Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en
Plant and Soil Science, 12(2), 60-68
Received xx.xx.2021 Revised xx.xx.2021 Accepted xx.xx.2021

UDC [[330.131.5: 621.9]:631.55/.86:633.15

DOI: 10.31548/agr2021.02.0060

K.S. Karabach*
PhD in Agricultural Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

E.M. Berezhniak
PhD in Agricultural Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

Influence of fertiliser systems with elements of biologisation and cultivation on the yield, economic and energy efficiency of spring barley

Abstract. The influence of the use of fertiliser systems with elements of biologisation and tillage on the yield, economic and energy efficiency of spring barley is investigated. The purpose of the study is to identify the impact of the implemented tillage systems with elements of minimisation and fertiliser with elements of biologisation on the productivity and economic indicators of spring barley. It is established that in the conditions of the Right-Bank Forest-Steppe of Ukraine, the aftereffect of applying high rates of organic and mineral fertilisers on typical chernozem has a positive effect on the yield of spring barley, increasing it, in comparison with the control, by 0.55-1.10 t/ha for ploughing, by 0.65-1.35 t/ha for deep chisel cultivation and by 0.55-1.30 t/ha for shallow. It was identified that the highest yield of the crop (3.85 t/ha) was obtained against the background of shallow flat tillage and the aftereffect of organo-mineral fertiliser using manure. The use of fertilisers contributed to an increase in the protein content of spring barley grain. The influence of tillage systems on the content of barley protein was reliably observed only in the fertiliser variant with the introduction of straw, green manure, and mineral fertilisers. The use of shallow chisel tillage against the background of organo-mineral fertiliser provides a reduction in the prime cost of production by UAH 142.9/tonne, an increase in conditional net profit by UAH 886/ha, and a 21.2% reduction in energy costs compared to ploughing

Keywords: spring barley, tillage, soil, fertilisers, grain quality, energy efficiency

Suggested Citation:

Karabach, K.S., & Berezhniak, E.M. (2021). Influence of fertiliser systems with elements of biologisation and cultivation on the yield, economic and energy efficiency of spring barley. *Plant and Soil Science*, 12(2), 60-68. doi: 10.31548/agr2021.02.060.

*Corresponding author

RELEVANCE

Ukraine belongs to the leading agricultural countries of the world, where grain crops have been grown and grain exported since ancient times. According to statistics, Ukraine owns approximately 12% of the world market in grain trade, and it is also one of the top 5 grain exporting countries. Due to this potential, the state manages to meet not only internal needs in the food sector, but also export a substantial part of the grain crop to many countries in Europe and around the world.

Among the crops that are conventionally grown in Ukraine, barley is one of the most productive and valuable grain crops with a high yield potential and is only behind winter wheat, rice, and corn in terms of acreage. In Ukraine, barley is sown on an area of approximately 3 million hectares (Kohut I.M., & Kohut S.G., 2018). According to the Ministry of Economic Development, Trade, and Agriculture, the barley harvest in 2020 amounted to 7.81 million tonnes. Experts conclude that it is quite difficult to substantially minimise the impact of climate change on global agriculture, but new approaches to management will help the situation (Ivanyshyn V.V. *et al.*, 2020). In this regard, the tasks of introducing new findings and improving modern technologies for growing spring barley in the Forest-Steppe zone of Ukraine, which would be economically and energetically justified, ensured high and stable yields of high-quality grain, are urgent.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Spring barley (Hordeum sativum) – a crop with high genetic potential, which is characterised by a wide range of changes in the resulting grain yield (up to 40%), depending on the influence of biotic and abiotic factors on it. Under favourable conditions, the grain yield can reach up to 10.0 t/ha. However, the available bioclimatic resources are not sufficient to fully realise the productivity potential of spring barley varieties (Hamaiunova V.V., Kasatkina T.O., 2018). It is known that the yield of barley depends on the elements of intensification of cultivation technology, and barley also has the ability to make good use of the aftereffect of organic and mineral fertilisers that were applied for the predecessor. If spring barley is sown after well-fertilised row crops, then to obtain a yield of 5 t/ha, applying fertilisers directly under the barley is not necessary (Lykhochvor V., 2018).

