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GRAIN PRODUCTIVITY, YIELD STABILITY AND NUTRITIVE VALUE OF FIELD PEA (*PISUM SATIVUM L.)* UNDER ORGANIC FARMING CONDITIONS (PLEVEN, BULGARIA)

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Abstract: The introduction of organic, alternative crops such as *Pisum sativum* can be seen as a contribution to the development of more sustainable agricultural practices worldwide. The present research aimed to study the grain productivity, stability and nutritional value of Pisum sativum under the use (alone and combined) of organic products (foliar nanofertilizers /Lithovit, Nagro/ and insecticides /Madex, Agricol/). The controls were two: 1) untreated control and 2) variants with conventional cultivation using synthetic preparations (foliar fertilizer Kristalon and insecticide Proteus 110 OD). A randomized block design with three replications was used. The results showed that the treatment with organic products increased the grain yield (by 7.8 to 32.8%) and the protein content (by 1.7 to 10.5%), and decreased the crude fiber content (by 14.7 to 49.1%) compared to the untreated control. The combination of Lithovit+Madex was distinguished by significantly higher productivity compared to a synthetic combination (fertilizer Kristalon+ insecticide Proteus OD 110). The treatment with Agricoll and its combinations (Nagro+Agricoll, Lithovit+Agricoll) had a particularly favorable effect on the seed biochemical composition. The mixed use of organic products resulted in very well-expressed manifestations of subadditive type of synergism. The complex evaluation in terms of stability parameters (criterion of stability YSi, stability variance σi^2 and ecovalence Wi) determined Nagro + Madex and Lithovite + Madex as stable combinations.

Keywords: organic products, field pea, grain productivity, stability, nutritive value.

INTRODUCTION

Organic farming can be defined as a form of farming that uses sustainable natural resources and strategies such as the application of organic fertilizers, biological pest control, and crop rotations. It uses natural fertilizers and plant protection products that differs it from traditional conventional agriculture, which applies synthetic fertilizers, growth regulators and pesticides as an increasing yield means (Epule et al., 2015). Compared to conventional agriculture, it is more efficient in using non-renewable energy, maintaining or improving soil quality, and has a less harmful impact on water quality and biodiversity (Clark, 2020).

Measured in land area, number of farms or product sales, organic farming marks stunning growth over the past few decades (Lockeretz, 2007; Clark, 2020). The reason is the increased societal interest in environmental protection and healthy nutrition (Clark, 2020). Prior to the 1980s, the organic farms number was “negligible”, according to Lockeretz (2007) in Organic Farming: An International History. Today, the organic farms occupy 1% or slightly more of the total agricultural area and significantly more in many developed countries (Reganold & Wachter, 2016; Meemken & Qaim, 2018; Willer et al., 2020). Sales of organic products reach USD 55 billion in the United States (Organic Trade Association, 2020) and USD 100 billion globally (Willer et al., 2020). This surge is largely due to a societal desire to limit the environmental damage caused by agriculture and to consume “healthy, high-quality foods” (Lockeretz, 2007).

Legumes are defined as critical species in organic production systems because they fix and use their own N and supply it back to the soil from biomass after harvesting at a rate of 40 million tons per year (Seufert et al., 2012; Udvardi and Poole, 2013). According to Powers & Thavarajah (2019), the introduction of organic, alternative crops such as field pea (*Pisum sativum* L.), rich in nutrients, can be seen as a contribution to the development of more sustainable agricultural practices worldwide. Field pea is one of the oldest domesticated species (Malcolmson et al., 2014). It is valued primarily for its high protein content combined with important minerals, vitamins (Ceyhan & Avci, 2005) and bioactive compounds (Ma, Boye & Hu, 2017). Starch and protein contents are usually in the range between 30 and 50% and 20–25%, respectively (Shi et al., 2014). Pea protein is a relatively new type of plant protein, and it is used as a functional ingredient in the global food and feed industry (Lu et al., 2020).

The aim of the present research was to study the grain productivity, stability and nutritional value of *Pisum sativum* under the use (alone and combined) of organic products.

