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COMPARATIVE ASSESSMENT OF THE YIELD AND QUALITY INDICATORS OF SOYBEAN VARIETIES ACCORDING TO TRADITIONAL AND ORGANIC TECHNOLOGY

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Topicality. *One of the alternatives to the intensification of agricultural production is the introduction of new ecological technologies that are aimed at realizing the natural potential of agrophytocenoses and are based on the effective use of their biological capabilities. Climate changes and development of environmentalization in agriculture create prerequisites for the selection of soybean varieties of different maturity groups and the study of their productivity potential and grain quality indicators under different cultivation technologies.* ***Purpose.*** *Assessment of soybean varieties by yield and grain quality indicators under traditional and organic technologies.* ***Methods.*** *Field, laboratory, mathematical, statistical analysis.* ***Results.*** *It was established that the grain yield of mid-early ripening soybean varieties (Everest, ES Professor and DH530) was 2.88 t/ha under traditional technology, and 2.24 t/ha under organic technology, and of mid-ripening soybean varieties (Windsor, ES Pallador and Emperor) – 3.25 and 2.44 t/ha, respectively, that is higher than in mid-early ripening varieties. The difference in grain yield under traditional and organic technologies was 0.63 t/ha for mid-early ripening varieties, and 0.81 t/ha for mid-ripening varieties. Over two years of research, we found that soybean grain contained an average of 39.8–42.5 % protein, 20.1–21.7 % fat, and 11.7–13.9 % moisture content. Protein yield ranged within 1.11–1.42 t/ha and fat yield – 0.57–0.72 t/ha due to higher soybean grain yield under traditional technology, which was by 21.0–24.7 and 21.5–25.6 % higher than under organic cultivation. It was found that the level of correlation between grain yield and protein content was above the average (r = 0.69 and 0.78) for traditional and organic cultivation, and the correlation between yield and fat content was high (r = 0.97 and 0.95).* ***Conclusions.*** *The quality indicators (protein and fat content) and grain moisture content of soybeans depended on the varietal characteristics and weather conditions and remained unchanged under the influence of cultivation technology. The soybean of Emperor variety had the highest grain yield (3.35 and 2.47 t/ha), protein yield (1.42 and 1.05 t/ha) and fat yield (0.72 and 0.54 t/ha), respectively, under traditional and organic cultivation technologies. Therefore, this variety can be recommended for cultivation under both technologies.*

Key words: *soybean, productivity, protein content, fat content, grain moisture content*

Introduction. In Ukraine, soybeans (*Glycine max* (L.)) occupy a prominent place as an export-oriented and fodder crop, and are also of strategic importance for the food and economic security of the country. Changes in the dietary patterns of people in developed countries, as well as population growth in Asia and the rapid development of the livestock industry in the European Union, have led to increased demand for this crop. This resulted in an increase in global demand for soybeans and a shift in many countries to soybean cultivation [1].

The issue of securing and improving the quality of protein plant products is relevant for all countries. The success and efficiency of agriculture and the economy largely depend on addressing this issue [2].Over the last 50 years, the geography of soybean cultivation has expanded,

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the number of countries that grow it has grown to 91, and the area of arable land allocated to this crop has increased significantly. In many countries, soybeans occupy from 18 to 50 % of the arable land [3].

In 2019, Ukraine ranked ninth among the world soybean producers with a gross yield of 3.7 mln tonnes [4]. In 2022, the soybean cultivation area in Ukraine was 1.5 mln hectares, and the gross yield was 3.7 mln tonnes [5]. The main Ukrainian soybean production is located in the so-called Soybean Belt, which includes the Forest-Steppe zone. In recent years, 64.5 % of soybean crops were planted in this zone, 25.1 % in the Steppe, and 10.4 % in Polissia. [6].

According to the Research Institute of Organic Agriculture FiBL, in 2020, soybeans occupied an area of 0.25 million hectares, accounting for 29 % of the total area of organically grown oilseeds worldwide [7]. At the same time, soybeans grown in accordance with organic standards account for less than 0.1 % of the total global production of this crop. Recently, the production of organically grown soybeans has been gradually increasing around the world [8].

