum present mainly the fungicidal effect of the product (Gewehr, 2011; Boček *et al*., 2012). The most pronounced effect among organic products applied alone had foliar fertilizer Biofa based on algae extract that led to an increase by 9.8% on average over the control. Algal biomass has been widely used in agriculture (FAO, 2008) as a source of nutritive, biostimulating and bioregulating compounds (Khan *et al.*, 2009). Especial meaning had the abundance of biostimulants, such as growth hormones, betaines, sterols micro- and macro nutrients and polysaccharides (Khan, 2009). In a research conducted in conditions of pot experiment, Sabh & Shallan (2008) found that treating with algae powders as organic fertilizers improved the vegetative characters as well as yield components of broad bean in comparison with untreated and chemically fertilized plants. Also seed treatment with bioactive compounds from algae was proved to enhance growth of cowpea, mung bean and lupin (Haroun & Hussein, 2003; Sivasankari *et al*., 2006; Kavipriya *et al*., 2011).

Less but satisfactory effect on field pea yield in our experiment showed Polyversum. Its application is in line with the current management strategy in the agriculture which relies on the intensive search for new, natural biological agents which act not only against different pathogens, but also have stimulating effect on plants (Dmytryk *et al*., 2015). According to the producer (Biopreparaty Ltd., Czech Republic) the fungus *Pythium oligandrum* directly inhibits the growth of phytopathogenetic microorganisms in a plant and influences the production of growth-stimulating substances in a plant.

Field pea productivity was positively influenced also by bioinsecticide treatments with values from 6.2 to 8.0% on average. This finding is in agreement with that obtained by Kalapchieva *et al*. (2010), who detected an increase in grain productivity (g/plant) of garden pea (*Pisum sativum* L.) after alone treatment with bioinsecticides (NeemAzal and Pyros).

In general, the productiveness after alone application of all organic products was 5.2% lower compared to that after alone application of synthetic products Flordimex and Nurelle D. In most variants the differences were not significant. The highest pea yield (2991.2 kg/ha) was realized after Biofa application which was compatible to the treatment with Flordimex with a small difference of 3.2%. A favorable effect on the vegetative and generative development after use of Flordimex or ethephon-based products in some forage crops was established by Dahnous *et al*. (1982), Sowinski (1994) and Jankowski *et al*. (2013).

It is worthy to note that the combined application of Biofa, Polyversym, NeemAzal and Pyrethrum was more effective than their using alone with a mean value of 8.8%. Accordingly, double treatment resulted to a higher productivity compared to single treatment but the effect was by half less pronounced (4.4%). The suitable bibliographic revision was performed and no analogous studies were found. Thus, there was no possibility to compare own results with those obtained by other researchers. But it has been found in many experiments that combined application of synthetic growth regulators, fertilizers and insecticides improves growth and productiveness of forage crops – pea, vetch and lucerne (Tsibulko *et al.*, 2000; Georgieva & Nikolova, 2010a,b). A number of producers of growth regulators recommend their joint application with leaf fertilizers and preparations for plant protection, by which the effect of the used preparation increases. According to data of Tsibulko *et al.* (2000), the best technological method of treatment with growth regulators is their joint application with insecticides. The results showed a yield increase of 14%, as against the control, after treatment with growth regulator Ferocor and 17 to 21% after combination of Ferocor with an insecticide (BI-58, Karate, Basudin and Fosalon). The same authors stated also that two-fold treatment (at budding and flowering) of lucerne (*Medicago sativa*) provided a yield increase of 12.0% compared to treatment only once at budding. In addition, the variants with twofold application of the combination of Biofa, Polyversum, Neemazal, Pyrethrum were distinguished as more stable and technologically valuable in regard to grain yield. These data are in agreement with results obtained in our previous experiments which studied the effect of combined application of synthetic regulators, fertilizers and insecticides in forage crops (Delchev *et al.*, 2013; Georgieva *et al.*, 2013).

In conclusion, the application of the organic products Biofa, Polyversum, NeemAzal and Pyrethrum positively influenced the forage pea productivity. The combined use of these products led to synergetic manifestations. The plants treated with the organic combinations formed an average yield of 3190.2 kg/ha, which was only 4.7% lower than that for the synthetic combination of Flordimex+Nurelle D. The highest yield was produced under application of two mixtures: foliar fertilizer Biofa+bioinsecticide Pyrethrum and growth regulator Polyversum+bioinsecticide Pyrethrum at budding and flowering stages. In addition, these combinations were also distinguished for their most pronounced protective effect against the pea weevil attack and decrease in its numbers of 37.0 and 38.5%, respectively. Technologically, the most valuable variant, which united high stability, productivity and protection against the pea weevil, was the combination of Biofa+Pyrethrum applied twice, whose parameters were similar to those of the synthetic tank mixture of Flordimex+Nurelle D. It may be recommended for organic pea cultivation. The results of this study showed that the use of organic products in field pea cultivation gives promising outcomes. Further investigations are indispensible to expand the range of products (bioinsectides, biofertilizers and growth regulators), which provides good insect control, high productivity and stability in conditions of organic farming.

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