MATERIAL AND METHODS

The field experiment was conducted in the Institute of Forage Crops (Pleven, Bulgaria) during the period of 2015 to 2017. Sowing was done in March at a rate of 120 seeds/m2 (Pleven 4 variety). Pleven 4 is Bulgarian

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variety of spring fodder peas. The plants are medium tall (80-120 cm) and well leafy. The mass of 1000 seeds varies from 190 to 200 g. It is characterized by relatively good resistance to economically important diseases and pests. It is used for green biomass and grain. The trial was situated on an area for organic production, with a 2-year conversion period. Eight variants of organicl production were studied, with alone and combined application of organic products (foliar fertilizers and bioinsecticides). Insecticide treatment is a mandatory technological element in field pea cultivation in Pleven region due to the high population density of *Bruchus pisorum.* Organic nanoproducts (Lithovit, Nagro), containing a complex of nutrients, were used as foliar fertilizers (Table 1). Organic insecticides (Madex, Agricoll) were based on granular virus and natural polysaccharides.

Table 1.

Characteristic of used products

Products	Composition	Producer
Organic production		
Lithovit	79.19% $CaCO_3$, 4.62% $MgCO_3$, 1.31% Fe, 0.33% N, 0.01% P, 0.005% Zn, 0.014% Mn, 0.002% Cu, 11.41% SiO_2	ZeoVITA, Germany
Nagro	humic acids – 5.6 g/l; fulvic acids – 2.07 g/l; N – 0.28 g/l; P – 0.226 g/l; K – 3.073 g/l; trace elements (Mg, Co, Mn, Zn, Fe, Cu, Mo, B, Ca, Se) – 1900 mg/l	BioPlant, Russia
Madex	2% granular virus with a titer of 6x10 granules + microparticles from the larvae of the apple fruitworm and water	Andermatt-Biocontrol, Switzerland
Agricoll	polysaccharide of plant origin	Biopol Natural, Netherlands
Conventional production		
Kristalon	N - 18% (ammonium nitrogen – 3.3%; nitrate nitrogen – 4.9%; amide nitrogen – 9.8%) P /P_2O_5/ - 18%; K /K_2O/ - 18%; Mg /MgO/ - 3%; S /SO_3/ - 5% trace elements: B - 0.025%; Fe - 0.070%; Mn - 0.040%; Cu - 0.010%; Mo - 0.0004%; Zn - 0.025%	Nu3 BV, Holand
Proteus OD 110	thiacloprid 100 g/l; deltametrin 10 g/l	Bayer CropScience, Germany

The controls were two: 1) untreated control and 2) variants with conventional cultivation using synthetic preparations (foliar fertilizer Kristalon and insecticide Proteus 110 OD). These variants were situated in an area with conventional production. At the time of experiment performance, Kristalon and Proteus 110 OD were one of the most frequently applied synthetic preparations in conventional production of field crops. Therefore, they were used as a second control.

The two-factor field experiment was carried out by a randomized block design: (i) factor A, years, including the three years of the research (a1, 2015; a2, 2016; a3, 2017); (ii) factor B, products and mixtures between them, including 12 levels (B_1 untreated control; B_2 Lithovit 2000 g/ha; B_3 Nagro 500 ml/ha; B_4 Madex 600 ml/ha; B_5 Agricoll 1000 ml/ha; B_6 Lithovit 2000 g/ha + Madex 600 ml/ha; B_7 Lithovit 2000 g/ha + Agricoll 1000 ml/ha; B_8 Nagro 600 ml/ha + Madex 600 ml/ha; B_9 Nagro 600 ml/ha + Agricoll 1000 ml/ha; B_{10} Kristalon 2000 g/ha; B_{11} Proteus 110 OD 600 ml/ha; B_{12} Kristalon 2000 g/ha + Proteus 600 ml/ha). The plot size was 10 m^2 with three replications. All products were applied twice, at budding and at flowering stages. The grain chemical composition of was determined as follows: crude protein (CP) – by Keldahl method, crude fiber (CF) by Weende method, phoshorus (P) – colorimetrically, by the hydroquinone method and calcium (Ca) – complexometrically.

