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Features of growth and development of alfalfa-cereal grass stands depending on the species composition and fertiliser

Abstract. The results of studies on the influence of the species composition of herbage, the level of fertiliser, and growth stimulator Fumar on the density and botanical composition of plants are presented. The experimental part of the study was performed in the scientific laboratories of the Department of feed production, land reclamation and meteorology in the production division of the National University of Life and Environmental Sciences of Ukraine "Agronomic Research Station". The territory of the station is located in the Right-Bank Forest-Steppe and is part of the Bilotserkivsky agro-soil district. Experimental plots were laid on chernozems of typical low-humus large-dusty light loamy mechanical composition, which are characterised by a high content of nutrients. The climate of the region is characterised by unstable humidity and moderate temperature conditions.

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The average annual air temperature is 6-8°C. The annual amount of precipitation reaches 562 mm, during the growing season – 354-394 mm (63-70% of the annual norm), which falls unevenly throughout the year. Based on the conducted studies, it was identified that sown herbage is formed with a density of 686-1250 shoots per 1 m2 and a height of 58-148 cm. Alfalfa-cereal and cereal stands are denser than alfalfa ones. For the period from 1 to 3 years of use of herbage, the density of alfalfa shoots decreases, while that of orchard grass and smooth brome increases, and more intensively with the introduction of N_{60}. During the first three years of use, grass stands are formed with the dominance of sown components with a share of alfalfa in single-species sowing of 85-98%, in alfalfa – cereal mixtures – 30-58%. For the period from the 1st to the 3rd year of use of alfalfa-cereal stands, the share of alfalfa decreases by 11-24%, and more intensively with the introduction of N60. In addition, between the two cereal components, there is a change of co-dominant – from meadow fescue to eastern fescue, eastern fescue to orchard grass, perennial ryegrass to smooth brome, like in the cereal stand, eastern fescue to smooth brome. In the 3rd year of use, ryegrass thins out, reducing the involvement rate to 5-14%

Keywords: alfalfa, cereal stand, shoot density, botanical composition, fertiliser

RELEVANCE

Improving the efficiency of using natural forage land plays an important role in creating a strong feed base for animal husbandry. The latter are a source of cheap grass feed (hay, haylage, green feed, artificially dried grass feed), which are well balanced in protein, minerals, and vitamins, and also act as a factor in improving the ecological situation in agricultural landscapes, protecting soils from erosion and water sources from siltation and pollution.

In Ukraine, the area of such land is approximately 7.8 million hectares, in the Right-Bank Forest-Steppe – 1 million hectares. However, their feed-producing and environmental capabilities are not yet fully used. Productivity in modern conditions of insufficient resource provision of agriculture remains too low (does not exceed 1.0-1.2 t/ha of feed units), which is several times less than the potential capabilities (Bohovin & Kurhak, 2007; Veklenko, 2003; Yarmolyuk, 2001).

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

It is necessary to improve nitrogen nutrition to increase the productivity of sown perennial grass stands because their need for nitrogen is the greatest. The average nitrogen dose per 1 ha of improved hayfields and pastures in Ukraine does not exceed 15-20 kg/ha along with its acute deficit balance. The removal of this element with the harvest is several times higher than the return. The need of meadow lands in Ukraine for nitrogen can be half covered by the effective use of the potential of perennial legumes through the enrichment of meadow stands with legume components (Bohovin, 2009; Davydyuk, 2000; Ohiyenko, 2008). Due to the insufficient supply of forage crops with mineral nitrogen, which is at the first minimum in most soil types, considerable attention should be paid to the creation of legume- cereal stands with an increased proportion of legume components in them (Kurhak & Luk'yanets', 2004; Satsik, 2000).

Among the sown grass stands, the legume-cereal ones fully comply with the principles of organic production, are one of the most promising areas of organic meadow farming, in which legume components ensure high productivity of land and feed quality without the introduction of mineral nitrogen. In the conditions of the Forest-Steppe, the best results in terms of productivity and feed quality in the composition of legume-cereal grass mixtures are provided by the use of alfalfa as a legume component. Its introduction into the composition of legume-cereal coenoses without the introduction of mineral nitrogen increases the productivity of meadow lands by 1.5-2.5, and protein collection – by 2-3 times compared to grass stands (Demydas' *et al.*, 2019, Slyusar, 2002).

One of the main conditions for creating highly productive sown herbage is the correct selection of cereal components, considering their cenotic characteristics, and environmental and agrotechnical factors. It is necessary to consider the relationships and interspecific functional relationships between plants in phytocenoses, starting from the moment of seed germination, so that cereals are characterised by low cenotic activity or aggressiveness. In grass mixtures, first of all, those types and varieties of herbs that are more productive and resistant in these soil and climatic conditions are used for sowing them in their pure form (Voloshyn & Sukaylo, 2014; Kurhak & Luk'yanets', 2002).

The purpose of the study consists in establishing the regularities of the development of high productivity of sown perennial grass stands with alfalfa sowing for the use of various cereal components, mineral fertilisers and growth stimulator Fumar on chernozems of typical low-humus Forest-Steppe of the right bank.

MATERIALS AND METHODS

The research was conducted in scientific laboratories of the Department of fodder production, land reclamation, and meteorology in the production division of the National University of Life and Environmental Sciences of Ukraine "Agronomic research station" during 2014-2016. The soil of the experimental field is the typical low-humus chernozem, with a large-dusty medium loamy granulometric composition. The humus content in the arable layer (according to Tyurin) is 4.34%, the pH of the salt extract is 6.8, the absorption capacity – 307 mg-Eq/kg of soil, alkaline hydrolysed nitrogen (according to Kornfield) – 101 mg/kg of soil, mobile phosphorus and exchange potassium (according to Chyrikov) – 113 and 91 mg/kg of soil, respectively. The scheme of the experiment is shown in Table 1.

Table 1. Experiment scheme

No.	*Factor A* – herbage (types of grasses and seeding rate, kg/ha)
1	Alfalfa, 16
2	Alfalfa seed, 12 + eastern fescue, 10 + meadow fescue, 8
3	Alfalfa seed, 10 + eastern fescue, 10 + orchard grass, 8
4	alfalfa, 10 + Smooth brome, 14 + perennial ryegrass, 10

Table 1, Continued

No.	*Factor B* – fertilisers (nutrients and their doses)
5	Alfalfa seed, 10 + stemless bonfire, 14 + eastern fescue, 8
6	Smooth brome, 14 + eastern fescue, 8 (cereal stand), control
1	Without fertilisers (control)
2	P60 K90
3	N60P60K90
4	N60P60K90 + growth stimulator Fumar

The area of the sown plot is 30 m², the accounting plot – 25 m², the repetition rate of the experiment is fourfold. The technology of growing perennial grasses, with the exception of the factors under study, was the generally accepted one for the Right-Bank Forest-Steppe of Ukraine. The following types of perennial grasses zoned with highly productive varieties were used in the experiment, namely alfalfa (*Medicago Sativa L.*), variety Regina; smooth brome (*Bromus inermis Leyss*), variety Mars; perennial ryegrass (*Lolium perenne L.*), variety Kyivska 101; eastern fescue (*Festuca arundinacea Schreb.*), variety Danka; meadow fescue (*Festuca pratensis Huds*), variety Dibrova; orchard grass (*Dactylis glomerata L.*) variety Natalka.

RESULTS AND DISCUSSION

It is known that the density of any grass stands, including alfalfa-cereals, serves as an important indicator because shoots are an important organ where the leaf surface is formed, which is crucial in the development of the crop (Solyanyk *et al.*, 2000).

According to the data obtained from the study of the density of the herbage, on average for 2014-2016, the total number of shoots in alfalfa, alfalfa-cereal, and cereal herbage ranged between 686-1250 pcs./m^2 (Table 2). Alfalfa-cereal and cereal stands were characterised by a higher density of 372-541 shoots per 1 m^2 more in comparison with single-species sowing of alfalfa. By the total number of shoots per 1 m^2 according to the average data, there was no big difference between the fertiliser options for alfalfa-cereal and cereal stands.However, these stands were somewhat thicker against the background of the introduction of $N_{60}P_{60}K_{90}$ + biostimulator of growth Fumar, that is 41-66 more shoots than without fertilisation.Alfalfa-cereal stands with orchard grass and perennial ryegrass were also thicker. With the additional input to the $P_{60}K_{90}$ of nitrogen in dose N_{60} there was a tendency to reduce the density of alfalfa grass stands and alfalfa-cereal mixtures by 29-84 shoots per 1 m^2 and an increase – on the cereal stand.

Table 2. Density of shoots of alfalfa, alfalfa-cereal, and cereal stands on different fertiliser backgrounds, pcs./ m² (average for 2014-2016)

Fertiliser	Total, pcs./ m²	Including				
		alfalfa	cereals			mixed grasses
			by components		total	
			1st	2nd		
Alfalfa						
Without fertilisers	756	696	–	–	–	60
$P_{60}K_{90}$	770	715	–	–	–	55
$N_{60}P_{60}K_{90}$	686	611	–	–	–	75
$N_{60}P_{60}K_{90}$+ Fumar	709	642	–	–	–	67
Alfalfa + eastern fescue + meadow fescue						
Without fertilisers	1128	508	303	263	566	54
$P_{60}K_{90}$	1160	517	300	293	593	50
$N_{60}P_{60}K_{90}$	1089	457	316	316	632	45
$N_{60}P_{60}K_{90}$+ Fumar	1169	489	300	337	637	43
Alfalfa + eastern fescue + orchard grass						
Without fertilisers	1194	547	330	263	593	54
$P_{60}K_{90}$	1236	558	338	290	628	50
$N_{60}P_{60}K_{90}$	1202	497	300	360	660	45
$N_{60}P_{60}K_{90}$+ Fumar	1250	523	290	394	684	43
alfalfa + stemless plum + perennial ryegrass						
Without fertilisers	1159	531	300	274	574	54
$P_{60}K_{90}$	1199	540	350	259	609	50
$N_{60}P_{60}K_{90}$	1168	478	355	290	645	45
$N_{60}P_{60}K_{90}$+ Fumar	1202	501	358	300	658	43
alfalfa + plumless + eastern fescue						
Without fertilisers	1246	516	326	350	676	54
$P_{60}K_{90}$	1191	530	311	340	611	50
$N_{60}P_{60}K_{90}$	1154	467	341	301	642	45
$N_{60}P_{60}K_{90}$+ Fumar	1192	497	353	299	652	43
Smooth brome + eastern fescue (cereal stand)						
Without fertilisers	1118	–	998	553	1051	67
$P_{60}K_{90}$	1145	–	500	585	1085	60
$N_{60}P_{60}K_{90}$	1178	–	600	521	1121	57
$N_{60}P_{60}K_{90}$+ Fumar	1184	–	616	515	1131	53
HIP_{05}		26	28	24	20	15

When analysing the density of legume-cereal herbage by components, it was identified that Alfalfa formed the most shoots, the number of which ranged between 457-696 shoots per 1 m². The number of shoots in cereal components was lower – each in the range of 263 to 353 shoots per 1 m². Therewith, the total number of shoots of two cereal components, which ranged between 574-658 shoots per 1 m², was approximately on the same level with the shoots of alfalfa.

Notably, both on single-species alfalfa sowing and in alfalfa-cereal stands for applying nitrogen fertilisers at a dose of N_{60} compared to the background of $P_{60}K_{90}$, the number of shoots of the legume component substantially decreased, which confirms the results of other researchers. In this case, in a single-species alfalfa crop, their number decreased by 104 shoots per 1 m², on alfalfa-cereals – by 60-63 shoots per 1 m².

However, in the case of using the growth biostimulator Fumar on the background of $N_{60}P_{60}K_{90}$, reducing the number of alfalfa shoots from applying N_{60} was about half as much. Therewith with the intoduction of $N_{60}P_{60}K_{90}$, compared to $P_{60}K_{90}$, the total number of shoots sown as part of grass mixtures of cereals is increased by 31-39 units. This was mostly due to an increase in the shoots of perennial ryegrass, smooth brome, and, especially, orchard grass, the number of which in the mixture alfalfa + eastern fescue + orchard grass increased by 70 shoots per 1 m².

An important factor in the development of yield and feed value of grass stands is its botanical composition, which is also determined by soil and climatic conditions, the age of the grass stand, usage regimes and fertilisers. With an increase in the proportion of the legume component in herbage, their productivity increases due to biological nitrogen fixation. Cereal components under conditions of joint cultivation with legumes contain more protein than in single-species crops (Olifirovych, 2008; Prykhod'ko & Kharytonchyk, 2010).

According to the data obtained from the study of the botanical composition of the herbage, on average for 2014-2016, alfalfa dominated the single-species sowing of alfalfa with a share of 88–94% (Table 3). The rest was mixed grasses with a share of 5-12%.

Table 3. Botanical composition of alfalfa, alfalfa-cereal, and cereal stands on different fertiliser backgrounds, % (average for 2014-2016)

[330.131.5: 621.9]:631.55/.86:633.15	Fertiliser	Alfalfa	Cereals by components			Mixed grasses
			1st	2nd	total	
Alfalfa	Without fertilisers	94	–	–	–	6
	$P_{60}K_{90}$	95	–	–	–	5
	$N_{60}P_{60}K_{90}$	88	–	–	–	12
	$N_{60}P_{60}K_{90}$+ Fumar	92	–	–	–	8
Alfalfa + eastern fescue + meadow fescue	Without fertilisers	43	28	23	51	6
	$P_{60}K_{90}$	43	27	25	52	5
	$N_{60}P_{60}K_{90}$	40	25	25	50	10
	$N_{60}P_{60}K_{90}$+ Fumar	41	24	26	51	8

Table 3, Continued

[330.131.5: 621.9]:631.55/.86:633.15	Fertiliser	Alfalfa	Cereals by components			Mixed grasses
			1st	2nd	total	
Alfalfa + eastern fescue + orchard grass	Without fertilisers	49	27	21	48	3
	$P_{60}K_{90}$	50	26	22	48	2
	$N_{60}P_{60}K_{90}$	44	22	26	48	8
	$N_{60}P_{60}K_{90}$+ Fumar	48	21	27	48	5
alfalfa + smooth brome + perennial ryegrass	Without fertilisers	48	28	20	48	4
	$P_{60}K_{90}$	49	29	19	48	3
	$N_{60}P_{60}K_{90}$	43	27	21	48	9
	$N_{60}P_{60}K_{90}$+ Fumar	46	26	22	48	6
alfalfa + plumless + eastern fescue	Without fertilisers	48	22	25	47	5
	$P_{60}K_{90}$	48	23	25	48	4
	$N_{60}P_{60}K_{90}$	42	27	22	49	9
	$N_{60}P_{60}K_{90}$+ Fumar	44	28	21	49	7
Smooth brome + eastern fescue (cereal stand)	Without fertilisers	–	43	47	90	10
	$P_{60}K_{90}$	–	44	49	93	7
	$N_{60}P_{60}K_{90}$	–	50	44	94	6
	$N_{60}P_{60}K_{90}$+ Fumar	–	52	43	95	5
HIP_{05}		3	2	2	2	2

In alfalfa-cereal stands, the share of alfalfa was lower and ranged between 41-50%. Among alfalfa-cereal stands, the smallest amount of it was observed in a mixture of alfalfa + eastern fescue + meadow fescue. The total share of cereals in alfalfa-cereal stands ranged between 47-52%, which was on par with the share of alfalfa. The total share of cereals in alfalfa-cereal mixtures was slightly higher in the same mixture (alfalfa + eastern fescue + meadow fescue), where the share of alfalfa was the largest.