The negative effects of agricultural production intensification can be overcome by creating new environmentally friendly technologies that focus on the realisation of the natural potential of ecosystems and are based on the efficient utilisation of their biological capabilities, optimising the interaction of microorganisms and plants in agrophytocenoses [9]. Environmentally friendly management is an alternative to traditional agricultural production, which is aimed at providing humanity with environmentally safe food [10].

Environmentally friendly management aims to enhance ecological processes in ecosystems that promote the nutrition of plants and preserve soil and water resources. Organic standards prohibit the use of synthetic pesticides, genetically modified organisms and sewage sludge in certified organic production [11]. According to forecasts, organic crop production will consume 39 % less energy on average and generate 77 % less greenhouse gas emissions compared to conventional crop production [12].

Organic production is characterised by nitrogen deficiency and competition of cultivated plants with weeds and insects. [13]. Weed control is often a challenge in organic cultivation since producers are limited to mechanical and biological weed control, while conventional agriculture applies mechanical, biological and chemical weed control practices [14]. In addition, there is a greater number and diversity of insects in organic fields compared to conventional ones [15].

In Ukraine, the development of organic cultivation technologies is an urgent priority to enhance the natural biological activity and restore the balance of nutrients in the soil [16]. Research of organic soybean production is also important. For the large-scale development of domestic organic production of this crop, Ukraine certainly needs to develop its own organic seed pool [17 The high level of weed infestation of organic fields, resulting from anthropogenic factors and biological characteristics of weeds, is a limiting factor that holds down the expansion of sown areas and growth of soybean yield. Therefore, the organic soybean cultivation system requires an enhancement of the overall agriculture standards, considering the agrotechnical practices of weed control, the highly competitive crop varieties [18].

According to G. Dozet et al. [19], the average soybean yield was 24.09 % higher in conventional production compared to organic production. However, the average price of organic soybeans was also 30–38 % higher compared to conventional soybean production. According to M. A. Cavigelli et al. [20], soybean yield was on average 19 % lower in three organic cultivation systems (2.88 t/ha) than in conventional cultivation systems (3.57 t/ha), which is explained by high competition with weeds in organic production.

The data analysed by T. De Ponti et al. [21], shows that the yield of crops under organic production is approximately 80 % from the conventional one. The analysis of 362 datasets also showed a high variation in the yield of organic production (standard deviation of 21 %). Some of these variations are systematic. The yield of some crops differed by more than 80 %, for example, for soybeans and other legumes, rice and maize.

However, according to other scientists [22, 23], the difference between conventional and organic soybean yields was not so significant. The advantages of organic cultivation technologies include lower energy and fuel consumption, stable yield, higher organic matter and nitrogen content, and conservation of moisture resources in the soil. Conventional agricultural technologies are used to meet the demands of people and livestock, making it more sustainable and economically viable [24].

Climate change and greening in agriculture require the selection of soybean varieties of different maturity groups and the study of their productivity potential and grain quality under different cultivation technologies.

The purpose of the research was to evaluate soybean varieties for yield and grain quality under conventional and organic cultivation technologies.

Materials and Methods. The research was conducted at the Training and Production Centre of Bila Tserkva National Agrarian University in 2021–2022. The research examined the mid-early soybean varieties Everest, ES Professor and DH530 and the mid-ripening varieties Windsor, ES Pallador and Emperor. The soybeans were grown using conventional and organic technologies.

The traditional technology included the application of soil herbicides Mistral (0.5 l/ha) and Kalif (0.25 l/ha) before sprouting of soybeans, post-emergence herbicides Agil (1 l/ha) and Eventus (1.8 l/ha) in the stage of 2–3 true soybean leaves and fungicide Custodia (1 l/ha) before flower-bud formation. Seeds pre-treated with Maxim XL fungicide were used for sowing. No mineral fertilisers were applied. We applied $N_{70}P_{40}K_{40}$ to the predecessor (winter barley). The organic technology included sowing with inoculated seeds only (no fungicide), use of a Striegel straw harrow as weed emergence (3–7 cultivations) and the bio-fungicide Phytohelp (0.8 l/ha) before flower-bud formation. The seeding rate was increased by 17 % to maintain the optimum plant density under organic cultivation technology as a result of damage caused by post-emergence harrowing. No mineral fertilisers or plant protection products were applied to the area allocated for organic production for 4 years. The buffer zone between the fields of organic and the conventional technologies was 15 m.