In order to characterize representativeness and significant influence of the grain yield a statistical estimation was made by the analysis of variance (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 value. The programme Stable of Louisiana State University Agricultural Center, Baton Rouge, USA (1993) was used to calculate these parameters. All data were statistically processed with the software product Statgraphics Plus for Windows Version 2.1.

RESULTS

The study period was characterized with different meteorological conditions. The vegetation period (March–July) of 2017 had the most favorable conditions for the pea growth and development: an average daily temperature of 17.3°C and rainfall sum of 439 mm. The experimental years 2015 and 2016 were distinguished by lower sums of rainfall (on average 39%) and almost the same average daily temperature (17.2 °C).

When applied alone, the organic nanofertilizers Lithovit and Nagro led to a high and significant yield increase by 23.1 and 19.3%, respectively, as against the untreated control (Figure 1). The excess compared to the second control (treatment with the synthetic fertilizer Kristalon) was 4.3%, with a significant difference for Lithovit. The alone application of bioinsecticides Madex and Agricol, thanks to their protective action against pests, also created conditions for improving field pea productivity by 12.7 and 7.8%, respectively. In contrast to the high positive effect of Litovit and Nagro, exceeding that of Kristalon, the effect of bioinsecticides in terms of productivity was less pronounced than that of the synthetic insecticide Proteus 110 OD (18.1%). It should be noted, however, the higher effect of the application of Madex, which approximates to the action of Proteus 110 OD. The low effectiveness of bioinsecticides can be explained by their mechanism of action (contact), while Proteus is a broad-spectrum insecticide with systemic and contact action.

The mixed use of organic products has resulted in very well-expressed manifestations of subadditive type synergism, with an increase in yield by 23.8 to 32.1%. The combinations of Lithovit and Nagro significantly exceeded the productivity in alone use of the corresponding product. As a comparative characteristic, it can indicated that one of the organic combinations (Lithovit+Madex) exceeded the yield of the synthetic combination Kristalon+Proteus with mathematically significant difference. The differences in the remaining three organic combinations (compared to the synthetic combination) were negligible and statistically insignificant.

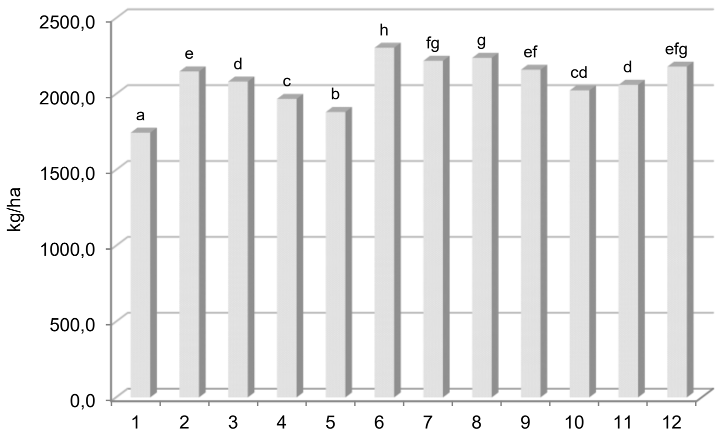

Fig. 1. Grain productivity in *Pisum sativum* under influence of organic and synthetic products. 1. Control 2. Lithovit 3. Nagro 4. Madex 5. Agricoll 6. Lithovit+Madex 7. Lithovit+Agricoll 8. Nagro+Madex 9. Nagro+Agricolle 10. Kristalon 11. Proteus OD 110 12. Kristalon+Proteus OD 110. a, b, c, d …… values followed by different letters are significantly different at $p < 0.05$.

The data analysis regarding 1000 seeds mass showed significant differences between the control plants and those treated with different products (organic and synthetic) and their combinations (Figure 2). The combination of Lithovit+Madex had the highest weight (150.82 g). There were no significant differences between most organic mixers, as well as between alone and combined applications of the fertilizers.