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When analysing legume-cereal stands by components, it was identified that alfalfa was the dominant, the amount of which, as already noted, ranged between 41-50%. In second place in terms of the number of sown crops were cereal components, the share of each of which ranged from 19 to 29%.

Therewith, both on single-species alfalfa sowing and in alfalfa-cereal stands with the introduction of N_{60} compared to the background of $P_{60}K_{90}$ the amount of legume component substantially decreased, which confirms the results of other researchers. Therewith, in single-species sowing, the amount of alfalfa decreased by 7%, and in alfalfa-cereal stands – by 3-6%. However, in the case of using the growth biostimulator Fumar on the background of $N_{60}P_{60}K_{90}$, the reduction of the share of alfalfa from the introduction of N_{60} was about 2% less. Thus, the biostimulator of growth Fumar, although tendentiously, still reduces to a certain extent the negative impact of fertiliser nitrogen on the stability of alfalfa in legume-cereal stands. Therewith, with the introduction of $N_{60}P_{60}K_{90}$, a tendency to increase the total number of cereals in some variants was observed compared to $P_{60}K_{90}$. The amount of mixed grasses in alfalfa-cereal mixtures ranged between 2-10% and there was a pattern that with the introduction of $_{60}K_{90}$ N_{60}, it was the largest.

CONCLUSIONS

Studies established that in the technology of growing legumes and grasses, important elements on which the density and botanical composition of plants depend are a successful combination of their species composition, optimisation of fertiliser backgrounds, and stimulation with the growth biostimulator Fumar.

Sown herbage is formed with a density of 686-1250 shoots per 1 m^2 and a height of 58-148 cm. Alfalfa-cereal and cereal stands are denser than alfalfa ones. For the period from 1 to 3 years of use of herbage, the density of alfalfa shoots decreases, while that of orchard grass and smooth brome increases, and more intensively with the introduction of N_{60}.

During the first three years of use, grass stands are formed with the dominance of sown components with a share of alfalfa in single-species sowing of 85-98%, in alfalfa – cereal mixtures – 30-58%. For the period from 1 to 3 years of use of alfalfa-cereal stands, the share of alfalfa decreases by 11-24%, and more substantially with the introduction of N_{60}. In addition, between the two cereal components, there is a change of co-dominant – from meadow fescue to eastern fescue, eastern fescue to orchard grass, perennial ryegrass to smooth brome, like in the cereal stand, eastern fescue to smooth brome. In the 3rd year of use, ryegrass thins out, reducing the involvement rate to 5-14%.

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Особливості росту і розвитку люцерно-злакових травостоїв залежно від видового складу та удобрення

Анотація. Наведено результати досліджень з вивчення впливу видового складу травостою, рівня удобрення та стимулятора росту Фумар на густоту та ботанічний склад рослин. Експериментальна частина роботи виконана в наукових лабораторіях кафедри кормовиробництва, меліорації та метеорології у виробничому підрозділі Національного університету біоресурсів і природокористування України "Агрономічна дослідна станція". Територія станції розташована в Правобережному Лісостепу і входить до складу Білоцерківського агроґрунтового району. Дослідні ділянки закладені на чорноземах типових малогумусних крупнопилувато-легкосуглинкових механічного складу, які характеризуються високим вмістом поживних речовин. Клімат регіону характеризується нестійким зволоженням та помірним температурним режимом. Середньорічна температура повітря становить 6-8°С. Річна кількість опадів досягає 562 мм, за вегетаційний період - 354-394 мм (63-70% річної норми), які випадають нерівномірно протягом року. На основі проведених досліджень встановлено, що посіяний травостій формується з густотою 686-1250 пагонів на 1 м2 і висотою 58-148 см. Люцерно-злакові та злакові травостої є більш густими, ніж люцернові. За період від 1 до 3 років використання травостою густота пагонів люцерни зменшується, а пагонів стоколосу лучного та лядвенцю лучного - збільшується, причому більш інтенсивно при внесенні N60. Протягом перших трьох років використання формуються травостої з домінуванням сіяних компонентів з часткою люцерни в одновидових посівах 85-98%, в люцерно-злакових травосумішках - 30-58%. За період з 1-го по 3-й рік використання люцерно-злакових травостоїв частка люцерни зменшується на 11-24%, причому більш інтенсивно при внесенні N60. Крім того, між двома злаковими компонентами відбувається зміна співдомінантів - від костриці лучної до костриці східної, від костриці східної до грястиці садової, від райграсу багаторічного до стоколосу лучного, як і в злаковому травостої, від костриці східної до стоколосу лучного. На 3-й рік використання райграс зріджується, зменшуючи частку участі до 5-14%

Ключові слова: люцерна, злаковий травостій, густота пагонів, ботанічний склад, добриво

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Productivity of Triticale Depending on the Content of Photosynthesizing Pigments at Anthesis

Abstract. Photosynthetic pigments play an important role in the accumulation of dry matter and they can be the markers of stress. Change in the ratio of chlorophyll A and B indicates physiological changes and adaptation of the organism to changes of environmental conditions. Sowing terms and application of nitrogen fertilizers are long-term factors, so the content of chlorophylls in the flag leaf indicates long-term adaptation of the photosynthetic system. Establishing a relationship between the chlorophyll content at anthesis and the accumulation of dry matter in posy-anthesis period indicates the varietal response of triticale to fertilization and sowing dates. It was conducted a three-factor field experiment. There are studied two winter and one facultative triticale cultivar, two autumn sowing terms and fertilization system with application the different rates of nitrogen fertilizers in different growth stages. It was found that the content of photosynthetic pigments in each variety diverged depending on sowing term and fertilizer system in terms of mg per 1 g of dry matter for chlorophyll A, B and the amount of A+B. At the same time, the difference between the factors and their interactions was insignificant for the total chlorophyll mass per unit area (g/m2) for chlorophyll A and the amount of A+B, but it was significant for chlorophyll B by the fertilizer system factor. This indicates that the main stress signal is chlorophyll B, so the ratio of chlorophyll A and B differed significantly depending on this factor. Cla: Clb ratio in the optimal sowing period is 5.3-8.1 in cv. Pidzimok kharkivskiy, 4.8-8.3 in cv. Amur and 5.0-6.7 in cv. Obriy mironivskiy. All cultivars have a strong positive correlation between the chlorophyll content at anthesis and accumulation of dry matter at post-anthesis perion under optimal conditions, but facultative triticale Pidzimok kharkivskiy has a negative correlation with unfavorable, due to increased chlorophyll, without increasing dry matter accumulation. Further research of the relationship between chlorophyll

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content and the synthesis of primary and secondary metabolites is promising in the study of varietal response to stress and agronomic factors

Keywords: chlorophyll, correlation, dry matter, facultative triticale

INTRODUCTION

Morphological features of the flag leaf of cereals significantly affect its productivity (Yang *et. al.*, 2016). The basis of the photosynthetic system of the plant are green pigments chlorophyll A and B, which have a similar structure, but differ in the spectrum of waves that absorb (Britton, 1983). Content and ratios of pigments are a varietal feature of cereals (Pryadkina & Makharinska, 2021), and chlorophyll content is higher and varies greatly in triticale (Arough *et al.*, 2016). Productivity of photosynthesis depends on the amount of these pigments in the plant, and their content in the flag leaf can predict the yield potential (Simpson, 1968).

The fertilizer system has an important effect on plant growth and development, but its impact on chlorophyll content is indirect. Nitrogen concentration in plants is related to chlorophyll content, and therefore indirectly to one of the basic plant physiological processes: photosynthesis (Haboudane *et al.*, 2002; Amaliotis *et al.*, 2004). Cereals have a different requirement to nitrogen in different growth stages (Akhter *et al.*, 2016), so chlorophyll content varies similar (Shadchina & Dmitrieva, 1995). Chlorophyll content can be a stress indicator in plants under unfavorable conditions or nutrient deficiency (Tejada-Zarco *et al.*, 2004). Nitrogen as a structural element of chlorophyll and its deficiency can impact on photosynthesis and dry matter accumulation (Ray Tucker, 2004).

MATERIALS AND METHODS

Field experiments were conducted in 2016-2019 in the Right-bank Forrest-Steppe of Ukraine (49°46´N, 30°44´E). The soil is typical low-humic black, the arable layer of which is characterized by the following agrochemical and agro-physical indices: humus content – 4.31-4.63%; pH – 7.2, easily hydrolyzed nitrogen (according to Kornfeld) – 152.3-167.0 mg; P_2O_5 in acetic acid extract (according to Chirikov) – 109.0-142.0 mg; exchangeable potassium (according to Chirikov) – 127.0-132.0 mg per 1 kg of soil.

Field experiment was conducted by 3-factorial scheme. Factor A is a cultivar, factor B is a sowing term and factor C is a fertile system. Pidzimok kharkivskiy (facultative), Amur (winter) and Obriy mironivkiy (winter) were observed. Each cultivar was sowed in two terms – 2nd and 3rd decade of October. Fertilization system included 4 options. There are $P_{36}K_{72}$ as a fone (B1), and 3 options with different nitrogen fertilizations (B2 – $P_{36}K_{72}$ + $N_{25(11-13)}$; B3 – $P_{36}K_{72}$ + $N_{25(11-13)}$ + $N_{55(23)}$; B4 – $P_{36}K_{72}$ + $N_{25(11-13)}$ + $N_{55(25)}$ + $N_{20(49)}$).

Tillage system included only one plowing after preceding crop harvesting (soybean). Cultivation on sowing depth (2-4 cm) was conducted before sowing. Triticale was sown with 15 cm inter-row spacing with rate 450 grains per square meter. Any pesticides were applied during the research. The experiment was established in 4 replications. The size of elementary plots was 32 m^2 (25.2 m^2 to harvesting).

10 plants were collected in anthesis and wax ripeness for establishing crop growth rate (Hunt *et al.*, 2002) and chlorophyll content in flag leaf at anthesis. Chlorophyll content was determined by spectrophotometric method and calculating according Wellburn (1994). Statistical elaboration date was done by

multifactorial analysis ANOVA in Statistica 13.0. Difference between variant was established by Fisher LSD post-hoc test.

RESULTS

Content of photosynthetic pigments in the flag leaf at anthesis is an important indicator of the productivity potential of triticale. Flag leaf can accumulate almost up to half of the dry matter of the seed under normal conditions, so the increase in its content indicates an increase in assimilation processes. Plants of different sowing terms in a certain phase may have different contents of photosynthetic pigments, have different ratios of chlorophyll species, and their concentration will depend on the structure of the leaf, area and nutrition. Time of anthesis will be different, so the weather conditions will also make their adjustments.

Content of chlorophyll A and B in the dry matter of the flag leaf (mg/g) varied significantly depending on the variety and sowing period (Table 1 and 2). Cultivar is one of the main factors in the variation of chlorophyll A and B, as well as their sum, it is necessary to consider each variety separately.

Table 1. Content of chlorophyll A and B in flag leaf at anthesis (average 2016-2019 years)

Sowing term	Fs	Pigment weight in dry matter							CGR, g/m^2 per day
		Cl_a, mg/g	Cl_b, mg/g	$Cl_a + Cl_b$, mg/g	Cl_a/Cl_b	Cl_a, g/m^2	Cl_b, g/m^2	Cl_a+Cl_b, g/m^2	
Pidzimok kharkivskiy									
I	B1	6.59^{cd}	1.08^{b}	7.67^{bc}	6.1	40.0^{abc}	6.5^{bcd}	46.6^{abcd}	4.93
	B2	6.69^{cd}	1.02^{b}	7.71^{bcd}	6.6	33.3^{ab}	5.0^{abc}	38.4^{abc}	4.47
	B3	5.88^{bc}	0.73^{a}	6.61^{ab}	8.1	28.4^{a}	3.5^{a}	31.9^{ab}	4.15
	B4	7.79^{de}	1.48^{d}	9.27^{de}	5.3	44.4^{abc}	8.4^{d}	52.8^{bcd}	4.42
II	B1	5.11^{ab}	0.83 ^{a}	5.94^{a}	6.2	27.3^{a}	4.4^{ab}	31.7^{a}	6.02
	B2	4.15^{a}	1.07^{b}	5.22^{a}	3.9	27.8^{a}	7.2^{bcd}	34.9^{abc}	5.61
	B3	8.85^{e}	1.38^{cd}	10.23^{e}	6.4	48.3^{bc}	7.6^{cd}	55.8^{cd}	5.02
	B4	7.53^{de}	1.30^{c}	8.83^{cde}	5.8	52.5^{c}	9.1^{d}	61.6^{d}	5.41
Amur									
I	B1	11.72^{d}	2.45^{c}	14.17^{e}	4.8	43.6^{a}	9.1^{c}	52.8^{b}	5.23
	B2	10.64^{cd}	1.28^{a}	11.92^{cd}	8.3	45.3^{a}	5.4^{ab}	50.7^{ab}	4.64
	B3	8.31^{ab}	1.35^{a}	9.66^{ab}	6.2	40.2^{a}	6.6^{bc}	46.8^{ab}	4.17
	B4	8.01^{ab}	1.41^{a}	9.42^{ab}	5.7	36.1^{a}	6.4^{bc}	42.4^{ab}	3.93
II	B1	8.46^{b}	1.31^{a}	9.77^{abc}	6.5	33.9^{a}	5.3^{ab}	39.2^{ab}	4.75
	B2	9.39^{bc}	0.98^{a}	10.37^{bc}	9.6	31.3^{a}	3.3^{a}	34.6^{a}	4.50
	B3	10.73^{cd}	2.01^{b}	12.78^{de}	5.3	45.8^{a}	8.6^{c}	54.4^{b}	4.73
	B4	6.47^{a}	1.16^{a}	7.63^{a}	5.6	43.9^{a}	7.9^{bc}	51.8^{ab}	5.06