The cultivation technology of organic soybeans complied with the basic principles of organic production and the requirements of the current legislation of Ukraine [25]. The research was conducted according to the following guidelines [26].

The soil of the experimental plot is typical leached, medium-deep, low-humus, coarse-dusty, light loamy chernozem on carbonate loess. The sowing area was 30 m^2, the registration area was 25 m^2, the experiment was repeated three times, and variants were arranged in a systematic manner. The predecessor in both technologies is winter barley. Sowing method was narrow-row (with row spacing of 15 cm). In both technologies, pre-sowing inoculation of seeds with HiStik Soy was applied. Soybean was sown in the early part of May. The seeding rate was 600 thousand seeds/ha for conventional technology and 700 thousand seeds/ha for organic technology. The crop was harvested with a Massey Ferguson 16 MF combine in stage of full grain maturity. The protein, fat and moisture content of soybean grain were determined using the analyser FOSS Infratec 1241. For the statistical analysis of the research results, the STATISTICA 12 programme was used.

The weather conditions of the growing season of 2021 were favourable for the growth and development of soybean plants. Total precipitation during the growing season (May – September) was 376.1 mm, and average air temperature was 17.7 °C. The climatic conditions in 2022 were unfavourable for the growth and development of soybean plants, due to droughts in July and August, in the period of grain formation and filling. The precipitation amounted to 220.3 mm with the average air temperature of 18.3 °C.

Results and Discussion. The research results showed that the soybean grain yield varied from 2.14 t/ha in the Everest variety under organic cultivation technology to 3.35 t/ha in the Emperor variety under conventional cultivation technology (Table 1). The higher grain yield (more than 3.0 t/ha) was in the mid-ripening varieties Windsor, ES Pallador and Emperor under conventional cultivation technology. The maximum grain yield was obtained in Emperor variety – 3.35 and 2.47 t/ha. Among the mid-early ripening varieties, the highest yields were recorded for DH530 – 2.96 and 2.35 t/ha under conventional and organic cultivation technologies, respectively. This coincides with the data of Yu. V. Ternovyi et al. who obtained the highest yield of organic soybean seeds in varieties with a longer growing season [27].

Table 1. Grain yield of soybean varieties, t/ha, (2021–2022)

Variety	Conventional technology			Organic technology		
	2021	2022	average	2021	2022	average
Mid-early varieties						
Everest	3.10	2.48	2.79	2.38	1.89	2.14
ES Professor	3.21	2.54	2.88	2.47	2.03	2.25
DH530	3.32	2.60	2.96	2.60	2.09	2.35
Mid-ripening varieties						
Windsor	3.53	2.81	3.17	2.70	2.05	2.38
ES Pallador	3.60	2.86	3.23	2.76	2.10	2.43
Emperor	3.74	2.96	3.35	2.84	2.09	2.47
LSD_{05}	0.08	0.06		0.08	0.06	

Weather conditions had a significant effect on the productivity of the crop during the studied years. In favourable moisture conditions of 2021 under conventional and organic cultivation technologies, soybean yield was 3.10–3.74 and 2.38–2.84 t/ha, respectively. In 2022, under the unfavourable weather conditions, the soybean grain yield was lower by 17.8–24.1 % compared to the previous year. At this year, the largest decrease in crop productivity was in the experiment variant that used organic technology. According to H. G. Nass et al. [28], in the unfavourable weather conditions of 2001, soybean yields decreased by 50 % in both conventional and organic cultivation compared to the more favourable 2000 through the reduction of available moisture and competition with weeds. Other researchers have also argued that meteorological conditions are one of the critical factors affecting soybean growth, development and productivity [29, 30]. Temperature and humidity may have an impact on soybean development and production in new regions [31]. Various technological practices in organic farming can lead to changes in yields from 673 to 3154 kg/ha and significantly affect the grain quality of soybeans [32].

The analysis of soybean grain yield by maturity groups revealed that the difference between mid-early and mid-ripening soybeans was 0.38 t/ha under conventional cultivation and 0.20 t/ha under organic cultivation (Fig. 1). The smaller difference in grain yields under organic cultivation technology is explained by the lower adaptability of late-ripening soybean varieties to limiting factors (weeds, nutrients, disease protection, etc.). The difference in grain yield between conventional and organic technologies was 0.63 t/ha for mid-early varieties and 0.81 t/ha for mid-ripening varieties.