Barley is quite sensitive to a lack of nutrients and moisture in the soil. The application of nitrogen fertilisers is reduced, and high yields are achieved by increasing the density of the stem and stimulating phosphorus-potassium nutrition of plants to obtain grain with high brewing qualities. According to researchers of the ESC "Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine", the combination of mineral fertilisers and foliar top dressing of plants contributed to an increase in the yield of barley grain from 0.79 to 0.95 t/ha (Kamins'ka V., 2016). It is established that the effect of foliar top dressing increases under stressful weather conditions (Rozhkov A., 2014). If there is a shortage of conventional types of organic fertilisers, grain straw and cruciferous green manure should become alternative sources of soil replenishment with organic substances (Sendets'kyy V.M., 2014). Their widespread use is an important element of the biologisation of modern agriculture, which improves soil fertility and the ecological state of the agroecosystem (Ivanyshyn V.V., 2016).

It is necessary to adhere to the appropriate tillage system, which should consider soil fertility, climatic, and weather conditions, terrain features, and agrotechnological maps for each crop rotation field to obtain high yields of barley.

Such a system consists of primary (autumn) and pre-sowing tillages and depends on the predecessors.

According to many researchers, the best way to cultivate the soil for spring barley is autumn ploughing tillage with preliminary stubble peeling, which gives substantial grain increases compared to other methods of tillage, especially in dry years (Kyrylyuk V.P. *et al.*, 2019). According to the recommendations of researchers of the Plant Production Institute named after V.Ya. Yuriev of the National Academy of Sciences of Ukraine, it is undesirable to conduct chisel tillage, since many weed seeds remain on the surface, and barley seedlings will be levelled and thin out due to a large amount of plant residues (Kyrychenko V., Kostromitin V., 2011). However, there are also opposing opinions on this issue. The use of ploughing and chiselling provides an almost equivalent yield of barley grain at the level of 2.69-3.35 and 2.35-3.32 t/ha, respectively. Disking the soil reduces the yield of grain crops by 0.14-0.48 t/ha (5.9-17.8%) due to the immobilisation of nitrogen by microorganisms during the decomposition of plant residues (Tsylyuryk O., 2016).

Due to the general tendency to minimise tillage, it was established that in recent decades the use of minimum and zero tillage technologies is promising for structural, well-drained soils, that have substantial advantages due to mulching the surface with plant residues in arid conditions, which preserves the moisture content in the arable layer (Nosenko Y., 2010). Shallow mulching tillage, which involves the use of by-products of previous crops, increases labour productivity, reduces prime production costs, protects soils from erosion, increases humus content, and preserves soil moisture by reducing physical evaporation (Tsylyuryk O., Shapka V., 2013; 2014). V.F. Sayko & A.M. Maliyenko suggest differentiating the cultivation of spring barley after row predecessors, i.e. ploughing is more expedient to use in favourable humidity years, and surface tillage – in dry ones (Sayko V., Maliyenko A., 2007).

Considering the contradictory views of researchers regarding the feasibility of using various methods of tillage for spring barley against the background of general heterogeneity of soil cover, changes in climatic conditions, and the manifestation of erosion processes, improving soil protection technologies for growing this crop is a promising area. These technologies are based on reducing total costs per unit of production, introducing alternative fertiliser systems, and minimising cultivation, selecting, and optimising growing conditions through the use of promising varieties, plant growth regulators, which will contribute to the realisation of the genetic potential of spring barley varieties.

Purpose. Examine the influence of minimising tillage and fertilising systems with elements of biologisation in the crop rotation link on the yield and quality indicators of spring barley grain, economic, and energy efficiency of cultivation technologies.

