Phytosanitary monitoring, soil condition and yield of wheat and einkorn in a field for biodynamic farming

Vasilina Maneva*, Dina Atanasova, Marina Stoyanova
Agricultural Academy, Institute of Agriculture – Karnobat
*E-mail: *maneva_ento@abv.bg*

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Abstract
In the field of biodynamic farming, cereals have been grown after peas as a predecessor. Phytosanitary monitoring was made and the change in the condition of the soil and the yield from the plants at the beginning of the creation of the field and after 4 years was reported. When monitoring the changes in soil parameters in the biodynamic field, there is a slight increase in digestible nutrients and humus over the years. The only exception is phosphorus. The differences are minimal and unproven, however. Significant is the increase in nitrogen compounds, from 7.4 to 21.3 mg/kg. Variety of weed species depends on the agro-meteorological conditions of the year and the culture. In 2015 we have a greater species diversity of weeds than in other years of research. Einkorn has significantly less weed species diversity during the study period than wheat. The species diversity of the pests is greater in wheat than in einkorn. Wheat plants with the appearance of reticulate spots, powdery mildew and root rot have been reported in the diseases. The registered diseases are of fungal nature. No diseases have been found on einkorn. The trend in phytosanitary monitoring - a greater variety of weeds, pests and diseases in wheat than in einkorn, has persisted over the years. When analyzing the data from the yield of wheat and einkorn in biodynamic farming, it was found that the yield differs by year due to weather conditions, but increases after the first year, ie. the influence of the inserted biodynamic preparations is taken into account.

Key words: biodynamic agriculture; cereals; phytosanitary status; soil; yield

INTRODUCTION

The productivist model implemented after the second world war has succeeded in improving production to meet growing demands for food, but it has also deeply affected soil physicochemical properties, as well as of aboveground and belowground biodiversity. Alternative farming systems such as organic farming, biodynamic farming and soil conservation farming are actually developing to enhance the sustainability of farming systems. Although the impact of agricultural practices on soil ecological quality is well known, there is little knowledge on the impact of the different farming systems as a whole. (Christel, et al., 2021). Biodynamic farming is an old but new alternative agriculture for sustainable development. However, it is not well understood and practiced. It is similar to organic farming but incorporates metaphysical ideas in treating soil and crop growth. Biodynamic farming is more than just a set of techniques; it is also a conceptual philosophy that applies to the farm's general structure. The foundation of biodynamics is the construction of a farm that functions holistically as an unbroken organism. Scientifically proofed, biodynamic farming has its own contribution to agriculture sustainability via effect on soil quality and improvement of quantity and nutritional quality of a produce and pest management. Hence, biodynamics is regarded as a promising road to tomorrow's integrated and sustainable agriculture (Muhie, 2022; Rigolot & Quantin, 2022; Banerjee & Saha, 2022; Wright, 2022). Biodynamic agriculture is an upgrade of organic farming, and its main goal is to revive the soil, harmonize ecosystems and obtain healthy food for humans. In this type of agriculture, biodynamic preparations are used, which are divided into compost - they are put into the compost and those for direct spraying. Based on long-term experience, Raupp (1996; 1996 (a); 1996 (b); 1997; 1997 (a); 2001) and Schaumann (1987) summarized the effect of biodynamic preparations on soil and cultivated plants. They found that the preparations stimulate the content of humus and the biological activity of the soil. The same authors found that in climatically favorable years, the yield of crops in biodynamic agriculture did not exceed that of conventional, but in unfavorable years it was significantly higher. Schaumann (1987), based on many field and vascular experiments, spoke of system regulation to characterize the equilibrating and harmonizing effect of preparations in extreme conditions. The author compares the action of preparations with homeopathic substances in medicine and points out three main, very different therapeutic approaches - substitution, suppression and stimulation. Based on many experiments, Schaumann (1987) claims that only the third way aims to support and increase the inherent ability of each organism or system of organisms to self-regulate and harmonize its life processes. The author points out that in agricultural terms, biodynamic preparations work in this direction, while the main question remains open - how this happens.

The purpose of the present study is to compare the initial results (2012/2013) obtained after the creation of the biodynamic field - the condition of the soil, plants, phytosanitary monitoring, with those obtained in the following four years.