The average protein content in soybean grain was 39.8–42.5 % over two years (Table 2). This indicator depended on varietal characteristics and hydrothermal conditions and remained unchanged under the influence of cultivation technology, which is confirmed by the research of V. V. Lyubych et al. [33]. All soybean varieties studied had a protein content of more than 40 %, except for the Everest variety, which had a protein content of 39.8 % under conventional technology.

In unfavourable 2022, the protein accumulation in the grain of most soybean varieties increased. So, this indicator was 1.2–2.3 % higher in the grain of Everest, ES Professor, DH530 and ES Pallador varieties compared to 2021. On the contrary, the protein content in soybean grain of Windsor and Emperor varieties was 0.9–1.4 % lower. This situation is explained by the lower adaptability of these varieties to adverse conditions and premature termination of the growing season, which, accordingly, affects the reduction of organic matter accumulation. On average, the highest protein content in soybean seeds was observed in the Windsor (42.2 %) and Emperor (42.3 %) varieties.

The fat content of soybean seeds did not depend on the cultivation technology. According to the DSTU 4694:2008 [34], the fat content in grain should be at least 12.0 %. According to this indicator, all soybean varieties met the requirements of the standard. On average, over two years, the fat content was within 20.1–21.7 % (Table 3).

The mid-ripening varieties exceeded the mid-early varieties by 0.6–1.6 % by fat content. The fat content of soybean seeds was significantly influenced by the weather conditions of

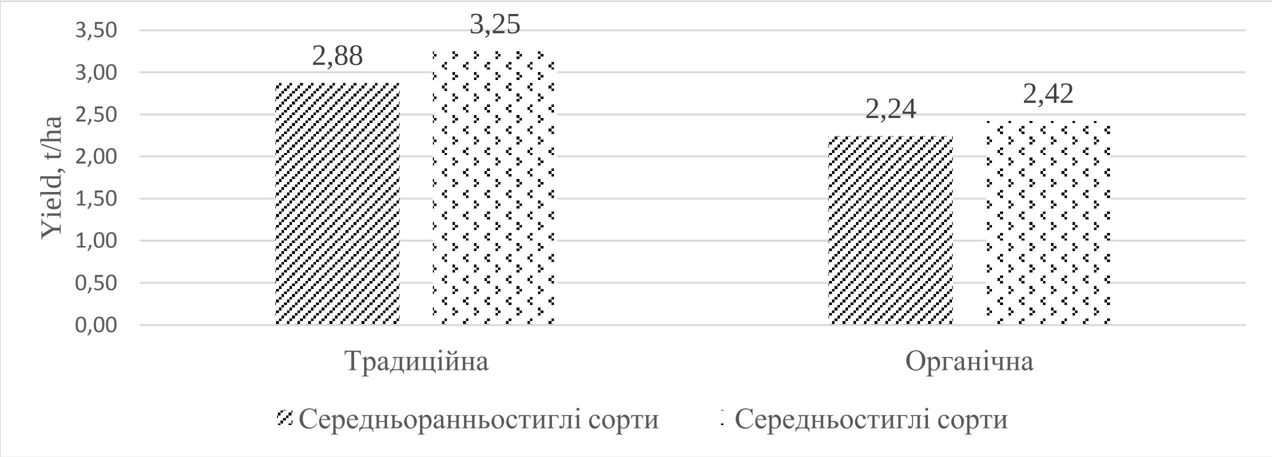

Fig. 1. Yields of mid-early and mid-ripening soybean varieties under different cultivation technologies, t/ha.