Table 1, Continued

Sowing term	Fs	Pigment weight in dry matter							CGR, g/m^2 per day
		Cl_a, mg/g	Cl_b, mg/g	$Cl_a + Cl_b$, mg/g	Cl_a/Cl_b	Cl_a, g/m^2	Cl_b, g/m^2	Cl_a+Cl_b, g/m^2	
Obriy mironivskiy									
I	B1	13.83^d	2.14^d	15.97^d	6.5	38.9^a	6.0^{ab}	44.9^{ab}	4.25
	B2	13.13^d	1.97^{cd}	15.10^d	6.7	43.8^a	6.5^{ab}	50.4^{ab}	4.71
	B3	8.07^{ab}	1.23^a	9.30^{ab}	6.6	36.8^a	5.6^a	42.3^{ab}	3.95
	B4	10.60^c	2.12^d	12.73^c	5.0	39.0^a	7.8^{bc}	46.8^{ab}	4.22
II	B1	8.94^b	1.77^c	10.71^b	5.1	44.4^a	8.8^c	53.3^b	4.56
	B2	6.96^a	1.11^a	8.07^a	6.3	41.4^a	6.6^{ab}	48.0^{ab}	3.92
	B3	7.87^{ab}	1.17^a	9.04^{ab}	6.7	34.0^a	5.1^a	39.1^a	3.50
	B4	8.64^b	1.48^b	10.12^b	5.8	43.7^a	9.0^c	52.7^b	4.22
LSD_{05}		**1.57**	**0.28**	**1.78**	**x**	**14.3**	**2.48**	**16.6**	

Note: *CGR – crop growth rate*

Table 2. ANOVA of chlorophyll content in flag leaf at anthesis

Effect	*df*	MS					
		Cl_a, mg/g	$Cl_в$, mg/g	$Cl_{a+в}$, mg/g	Cl_a, g/m^2	Cl_b, g/m^2	Cl_a+Cl_b, g/m^2
Cultivar (C)	2	70.70**	1.90**	95.58**	45.6^{ns}	1.42^{ns}	58.9^{ns}
Sowing term (ST)	1	39.87**	0.72**	51.31**	2.6^{ns}	4.24^{ns}	13.6^{ns}
Fertile system (FS)	3	2.94*	0.54**	4.66*	133.1^{ns}	19.48**	247.6^{ns}
C x ST	2	14.16**	0.36**	18.37**	40.7^{ns}	5.55^{ns}	76.2^{ns}
C x FS	6	13.51**	0.59**	17.98**	163.3^{ns}	9.13**	216.6^{ns}
FS x ST	3	25.18**	0.84**	34.85**	285.3*	7.46*	374.5*
C x ST x FS	6	1.73^{ns}	0.19**	2.44^{ns}	118.8^{ns}	9.23**	183.7^{ns}
Error	48	0.92	0.30	1.18	76.0	2.29	102.0

Note: * – $p<0.05$; ** – $p<0.01$; ^{ns} – factor/interaction insignificant at 95% level ($p>0.05$)

Cv. Pidzimok kharkivskiy is characterized by a much lower content of chlorophyll A in the flag leaf than other cultivars. Content of chlorophyll A in the variants without nitrogen application and at the rate of 25 kg/ha do not differ significantly, because the habitus of plants is similar, and the area of the flag leaf and its weight did not differ significantly. The content of chlorophyll A is significant in the plants of the first sowing term only at the norms of 100 kg/ha, and such effect was already at the norms of 80 kg/ha and 100 kg/ha in the second one. That is, the effect of nitrogen was prolonged, the content of chlorophyll B also increased accordingly, but the ratio of Cl_a:Cl_b differed significantly, and its low value is evidence of stress.

Cv. Amur has a different reaction to nitrogen fertilization according to the chlorophyll A content depending on the sowing term. Content of Cl_a is significantly reduced at the rates of application of 80-100 kg/ha of nitrogen compared to the options without application 25 kg/ha in plants of first sowing term. For other side, content of chlorophyll A increases when nitrogen is applied at the rate of 25-80 kg/ha, but fertilization at 100 kg/ha significantly reduces its content.

Cultivar Obriy myironivskiy was characterized by a much higher content of chlorophyll A than other varieties, although the trends during the first sowing period were similar to cv. Amur, but the nitrogen rate of 100 kg/ha had a stimulating effect. During the second sowing period, the chlorophyll content did not have a significant difference between the fone, and rates of 80 and 100 kg/ha, but significantly decreased at the rate of 25 kg/ha of nitrogen.

Chlorophyll content (A and B) differed significantly between cultivars, sowing terms, but the effect of the fertilizer system was ambiguous (Table 2). Content of chlorophyll A (figure 1) in the cv. Amur and cv. Obriy mironivskiy did not differ significantly, but the content of chlorophyll B was higher in cv. Obriy mironivskiy compared to other cultivars.

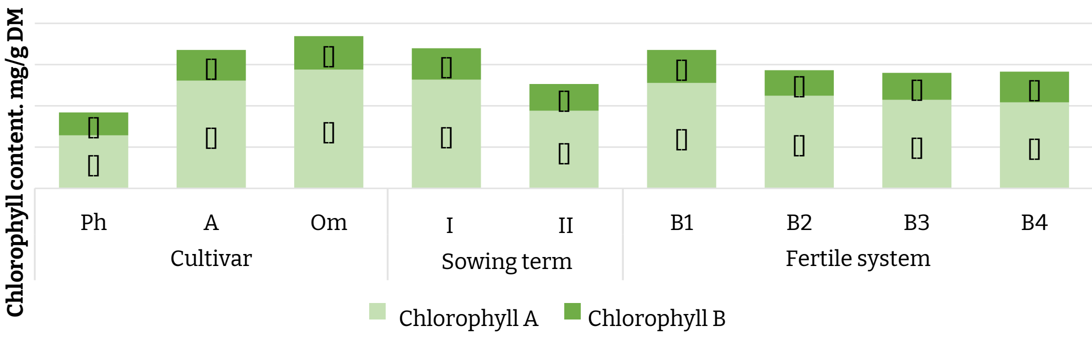

Figure 1. Chlorophyll content depends on cultivar, sowing terms and fertile system

The interaction of FS x ST factors is one of the strongest among other interactions (exclude primeval factors), which indicates a different reaction of crops of different sowing terms to the fertilizer system, i.e., the lack of a specific algorithm for fertilization for each variety. At the same time, the interaction of C x ST and C x FS also significantly affects the content of chlorophyll A and B. Interaction of primeval factors at the same time was insignificant, which indicates an independent reaction of each cultivar.

The weight of chlorophyll A and B per unit area (g/m^2) is almost independent of the factors and their interactions, but the FS x ST relationship is significant for both the amount of chlorophyll A, B and their sum. If the amount of chlorophyll A was almost unaffected by the main factors and their interactions, the amount of chlorophyll B significantly depended on the fertilizer system and its interaction with the varietal factor, sowing term and their combination.

According to the results of ANOVA and post-hoc Fisher`s LSD found that plants of the first sowing term formed more photosynthetic pigments on average than the second term. The effect of the fertilizer system was manifested in a significant decrease in the content of chlorophyll A with increasing the rate to 80 and 100 kg/ha compared to the fone, but insignificant compared to the rate of 25 kg/ha of nitrogen.

The content of chlorophyll B decreased at the norms of 25 and 80 kg/ha, while it did not have a significant difference with the fone at the rates of 100 kg/ha, its content increased compared to fertilization with lower rates. Change in the amount of chlorophyll B is the plant's response to stressful conditions and the adaptation of the photosynthetic system to these changes. It was found in resent research (Spanic *et al.*, 2013) that the grain yield of winter wheat did not depend on photosynthesis in optimal conditions, but on other physiological process which might be related to the energy usage efficiency. The present research showed a strong correlation between chlorophyll content (Cl_a+Cl_b) at anthesis with dry matter accumulation after anthesis (Fig. 2).

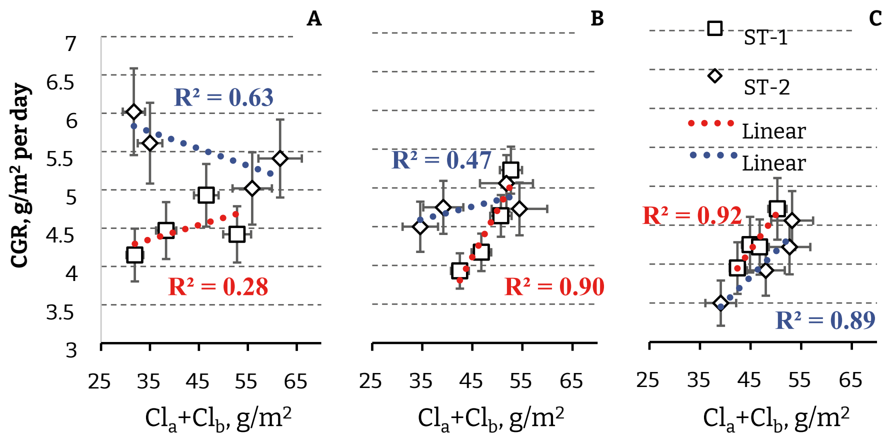

Figure 2. Relation between crop growth rate (CGR) in period "anthesis – wax maturity" and chlorophyll content at anthesis

Note: Annex. Cultivars: A – Pidzimok kharkivskiy; B – Amur; C – Obriy mironivkiy. Sowing term: ST-1 – II decade of October, ST-2 – III decade of October; means presented with standard errors (SE)

Silva *et al.* (2014) established that chlorophyll photosynthetic potential, characterizing the total amount of chlorophyll in the aboveground plant parts during the vegetative period under optimal environmental and climatic conditions correlated with the yield. This statement is true if the growth and development of triticale and wheat follows a typical path. In a previous study (Mazurenko & Novytska, 2020), it was found that the accumulation of dry matter in those varieties of triticale corresponded to the normal development cycle, and the accumulation of dry matter had a strong correlation with yield. All studied cultivars have a strong positive correlation between chlorophyll content and dry matter accumulation in optimal condition (sowing term: II decade of October), but they have a difference in these relations in unfavorable conditions. Pidzimok kharkivskiy has a negative correlation, when winter cultivars have a positive. The reason for this phenomenon may be a significant increase in chlorophyll in facultative triticale, which does not play a photosynthetic role, but is a reaction to stress.

CONCLUSIONS

Winter cultivars have a strong positive correlation between the content of chlorophyll and the accumulation of dry matter in the post-anthesis period. At the same time, this relation differs in facultative triticale Pidzimoc kharkivskiy depend on sowing term. Fertilizer system has a significant effect on these indicators – an increase in the rate of nitrogen leads to an increase in the content of pigments, which in turn increases the CGR in winter cultivars Amur and Obriy mironivskiy. Cv. Pidzimoc kharkivskiy has high CGR values in crops of the second sowing term, so the reaction to the increase in the nitrogen rate is ambiguous, as a larger quantity of pigments does not increase the accumulation of dry matter.

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Продуктивність тритикале залежно від вмісту фотосинтезуючих пігментів в антецезії

Анотація. Фотосинтетичні пігменти відіграють важливу роль у накопиченні сухої речовини і можуть бути маркерами стресу. Зміна співвідношення хлорофілів А і В свідчить про фізіологічні зміни та адаптацію організму до змін умов навколишнього середовища. Строки сівби та внесення азотних добрив є довготривалими факторами, тому вміст хлорофілів у прапорцевому листку вказує на довготривалу адаптацію фотосинтетичної системи. Встановлення взаємозв'язку між вмістом хлорофілів у фазі виходу в трубку та накопиченням сухої речовини в період кущіння-колосіння вказує на сортову реакцію тритикале на удобрення та строки сівби. Проведено трифакторний польовий дослід. Досліджували два озимих і один факультативний сорт тритикале, два осінніх строки сівби та систему удобрення з внесенням різних норм азотних добрив у різні фази розвитку. Встановлено, що вміст фотосинтетичних пігментів у кожного сорту відрізнявся залежно від строку сівби та системи удобрення в перерахунку на мг на 1 г сухої речовини для хлорофілу А, В та суми А+В. При цьому різниця між факторами та їх взаємодією була несуттєвою для загальної маси хлорофілу на одиницю площі (г/м2) для хлорофілу А та суми А+В, але достовірною для хлорофілу В за фактором системи удобрення. Це свідчить про те, що основним стресовим сигналом є хлорофіл В, тому співвідношення хлорофілу А і В суттєво відрізнялося залежно від цього фактора. Співвідношення Cla: Clb за оптимального строку сівби становить 5,3-8,1 у cv. Підзімок харківський, 4,8-8,3 у cv. Амурський та 5,0-6,7 у cv. Обрій миронівський. Всі сорти мають сильну позитивну кореляцію між вмістом хлорофілу в фазі виходу в трубку та накопиченням сухої речовини в післяфазний період за оптимальних умов, але факультативне тритикале Підзімок харківський має негативну кореляцію за несприятливих умов, що пояснюється збільшенням вмісту хлорофілу, без збільшення накопичення сухої речовини. Подальші дослідження взаємозв'язку між вмістом хлорофілу та синтезом первинних і вторинних метаболітів є перспективними при вивченні сортової реакції на дію стресових та агротехнічних факторів

Ключові слова: хлорофіл, кореляція, суха речовина, факультативне тритикале

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Productivity of winter barley depending on its predecessors in Transcarpathia of Ukraine

Abstract. Winter barley is a valuable food, fodder, and technical crop. The purpose of the study is the establishing and developing of an economically and energetically feasible, adequate bioresource potential for the yield of winter barley grain, depending on its predecessors in Transcarpathia of Ukraine. Studies and calculations of the balance of available moisture in the soil showed that in the conditions of Transcarpathia, it is negative and ranges from 250 to 1210 t/ha, or 25-121 mm. The accumulation and effective use of available moisture in the soil depends on the amount of precipitation and its frequency, the alternation of crops in crop rotation (predecessors), the system of tillage, fertilisation, and the extent of how weeded the fields are. The largest reserves of available moisture in the soil during the sowing period of winter barley were after winter rapeseed and buckwheat, the smallest – after sunflower and, especially, corn for grain. During the autumn-winter period, the reserves of available moisture in the meter-deep soil layer were replenished by 21-35%, but the pattern, according to its predecessors, was preserved. The critical period of winter barley in terms of moisture occurs during earing – grain ripening. Predecessors of early harvesting periods (winter rapeseed and buckwheat) have a positive effect on the accumulation and preservation of moisture in the soil. Predecessors of late harvesting periods (corn for grain and sunflower) reduce the content of available moisture and its reserves by up to 18% compared to crops of early harvesting. On average, for three years,

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the highest yield of winter barley was after buckwheat and amounted to 5.9 t/ha, the lowest – after corn for grain and was at the level of 4.9 t/ha, which is 0.8 t/ha lower than the control option

Keywords: available moisture content, winter barley, predecessor, yield

RELEVANCE

Winter barley is a valuable food, fodder, and technical crop. According to FAO, 48% of the barley grain produced goes to industrial processing, 36% – to mixed feed, and 16% – to food purposes. It is proved that the productivity of this crop depends on providing plants with all the necessary factors of life in the optimal amount and optimal proportions. (Wicket & Yaloha, 2011; Moisienko & Podolsky, 2019; Sokolovskaya & Al-Brud, 2010).