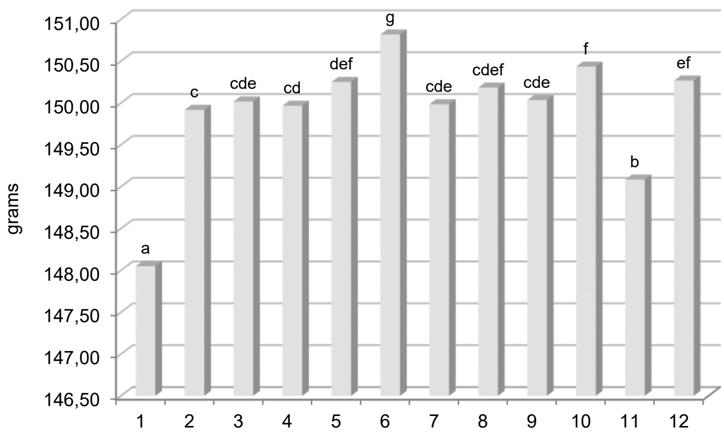

Fig. 2. Mass of 1000 seeds in *Pisum sativum* under influence of organic and synthetic products. 1. Control 2. Lithovit 3. Nagro 4. Madex 5. Agricoll 6. Lithovit+Madex 7. Lithovit+Agricoll 8. Nagro+Madex 9. Nagro+Agricolle 10. Kristalon 11. Proteus OD 110 12. Kristalon+Proteus OD 110.

By the analysis of variance in terms of the grain yield it was found that the years had the strongest influence on this indicator – 66.8% of the total variation (Table 2). This is due to the unequal response of the variants to the environmental conditions change. The strength of influence of the preparations, although less pronounced, was considerable - 27.5%. The influence of the years and products was very well demonstrated at a level of probability p≤0.01.There was a weak but significant interaction of the products and tank mixtures among them with the year conditions (A×B) - 1.1% at a level of probability level p≤0.5. The weak interaction showed that the year conditions had little influence on their action regarding the pea grain yield.

Table 2.

Analysis of variance for grain productivity in *Pisum sativum*

Source of variation	Degrees of freedom	Sum of squares	Influence of factor, %	Mean square	F-count	P-value
Total	107	9291712	100	-	-	-
Blocks	2	1088	0.1	544.0	0.1	n.s.
Varinants	35	8872544	95.4	253501.3	42.4	***
Factor A - years	2	6223792	66.8	3112400.0	521.1	***
Factor B - products	11	2553792	27.5	232162.9	38.9	***
A × B	22	93952	1.1	4270.3	0.7	*
Error	70	418080	4.5	5972.6	-	-

*p≤0.5 **p≤0.1 ***p≤0.01

On the basisi of the significant A×B interaction, the stability of manifestations of each variant with respect to the years was estimated (Table 3). The variances of stability (σi^2 and Si^2) of Shukla (1972), the ecovalence (Wi) of Wricke (1962) and the stability criterion (YSi) of Kang (1993) were calculated. The results showed that the foliar fertilizer Nagro and the insecticides Madex and Agricoll were the most unstable when using them alone. For these variants the values of the variance of stability σi^2 and ecovalence Wi were the highest and mathematically significant. Also, instability was found in the combination of Nagro+Agricoll. For the abovementioned variants there was instability of a linear type - significant values for σi^2. The instability was due mainly to the essential differences in the yields during the diffferent years, since the meteorological conditions influenced these variants most strongly. The rest of the products and their mixtures demonstrated relatively good stability (well-expressed in Nagro+Madex and Lithovit+Madex), regardless of the changes in weather conditions during the field pea growing season.

Kang's (1993) stability criterion YSi, which calculates both yield value and stability, gave a negative estimation for the untreated control and bioinsectide Agricoll (applied alone), characterizing them as the most unstable and low-yielding variants. According to that criterion, the combinations Lithovit + Madex, Nagro + Madex and Lithovit + Agricoll were technologically most valuable. These variants combined high yield values and high stability over the years. From the point of view of the pea cultivation technology, the combination Kristalon + Proteus also received a high estimation. It united good grain yields with high stability.

Table 3.