Table 2. Protein content in grain of soybean varieties, (2021–2022)

Variety	Conventional technology			Organic technology		
	2021	2022	average	2021	2022	average
Mid-early varieties						
Everest	38.8	40.8	39.8	39.2	41.0	40.1
ES Professor	40.5	42.3	41.4	40.1	41.9	41.0
DH530	39.4	41.7	40.6	39.5	41.5	40.5
Mid-ripening varieties						
Windsor	42.8	41.4	42.1	42.8	41.8	42.3
ES Pallador	40.0	41.5	40.8	40.6	41.8	41.2
Emperor	42.5	41.6	42.1	42.9	42.0	42.5
LSD_{05}	0.4	0.3		0.4	0.3	

Table 3. Fat content in grain of soybean varieties, %, (2021–2022)

Variety	Conventional technology			Organic technology		
	2021	2022	average	2021	2022	average
Mid-early varieties						
Everest	20.8	19.7	20.3	20.8	19.4	20.1
ES Professor	21.0	20.2	20.6	21.0	19.8	20.4
DH530	21.5	20.0	20.8	21.3	19.9	20.6
Mid-ripening varieties						
Windsor	22.0	20.7	21.4	22.3	21.0	21.7
ES Pallador	21.8	20.6	21.2	22.0	20.5	21.3
Emperor	22.2	20.8	21.5	22.2	21.0	21.6
LSD_{05}	0.2	0.2		0.2	0.2	

the studied years. In 2021, this indicator was 20.8–22.3 %, and in the stressful year of 2022, it was 19.4–21.0 %, which is 0.8–1.5 % less. The lowest variability in fat content over the years was in the ES Professor variety.

According to T. Bøhn et al. [35], organic soybean seeds had higher amounts of sugars such as glucose, fructose, sucrose and maltose, higher total protein and zinc content, and lower amounts of fibre and saturated fat, omega-6 fatty acids than seeds obtained from conventionally cultivated and genetically modified soybeans.

Grain moisture content in the studied varieties was 11.7–13.9 % and depended on the conditions of the year and genotype characteristics (Table 4).

According to this indicator, mid-ripening varieties exceeded the mid-early ones by 0.5-1.9 %.

Table 4. Grain moisture content of soybean varieties, %, (2021–2022)

Variety	Conventional technology			Organic technology		
	2021	2022	average	2021	2022	average
Mid-early varieties						
Everest	11.2	12.3	11.8	11.2	12.1	11.7
ES Professor	11.6	12.9	12.3	11.5	12.7	12.1
DH530	11.8	13.0	12.4	11.6	13.0	12.3
Mid-ripening varieties						
Windsor	12.4	13.5	13.0	12.6	13.7	13.2
ES Pallador	13.2	14.4	13.8	13.3	14.5	13.9
Emperor	13.5	14.2	13.9	13.4	14.3	13.9
LSD_{05}	0.2	0.3		0.2	0.3	

Despite the unfavourable weather conditions in spring and summer of 2022, there was a significant amount of precipitation in September, which influenced the increasing of moisture content in soybean grain. In 2022, the moisture content was within 12.1–14.5 %, and in 2021 – 11.2–13.5 %.

Under conventional technology, the yield of soybean grain was higher, the yield of protein was 1.11–1.42 t/ha, and fat – 0.57–0.72 t/ha, which is 21.0–24.7 and 21.5–25.6 % more than under organic cultivation technology (Table 5). On average, over the two years of research, there was no significant difference in the yield of protein and fat per 1 ha between some varieties (LSD_{05} = 0.03 for protein and LSD_{05} = 0.05 for fat). The highest average values of these indicators were obtained in the Emperor variety (1.24 and 0.63 t/ha, respectively).

The correlation between grain yield and protein content under conventional cultivation technology (Fig. 2) and the correlation between yield and fat content under organic technology (Fig. 3) are given. There was an above-average correlation between grain yield and protein content (r = 0.69 and 0.78 for conventional and organic cultivation). The correlation between grain yield and fat content was high (r = 0.97 and 0.95, respectively).

Table 5. Yield of protein and fat from soybean yield, t/ha, (2021–2022)

Variety	Conventional technology		Organic technology	
	protein yield	fat yield	protein yield	fat yield
Mid-early varieties				
Everest	1.11	0.57	0.86	0.43
ES Professor	1.19	0.59	0.92	0.46
DH530	1.20	0.62	0.95	0.48
Mid-ripening varieties				
Windsor	1.33	0.68	1.00	0.52
ES Pallador	1.33	0.68	0.99	0.51
Emperor	1.42	0.72	1.05	0.54
LSD_{05}	0.03	0.05	0.02	0.05

Conclusions. It was found that the grain yield of mid-early varieties Everest, ES Professor and DH530 was 2.88 t/ha under conventional technology and 2.24 t/ha under organic technology. Mid-ripening varieties Windsor, ES Pallador and Emperor had grain yields of 3.25 and 2.44 t/ha, which is 0.37 and 0.20 t/ha higher compared to mid-early varieties.