Ultimately, the investigation of the features of the establishment of productivity of winter barley and the degree of reproduction of soil fertility elements, depending on the optimisation of elements of cultivation technology, is now relevant and has led to the choice of a research algorithm.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The main task of modern agriculture is to ensure food security of the country by producing the quantity and quality of products necessary for society (Tanchyk, 2009). When growing winter barley, an important task is to increase grain production and yields, effectively use mineral and organic fertilisers, the best precursors, and the preserving soil treatment. (Sinchenko & Tanchik, 2018; Tanchik & Babenko, 2015)

The intensification of agriculture is accompanied by the degradation and depletion of soils, contamination with chemical and biological impurities, a drop in fertility, and a decrease in the yield of cultivated crops. (Tanchik, 2009). In modern conditions of agricultural development, the role of crop rotations as the most effective environment and ensuring high, stable, environmentally, economically, and energetically adequate winter barley yields is growing. Along with this, modern technologies for growing this crop have quite a few reserves of improvement, considering not only the selection of varieties adapted to the soil and climatic conditions of a particular region, optimising the placement of winter barley in crop rotations (of various specialisations), but also the choice of effective methods and depth of the main tillage to ensure maximum crop productivity and cost recovery (Tanchyk, 2009; Melnik & Govorun, 2014; Gamayunova & Litovchenko, 2017).

The purpose of the study consists in determining and developing regularities in the establishment of economically and energetically expedient, adequate to the bioclimatic potential of the winter barley grain yield zone, depending on its predecessors in Transcarpathia of Ukraine. It was planned to solve the following tasks to achieve this goal: establish the influence of various precursors on the content of available moisture in the soil, phytosanitary condition, and productivity of winter barley. Provide an economic and energy assessment of crop cultivation under different predecessors.

MATERIALS AND METHODS

Experimental studies on the influence of precursors on winter barley were conducted during 2018-2020 in the experimental crop rotation of the separated subdivision "Mukachevo Agricultural College of the National University of Life and Environmental Sciences of Ukraine" of the Transcarpathian region. The soils of the experimental field are podzolic gumbo turf, which contain an average of 2.6% humus in the humus horizon. With depth, the amount of humus decreases gradually and at a depth of 100-130 cm it reaches 1.0-1.7%. Formation on carbonate-free parent rocks and the influence of the podzolic process of soil formation caused a high active and potential acidity of soils, the pH of salt extract ranges between 5.0-6.0.

The soil under study, according to the agrochemical analysis of the initial samples, contains available forms of nitrogen – 35-45 mg/kg, mobile phosphorus (according to Kirsanov) – 130-160 mg/kg, mobile potassium (according to Kirsanov) – 120-170 mg/kg. The soil is typical for the area of the studies and is moderately provided with mobile forms of phosphorus, potassium, and nitrogen. A qualitative assessment of the surveyed soils showed that the soil requires constant use of organic and mineral fertilisers, liming, and the introduction of crop rotations.

The climate of the area is moderate with unstable humidity. The average long-term precipitation rate for the year is 618.0 mm. Over the years of the studies, the amount of precipitation for the year was: 2018 – 568.3 mm, 2019 – 558.1, and 2020 – 513.1 mm, which is 10-13% less than normal. The following precursors were studied for the cultivation of winter barley: soy (control), winter rapeseed, buckwheat, corn for grain, and sunflower. The repetition rate of the experiment is fourfold, the total area of one plot is 240 m^2, accounting plot – 150 m^2. Land plot placement is randomised.

The content of available moisture in the soil was determined by the thermostatic-weight method according to DSTU ISO 16586 : 2005; actual contamination with weeds in the phase of germination of cultivated plants and spring restoration of vegetation was determined by quantitative, and the earing phase – by quantitative-weight method. Crop accounting was conducted by direct combining.

RESULTS AND DISCUSSION

Available moisture in the soil is one of the main terrestrial factors of plant life. Many studies, including this one, have established that in recent years in Ukrainian agriculture, moisture is a limiting factor that negatively affects seed germination, the dissolution of mineral and organic substances in the soil, the maintenance of cellular turgor, transpiration, the vital activity of microorganisms, and, ultimately, their productivity.

The study established that the initial reserves of available moisture in the soil and its accumulation in the autumn-winter and growing seasons depend on the amount of precipitation and predecessors. Thus, during the sowing period of winter barley, the largest moisture reserves in 0-30 cm and a meter layer of soil were 30.0 and 121.0 mm after winter rapeseed, respectively (Table 1). The smallest ones are after corn for grain (25.0 and 109.0 mm, respectively). This depends on the morphobiological and ecological characteristics of the culture.

Table 1. Content of available moisture in 0-100 cm of the soil layer in winter barley crops, depending on the predecessor, mm (average for 2018-2020)

Predecessor	Soil layer, cm	Sampling period (phase)			
		Sowing	Spring vegetation restoration	Earing	Harvest period
Soy (control)	0-30	26	32	24	21
	0-100	115	148	127	107
Winter rapeseed	0-30	30	33	27	23
	0-100	121	147	129	111
Buckwheat	0-30	29	32	25	22
	0-100	119	144	128	113
Corn for grain	0-30	25	29	23	20
	0-100	109	133	113	99

Table 1, Continued

Predecessor	Soil layer, cm	Sampling period (phase)			
		Sowing	Spring vegetation restoration	Earing	Harvest period
Sunflower	0-30	27	30	24	22
	0-100	112	140	119	109

Winter rapeseed begins the spring restoration of vegetation in Transcarpathia of Ukraine, in most cases, in the first half of April. The full growing season ends in late June and early July. This creates conditions for the economical use of moisture by the crop, early releasing of the field and promoting the accumulation and preservation of moisture for the next crop – winter barley.

Corn for grain develops a powerful root system that intensively uses moisture and nutrients dissolved in it throughout the growing season. With the appearance of panicles, the need for corn moisture increases sharply and reaches its maximum from the beginning of flowering to the beginning of milk ripeness. This study proved that during this period, corn uses approximately 70% of the total amount of moisture consumed. All this leads to intensive consumption of moisture from the soil and reduces its reserves, which negatively affects the growth, development, and productivity of the subsequent crop – winter barley.

Buckwheat is one of the hygrophilous plants. The transpiration coefficient of buckwheat is 500-600. Buckwheat plants absorb the greatest amount of moisture during mass flowering – fruit formation. This period in buckwheat is critical in terms of moisture. Nevertheless, buckwheat is one of the precocious field crops, the duration of the growing season is in the range of 70-80 days. All this contributes to the economical use of moisture from the soil, its accumulation, and preservation of it for subsequent crops of crop rotation.

Soy is a hygrophilous short-day plant. After sowing, soybean seeds consume at least 130-160% volume of moisture compared to their own mass. It is necessary to have a reserve of moisture in the soil of about 30 mm in a soil layer of 0-20 cm to get full shoots. The critical period of soybeans in terms of moisture is the period of flowering – the formation and development of beans. Hence, soybeans most intensively use moisture from the soil in the second half of the growing season. This usage is incurred by soybean plants for transpiration and photosynthesis, and soil evaporation, especially during the ripening period of the crop.

Thus, soy, as a legume crop, has preserved the properties of the legume plant to increase soil fertility, especially the fixation of biological nitrogen. However, soybeans are not a moisture accumulator and in dry years do not provide full shoots of winter barley, which leads to a decrease in its yield.

Sunflower is one of the controversial precursors of winter crops, including winter barley, in Ukraine. This study established that sunflower seeds takes approximately 250 kg of NPK per 1 ton of dry matter. During the growing season, the root system penetrates the soil to a depth of 1.5-2.0 m or more. In the initial periods (before the formation of 5-6 leaves), moisture and nutrients of the sunflower plant are used from a soil layer of up to 40 cm. During the period of basket formation and flowering, the root system penetrates to a depth of more than 2.0 meters. It was identified that at the beginning of the growing season, the most active root system of sunflowers is in the upper layer of the soil, while in the second half of the growing season – in the lower layers. Hence, the most active soil factors of plant life in the first half of the growing season are used from the upper layers of the soil, which are renewed due to the introduction of mineral and organic fertilisers for the main, pre-sowing treatment and plant care, and moisture is renewed due to spring-summer precipitation.

In the second half of the growing season, the most active root system of sunflowers is at a depth of 60 cm and deeper. Hence, sunflower plants intensively use the life factors of the soil, especially moisture and nutrients. During this period, due to precipitation, the application of mineral fertilisers during plant care, the high activity of microorganisms, etc., the soil factors of plant life of the upper 0-40 cm of the soil layer are restored.

Consequently, sunflower seeds use nutrients and moisture more actively from the lower layers during the growing season than from the upper ones. Due to this, sunflower is not a critically negative precursor of winter barley.

Table 2. Yield of winter barley depending on its predecessors in Transcarpathia of Ukraine, t/ha

Predecessor	Years			Average for 2018-2020	Deviation	
	2018	2019	2020		t/ha	%
Soy (control)	6.2	5.7	5.3	5.7	0	0
Winter rapeseed	6.0	5.8	5.4	5.7	0	0
Buckwheat	6.3	5.8	5.7	5.9	+0.2	+3.5
Corn for grain	5.0	4.9	4.8	4.9	-0.8	-14.1
Sunflower	5.4	5.2	5.0	5.2	-0.5	-8.8
$HIP_{0,5}$, %				1.9		

Thus, the accumulation of moisture in the soil and its effective use is influenced by many factors – the amount of precipitation, the introduction of crop rotations, tillage, fertilisation, etc. The correct strategy and tactics for managing the reserves of available soil moisture allow for reducing unproductive costs to a minimum.

An intensive indicator of the effectiveness of various predecessors for growing spring barley is its productivity. The highest yield of winter barley, on average for three years, was after buckwheat and amounted to 5.9 t/ha, the lowest – after corn for grain and was at the level of 4.9 t/ha, which is 0.8 t/ha lower than the control option (Table 2).

CONCLUSIONS

In Transcarpathia of Ukraine, on turf-podzolic winter soils, barley sown after buckwheat, soybeans, and winter rapeseed had the best indicators of available moisture throughout the growing season. The crop spent it most economically and efficiently during the growing season compared to the predecessors of late harvesting periods – sunflower and corn for grain.

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Продуктивність ячменю озимого залежно від попередників в умовах Закарпаття України

Анотація. Ячмінь озимий – цінна продовольча, кормова та технічна культура. Метою дослідження є встановлення та розробка економічно та енергетично обґрунтованого, достатнього біоресурсного потенціалу врожайності зерна ячменю озимого залежно від попередників в умовах Закарпаття України. Дослідження та розрахунки балансу доступної вологи в ґрунті показали, що в умовах Закарпаття він від'ємний і коливається від 250 до 1210 т/га, або 25-121 мм. Накопичення та ефективне використання доступної вологи в ґрунті залежить від кількості опадів та їх періодичності, чергування культур у сівозміні (попередників), системи обробітку ґрунту, удобрення, а також від ступеня забур'яненості полів. Найбільші запаси доступної вологи в ґрунті на період сівби озимого ячменю були після озимого ріпаку та гречки, найменші – після соняшнику і, особливо, кукурудзи на зерно. За осінньо-зимовий період запаси доступної вологи в метровому шарі ґрунту поповнилися на 21-35%, але закономірність по попередниках збереглася. Критичний період озимого ячменю за вологозабезпеченістю припадає на період колосіння - дозрівання зерна. Попередники ранніх строків збирання (озимий ріпак та гречка) позитивно впливають на накопичення та збереження вологи в ґрунті. Попередники пізніх строків збирання (кукурудза на зерно та соняшник) знижують вміст доступної вологи та її запаси до 18% порівняно з культурами ранніх строків збирання. В середньому за три роки найвища врожайність ячменю озимого була після гречки і становила 5,9 т/га, найнижча – після кукурудзи на зерно і була на рівні 4,9 т/га, що на 0,8 т/га нижче контрольного варіанту

Ключові слова: вміст доступної вологи, ячмінь озимий, попередник, урожайність

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Spectral assessment of winter wheat varieties and breeding lines in the autumn period

Abstract. The introduction of modern methods of field assessment of winter wheat genotypes is an integral part of improving the quality of the breeding process. The creation, adaptation, and use of innovative screening technologies in breeding are becoming increasingly popular and allow the breeder to evaluate the original forms and newly created material more broadly and objectively. The autumn period is important for winter crops, when under favourable weather conditions (a gradual decrease in temperature) there is a slowdown in the growth rate of winter wheat, physiological and biochemical processes in the plant's body change, which contribute to its transition to a state of winter dormancy. The state of winter wheat crops (morpho-biometric indicators of plants) in the autumn period is largely decisive in the development of a sufficient level of winter hardiness, and therefore affects the further productivity of the crop. According to the results of the examination of morpho-biological and spectral analysis data, it was identified that before overwintering, the best condition for

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the first sowing period was distinguished by plants of winter wheat varieties: MIP Lada (NDVI=0.48), Erythrospermum 55023 line (NDVI=0.46), Lutescens 60049 (NDVI=0.46), varieties of MIP Vidznaka (NDVI=0.46) MIP IUvileina (NDVI=0.46), MIP Dniprianka (NDVI=0.46), and Lutescens 55198 line (MIP Darunok) (NDVI=0.47). In the standard Podolianka variety, the index value was at the level of 0.45. During the second sowing period, the following varieties were identified: MIP Assol (NDVI=0.32), Balada myronivs'ka (NDVI=0.32), Erythrospermum 55023 (NDVI=0.33), MIP Lada (NDVI=0.33), MIP IUvileina (NDVI=0.32), Lutescens 55198 (MIP Darunok) (NDVI=0.32), and Lutescens 60107 (NDVI=0.32). The NDVI index of the Podolianka variety was at the level of 0.32

Keywords: soft winter wheat, varieties, breeding samples, lines, autumn vegetation termination time, NDVI, morpho-physiological analysis, phenotyping

RELEVANCE

One of the factors in the intensification of agriculture in Ukraine is the use of remote sensing data. The introduction of modern methods for evaluating source material is becoming an integral part of accelerating the breeding process. It is necessary to analyse modern achievements in science and technology and learn how to use them to improve the research of new varieties and promising lines. Every day, the relevance of using UAVs (unmanned aerial vehicles) equipped with modern high-resolution cameras that can photograph plants in the visible and near-infrared spectra increases.