METHODS

The study was conducted in a two-factor stationary experiment of the Professor M.K. Shykula Department of Soil Science and Soil Conservation of the National University of Life and Environmental Sciences of Ukraine in the educational and experimental farm named after O.V. Muzychenko of the Fastovsky district of the Kyiv region. Three tillage systems and three fertiliser systems were analysed in experiments (Table 1). Observations were conducted in the crop rotation link: winter wheat – sugar beet – spring barley with the sowing of perennial grasses. The repetition of the experiment is threefold, the placement of variants is randomised in repetitions. The soil of the experimental plots is typical low-humus coarse-dusty medium-loamy chernozem. Accounting of the harvest of barley grain of the Vakula variety was conducted by plots. The protein content in barley was determined using a grain analyser "Infratec 122". The economic and energy efficiency of various technologies for growing spring barley was determined according to technological maps and relevant recommendations and according to the methods of Yu.O. Tarariko.

RESULTS

Barley cultivation should be based on elements of technologies aimed at ensuring high productivity of the crop and realising the genetic potential of the variety, depending on the area of use. Therewith, modern technology should save resources and minimise the negative impact on the ecological state of the natural environment. The introduction of elements of biologisation aims to reduce the chemical and anthropogenic burden on agroecosystems and meet the requirements for a gradual transition to organic farming in the context of regional climate changes. It is possible to achieve this goal by improving modern technologies for growing agricultural crops with their adaptation to environmental requirements, so the area of these studies is relatively new and requires further study.

In this experiment, spring barley was sown in stationary plots after sugar beet in crop rotation. The good aftereffect of barley's use of high rates of organic and mineral fertilisers applied for beet is notable (Table 1). The yield of barley substantially depended mainly on soil fertilisation systems, where the most effective aftereffect had the application of 12 t/ha of manure + $N_{55}P_{45}K_{45}$. Thus, during ploughing, the yield of barley was 3.45 t/ha, which is 46.8% more than in the control (without fertilisers).

Table 1. Influence of fertiliser systems with elements of biologisation on the yield of spring barley grain under various tillages, t/ha *(average data for 4 years)*

Soil fertilisation system *(per 1 ha of crop rotation plot)*	**Yield, t/ha**	**Increase in yield, %**		**Protein content,**
		t/ha	**%**	
Ploughing to a depth of 23-25 cm				
Control (without fertilisers)	2.35	–	–	10.2
Manure (12 t/ha) + $N_{55}P_{45}K_{45}$	3.45	+1.10	46.8	11.6
Manure (6 t/ha) + straw 1.2 t/ha+ N_{12} + $N_{55}P_{45}K_{45}$	3.00	+0.65	27.7	12.5
Straw (2.4 t/ha) + $N_{55}P_{45}K_{45}$	2.70	+0.35	14.9	11.8
Straw (1.2 t/ha) + N_{12} + green manure + $N_{55}P_{45}K_{45}$	2.90	+0.55	23.4	11.0
Flat tillage to a depth of 23-25 cm				

Table 1, Continued

Soil fertilisation system *(per 1 ha of crop rotation plot)*	Yield, t/ha	Increase in yield, %		Protein content,
		t/ha	%	
Control (without fertilisers)	2.40	–	–	10.6
Manure (12 t/ha) + $N_{55}P_{45}K_{45}$	3.75	+1.35	56.3	11.8
Manure (6 t/ha) + straw 1.2 t/ha+ N_{12} + $N_{55}P_{45}K_{45}$	3.05	+0.65	27.1	11.4
Straw (2.4 t/ha) + $N_{55}P_{45}K_{45}$	3.10	+0.70	29.2	11.2
Straw (1.2 t/ha) + N_{12} + green manure + $N_{55}P_{45}K_{45}$	3.20	+0.80	33.3	11.1
Flat tillage to a depth of 10-12 cm				
Control (without fertilisers)	2.55	–	–	10.5
Manure (12 t/ha) + $N_{55}P_{45}K_{45}$	3.85	+1.30	51.0	11.3
Manure (6 t/ha) + straw 1.2 t/ha+ N_{12} + $N_{55}P_{45}K_{45}$	3.20	+0.65	25.5	12.2
Straw (2.4 t/ha) + $N_{55}P_{45}K_{45}$	3.55	+1.00	39.2	11.9
Straw (1.2 t/ha) + N_{12} + green manure + $N_{55}P_{45}K_{45}$	3.10	+0.55	21.6	11.5