MATERIAL AND METHODS

In 2013, a mini experimental biodynamic field of 20 dka was formed in the certified organic experimental field of the Institute of Agriculture - Karnobat (in Bulgaria there is no certifying body for biodynamic agriculture, if necessary, one from Germany is used).

A two-pole crop rotation was formed - cereals (wheat Miryana and einkorn) - peas for sideration. The object of the study is the condition of the soil, phytosanitary monitoring and production of wheat and spelt in the years 2013-2017.

Eight biodynamic preparations were used in biodynamic farming - BD 500, BD 501, BD 502, BD 503, BD 504, BD 505, BD 506, BD 507. The first two were applied by spraying, and BD 502 to BD 507 were embedded in the compost. They aim at revitalizing the soil - increasing microbiological activity and carbon content. Biodynamic compost is applied annually to the field in a dose of 4-5 t/da. Soil fertility was characterized in the horizon 0-40cm mineral N (according to Tyurin - Kononova), absorbable K2O (according to Milcheva in 2 nHCl) and mobile P2O5 (according to Egner - Reem). Humus in the soil was determined according to Tyurin (Kononova, 1966).

The species composition of the weeds was determined according to Delipavlov et al. (2003). Observations to count the pests were carried out weekly in wheat and einkorn, in the phase from germination to wax maturity of the crops. The pests were counted with standard entomological methods - mowing with an entomological bag and direct counting on 100 stems (in 10 places of 10). The diseases were determined by surveying the crops throughout the growing season. The diagnosis of the diseases was made on the basis of external manifestations, in some cases microscopic and biological analysis was additionally carried out under laboratory conditions. The yield to 13% moisture, kg/da, is reported.

Analysis of variance (Statistica) and Statgrafics 16 were used for data processing.

The soil in the study area is Haplic Vertisols. In the cultivated 0 - 40 cm horizon, it can be characterized as a soil with a heavy mechanical composition (bulk density 1.10 - 1. 20 g/cm^3), slightly acidic reaction (pH (KCl) 6.5), very low stock of mineral nitrogen (18.61 – 35 mg /kg soil) and mobile phosphorus (1.90 – 4.64 mg/100 g soil) and medium to good supply of absorbable potassium (26.90 – 32.40mg/100g soil). (Maneva, et al., 2008; Atanasova & Koteva, 2013).

The climate in the area is transitional - continental, with an average annual rainfall of 549 mm. Winter is relatively warm, spring is short and cool, summer is hot and dry, and autumn is long and warm.

RESULTS AND DISCUSSION

Soil condition

The condition of the soil was studied before the establishment of the biodynamic field and for four years after its establishment. In the following years, the monitoring of the soil indicators continues. The results will continue to be followed over the years to obtain a clearer assessment of how the biodynamic preparations affect the soil and plants. Because according to literature data (Abele, 1987; Abele, 1990; Ahrens & Koop, 1990; Bachinger, 1995; Bachinger, 1996, 1996 (a); Heinze et al., 2007; Raupp, 2002; Raupp & Bachinger, 1998; Raupp & Oltmanns, 2003; Schuler et al., 2008; Thomsen, 2000), biodynamic preparations increase the humus content and microbiological activity in the soil, has been studied the content of humus (carbon) in the fields before applying the compost with the preparations and the microbiological activity before and after applying the compost was followed. The results will be tracked in the following years.

It was found that the carbon (C) content in 2013 in the conventional field was 1.92%, in the organic field - 1.77%, and in the forest belt surrounding the field - 2.32%. In the organic field, since no organic fertilizer has been applied so far and the amount of plowed organic matter is small, the C content of the soil is the lowest. After the introduction of compost, this indicator will be taken into account again. Since the condition of the soil is one of the most important indicators in biodynamic farming, a thorough analysis was made after 4 years to determine whether the indicators are moving in a positive direction.

Agrochemical analyses

The recreated biodynamic field was sampled 9 times in a uniform grid using a GPS GARMIN etrex30 (Figure 1).