The development and implementation of field spectral analysis as one of the methods of plant phenotyping can increase the volume of breeding samples under study and simultaneously improve the quality of morphological analysis. The introduction of such diagnostic methods in the breeding process allows the breeder to comprehensively assess the state of development of each individual genotype in a relatively short period of time, and objectively assess their resistance against certain factors (drought resistance, frost and winter hardiness, resistance against phytopathogens). Digitisation of the obtained data becomes a replacement for outdated exclusively ocular records and eliminates the influence of the breeder's subjective assessment during accounting.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The genetic potential of modern winter wheat varieties, provided that favourable growing conditions are created, is able to provide a yield of 11.0-12.0 t/ha (Riznyk O.I. *et al*., 1994; Kovalyshyna H.M. *et al*., 2020). Therewith, modern varieties of winter wheat are characterised by increased requirements for growing conditions during the autumn growing season (Buhay S.M., 1965; Bulavka N.V. *et al*., 2018). In conditions of insufficient and unstable moisture, the study of the development of plants in the autumn growing season, when the resistance of winter crops to unfavourable conditions of the winter period and the size of the future crop are formed, especially when growing after non-paired predecessors, is important (Sayko V.F. *et al*., 2002; Pirych A.V. *et al*., 2018; Pirych A.V. *et al*., 2021).

Currently, methods of phenotyping winter wheat are the main ones in breeding this crop in leading breeding institutions of developed countries of the world. All spectral studies are conducted using the basic NDVI index, which is the basis for assessing biomass (Normalised Difference Vegetation Index. Rouse B.J. *et al*, 1973). Recent studies show a close correlation between NDVI obtained during winter wheat flowering and yield results (Duan T. *et al.*, 2017).

Given that the operation of collecting images using UAVs is less time-consuming, and due to the higher accuracy than the proximal sensing without the image previously used, it is expected that multispectral sensing based on aerial UAVs will increase the efficiency of high bandwidth phenotyping (Maimaitijiang M. *et al.*, 2017; Tattaris M. *et al.*, 2016).

Spectral assessment of winter wheat varieties, with parallel morpho-physiological analysis during the end of the autumn growing season, allows for fully assessing the state of autumn development of each individual genotype.

The purpose of the study is to conduct a spectral field and morpho-physiological assessment of winter wheat varieties and lines in the Forest-Steppe of Ukraine and assess the state of autumn development of the genotypes under study.

MATERIALS AND METHODS

The research was conducted during 2018-2020 in the crop rotation of the winter wheat breeding laboratory of the V.M. Remeslo Myronivka Institute of Wheat of the National Academy of Agrarian Sciences of Ukraine. Sowing was conducted after the soybeans in two terms: 2018 – September 25 and October 5; 2019 and 2020 – October 5 and 15.

Spectral evaluation of varieties and lines was performed using a Mavic zoom 2 UAV using a Parrot Sequoia multispectral camera. Pix4Dcapture and Pix4Dmapper software were used to form the orthophoto plan. For the high-quality formation of the orthophoto plan, photofixing with a multispectral camera was conducted at a height of 30 m above the level of the object under study with an overlap of 80% of the images with a time interval of 2 seconds.

Morpho-biological analysis was conducted according to the method of F.M. Kuperman (Kuperman F.M., 1977), and according to the scientific paper of the Mironivka Institute of Wheat (Kolyuchuy V.T., 1977).

RESULTS AND DISCUSSION

The study was conducted during 2018-2020 in the crop rotation of the winter wheat breeding laboratory of the V.M. Remeslo Mironivka Institute of Wheat of the National Academy of Agrarian Sciences of Ukraine. Sowing was conducted after the predecessor of soybeans in two sowing periods: 2018 – September 25 and October 5; 2019 and 2020 – October 5 and 15. Contrasting weather conditions during the research period allowed for obtaining objective results. The autumn period of 2018 was excessively humid (GTC=1.76), and the temperature regime in September-October was very warm: the average air temperature was 16.6 and 10.6°C, respectively (the multi-year average – 14.2 and 8.3°C). In November, the average monthly temperature was 1.1°C below the climatic norm. The condition of the crops was assessed as good, the plants developed normally, which contributed to their successful overwintering. Weather conditions in the pre-sowing and sowing period of 2019 were quite dry: the amount of precipitation in August-October was 28.7 mm (the multi-year average value – 163.2 mm). Plants did not receive enough moisture for normal growth and development, and for rooting and forming a proper aboveground mass. The total amount of precipitation in August-September 2020/21 of the growing year reached only 10-20% of the norm. Weather conditions in October were quite favourable for the autumn development of winter wheat, rapid growth and development of plants were noted.

Seven new varieties and four breeding lines of winter wheat were used as the source material: MIP Assol, Balada myronivs'ka, Hratsiia myronivs'ka, Erythrospermum 55023 (Aurora myronivs'ka), MIP IUvileina, MIP Lada, MIP Dniprianka, Lutescens 55198 (MIP Darunok), Lutescens 37519 (MIP Vidznaka), Lutescens 60049, Lutescens 60107, and standard Podolianka variety.

The dates of morpho-biometric analysis of winter wheat plants and spectral survey of crops are 21.11.2018, 29.11.2019, and 10.11.2020. For three years of the studies, it was established that the value of biometric indicators of plants of varieties and breeding lines before wintering depended on the hydrothermal regime in the pre-sowing and sowing periods, during the autumn growing season: the amount of precipitation and uniformity of their distribution, moisture reserves in the soil, air temperature and its differences.

As a result of the conducted studies, it was identified that the height of plants after the end of the autumn growing season on average in the experiment was 10.24 cm (the first sowing period) and 8.11 cm (the second), the number of shoots per plant varied in the range of 3.35-3.10 pcs., respectively, the number of leaves – 7.34 and 3.59 pcs., the mass of one plant – 4.59 and 2.76 g, the vegetative mass after sampling and absolutely dry 25 plants – 14.35 and 6.22 g, 2.50 and 1.19 g, respectively. The greatest vegetative mass before the start of wintering was developed by winter wheat plants during the first sowing period in the 2018/19 growing year. Depending on the genotype and weather conditions, the plant height was in the range of 6.10 cm (Lutescens 60107) and 9.10 cm (Hratsiia myronivs'ka) in 2019/20 g.y.; 13.63 cm (Podolianka standard) and 21.28 cm (MIP Assol) in 2020/21 g.y.; 19.91 cm (Lutescens 55198) and 25.63 cm (MIP IUvileina) in 2018/19 g.y. In 2019/20 g.y. before wintering, plants of the first sowing period formed an insubstantial vegetative mass – 6.92 and 2.35 g (Lutescens 55198) and 3.65 and 6.92 g (Erythrospermum 55023). The lowest indicators of aboveground mass according to the experiment were identified in plants during the second sowing period of 2019/20, which negatively affected their resistance to adverse conditions of the cold period (low air temperatures in the absence of snow cover) (Table 1 and Table 2).

Table 1. Weighted average morpho-physiological and spectral characteristics of winter wheat varieties and lines for 1st sowing period (Myronivka Institute of Wheat, 2018-2020)

Variety, line	Number of stems, pcs.	Number of leaves, pcs.	Plant height, cm	Weight of 1 plant, g	Weight 25 plants, g	Weight of absolutely dry 25 plants, g	NDVI
MIP Assol	1.72	4.41	16.75	0.58	14.74	2.69	0.45
Balada myronivs'ka	1.94	5.24	15.63	0.70	17.14	2.89	0.44
Hratsiia myronivs'ka	1.63	4.06	15.87	0.55	14.62	2.68	0.45
Erythrospermum 55023	1.88	5.28	15.07	0.62	14.92	2.70	0.46
MIP IUvileina	1.30	3.85	16.38	0.54	12.98	2.37	0.46

Table 1, Continued

Variety, line	Number of stems, pcs.	Number of leaves, pcs.	Plant height, cm	Weight of 1 plant, g	Weight 25 plants, g	Weight of absolutely dry 25 plants, g	NDVI
MIP Lada	1.72	4.61	16.11	0.65	15.17	2.63	0.48
MIP Dniprianka	1.82	5.04	16.30	0.58	14.08	2.56	0.46
Lutescens 55198 (MIP Darunok)	1.95	5.17	16.97	0.65	16.75	3.03	0.47
Lutescens 37519 (MIP Vidznaka)	1.75	4.56	15.81	0.58	14.55	2.49	0.46
Lutescens 60049	1.87	4.96	13.32	0.53	12.94	2.37	0.46
Lutescens 60107	1.71	4.65	16.62	0.52	13.03	2.37	0.45
Podolianka St	**1.72**	**4.64**	**13.07**	**0.47**	**11.28**	**2.04**	**0.45**

Table 2. Weighted average morpho-physiological and spectral characteristics of winter wheat varieties and lines for 2nd sowing periods (Myronivka Institute of Wheat, 2018-2020)

Variety, line	Number of stems, pcs.	Number of leaves, pcs.	Plant height, cm	Weight of 1 plant, g	Mass 25 plants, g	Weight of absolutely dry 25 plants, g	NDVI
MIP Assol	1.04	2.32	11.46	0.23	5.77	1.06	0.32
Balada myronivs'ka	1.24	2.59	11.49	0.31	6.68	1.31	0.32
Hratsiia myronivs'ka	1.00	2.15	10.46	0.27	5.77	1.14	0.31
Erythrospermum 55023	1.08	2.41	10.62	0.28	5.86	1.12	0.33
MIP IUvileina	1.20	2.58	11.82	0.30	6.42	1.14	0.32
MIP Lada	1.07	2.43	11.37	0.29	6.42	1.31	0.33
MIP Dniprianka	1.24	2.84	11.37	0.31	6.80	1.28	0.30
Lutescens 55198 (MIP Darunok)	1.13	2.55	11.59	0.33	6.83	1.32	0.32
Lutescens 37519 (MIP Vidznaka)	1.00	2.21	11.71	0.31	6.39	1.29	0.31
Lutescens 60049	1.31	2.77	9.98	0.29	5.79	1.07	0.30
Lutescens 60107	1.39	3.04	11.21	0.30	6.00	1.14	0.32
Podolianka St	**1.23**	**2.55**	**10.93**	**0.26**	**5.87**	**1.15**	**0.32**

According to the results of the examination of morpho-biological and spectral analysis data, on average for three years, before overwintering, the best varieties of winter wheat during the first sowing period were: MIP Lada (NDVI=0.48), MIP IUvileina, MIP Dniprianka (NDVI=0.46), and the lines Erythrospermum 55023 (Aurora myronivs'ka), Lutescens 37519 (MIP Vidznaka), Lutescens 60049 (NDVI=0.46), and the Lutescensline 55198 (MIP Darunok) (NDVI=0.47). In the Podolianka standard variety, the index value was lower (NDVI=0.45). These varieties dominated the standard for several biometric indicators (Table 1).

During the second sowing period, the MIP Lada variety and the Erythrospermum 55023 (Aurora myronivs'ka) line were highlighted (NDVI=0.33). Varieties MIP Assol, Balada myronivs'ka, MIP IUvileina, and lines Lutescens 55198 (MIP Darunok) and Lutescens 60107 had index values at the level of the Podolianka standard variety (NDVI=0.32) (Table 2). In the future, the data of biometric indicators of winter wheat plants and spectral assessment during the resumption of spring vegetation and flowering will be analysed, followed by establishing their relationship with grain yield.

CONCLUSIONS

Based on the data obtained, the following conclusions can be drawn: before entering the winter, the best varieties and lines of winter wheat during the first sowing period were MIP Lada (NDVI = 0.48), MIP IUvileina, MIP Dniprianka (NDVI = 0.46), Erythrospermum 55023 (Aurora myronivs'ka), Lutescens 37519 (MIP Vidznaka), Lutescens 60049 (NDVI = 0.46), and line Lutescens 55198 (MIP Darunok) (NDVI = 0.47); on the second – MIP Lada and line Erythrospermum 55023 (Aurora myronivs'ka) (NDVI = 0.33), while for the variety of the Podolianka standard, the NDVI Index is determined at the level of 0.45 and 0.32, respectively.

These results will help to form methodological recommendations for spectral diagnostics of winter wheat.