Note: for fertiliser 0.23; for tillage 0.20

Application of alternative fertiliser systems for ploughing (straw 2.4 t/ha + $N_{55}P_{45}K_{45}$) and (straw 1,2 t/ha +N_{12} + green manure + $N_{55}P_{45}K_{45}$) were noticeably lower, where their effectiveness was 14.9-23.4%. Fertiliser systems worked most effectively for the use of deep and shallow chisel tillages, the yield on the background of fertilisers manure is 12 t/ha + $N_{55}P_{45}K_{45}$ was 3.75 and 3.85 t/ha, respectively. A slightly lower yield was observed on variants where part of the manure was replaced with straw, and the yield of barley grain on them was in the range of 3.05-3.55 t/ha. Comparative analysis of barley cultivation shows that with alternative fertiliser systems using straw and green manure, the option of tillage with chisel tools to a depth of 10-12 cm was more effective, where the yield increase was 0.55-1.00 t/ha or 21.6-39.2%, compared to the control.

The prospects for applying new and improved technologies for growing agricultural crops require economic, energy, and environmental justification. From the standpoint of economic benefits, the largest net profit from the use of fertilisers under ploughing conditions was obtained on the manure variant 12 t/ha + $N_{55}P_{45}K_{45}$, which was 2895 UAH. Using chisel tillages, the economic effect was noticeably higher and amounted to 3572 and 3781 UAH/ha, respectively. The use of a nutrient-adaptive growing system allows for increasing the yield of spring barley while reducing the prime cost of 1 tonne of grain and increasing the level of profitability of production, compared to intensive technology (Table 2).

Table 2. Economic and energy efficiency of spring barley cultivation depending on fertiliser and tillage systems

Fertiliser variant	Economic indicators		Energy indicators		
	Prime cost of 1 tonne, UAH	Net profit, UAH/ha	Energy consumption per 1 tonne, MJ	Energy output, MJ/ha	Kee
Ploughing to a depth of 23-25 cm					
Without fertilisers (control)	510.8	2090	3887.1	61223	4.12
Manure (12 t/ha) + $N_{55}P_{45}K_{45}$	560.8	2895	6120.0	76998	3.70
Manure (6 t/ha) + straw (1.2 t/ha) + $N_{55}P_{45}K_{45}$	643.2	2270	6189.9	75308	3.27
Straw(2.4 t/ha) + $N_{55}P_{45}K_{45}$	800.3	1439	6293.1	72115	2.72
Straw (2.4 t/ha) + green manure + $N_{55}P_{45}K_{45}$	663.5	2136	6698.1	66481	3.24
Flat tillage to a depth of 23-25 cm					
Without fertilisers (control)	391.8	2420	3396.4	62162	5.81
Manure (12 t/ha) + $N_{55}P_{45}K_{45}$	445.0	3572	5009.1	85825	5.35
Manure (6 t/ha) + straw (1.2 t/ha) + $N_{55}P_{45}K_{45}$	545.9	2605	5452.7	80378	4.41
Straw(2.4 t/ha) + $N_{55}P_{45}K_{45}$	534.0	2684	5440.2	77749	4.64
Manure (2.4 t/ha) + green manure + $N_{55}P_{45}K_{45}$	519.1	2819	6276.5	68923	4.73
Flat tillage to a depth of 10-12 cm					
Without fertilisers (control)	344.1	2692	3316.1	59533	7.52
Manure (12 t/ha) + $N_{55}P_{45}K_{45}$	417.9	3781	4820.3	88642	6.42
Manure (6 t/ha) + straw (1.2 t/ha) + $N_{55}P_{45}K_{45}$	499.6	2881	5927.0	70237	5.50
Straw(2.4 t/ha) + $N_{55}P_{45}K_{45}$	448.9	3376	5955.1	67045	6.25
Manure (2.4 t/ha) + green manure + $N_{55}P_{45}K_{45}$	515.1	2743	5874.5	70425	5.38

Energy costs for growing 1 tonne of barley grain increased from 3396 MJ in the control without fertilisers to 5009-6277 MJ when using various nutrient-mineral fertiliser systems. The highest energy yield of 88,642 MJ/ha was obtained with a manure fertiliser aftereffect of 12 t/ha + $N_{55}P_{45}K_{45}$ for shallow chisel tillage. From an ecological standpoint, tillage with chisel tools contributes to the preservation of crop residues on the soil surface, and this also protects it from water and wind erosion, reduces the physical evaporation of moisture from the soil.