Stability parameters for grain yield in *Pisum sativum*

Variants	σ_i^2	S_i^2	W_i	YS_i
Control (untreated)	3115.3	157.1	6086.6	-2
Lithovit	-134.4	190.5	497.0	9+
Nagro	**5152.3***	3034.7	**9274.9**	5
Madex	**7982.3***	-129.1	**41024.8**	1
Agricoll	**9761.2***	397.2	**17000.0**	-1
Lithovit + Madex	3103.1	4319.8	4226.2	**15+**
Lithovit + Agricoll	-97.7	86.7	558.2	**13+**
Nagro + Мадекс	1884.3	2672.2	1861.5	**14+**
Nagro + Agricoll	**7560.6**	6003.5	**13322.1**	10+
Kristalon	4102.6	1713.7	7558.6	2
Proteus 110 OD	465.5	1466.6	1496.9	4
Kristalon + Proteus 110 OD	931.0	1169.5	1271.6	11+

The content of crude protein and crude fiber in field pea grain averaged 252.5 and 55.3 g/kg, respectively (Table 4). The obtained values were close to those indicated by other authors in the conditions of the country (Krachunov et al., 2007; Zhelyazkova, 2007). Compared to the control untreated variant, the organic products application increased the crude protein (by 1.7 to 10.5%) and decreased the crude fiber content (by 14.7 to 49.1%). The treatment with Agricoll and its combinations (Nagro+Agricoll, Lithovit+Agricoll) had

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a particularly favorable effect on the biochemical composition. The combined application of the organic products increased the content of CP (264.0 g/kg) and decreased the content of CF (47.4 g/kg) to a greater extent compared to the alone treatment (251.9 and 58.4 g/kg). The use of synthetic preparations resulted in a decrease in both the fiber content (on average by 30.0% compared to the untreated variant) and the protein content (on average by 5.6%).

Table 4.

Biochemical composition of field pea grains under influence of organic and synthetic products (g/kg)

Variants	Crude protein	Crude fiber	Ca	P
Control (untreated)	244.7 d	77.8 h	1.37 c	5.44 ab
Lithovit	248.9 e	59.6 e	1.42 cd	5.42 a
Nagro	259.7 g	62.5 f	1.28 b	5.56 c
Madex	259.2 f	66.3 g	1.14 a	5.45 b
Agricoll	268.7 k	45.3 b	1.53 e	5.86 g
Lithovit + Madex	262.9 j	55.7 d	1.42 cd	5.85 h
Lithovit + Agricoll	262.4 i	43.8 b	1.88 f	5.88 g
Nagro + Madex	260.3 h	50.4 c	1.08 a	5.69 e
Nagro + Agricoll	270.3 l	39.6 a	1.44 d	5.63 d
Kristalon	237.8 c	45.9 b	1.42 cd	5.68 e
Proteus 110 OD	226.4 a	59.1 e	1.36 c	5.83 f
Kristalon + Proteus 110 OD	229.1 b	58.1 e	1.47 d	5.86 g

Values within a column followed by the same letters are not significantly different (*p*≤0.5)

The average phosphorus content in the grain dry matter was 5.68 g/kg. The course of its accumulation (except for Lithovit treatment) was similar to that of crude protein, but with less differences (from 0.2 to 8.1%) compared to the control. Treatments with Agricoll and Litovit+Agricol had a strong influence on the phosphorus amount.

The calcium content averaged 1.40 g/kg with a range of 1.08 to 1.88 g/kg. An increase was observed in some variants and in others - a decrease in the calcium content, and it is difficult to establish trends depending on the type of product used. The plants treated with Agricoll and Lithovit+Agricol had the highest amount of calcium - on average by 12.1 and 37.2% compared to the control (untreated) variant.

DISCUSSION

In 2022, a total of 7,159,928 ha of field peas were harvested globally with an average yield of 1978.5 kg/ha (FAOSTAT, 2024). Over the past 30 years, the cultivated land acreage for field pea has been decreasing steadily, mostly due to low and unstable yields (Stagnari et al., 2017). Also, low and unstable yields are defined by many authors (Stancheva, 2000; Niggli et al, 2007; Uhr & Ivanov, 2015) as one of the main disadvantages in organic production conditions.