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Спектральна оцінка сортів і селекційних ліній пшениці озимої в осінній період

Анотація. Впровадження сучасних методів польової оцінки генотипів озимої пшениці є невід'ємною частиною підвищення якості селекційного процесу. Створення, адаптація та використання інноваційних технологій скринінгу в селекції набувають все більшої популярності і дозволяють селекціонеру більш широко та об'єктивно оцінювати вихідні форми та новостворений матеріал. Для озимих культур важливим є осінній період, коли за сприятливих погодних умов (поступове зниження температури) відбувається уповільнення темпів росту озимої пшениці, змінюються фізіолого-біохімічні процеси в організмі рослини, які сприяють її переходу до стану зимового спокою. Стан посівів пшениці озимої (морфо-біометричні показники рослин) в осінній період значною мірою є визначальним у розвитку достатнього рівня зимостійкості, а отже, впливає на подальшу продуктивність культури. За результатами вивчення даних морфо-біологічного та спектрального аналізу встановлено, що перед перезимівлею найкращим станом для першого строку сівби вирізнялися рослини сортів пшениці озимої сорту Лада: МІП Лада (NDVI=0,48), лінії Erythrospermum 55023 (NDVI=0,46), Lutescens 60049 (NDVI=0,46), сортів МІП Відзнака (NDVI=0,46), МІП ІУвілейна (NDVI=0,46), МІП Дніпрянка (NDVI=0,46) та лінії Lutescens 55198 (МІП Дарунок) (NDVI=0,47). У стандартного сорту Подолянка значення індексу було на рівні 0,45. Під час другого строку сівби були виділені наступні сорти: МІП Ассоль (NDVI=0,32), Балада миронівська (NDVI=0,32), Еритроспермум 55023 (NDVI=0,33), МІП Лада (NDVI=0,33), МІП Іувілейна (NDVI=0,32), Лютесценс 55198 (МІП Дарунок) (NDVI=0,32) і Лютесценс 60107 (NDVI=0,32). У сорту Подолянка індекс NDVI був на рівні 0,32

Ключові слова: пшениця м'яка озима, сорти, селекційні зразки, лінії, час припинення осінньої вегетації, NDVI, морфо-фізіологічний аналіз, фенотипування

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Productivity of seed potatoes with local application of phosphorous and potassium fertilisers

Abstract. Ukraine occupies a leading position in potato production, being one of the top three producing countries and ranks second in the world in terms of potato consumption per capita, second only to Belarus – 139 kg per year per 1 person, with a global average of approximately 33 kg/person/year. According to the UCAB, in recent years, the area under potatoes has increased by 2.7% to 1,325 thousand hectares. However, the average yield over the past three years was at the level of 15.8 t/ha. In some advanced farms in Ukraine, the yield reaches 30-40 t/ha due to the introduction of scientific findings into production. However, in general, in Ukraine, the potential for the economic productivity of potatoes now remains unused to the full extent. Potato plants are demanding in terms of the availability of nutrients in the soil. They should be in an accessible form and in sufficient quantity. This is largely due to the biological characteristics of potatoes. The effectiveness of mineral fertilisers depends on the methods and quality of their application. The conventional method of fertilisation involves spreading fertilisers on the surface and then covering them with soil. As a result of the uneven placement of fertiliser granules in the soil layer, nutrients transition to a form inaccessible to plants, which leads to uneven development and maturation of tubers. Therefore, one of the ways to improve potato nutrition, reduce nutrient losses, and obtain high, stable crop yields is to apply mineral fertilisers locally to the root system of plants. Local application of phosphorus leads to its better availability throughout the growing season, which ensures accelerated growth and development of roots and shoots, and the formation of an optimal number of tubers. Local

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placement of potassium improves its availability and provides enhanced synthesis and transport of carbohydrates in plants, increases the absorption of moisture and nutrients by roots, strengthens their resistance to diseases, and improves the quality of tubers. The purpose was to examine the efficiency of using phosphorus and potassium in various methods and norms of fertiliser application and to establish the effect on the productivity of seed potatoes. The studies were conducted in the field experiment by the Department of Agricultural Chemistry and Quality of Plant Products named in honour of O.I. Dushechkin of the National University of Life and Environmental Sciences of Ukraine on the territory of Biotech Ltd. (Boryspil district, Kyiv region) during 2019-2020. An early-maturing Tyras variety was chosen for the research. The area of the sown plot was 495 m^2, accounting plot – 312 m^2. The experiment is repeated four times. The placement of options was systematic. As a result of the experiment, it was identified that local application of phosphorous and potassium fertilisers provided such a level of the yield of potatoes of the Tyras variety, which was not inferior to the option with a spreading method. The yield increase in variants with local application ranged from 0.6 t/ha to 2.9 t/ha, depending on the norm. Application of local fertiliser with the P60K135 norm caused the highest yield of seed potatoes among the variants (33.4 t/ha), and the highest yield of the seed fraction – 31.6 t/ha

Keywords: potatoes, phosphorus, potassium, local application, fertilisers, yield

RELEVANCE

Ukraine occupies a leading position in potato production, being one of the top three producing countries. In recent years, China has the highest potato production volumes (93 million tonnes), India (51 million tonnes), and Ukraine (23 million tonnes), which together accounts for approximately 45% of global production. Countries such as the United States, Russia, Bangladesh, Germany, Poland, The Netherlands, Canada, and Belarus are increasing their production volumes, which together produce approximately 23% (Indexbox, 2021; Lomovskykh L., 2021). Ukraine ranks second in the world in terms of potato consumption per capita, second only to Belarus – 139 kg per year per 1 person, with a global average of approximately 33 kg/person/year. These data allow understanding the importance of potatoes for Ukrainians (Agroportal, 2021).

According to the UCAB, in recent years, the area under potatoes has increased by 2.7% or 35 thousand hectares, to 1,325 thousand hectares. However, the yield, for example, in 2018 was at the level of 16.8 t/ha, in 2019 – 15.2 t/ha, and in 2020 – 15.6 t/ha. In the leading countries of the world, such as the United States, this figure reached the level of 49 t/ha, Canada – 43 t/ha, Holland – 40 t/ha, France – 39 t/ha, Germany – 36 t/ha. In some advanced farms in Ukraine, the yield reaches 30-40 t/ha due to the introduction of scientific findings into production. However, in general, in Ukraine, the potential for the economic productivity of potatoes now remains unused to the full extent (Kolodiazhnyi I., 2020; Grados D. *et al.*, 2020).

Problem statement. Obtaining high potato yields involves the use of substantial standards of nutrients. According to the conventional method of application, fertilisers are spread on the surface of the field and mixed with the soil. This method is very common but simultaneously has many disadvantages. One of them is the uneven distribution of fertilisers, especially with a problematic granulometric composition, which causes variegation of fields, and, consequently, uneven germination, growth, and development of potato plants. It is also important to understand that mixing fertiliser pellets with a large volume of soil activates the process of their dissolution, absorption, and binding of nutrients by the soil.

The optimisation of the fertiliser application method is required. One of the ways that contribute to this is the local application of phosphorous and potassium fertilisers. With this arrangement, food elements become more accessible, which allows plants to fully receive nutrients during the growing season and leads to a high yield with good quality indicators.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Long-term studies conducted in many countries convincingly prove the importance of the proper use of mineral fertilisers, which provide a substantial increase in yield (Bykin A.V. *et al.*, 2021; Hnatiuk T.O., 2018).

Potato plants are demanding in terms of the availability of nutrients. They should be in the soil in an accessible form and in sufficient quantities. This is largely due to the biological characteristics of potatoes, and, above all, an underdeveloped root system located mainly in the upper layer of the soil (Ostrenko M.V. *et al.*, 2020).

The effectiveness of mineral fertilisers directly depends on the methods and quality of their application. According to the conventional method, fertilisers are distributed over the soil surface using spreaders. About 50% of fertiliser pellets are placed in a soil layer of 0-15 cm and a substantial part of them may be poorly accessible to plants. The reason for this is that the root system of potatoes during the growing season in search of moisture and nutrients develops and is located deeper than this layer. In addition, no less important is the fact that the climatic conditions in Ukraine are changing, and a fairly frequent meteorological phenomenon is drought, which provokes drying out of the top layer of soil in which fertilisers are placed. This increases the proportion of inaccessible nutrients for the root system mainly due to improper granulometric composition. Quite often, when spreading fertilisers, there is an uneven distribution of their distribution. In production conditions, it is even more difficult to maintain the necessary intervals between the spreader passes without using special equipment, so the quality of fertiliser application is sharply reduced. Uneven distribution of nutrients in the soil causes uneven germination of plants, their development and maturation, and as a result, a shortage of yield and deterioration of their quality. During the spreading of fertilisers, the soil is compacted with equipment, which further causes a negative impact on the growth and development of potato plants. It is established that up to 50% of the total area is compacted (Sergeyev N.S., Zapevalov M.V., 2012).

An important technological technique is the introduction of fertilisers into the soil. The time interval between fertiliser spreading and covering should not exceed 6 hours. Late mixing of fertilisers with the soil leads to high nutrient losses and environmental pollution. It is worth noting that the intensive mixing of fertilisers with a large volume of soil activates the processes of binding nutrients and their transition to hard-to-reach forms (Sergeyev N.S., Zapevalov M.V., 2012).

Increasing the availability of nutrients and reducing costs is possible only through fertiliser optimisation. Therefore, one of the ways to improve potato nutrition and reduce nutrient losses, eliminate the negative impact of fertilisers on the environment, and obtain high, stable crop yields is the local application of mineral fertilisers in the area of the root system of plants (Ponomarenko N.O. *et al.*, 2016)

Local fertilisation has a positive effect on potato plants, their nutrition, development, and yield formation. According to the local method, the development of roots in the fertiliser application area increases, but the total mass may vary slightly. It was identified that the root system is mainly concentrated in nutrient-rich areas. With this method of application, there is an increase in the utilisation rates of nutrients compared to the spreading one. The high content of nutrients in the soil in a state accessible to plants with local fertilisation persists for a long time, providing more substantial yield increases. This method enables the creation of favourable conditions for the mineral nutrition of plants and makes better use of nutrients. However, the effectiveness of this method of application is influenced by a number of factors: fertiliser properties, soil fertility, its granulometric composition, moisture supply of plants, and varieties (Abdulnatipov M.G., 2019; Lichman G.I. *et al.*, 2018)

The placement of fertilisers in this way has a positive effect on the ability of agricultural crops to withstand stressful conditions, improves the synthesis of storage substances, and reduces the use of nutrients by weeds. Water consumption of plants per unit of production is reduced by 10-15%. According to generalised data, the increase in potato yield from local fertiliser placement is on average 3-4 t/ha (Paskal' V.N., Zubovich D.G., 2020; Zubovich D.G., Tymoshenko V.YA., 2017).

Local application of phosphorus provides accelerated growth and development of roots and shoots, energy supply for such processes as ion absorption and transportation. Due to their local placement, phosphorus compounds become more accessible during the growing season. This leads to the formation of the optimal number of tubers. Applying potassium fertilisers locally increases the supply of potassium to plants. Optimal potassium nutrition ensures the synthesis and transport of carbohydrates in plants, improves the absorption of moisture and nutrients by the roots. Potassium regulates water metabolism in plants, strengthens their resistance to diseases, and improves the quality of tubers (Rosen, C.J. *et al.*, 2014; Kelling, K.A. *et al.*, 2020).

Thus, the development of a technology for the local application of phosphorous and potassium fertilisers is justified since it is able to optimise the nutrition of potatoes and provide a substantial increase in the yield of high quality.

The purpose of the study. Investigate the effectiveness of using phosphorus and potassium in various methods and norms of fertiliser application and establish the impact on the productivity of seed potatoes.

MATERIALS AND METHODS

The studies were conducted in the field experiment by the Department of Agricultural Chemistry and Quality of Plant Products named in honour of O.I. Dushechkin of the National University of Life and Environmental Sciences of Ukraine on the territory of Biotech Ltd. (Boryspil district, Kyiv region) during 2019-2020 according to the developed experiment scheme (Table 1).

An early-maturing Tyras variety was chosen for the research. The area of the sown plot was 495 m^2, the registered area was 312 m^2, and the repetition rate of the experiment is fourfold. The placement of options was systematic. The soil of the experimental site is dark grey podzolic coarse–dusty light loamy. It was characterised by a slightly acidic reaction of the soil solution (5.48), a high degree of provision of mobile compounds of phosphorus (246 mg/kg) and exchange potassium (224 mg/kg), increased content of exchange magnesium (2.64 mg/100 g), an average content of calcium (7.93 mg/100 g), a low content of mobile sulfur (3.64 mg/kg) and mineral nitrogen (14.5 mg/kg).

Table 1. Scheme of a field experiment to examine the effectiveness of various methods of fertiliser application, 2019-2020

No.	Method and rate of fertiliser application	
	spreading	local
1	$N_{150}P_{80}K_{180}$	-
2	N_{150}	$P_{80}K_{180}$
3	N_{150}	$P_{60}K_{135}$
4	N_{150}	$P_{40}K_{90}$

The following fertilisers were used in the studies: UAN-25: N – 25%, S – 2.4% (TU U 24.1-00203826.024-2002); LCF 8: 24: N – 8% P_2O_5 – 24% (TU 2186-627-00209438-01), potassium chloride: K_2O – 60% (TU 2184-042-00209527-97), magnesium sulfate: MgO – 16% (TU 2141-073-00206457-2007), calcium nitrate – N – 15.5% Ca – 19% (TU U6-13441912.004-99). Pre-planting treatment of tubers with growth stimulants was conducted: Gros Rootgrowth (1.5 l/t), Ecoline phosphite (K) (1 l/t) using an applicator on the inspection table.

Nitrogen fertilisers in the form of UAN-25 were applied as a background in all variants in the N_{150} norm on the surface of the soil with their subsequent covering. In the version with the spreading method, the LCF was applied with a John Deere 6195M unit with a mounted JAR-MET sprayer (Lechler nozzles), potassium chloride using John Deere 6195M and an MVD 1000 spreader, followed by their covering with a Vanderstad Carrier CR 400 discator to a depth of 10-15 cm. Local fertilisation was conducted by JohnDeere 8300 and the Peliper multifunctional unit with the application of phosphorous fertilisers to a depth of 15 cm, and potassium fertilisers to 18-20 cm with a strip width of 10-12 cm. Samples of soil and potato plants were taken during the following growth and development phases: germination, budding, flowering, "green berry", and technical ripeness.

Selection and preparation of soil samples for analysis were conducted in accordance with DSTU ISO 10381-2:2004 and DSTU ISO 11464-2001. Harvesting was conducted mechanically from the entire experimental site in the phase of technical ripeness according to generally accepted methods. Mathematical processing of research results was performed using statistical (variance and correlation) analysis using the MS Excel computer programme.

RESULTS

The research established that in the control, where the use of fertilisers was conducted in a spreading way in the $N_{150}P_{80}K_{180}$ norm, the yield was 30.5 t/ha. Local introduction of the full $P_{80}K_{180}$ norm on the background of N_{150} led to an increase in this indicator to the level of 31.1 t/ha, which exceeds the above option by 0.6 t/ha (Fig. 1).

Reduction of the norm of phosphorous and potassium fertilisers to $P_{60}K_{135}$ and their placement locally provided an increase in yield to 33.4 t/ha, which is 2.3 t/ha more than in variants with a similar method of application in the full norm of $P_{80}K_{180}$.