The difference in grain yields between conventional and organic technologies was 0.63 t/ha for mid-early varieties and 0.81 t/ha for mid-ripening varieties. The protein, fat and moisture content of soybean grain depended on varietal characteristics, weather conditions and did not depend on the cultivation technology. On average, over the two years, the protein content of soybean grain ranged from 39.8–42.5 %, fat content from 20.1–21.7 %, and moisture content from 11.7–13.9 %. As a result of the higher grain yield of soybeans under conventional technology, the protein yield

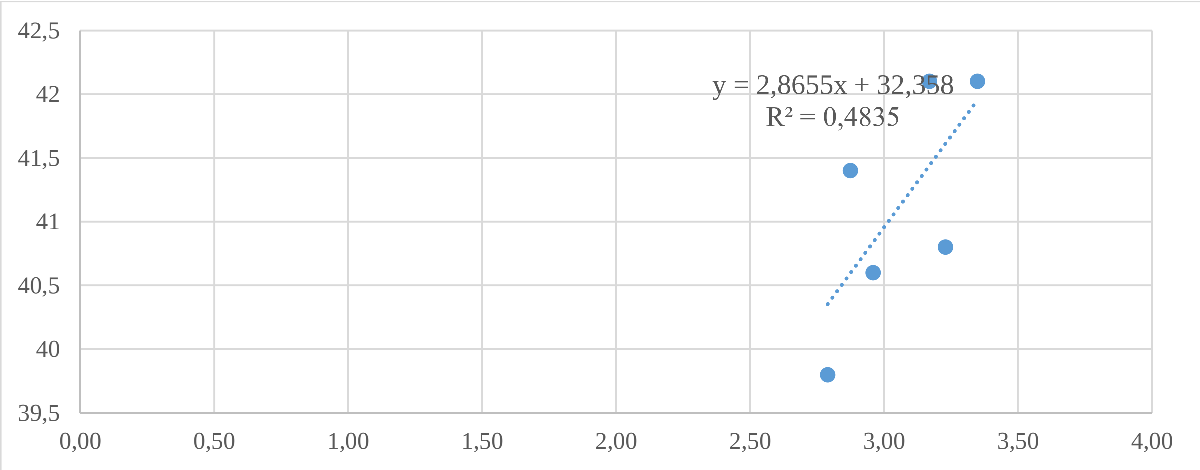

Fig. 2. Correlation between soybean grain yield and protein content under conventional cultivation technology, average for 2021–2022.