The field is characterized as poorly stocked with mineral nitrogen (Table 1). The average is 33.4 mg/kg (10kg/da). The coefficient of variation is quite high - 43.8%, and correspondingly the minimum and maximum are 17.7 mg/kg and 60.8 mg/kg. Although the field is poorly stocked, the values are significantly higher than the average for the soil type and other studies in the area (Stoyanova, 2016). The reason is the green fertilization of the field, as well as the imported compost with biodynamic preparations added to it. The average content of absorbable phosphorus is within the normal range for the region - 12.2 mg/100g, characterizing the field as poorly stocked. The content of absorbable potassium is low - the average is 22.3 mg/100g respec-

Figure 1. Satellite image of the sampling site - biodynamic field

Table 1. General statistics of the studied soil indicators, mineral nitrogen, absorbed phosphorus, absorbed potassium and humus

Index	*Count*	*Average*	*Standard deviation*	*Coeff of variation, %*	*Min*	*Max*	*Range*	*Stnd. skewness*	*Stnd. kurtosis*
Nmin	9	33,4389	14,6384	43,7767	17,66	60,8	43,14	1,06718	-0,0157817
P2O5	9	12,2356	4,21679	34,4634	5,44	20,63	15,19	0,728875	0,978327
K2O	9	22,2656	5,2243	23,4636	16,03	32,71	16,68	1,22579	0,400566
Humus	9	2,32	0,275953	11,8945	1,86	2,68	0,82	-0,541331	-0,557207
Total	36	17,565	14,03	79,875	1,86	60,8	58,94	2,79777	1,9997

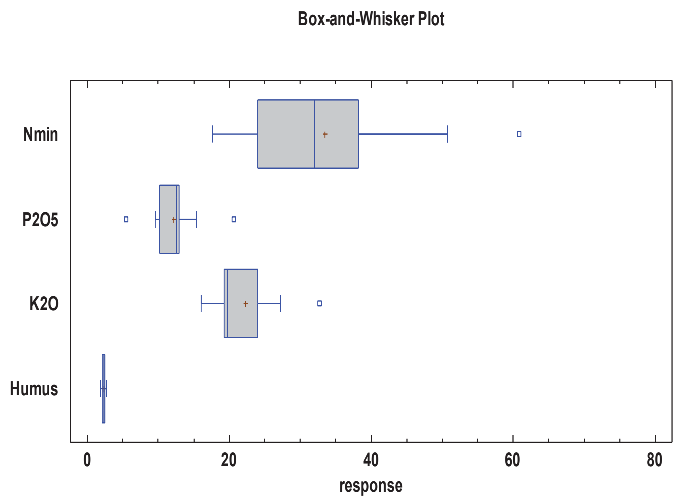


Figure 2. Box and wishkes diagram of soil indicators

tively. This result is very unusual and unexpected for the soil type of the field, where K2O values according to Milcheva are within 40 - 50 mg/100g. The field is characterized by a significant potassium deficiency. The data confirm last year's biological field studies, where the results for phosphorus and potassium were quite similar. It is necessary to use the potassium preparations allowed for organic farming to eliminate the limitation of yields due to nutritional deficiency.

Regarding hummus, there is a slight increase, which is still not statistically proven compared to last year's studies (2013). It ranges from 1.86% to 2.68%.

All indicators have a normal distribution, indicating their natural character and absence of anthropogenic impact.

On the Box and Wishkes diagram (Figure 2) you can see the number of points that have values lying outside the normal distribution. They are one for potassium and nitrogen and two for phosphorus.

There are statistically proven correlations between phosphorus and potassium - 0.68, which is related to the influence of parent rock. A strong

Table 2. General statistics of the humus data from 2017 for the organic field and the data for the humus from the biodynamic field in 2017 Summary Statistics

Index	*Humus, biodynamic*	*Humus, organic*
Count	9	9
Average	2,32	2,10111
Standard deviation	0,275953	0,48354
Coeff. of variation	11,8945%	23,0135%
Minimum	1,86	1,27
Maximum	2,68	2,43
Range	0,82	1,16
Stnd. skewness	**-0,541331**	**-1,49208**
Stnd. kurtosis	**-0,557207**	**-0,197897**

impression is made by the high statistically proven correlation between humus and nitrogen – 0.82 due to field sideration and biodynamic preparations. The regression analysis yielded the following results:

Correlation Coefficient = **-0,816987**

R-squared = **66,7468** percent

R-squared (adjusted for d.f.) = 61,9964 percent

Standard Error of Est. = **9,02418**

Mean absolute error = **5,25689**

Durbin-Watson statistic = 2,39158 (P=**0,7094**)

Lag 1 residual autocorrelation = -0,196044

Mean absolute deviation = 5,18964

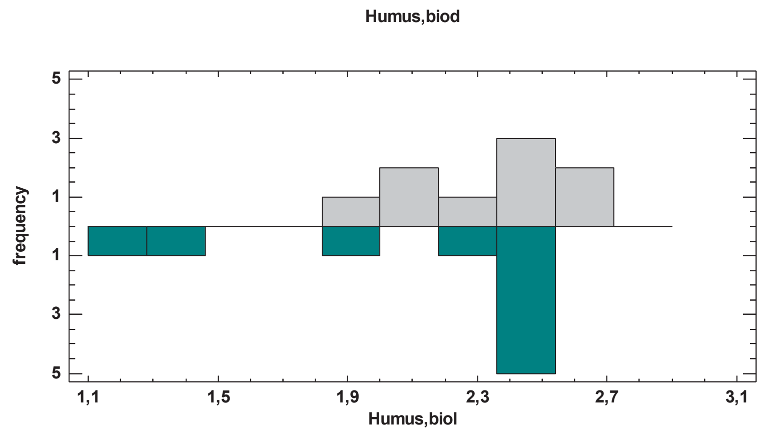


Figure 3. Comparative histogram of the frequency distribution of humus data from 2017 for the organic field and humus data from the biodynamic field in 2017

Table 3. Correlation matrix of soil indicators in 2017 and altitude Correlations

Index	Nmin	P2O5	K2O	Humus, biodynamic	Humus, organic	NV
Nmin		0,5723	0,1508	-0,8170	0,4311	0,3774
		(9)	(9)	(9)	(9)	(9)
		0,1073	0,6986	**0,0072**	0,2466	0,3167
P2O5	0,5723		0,6782	-0,4422	0,5666	0,0219
	(9)		(9)	(9)	(9)	(9)
	0,1073		**0,0446**	0,2333	0,1117	0,9554
K2O	0,1508	0,6782		0,0242	0,6046	-0,0445
	(9)	(9)		(9)	(9)	(9)
	0,6986	**0,0446**		0,9507	0,0846	0,9095
Humus, biod	-0,8170	-0,4422	0,0242		-0,2602	-0,5782
	(9)	(9)	(9)		(9)	(9)
	0,0072	0,2333	0,9507		0,4989	0,1029
Humus, organic	0,4311	0,5666	0,6046	-0,2602		0,3304
	(9)	(9)	(9)	(9)		(9)
	0,2466	0,1117	0,0846	0,4989		0,3852
NV	0,3774	0,0219	-0,0445	-0,5782	0,3304	
	(9)	(9)	(9)	(9)	(9)	
	0,3167	0,9554	0,9095	0,1029	0,3852	

Nmin = 133,985 - 43,3386*Humus,biodynamic

Statgrafics 16 software product was used for the statistical analysis.

The spatial dependence of the two indicators is also clearly expressed.

The highest nitrogen values are observed in the center of the field and decrease along the periphery. The dependence is exactly the opposite with humus. The highest values are observed on the periphery. This also corresponds very well with the negative correlation between the indicators.