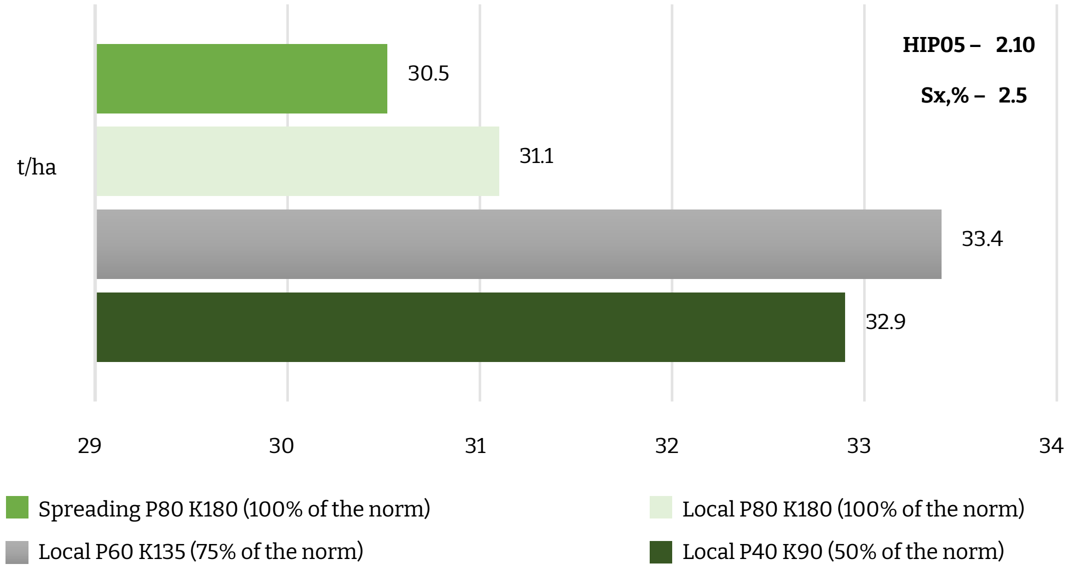

Figure 1. Yield of seed potatoes (t/ha) by various methods of fertilisation, 2019-2020

Local application of phosphorous and potassium fertilisers in the $P_{40}K_{90}$ norm led to an increase in yield to the level of 32.9 t/ha, which is 1.8 t/ha more than the full norm of phosphorous and potassium fertilisers in the same way.

The structure of the yield is one of the components that determine its value. The resulting yield must meet the requirements of DSTU in terms of size and must not deviate from the established indicators. The uniformity and size of potato seed material are important for the correct establishment of the rate and quality of planting, and also affect the cost per hectare of seeds.

In the conditions of this experiment, in the variant with spreading of $N_{150}P_{80}K_{180}$, the yield of standard tubers was 22.6 t/ha, and the non-standard part – 7.89 t/ha (Table 2).

Local application of the same rate of phosphorous and potassium fertilisers contributed to an increase in the share of seed fraction in the yield compared to the spread application by 6.5 t/ha to the level of 29.1 t/ha. The non-standard part of the yield under these conditions was smaller compared to the option where fertilisers were applied in a spreading method and amounted to 2.01 t/ha. Simultaneous reduction of the norm of phosphorus and potassium to $P_{60}K_{135}$ and their introduction locally allowed obtaining the highest yield of the seed fraction in the experiment – 36.1 t/ha. The non-standard part of the yield was at the level of 1.85 t/ha. Local application contributed to a better supply of phosphorus and potassium to plants during the growing season, which had a positive effect on tuber formation. Further reduction of the norm for local application to $P_{40}K_{90}$ caused the production of 26.3 t/ha of standard tubers, which is 9.8 t/ha less compared to the local introduction of phosphorus and potassium in $P_{60}K_{135}$ norm.

Thus, the use of a local method of applying phosphorous and potassium fertilisers in the $P_{60}K_{135}$ norm, on the background of N_{150} is advisable since it causes a substantial increase in the productivity of seed potatoes.

Table 2. Structure of the seed potato yield using different fertiliser application methods, 2019-2020

Fertiliser application method	Application rate, kg/ha a.s.	Tuber fraction, mm													
		standard								non-standard					
		28-35		35-45		45-55		t/ha	%	<28		>55		t/ha	%
		t/ha	%	t/ha	%	t/ha	%			t/ha	%	t/ha	%		
Spreading	$P_{80}K_{180}$*	3.99	17.6	11.2	49.5	7.44	32.9	22.6	74.1	1.50	19.1	6.39	80.9	7.89	25.9
Local	$P_{80}K_{180}$*	2.72	9.34	14.3	49.1	12.1	41.6	29.1	93.5	1.11	55.3	0.90	44.7	2.01	6.50
	$P_{60}K_{135}$*	2.66	8.43	15.8	50.1	13.1	41.5	31.6	94.5	0.82	44.3	1.03	55.7	1.85	5.50
	$P_{40}K_{90}$*	3.45	13.1	13.0	49.5	9.86	37.4	26.3	80.0	1.19	18.0	5.41	82.0	6.60	20.0
HIP_{05}		0.17		0.9		1.17				0.14		0.49			
Sx.%		0.8		0.9		1.4		1.9			2.9				

Note: * – against the background of introduction of N_{150}

CONCLUSIONS

Local application of phosphorous and potassium fertilisers provided such a level of the yield of potatoes of the Tyras variety, which was not inferior to the option with a spreading method. The yield increase in variants with local application ranged from 0.6 t/ha to 2.9 t/ha, depending on the norm. Application of local fertiliser with the $P_{60}K_{135}$ norm caused the highest yield of seed potatoes among the variants (33.4 t/ha), and the highest yield of the seed fraction – 31.6 t/ha.

In the conditions of intensive farming, the introduction of local fertilisation in the technology of growing agricultural crops has great prospects.

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Продуктивність насіннєвої картоплі за локального внесення фосфорних і калійних добрив

Анотація. Україна займає провідні позиції у виробництві картоплі, входячи до трійки країн-виробників та посідає друге місце у світі за рівнем споживання картоплі на душу населення, поступаючись лише Білорусі – 139 кг на рік на 1 особу, при середньосвітовому показнику близько 33 кг/особу/рік. За даними УКАБ, за останні роки посівні площі під картоплею збільшилися на 2,7% до 1 325 тис. га. Однак середня врожайність за останні три роки була на рівні 15,8 т/га. У деяких передових господарствах України врожайність досягає 30-40 т/га завдяки впровадженню наукових розробок у виробництво. Однак, в цілому, в Україні потенціал економічної продуктивності картоплі зараз залишається невикористаним повною мірою. Рослини картоплі вимогливі до наявності поживних речовин у ґрунті. Вони повинні бути в доступній формі і в достатній кількості. Це значною мірою пов'язано з біологічними особливостями картоплі. Ефективність мінеральних добрив залежить від способів та якості їх внесення. Традиційний спосіб внесення добрив полягає в розкиданні добрив по поверхні і подальшому засипанні їх ґрунтом. В результаті нерівномірного розміщення гранул добрив у шарі ґрунту поживні речовини переходять у недоступну для рослин форму, що призводить до нерівномірного розвитку і дозрівання бульб. Тому одним із шляхів покращення живлення картоплі, зменшення втрат поживних речовин та отримання високих, стабільних врожаїв є локальне внесення мінеральних добрив під кореневу систему рослин. Локальне внесення фосфору призводить до кращої його доступності протягом усього вегетаційного періоду, що забезпечує прискорений ріст і розвиток коренів та пагонів, формування оптимальної кількості бульб. Локальне внесення калію покращує його доступність та забезпечує посилений синтез і транспорт вуглеводів у рослинах, підвищує поглинання вологи та поживних речовин корінням, посилює їх стійкість до хвороб, покращує якість бульб. Метою досліджень було вивчити ефективність використання фосфору і калію за різних способів і норм внесення добрив та встановити вплив на продуктивність насіннєвої картоплі. Дослідження проводили в польовому досліді кафедри агрохімії та якості продукції рослинництва ім. О.І. Душечкіна Національного університету біоресурсів і природокористування України на території ТОВ «Біотех» (Бориспільський р-н, Київська обл., м. Бориспіль). (Бориспільський район, Київська область) протягом 2019-2020 років. Для досліджень було обрано ранньостиглий сорт Тирас. Площа посівної ділянки становила 495 м^2, облікової – 312 м^2. Повторність досліду чотириразова. Розміщення варіантів було систематичним. У результаті досліду встановлено, що локальне внесення фосфорних і калійних добрив забезпечило такий рівень урожайності картоплі сорту Тирас, який не поступався варіанту з розкидним способом. Прибавка врожаю у варіантах з локальним внесенням становила від 0,6 т/га до 2,9 т/га залежно від норми. Застосування локального внесення добрива в нормі Р60К135 забезпечило найвищу серед варіантів врожайність насіннєвої картоплі (33,4 т/га), а також найвищу врожайність насіннєвої фракції – 31,6 т/га

Ключові слова: картопля, фосфор, калій, локальне внесення, добрива, урожайність

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Methodological approaches to identifying plants on high resolution images of multispectral monitoring using UAVs

Abstract. Plant growers need accessible and effective information about the state of crops to implement crop management. The purpose of the study is to develop a method for identifying plants on high-resolution multispectral images for continuous sowing crops, using the example of winter wheat. The studies are conducted in the Left-Bank Forest-Steppe zone, on industrial crops of winter wheat, Mulan variety. At the time of remote monitoring through UAVs (2019.03.17), the plants were in the tillering stage. Monitoring from an altitude of 100 meters is conducted using the Slantrange 3p spectral system installed on the DJI Matrice 600 UAV. A full-screen copy of the snapshot window is made to extract reference graphic data from the SlantView programme. Statistical processing of graphical data of spectral monitoring results is performed in the MathCad programme. It is noted that reliable determination of the spectral portrait of the soil for its pixel filtration from multispectral images is a difficult task, since its colour substantially depends on the state of moisture and may differ in open and shaded areas. A fundamentally new way to filter out random inclusions is to use a spectral portrait of plants based on the intensity ratios of their components. A promising parameter for assessing the condition of crops is the estimation of their horizontal surface area, which can be determined by pixel-by-pixel image analysis. A filtering option that requires debugging is suggested.

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In further studies, it is advisable to consider the issue of methodological support for assessing the quality of filtering data from spectral monitoring of plantings.

Keywords: Slantrange, crop identification, filtering

INTRODUCTION

The relevant criterion of optimality for crop production in a market economy is the rational consumption of funds and energy, which implies the introduction of precision farming technologies. Crop management is one of the key trends in the modernisation of technologies in crop production. Plant growers need accessible and effective information about the state of crops to implement crop management. The monitoring technologies currently used require serious methodological findings. For ground-based equipment such as the Yara N-Sensor presented by (Matveenko *et al.*, 2017) data is available because it can be obtained promptly in the right place in a format acceptable for technical implementation, but inefficient because it is not adapted to industrial scale. Setting up such ground-based equipment provides for the optimal criterion – maximum yield. Satellite technologies are effective because they will allow getting information for the entire field, but are limited because they depend on weather conditions and have a high cost even with an average image resolution. Unmanned aerial vehicles (UAVs) also have their limitations, but for crop monitoring, this is undoubtedly a revolutionary solution. Unlike satellite technologies, they can work under the cloud and allow getting high-resolution images at an affordable price. One of the reasons constraining the introduction of these monitoring technologies is the complexity of using spectral sensor equipment for measurement purposes to make a decision on the use of ground-based equipment. In the initial stages of vegetation, when it is possible to effectively manage the crop, vegetation indices will depend on the condition of the soil and the presence of plant residues recorded in the images (Pasichnyk *et al.*, 2020), which affects the reproducibility of the results. There are serial multispectral systems, such as Slantrange, where developers in proprietary software offer a system for filtering soil and foreign objects, but its configuration is based on a visual assessment of the image, while the filtering algorithm implemented by the developer is closed. In general, existing remote air and satellite monitoring technologies have substantial problems, primarily of a methodological nature. Thus, according to the results of the study (Duan *et al.*, 2017) by combining data from GreenSeeker ground-based equipment and a UAV-mounted RedEdge camera, a substantial difference was recorded for the NDVI index, which had both static and dynamic components, which was recorded at different stages of vegetation. The authors made adjustments to consider old leaves to increase the correlation, but in the initial stages of vegetation, when the plant dome is not dense and a substantial percentage of soil is captured, reproducibility will decrease. This phenomenon is due to the fact that the spectral parameters of the soil, both in the visible and infrared ranges, depend on the state of its moisture content, which can change over several hours. The results were confirmed in the experiments (Zhelezova *et al.*, 2016), where it was identified that during the autumn and spring tillering period, the results of measurements from the GreenSeeker® RT200 ground sensor and the Canon S110 NIR camera installed on the UAV were close in row spacing of 12 cm, and for 18 cm they had a substantial difference. During the tillering growing stage, a stable difference in indicators was present, regardless of the width of the row spacing, which the authors explain by different lighting conditions. This explanation is debatable, since the monitoring height did not depend on the stage of vegetation, and the characteristic difference in sensor indicators was recorded with a larger row spacing width. A possible explanation for this is soil capturing during aerial monitoring. Soil can be identified by the pixel-by-pixel analysis, as shown in the papers (Komarchuk *et al.*, 2019; Xiuliang Jin *et al.*, 2017). An example of such indices for wheat identification are the ExG, EGVI, and ERVI presented in the paper, which were used by developers for the image resolution of 0.2 mm/pixel. However, for industrial monitoring systems, lower resolution image distinguishing is more suitable, as shown in the paper (Linyuan *et al.*, 2018). The infrared range is used as part of the ground line concept to identify plants from satellite imagery, so it can also be effective for UAVs, which needs to be checked. Based on this, ***the purpose of the study*** is the development of a method for identifying plants on multispectral images of high resolution for continuous sowing crops, using the example of winter wheat.

MATERIALS AND METHODS

The above survey was conducted on 2019.03.17 on industrial crops of winter wheat, Mulan variety, geographically in the Left-Bank Forest-Steppe zone (50º16 'N, 30º58'E). The plants were in the tillering stage. The exposed areas of soil were in an air-dry state. Two areas without vegetation were selected (dried lowland – "saucer") were used to conduct research on the effect on the spectral parameters of wet soil, one of which was previously abundantly moistened so that 15 minutes before the flight, the puddles would not be visible from the ground level.

Aerial monitoring was conducted using the Slantrange 3p spectral system installed on the DJI Matrice 600 UAV. The flight altitude is 100 meters, which provided a spatial resolution of 14 mm/pixel for each of the channels. The Slantrange 3p system has 4 monochrome measurement channels (Green, Red, RedEdge, iRed) and a standard lighting correction system based on an areal sensor. Specialised SlantView software allows calibrating the results of photography by lighting and positioning and creates maps of the distribution of vegetation indices (VI). Since the programme does not provide access to the distribution map by source channels, an additional interface of the snapshot window was used. Figure 1 shows the SlantView snapshot windows in the green channel (left) and in pseudo-colours (right), with the areas under study highlighted directly in the programme.