A positive effect on the growth and development of main field crops (wheat, barley, corn, sunflower) after using foliar fertilizer products (on different bases - vegetable, bacterial) has been established by a number of researchers (Milošević et al., 2003; El-Sirafy et al., 2006; Yankov and Drumeva, 2012; Stanojković et al., 2012; Stoyanova et al., 2015). After testing the organic fertilizers Humusil S, Megagreen and Biohumus in common bean and field pea, Stoyanova et al. (2014) reported an increase in grain yield by 7 - 14% and 17 - 19%, respectively. The obtained average yields were 109.3 and 198.3 kg/da, respectively. Megagreen had the highest positive effect in common bean and Biohumus in field peas. These results show a different biological response of common bean and peas to treatment with the same set of biological products. It is obvious that it should be approached individually, depending on the crop, looking for the most suitable product(s) where the respective species can show its full biological potential. The modern stage of organic agriculture development requires the search for alternative solutions related to the use of products that have the potential to provide yields close to and possibly higher than those obtained under conventional cultivation conditions and after treatment with synthetic products (Stoyanova et al., 2014, Georgieva et al., 2015). In our previous study (Georgieva et al., 2015), the individual and combined effects of an organic foliar fertilizer (Biofa), growth regulator (Polyversum) and bioinsecticides (NeemAzal, Pyrethrum) on pea grain productivity were investigated. The yield differences ranged from 5.3 тo 22% compared to the untreated control. Technologically the most valuable variant, which united high stability and productivity was the combination of Biofa+Pyrethrum applied twice.

In recent years, particular emphasis puts on the use of nanotechnological products (Vysokov and Tsvetkov, 2008; Ilieva-Obretenova, 2013; Sertova, 2015), whose molecular structures in a nano-sized state are considerably better absorbed by plant cells. Derosa et al. (2010) and Valizadeh & Milic (2016) indicated that nanofertilizers have some special characteristics as large surface area and small size (less than 100 nm), that help them penetrate into cells and improve availability of nutrients relevant to the crop productivity. Nanofertilizers can improve crop growth and yields, accelerate seed germination, enhance productivity, and stimulate plant protection system (Ram et al., 2018). According to some authors, nanofertilizers are more effective (Liu et al., 2006) and have the potential to surprass conventional fertilizers (Sekhon, 2014). A number of researchers recommended the nanofertilizers application to improve the low productivity of crops (Mahajan et al., 2011; Valizadeh and Milic, 2016; Ram et al., 2018). They had an essential effect on the morphological, physiological and biochemical parameters of plants (Yadav and Yadav, 2016). In a field experiment with *Cicer arietinum* L., Morovat et al. (2019) found that the application of nanofertilizers with micronutrients (Zn, Fe) resulted in significant differences in yield structural elements (pods number, 100 seeds mass), grain yield and biomass. Kara & Sabir (2010) tested a natural product made of Ca, Fe, Mg and Si elements in *Vitis vinifera*. They reported accelerated vegetative growth and a beneficial effect on photosynthesis. Soybean plants treated with calcium carbonate nanoparticles (500 g/fadan) demonstrated higher seed yield and biological yield (Abd El-Hady & Hussein, 2021). The absolute values in the control variant were 1.353 and 4.580 tons/fad for seed yield and biological yield, respectively, and after treatment they increased to 1.481 and 5.122 tons/fad. A similar dependence was reported for 1000 seeds mass. However, there were no significant differences in seed protein content between treated and untreated plants. According to data of Abd El-Aal & Eid (2018), foliar application of Litovit (at a dose of 250 and 500 mg/l) increased the mass of 100 seeds and the productivity of soybean plants. The author also found an improved chemical composition (crude protein, total carbohydrates, N, P, K, Ca, Mg, Fe) of the leaves. Similar stimulating effects of nano calcium carbonate have been observed by other researchers who reported increased soluble protein and soluble sugars in peanut (Liu et al., 2005) and cotton plants (Shallan et al., 2016). According to a review of Lairon (2010), which is based on a report of the French Agency for Food Safety (AFSSA), organic products (obtained as a result of different treatments) usually have more favorable chemical composition, more dry matter, minerals and antioxidants.