CONCLUSIONS

Systematic use of resource-saving technologies for growing crops in the crop rotation link with minimisation of tillage and the use of alternative fertiliser systems with elements of biologisation contributed to an increase in the yield of spring barley and an improvement in grain quality indicators while reducing energy costs for growing products and, accordingly, the prime cost, which contributed to the growth of conditionally net profit.

1. The highest yield of spring barley grain (3.75-3.85 t/ha) was observed after the application of 12 t/ha of manure + $N_{55}P_{45}K_{45}$ per 1 ha of crop rotation plot with shallow and deep chisel tillage systems.

2. The use of nutrient-mineral fertiliser helped to increase the protein content in the grain of spring barley. Since this variety of barley is used in brewing, the protein content in it on fertilised agricultural zones was also relatively low (11.0-12.5%). A substantial effect of tillage on the protein content was identified when fertilising the soil with mineral fertilisers with straw and green manure.

3. For the Right-Bank Forest-Steppe of Ukraine, aftereffects of applying 12 t/ha of manure and $N_{55}P_{45}K_{45}$ per 1 ha of crop rotation area were economically effective for shallow chisel cultivation, which provided a conditionally net profit of UAH 3,781 per hectare. The cost of production using this technology was the lowest and amounted to 417.9-445.0 UAH/tonne. The use of manure and straw against the background of mineral fertilisers was identified to be the most energy-consuming. The highest energy yield was observed when applying manure and mineral fertilisers during shallow, chisel cultivation, where the advantage over ploughing was 21,385 MJ/ha.

REFERENCES

[1] Hamaiunova V.V., & Kasatkina T.O. (2018). Erspectiveis that the particularity of the barley is vivid on the countryside. *Naukovi horyzonty*, 7-8(70), 131-138. doi: 10.33249/2663-2144-2018-70-7-8-131-138.

[2] Ivanyshyn V.V., Roy H.V., & Shuvar A.I. (2016). Biology of Agriculture in Ukraine: Realities and Prospects. Ivano-Frankivsk: Forte Symphony, 284 p.

[3] Ivanyshyn V.V., Shuvar I.A., Bakhmat M.I., Sendets'kyy V.M. Tanchyk S.P., Tsentylo L.V., Bunchak O.M., Mel'nychuk T.V., Kolisnyk N.M., Tymofiychuk B.V., Mel'nyk I.P., Shuvar B.I., & Tymofiychuk P.B. (2020). Straw, post-harvest residues and green manures – agrotechnological elements of biologization of modern agriculture. Ivano-Frankivs'k. Symfoniya forte, 292 p.

[4] Kamins'ka V., Dudka O., & Mushyk B. (2016). Productivity of spring barley by different cultivation technologies. Zbirnyk naukovykh prats' NNTS "Instytut zemlerobstva NAAN", 3-4, 114-122.

[5] Kohut I.M., & Kohut S.H. (2018). Formation of productivity of winter barley depending on sowing norms in the conditions of the Northern Steppe of Ukraine. *Ahrarnyy visnyk Prychornomor'ya*. 87, 109-115.

[6] Kyrychenko V.V., Kostromitin V.M., Popov S.I. *et al.* (2011). Technology of spring barley cultivation in the conditions of the eastern part of the Forest-Steppe of Ukraine. Kharkiv: NAAN. Instytut roslynnytstva im. V.YA. Yur'yeva. 170 p.

[7] Kyrylyuk V.P., Tymoshchuk T.M., & Kotel'nyts'ka H.M. (2019). Influence of basic tillage and fertilization systems on the productivity of spring barley. *Naukovi horyzonty*, 9(82), 36-44. doi: 10.33249/2663-2144-2019-82-9-36-44.