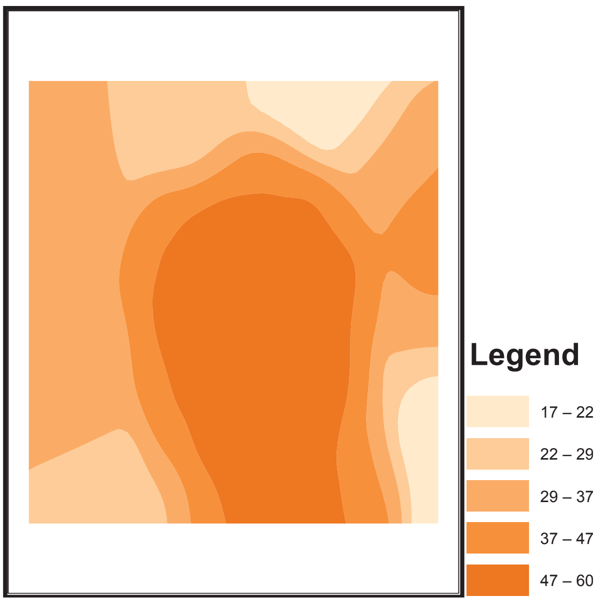


Figure 4. Spatial dependence of the mineral nitrogen content, mg/kg

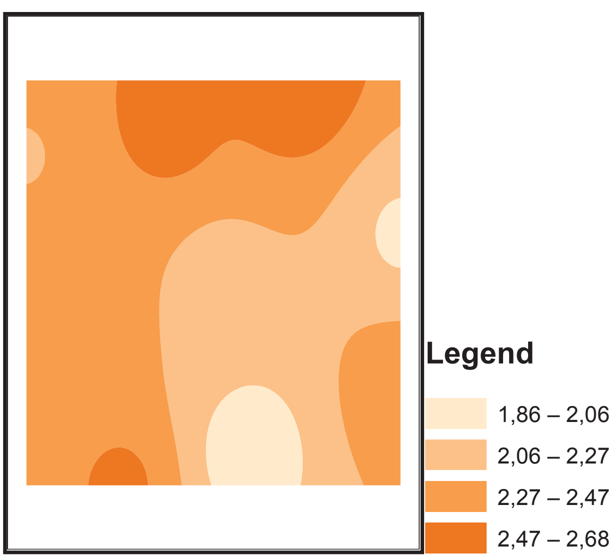


Figure 5. Spatial dependence of humus content, %

The software product ArcGis 10.3.1 was used to create the interpolation maps. The IDW (weighted inverse distance interpolation) interpolation method is selected.

In the fall of 2017, two average samples were taken from the biodynamic field to monitor changes in soil parameters. There is a slight increase in digestible nutrients and humus. The only exception is phosphorus. The differences are minimal and unproven, however. More significant is the increase in nitrogen compounds, from 7.4 to 21.3 mg/kg. The reason is microbiological fixation and mineralization of post-harvest residues.

Phytosanitary monitoring

The phytosanitary monitoring carried out to study the species composition of weeds in biodynamic farming, for wheat and einkorn, shows that in autumn all crops are weed infestation by the ephemeral weeds - *Veronica hederifolia* L. and *Viola tricolor* L.. Winter-spring weeds are the most common in both crops – *Anthemis arvensis* L, *Capsella bursa-pastoris* (L.) Medic, *Consolida orientalis* L and *Papaver phoeas* L. The next group which is also well represented are early spring weeds – *Caucalis daucoides* L., *Sinapis arvensis* L., *Vicia striata* M.B., *Polygonum convolvulus* L., *Polygonum aviculare* L. and *Avena* spp..

After the monitoring, it was established that a variety of weed species depends on the agro-meteorological conditions of the year and the crop (table 4). In 2015 we have a greater species diversity of weeds than in other years of the study. In general, einkorn had significantly less species diversity over the study period than wheat.

Table 4.

In wheat, single specimens of the aphid *Sitobion avenae* L. were found. In wheat and einkorn, the cycads – *Psammotettix provincialis* (RIB) and *Psammotettix striatus* (L.) were found. *Eurygaster integriceps* Put., *Eurygaster maura* L. and *Aelia acuminata* L., *Oscinella frit* L., *Phorbia securis* T., *Chlorops pumilionis* Bjerk are observed in wheat. In einkorn, only *Phorbia securis* T. was found on individual plants. The species diversity of pests is