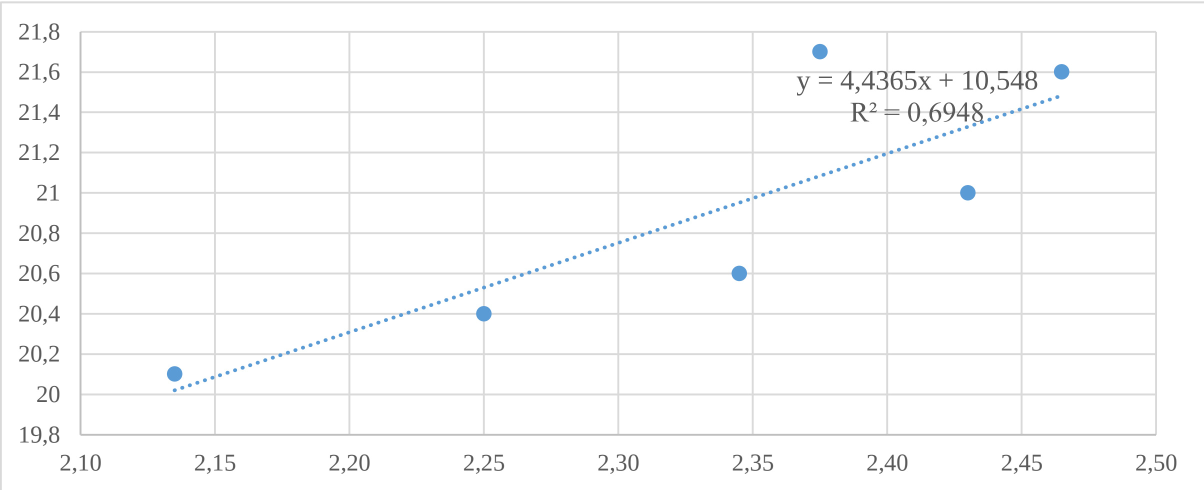

Fig. 3. Correlation between soybean grain yield and fat content under organic cultivation technology, average for 2021–2022.

was 1.11–1.42 t/ha and the fat yield was 0.57–0.72 t/ha, which is 21.0–24.7 and 21.5–25.6 % higher than under organic cultivation technology. The correlation between grain yield and protein content was above average (r = 0.69 and 0.78 for conventional and organic cultivation, respectively), and the correlation between grain yield and fat content was high (r = 0.97 and 0.95). The maximum yield of grain (3.35 and 2.47 t/ha) and protein (1.42 and 1.05 t/ha) and fat (0.72 and 0.54 t/ha) were obtained in the Emperor variety, under conventional and organic cultivation technologies, respectively. Therefore, this variety can be recommended for cultivation under both technologies.

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Грабовський М. Б., Федорук Ю. В., Грабовська Т. О., Лозінський М. В., Козак Л. А.. Порівняльна оцінка урожайності та якісних показників сортів сої за традиційної та органічної технологій вирощування. *Зернові культури. 2023. 7 (1). 105–113.*
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Актуальність. Однією з альтернатив інтенсифікації сільськогосподарського виробництва є впровадження нових екологічних технологій, які спрямовані на реалізацію природного потенціалу агрофітоценозів і ґрунтуються на ефективному використанні їх біологічних можливостей. Зміни клімату та розповсюдження екологізації в сільському господарстві створюють передумови для добору сортів сої різних груп стиглості та вивчення їх потенціалу продуктивності і якісних показників зерна за різних технологій вирощування. **Мета роботи.** Оцінка сортів сої за урожайністю та якісними показниками зерна за традиційної та органічної технологіями вирощування. **Методи.** Польовий, лабораторний, математичний, статистичний аналіз. **Результати.** Встановлено, що врожайність зерна у середньоранньостиглих сортів сої (Еверест, ЕС Професор і ДХ530) становила за традиційної технології 2,88 т/га, за органічної – 2,24 т/га, а у середньостиглих сортів (Вінздор, ЕС Палладор і Емперор) – 3,25 і 2,44 т/га, що на 0,38 і 0,20 т/га більше порівняно з середньо-раньостиглими сортами. Різниця у врожайності зерна між традиційною і органічною технологіями становила у середньоранньостиглих сортів 0,63 т/га, а у середньостиглих – 0,81 т/га. В середньому за два роки досліджень вміст протеїну в зерні сої становив 39,8–42,5 %, жиру – 20,1–21,7 %, вологість – 11,7–13,9 %. За рахунок вищої урожайності зерна сої за традиційної технології вихід протеїну був у межах 1,11–1,42 т/га, а жиру – 0,57–0,72 т/га, що на 21,0–24,7 і 21,5–25,6 % більше ніж за органічного вирощування. Між врожайністю зерна та вмістом протеїну встановлений вище середнього рівень взаємозв’язку – r=0,69 і 0,78 за традиційного і органічного вирощування, а між урожайністю та вмістом жиру залежність мала високий рівень (r =0,97 і 0,95). **Висновки.** Якісні показники (вміст протеїну і жиру) та вологість зерна сої залежали від сортових особливостей та погодних умов року і не змінювалися під впливом технології вирощування. Сорт сої Емперор мав максимальні показники урожайності зерна (3,35 і 2,47 т/га), вихід протеїну (1,42 і 1,05 т/га) і жиру (0,72 і 0,54 т/га), відповідно за традиційної та органічної технологій вирощування. Тому даний сорт можна рекомендувати для вирощування за обох технологій.
Ключові слова: *соя, продуктивність, вміст протеїну, вміст жиру, вологість зерна*