In the present study conditions, the treatment (alone and combined) with Lithovit, Nagro, Madex and Agricoll significantly increased the pea yield on average by 21.8% and improved the biochemical composition. The content of CP increased on average by 6.9%, and the content of CF decreased on average by 32%. Regarding the seed biochemical composition and CP content, a positive effect was observed after applying the nanofertilizers (an average increase of 4%) and bioinsecticides (an average increase of 7.9%). In contrast, the effect was negative in synthetic preparations - a decrease of 5.6 and 30.1% after treatment with Kristalon and Proteus 110 OD. In terms of productivity, in accordance with the established and abovementioned conclusions of Liu et al. (2006a) and Sekhon (2014), nanofertilizers had a high effect, exceeding (in the case of Lithovit) or equal (in Nagro) to that of the synthetic fertilizer Kristalon. A similar dependence was established in combined application. The high effect of using Lithovit and Nagro can partly be explained by the influence they had on pollen germination and pollen tube elongation in *P. sativum*. In our previous research (Georgieva et al., 2017), an increased pollen germination and a greater pollen tube elongation (44.2 and 47.23%, respectively) were reported after Lithovit and Nagro treatment compared to the control (untreated).

According to Petroff (2008), the combined use of products with different biological effects (foliar fertilizers, growth regulators and plant protection preparations) increases their efficiency and has a high economic effect, saving time, energy and costs. However, the issue of yield stability and combination of fertilizers with plant protection products under organic production conditions is slightly studied. Research has been carried out mainly in conventional farming. For example, Atanasova & Maneva (2021) recommend mixed application of some herbicides with Nagro to reduce the occurrence of phytotoxicity in oats. An increase in yield was also observed, especially at the combination between Nagro and Derby Super. Delchev (2010) reported for synergism after the combined use of organic foliar fertilizers (Humustim, Lactofol, Terasorb) with herbicides (Granstar, Lintur, Derby) in durum wheat. Meena et al. (2015) found improved growth, seed yield, quality parameters (protein, nitrogen, phosphorus and potassium) and synergistic effects in *Vigna radiata* (L.) Wilczek after using different bioinorganic combinations (NPK, Rhizobium, phosphorus solubilizing bacteria and Vermicompost).

What we can say in conclusion is that organic farming today has changed significantly since the 1970s, when it was described as "scientific nonsense" by a group of scientists at an annual meeting of the American Association for the Advancement of Science (Lockeretz, 2007). It is impossible to know how this will change in the future, but the pursuit to produce more organic production and the recent calls to find ways to increase organic yields must be examined carefully to ensure they are efficient, economically viable and environmentally friendly (Clark, 2020).

CONCLUSIONS

The grain productivity and biochemical composition of Pisum sativum were affected favorably under organic cultivation conditions and treatment with the organic nanofertilizers Lithovit and Nagro, used alone and in combination with the bioinsecticides Madex and Agricoll. After applying the products, an increase in grain yield (by 7.8 to 32.8%) and protein content (by 1.7 to 10.5%), and a decrease in crude fiber content (by 14.7 to 49.1%) were found compared to the untreated control. The combination of Lithovit+Madex was distinguished by significantly higher productivity compared to a synthetic combination (fertilizer Kristalon+ insecticide Proteus OD 110). The treatment with Agricoll and its combinations (Nagro+Agricoll, Lithovit+Agricoll) had a particularly favorable effect on the seed biochemical composition.

The mixed use of organic products resulted in very well-expressed manifestations of subadditive type of synergism.

The complex evaluation in terms of stability parameters (criterion of stability YSi of Kang /1993/, stability variance σi^2 of Shukla /1972/ and ecovalence Wi of Wricke /1962/) determined Nagro + Madex and Litovite + Madex as stable combinations. These

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variants united high values of grain yield and high stability.

AUTHORS CONTRIBUTIONS

Conceptualization, N.G.; methodology, N.G.; data collection, N.G.; data validation, N.G.; data processing, N.G., M.B. and G.D.; writing–original draft preparation, N.G., M.B.; writing—review and editing, N.G., M.B. All authors read and approved the final manuscript.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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