Table 4. Species compositionof weeds in wheat and einkorn, 2013-2017

Weeds	Wheat					Einkorn				
	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
Veronica hederifolia L.	+	+	+	+	+	+	+	+	+	+
Viola tricolor L.	+	+	+	+	+	+	+		+	+
Anthemis arvensis L.	+		+			+	+	+		
Caucalis daucoides L.				+					+	
Capsella bursa-pastoris (L.) Medic.	+	+	+	+	+	+	+	+	+	+
Centaurea cyanus L.	+									
Consolida regalis S.F. Gray.		+								
Consolida orientalis L.			+					+		
Papaver phoeas L.			+		+			+		
Polygonum convolvulus L.	+		+		+			+		
Polygonum aviculare L.	+	+	+	+	+	+				
Sinapis arvensis L.	+	+	+			+		+		
Vicia hirsuta (L.) S.F.Gray				+	+					+
Vicia striata M.B.				+	+					+
Avena spp.		+	+				+	+		
Bromus ssp.			+							
Hordeum murinum L.	+									
All kinds of weeds	9	7	11	7	8	6	5	8	4	5

Table 5. Species composition of pests in wheat and einkorn, 2013-2017

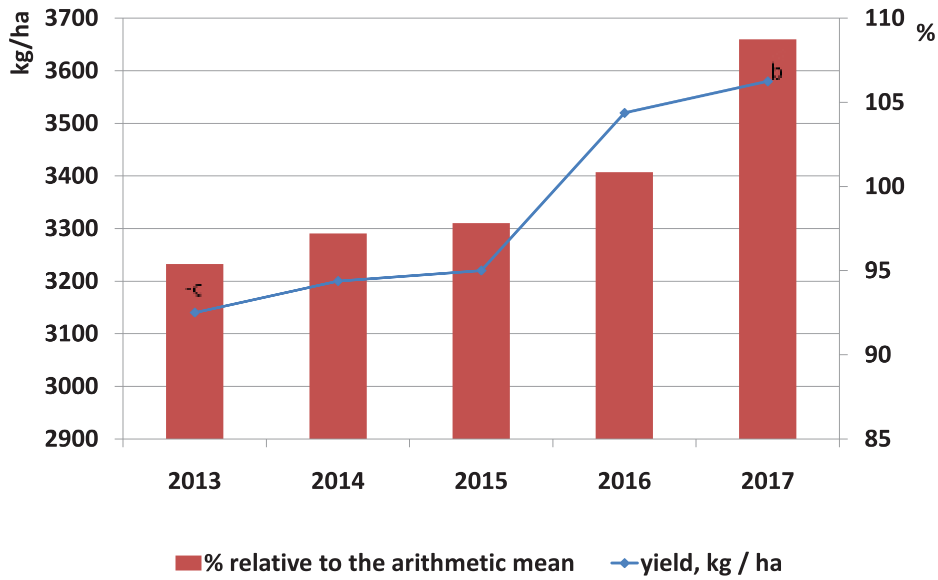
Pests	wheat					einkorn				
	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
Sitobionavenae L.	+	+	+	+	+	-	-	-	-	-
Psammotettixprovincialis (RIB)	+	+	+	+	+	+	+	+	+	+
Psammotettixstriatus (L.)	+	+	+	+	+	+	+	+	+	+
Eurygasterintegriceps P u t .	+	+	+	+	+	-	-	-	-	-
Eurygastermaura L.	+	+	+	+	+	-	-	-	-	-
Aeliaacuminata L.	+	+	+	+	+	-	-	-	-	-
Oscinellafrit L.	+	+	+	+	+	-	-	-	-	-
Phorbiasecuris T.	+	+	+	+	+	+	-	+	+	-
Chloropspumilionis Bjerk.	+	+	+	+	+	-	-	-	-	-

Table 6. Species composition of diseases in wheat and einkorn, 2013-2017

Diseases	wheat					einkorn				
	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
Drechslera teres	+	+	-	+	-	-	-	-	-	-
Erysiphe graminis	+	+	-	-	+	-	-	-	-	-
Ophiobolus graminis	+	+	-	-	-	-	-	-	-	-
Puccinia triticina	-	-	-	-	-	-	-	-	-	-

greater in wheat than in einkorn. This trend has persisted over the years (Table 5).