[8] Lykhochvor V.V., Horash O.S., & Potoplyak O.I. (2018). Barley yield depending on the elements of intensification of cultivation technology. *Ahronom*, 1.

[9] Nosenko Y. (2010). Tillage systems and aspects of development AgroPerspective. *AhroPerspektyva*, 3, 64-66.

[10] Rozhkov A.O., & Chernobay S.V. (2014). Yield of spring barley Dokuchaevsky 15 depending on the application of different seeding rates and foliar fertilization. *Visnyk Poltavs'koyi derzhavnoyi ahrarnoyi akademiyi*, 4, 30-34.

[11] Sayko V.F., & Maliyenko A.M. (2007). Tillage systems in Ukraine. Zbirnyk naukovykh prats' Natsional'noho naukovoho tsentru Instytut zemlerobstva NAAN, 1, 3-10.

[12] Scientific bases of effective development of agriculture in agrolandscapes of Ukraine / Za red. V.F. Kaminskoho (2015). K.: VP "Edel'veys". P. 208-213.

[13] Sendets'kyy V.M. (2014). The use of straw and other plant residues to increase soil fertility. *Zbirnyk naukovykh prats' Podil's'koho derzhavnoho ahrarno-tekhnichnoho universytetu*, Kamyanets-Podil's'kyy: PP Zvoleyko D.H., 22, 25-27.

[14] Tsilyurik O.Í., & Shapka V.P. (2017). Minimization of tillage for spring barley in the northern Steppe of Ukraine. Ş*tiinţa agricol*ă, 2, 25-29.

[15] Tsylyuryk O.I., Shapka V.P. (2014). Efficiency of shelfless tillage for growing spring barley in the northern steppe. *Visnyk Poltavs'koyi derzhavnoyi ahrarnoyi akademiyi*, 1(72), 25-29.

[16] Tsylyuryk O.I., & Shapka V.P. (2016). Influence of tillage and fertilizers on the growth and development of spring barley plants in the northern steppe of Ukraine. *Tavriys'kyy naukovyy visnyk*, 95, 87-95.

К.С. Карабач

Кандидат сільськогосподарських наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

Є.М. Бережняк

Кандидат сільськогосподарських наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

Вплив систем удобрення з елементами біологізації та культивації на врожайність, економічну та енергетичну ефективність ячменю ярого

Анотація. Досліджено вплив застосування систем удобрення з елементами біологізації та обробітку ґрунту на врожайність, економічну та енергетичну ефективність вирощування ячменю ярого. Мета дослідження – виявити вплив впроваджених систем обробітку ґрунту з елементами мінімалізації та удобрення з елементами біологізації на продуктивність і економічні показники ячменю ярого. Встановлено, що в умовах Правобережного Лісостепу України післядія внесення високих норм органічних і мінеральних добрив на чорноземі типовому позитивно впливає на врожайність ячменю ярого, підвищуючи її, порівняно з контролем, на 0,55-1,10 т/га за оранки, на 0,65-1,35 т/га за глибокого чизельного обробітку та на 0,55-1,30 т/га за мілкого. Встановлено, що найвищу врожайність культури (3,85 т/га) було отримано на фоні мілкого плоскорізного обробітку ґрунту та післядії органо-мінерального удобрення з використанням гною. Застосування добрив сприяло підвищенню вмісту білка в зерні ячменю ярого. Вплив систем обробітку ґрунту на вміст білка в зерні ячменю достовірно спостерігався лише у варіанті удобрення із внесенням соломи, сидератів та мінеральних добрив. Застосування мілкого чизельного обробітку ґрунту на фоні органо-мінерального удобрення забезпечує зниження собівартості продукції на 142,9 грн/т, збільшення умовно чистого прибутку на 886 грн/га та зниження енергетичних витрат на 21,2% порівняно з оранкою

Ключові слова: ярий ячмінь, обробіток ґрунту, ґрунт, добрива, якість зерна, енергоефективність