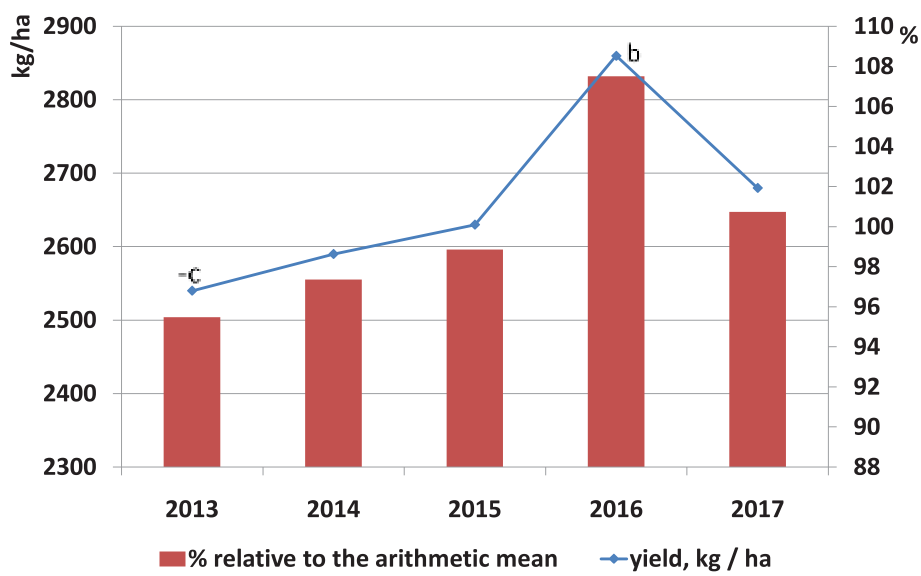
Observations to record the species composition of diseases were carried out in the 3-leaf period - the beginning of crop germination, by visiting the plots and examining the plants. Wheat plants with net spots, powdery mildew and root rot were reported. The registered diseases are of a fungal nature



$LSD_{5\%}$ - 10.84 $LSD_{1\%}$ - 17.93 $LSD_{0,1\%}$ - 33.57

In the figure, different letters (a, b, c) express significant differences between the compared variants, with "a" representing the highest value.

Figure 6. Yield of wheat in biodynamic farming



$LSD_{5\%}$ - 7.74 $LSD_{1\%}$ - 12.81 $LSD_{0.1\%}$ - 23.98

In the figure, different letters (a, b, c) express significant differences between the compared variants, with "a" representing the highest value.

Figure 7. Yield of einkorn in biodynamic farming

and are presented in table 6. No diseases were found on einkorn. This trend has been maintained over the years.

Wheat and einkorn yield in biodynamic farming

Analyzing the yield data of wheat and einkorn in biodynamic farming, it was found that the yield differs between years due to weather conditions, but increases after the first year, i.e. the influence of the inserted biodynamic preparations is taken into account (Figures 6 and 7).

CONCLUSIONS

When tracking changes in soil indicators in the biodynamic field, a slight increase in digestible nutrients and humus is observed over the years. The only exception is phosphorus. The differences are minimal and unproven. More significant is the increase in nitrogen compounds, from 7.4 to 21.3 mg/kg.

The variety of weed species depends on the agrometeorological conditions of the year and the crop. In 2015 we have a greater species diversity of weeds than in other years of the study. In einkorn, there was significantly less weed species diversity during the study period than in wheat. The species diversity of pests was greater in wheat than in einkorn. Among the diseases, wheat plants with the manifestation of *Drechslera teres*, *Erysiphe graminis* and *Ophiobolus graminis* were reported. The registered diseases are of a fungal nature. No diseases were found on the einkorn. The trend in the phytosanitary status of the field - a greater species diversity of weeds, pests and diseases in wheat than in einkorn, being preserved over the years.

Analyzing the yield data of wheat and einkorn in biodynamic farming, it was found that the yield differs between years due to weather conditions, but increases after the first year, i.e. the influence of the inserted biodynamic preparations is taken into account.

The study was reported at the scientific conference “Innovations in Agrarian Science for Efficient Farming”, held in 2022 at the Agriculture Institute-Shumen, co-financed by the Ministry of Education and Culture under a contract with the Scientific Research Fund - № KP 06-MNF/14

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