A full-screen copy of the snapshot window was made to extract reference graphic data from the SlantView programme, which was saved in the Windows 7 pro Paint image editor in bmp format (24 bits). Cropping the image with positioning on reference points was done in the MS Office Picture manager programme. Statistical processing of graphical data of spectral monitoring results was performed in the MathCad (ver.14) programme according to the methodology presented in the paper (Pasichnyk *et al.*, 2019) [8]. In the programme, the original bmp or jpeg image was first converted to a matrix, which allowed clearly identifying each pixel of the image, and then the number of pixels for each of the 256 gradations of colour intensity was counted.

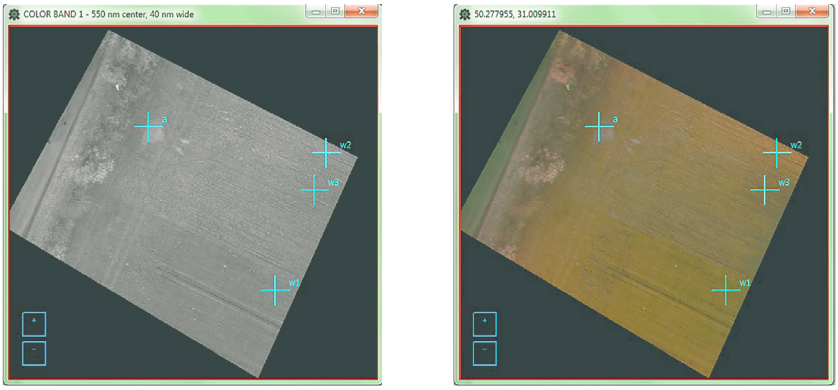

Figure 1. SlantView snapshot window interfaces:
on the left – a monochrome image in the green channel (530-570 nm), on the right – an image in pseudo-colours (without the blue channel). Designations on placemarks set by the operator: *a – open ground in an air-dry state, w1 – without prolonged action of herbicides, w2 – poorly affected areas, w3 – areas with maximum plants affected.*

RESULTS

A programme was written that counted the number of pixels based on the intensity of the colour components for the selected area to set up soil filtration during the analysis. The results obtained are shown in Figure 2.

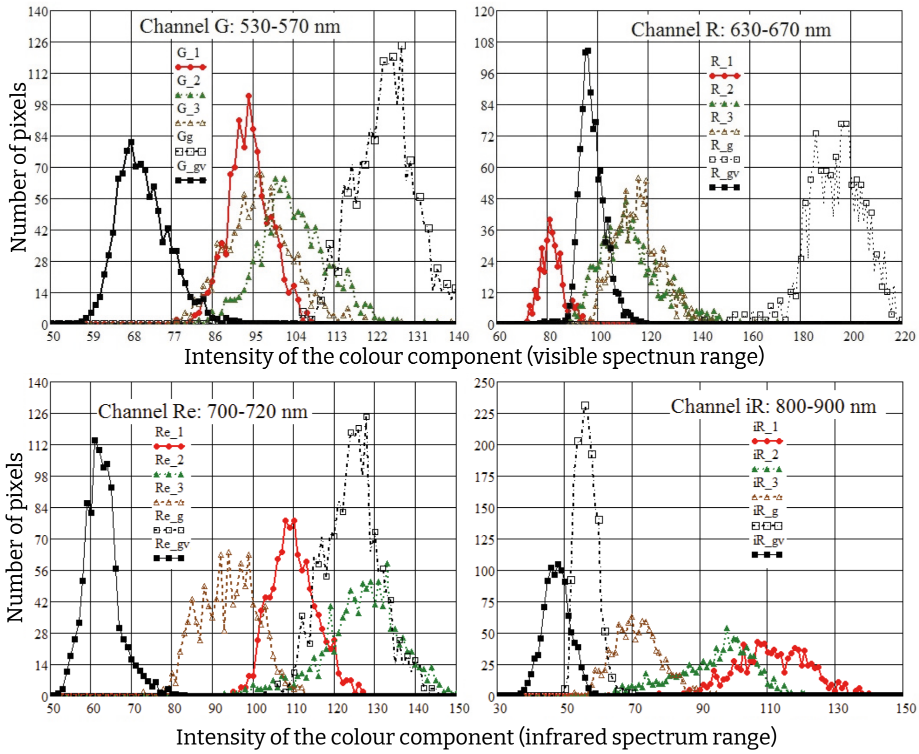

Figure 1. Distribution of the number of pixels depending on the intensity of the colour component
where: *1-3 – wheat, g – dry soil, and gv – wet soil*

Given the results obtained, it is problematic to reliably determine the soil parameters for filtration exclusively through a separate channel. If there are matches for an area with sparse vegetation for the iR channel with dry soil, but not with wet soil, then the opposite happens for the red one. A possible reason for this is the different topography of the soil in arable land and lowland. In addition, the soil in the shade of plants can also have an intermediate state of drying. When considering the prospects for the industrial application of this technology, it is necessary to consider the difficulties in determining soil filtration.

Considering possible variations in soil types and subtypes, a greater versatility of the identification method can be obtained by filtering not soil from the total mass, but by the spectral portraits of the plants. For the plants under study, the value of the G component is lower or close to iR, in contrast to dry or wet soil. According to this assumption, to identify plants, it is proposed to filter out pixels for which the iR-G ≥ F condition is not met. The value of F is configurable and can be determined by the characteristics of the variety (crop). The results obtained are presented in Table 1.

Table 1. Dependence of the spectral parameters of plots and the calculated plant area (S) on the plot on filtration parameters

F	1					2					3				
	G	R	Re	iR	S,%	G	R	Re	iR	S,%	G	R	Re	iR	S,%
-20	94	81	110	111	100	103	111	128	97	83	93	110	98	77	18
-15	94	81	110	111	100	103	110	129	100	67	94	109	102	82	4
-10	94	81	110	112	99	102	109	129	102	50	93	108	104	86	0.5
-5	94	81	110	112	98	101	108	129	104	33	93	108	104	86	
-0	94	80	110	112	95	101	107	129	107	20	93	108	104	86	

By evaluating the effect of filtering on spectral parameters, it was identified that the largest adjustment occurred in the R and iR channels, which will affect the vegetation indices based on them. Interesting are the results of the calculated horizontal area of plants, which has changed substantially, which can be used to assess the condition of plants as an additional parameter.

THE PROSPECTS OF FURTHER RESEARCH

The authors proposed a filtering option, which, just like in solutions implemented in the SlantView software, requires debugging.Debugging is conducted in expert mode, which determines subjectivity, and there are no objective criteria for evaluating the quality of filtering. Therefore, in further studies, it is advisable to consider the issue of methodological support for assessing the quality of filtering data from spectral monitoring of plantings.

CONCLUSIONS

- Reliable determination of the spectral portrait of the soil for its pixel-by-pixel filtration from multispectral images is a difficult task since its colour substantially depends on the state of moisture, which can vary in open and shaded areas.
- A more promising way to filter out random inclusions is to use a spectral portrait of plants, namely the intensity ratios of their components.

n A promising parameter for assessing the condition of crops is the estimation of their horizontal surface area, which can be determined by pixel-by-pixel image analysis. Preliminary results of the study were presented in the materials of the "Identification of plants in images using unmanned aerial vehicles" of the international scientific-practical conference dedicated to the 125th anniversary of the birth of T.S. Maltsev, 5.11.2020, the city of Kurgan, Belarus [6].

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Методичні підходи до ідентифікації рослин на знімках високої роздільної здатності багатоспектрального моніторингу з використанням БПЛА

Анотація. Рослинники потребують доступної та ефективної інформації про стан посівів для здійснення управління посівами. Метою роботи є розробка методу ідентифікації рослин на мультиспектральних знімках високої роздільної здатності для культур суцільного посіву на прикладі озимої пшениці. Дослідження проводяться в зоні Лівобережного Лісостепу, на промислових посівах озимої пшениці сорту Мулан. На момент проведення дистанційного моніторингу за допомогою БПЛА (2019.03.17) рослини перебували у фазі кущіння. Моніторинг з висоти 100 метрів проводиться за допомогою спектральної системи Slantrange 3p, встановленої на БПЛА DJI Matrice 600. Повноекранна копія вікна знімка робиться для вилучення еталонних графічних даних з програми SlantView. Статистичну обробку графічних даних результатів спектрального моніторингу виконано в програмі MathCad. Відзначено, що достовірне визначення спектрального портрета ґрунту для його піксельної фільтрації за багатоспектральними знімками є складним завданням, оскільки його колір суттєво залежить від стану зволоження і може відрізнятися на відкритих і затінених ділянках. Принципово новим способом фільтрації випадкових включень є використання спектрального портрета рослин на основі співвідношення інтенсивностей їхніх компонентів. Перспективним параметром для оцінки стану посівів є оцінка площі їх горизонтальної поверхні, яка може бути визначена шляхом попіксельного аналізу зображення. Запропоновано варіант фільтрації, який потребує налагодження. У подальших дослідженнях доцільно розглянути питання методичного забезпечення оцінювання якості фільтрації даних спектрального моніторингу насаджень

Ключові слова: Косокутний радар, ідентифікація сільськогосподарських культур, фільтрація

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Antagonistic activity of dominant bacteria isolated from the rhizosphere of spring barley against phytopathogenic micromycetes

Abstract. The purpose of the study was to examine the manifestation of representatives of the bacterial biome that dominate the spring barley rhizosphere, antagonistic activity against phytopathogenic micromycetes. The standard diffuse method of double culture in Petri dishes was used to examine the antagonistic properties of bacterial strains,dominating the rhizosphere. The level of antagonistic activity of microorganisms was evaluated by indicator (%) of inhibition of growth and development of mycelium of micromycetes *Fusarium sporotrichioides* Sherb. 23.2, *Alternaria alternata* (Fr.) Keissl. 3.45, *Nigrospora oryzae* (Berk. & Broome) Petch. 18.77. As a result of the conducted studies, it was identified that bacteria *Bacillus methylotrophicus* 10 had an inhibitory effect on *Fusarium sporotrichioides* Sherb. 23.2 – 77,4%, *Alternaria alternata* (Fr.) Keissl. 3.45 – 66.6% and *Nigrospora oryzae* (Berk. & Broome) Petch. 18.77 – 86.7%, while bacteria *Phyllobacterium ifriqiyense* 1 showed activity against phytopathogens by 45.1%, 63.1%, and 65.0%, respectively. Thus, both strains of dominating rhizospheric bacteria have high antagonistic activity against phytopathogenic micromycetes, which gives grounds for their further study

Keywords: *Bacillus methylotrophicus* 10, *Phyllobacterium ifriqiyense* 1, antagonistic properties, phytopathogenic micromycetes

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INTRODUCTION

Nature has laid down all the mechanisms for controlling the most important biosphere processes: nitrogen fixation, antagonism of certain microorganisms to pathogens, synthesis by microorganisms of biologically active substances that can substantially affect the physiological state of plants and their immunity, etc. (Andreiuk, 1992). In the root zone of plants, all the positive and negative aspects of inter-microbial and plant-microbial interaction are most active (Kiroiants, 2020).

During the study of the features of the formation of the microbial complex of chernozem typical in the agrophytocenosis of spring barley, a comparative characterisation of the number of the main physiological and taxonomic groups of microorganisms is conducted. The qualitative composition, structure, and diversity of the microbial complex formed in the ontogenesis of spring barley under various farming systems are analysed (Novikova, 2011). Microbiota formation is analysed using the Shannon and Simpson biodiversity indices in various phases of spring barley ontogenesis, and strains of microorganisms dominating the spring barley rhizosphere are identified. Laboratory molecular-biological methods identified the dominating bacteria – *Bacillus methylotrophicus 10* and *Phyllobacterium ifriqiyense 1* (registered in GenBank database MK947056, MK947049 (Berg et al, 2016); https://www.ncbi.nlm.nih.gov/nuccore/MK947056; https://www.ncbi.nlm.nih.gov/nuccore/MK947049.

Rhizospheric bacteria can exhibit high antagonistic activity against phytopathogenic microorganisms due to the synthesis of exometabolites of various chemical nature, and act as potential elicitors with which it is possible to control and reduce the level of phytopathogenic damage at the stages of plant ontogenesis (Goudjal, 2016).

The study of the properties of highly active microorganisms as potential bioagents of drugs, in particular, protective action for use in environmentally safe agricultural technologies, is one of the priority tasks of modern agroecology.

The purpose of the study was to research the manifestation of representatives of the bacterial biome that dominate the spring barley rhizosphere, antagonistic activity against phytopathogenic micromycetes.

MATERIALS AND METHODS

The studies used identified and classified strains of dominant microorganisms – *Bacillus methylotrophicus 10* and *Phyllobacterium ifriqiyense 1* (GenBank MK947056, MK947049). Strains of phytopathogenic micromycetes *Fusarium sporotrichioides* Sherb. 23.2, *Alternaria alternata* (Fr.) Keissl. 3.45, *Nigrospora oryzae* (Berk. & Broome) Petch 18.77 (Fig.1) were provided from the collections of the Plant Biochemistry and Bioenergetics V.F. Peresypkin Department of Phytopathology of the National University of Life and Environmental Sciences Of Ukraine.

a) b) c)

Figure 1. Phytopathogenic micromycetes

Note: a) *Fusarium sporotrichioides* Sherb. 23.2; b) *Alternaria alternata* (Fr.) Keissl. 3.45; c) *Nigrospora oryzae* (Berk. & Broome) Petch. 18.77

Antagonistic properties were determined by the diffuse method of double culture in Petri dishes on a glucose-peptone agarose medium (GPA-Zviagintsev). The studies used the classical block method (Ehorov, 2004) involving dominant rhizospheric bacteria *Bacillus methylotrophicus 10* and *Phyllobacterium ifriqiyense 1*.

During the study of rhizospheric bacteria, they were cultured at 28°C for a day for the formation and accumulation of biologically active metabolites in an agarose nutrient medium. Sample preparation of ten-day test cultures of phytopathogenic micromycetes was conducted under incubation conditions by the block method and the temperature range from 24 to 28°C.

The antagonistic activity of rhizospheric prokaryotes was evaluated by the degree of inhibition of growth and development of test micromycetes. The colony diameter was measured on day 14, and the percentage of growth inhibition of fungi colonies was determined by the formula:

$$\text{Growth inhibition (\%)} = \frac{D_k - D_o}{D_k} \times 100\%,$$

where: D_k – diameter of the fungal colony in the control, mm; D_o – diameter of the mushroom colony in the experiment, mm.

The colony diameter was measured twice on radially opposite sides, and the arithmetic mean was calculated.

The degree of antagonistic activity of the tested rhizosphere bacteria strains was defined according to the size of the test strain growth inhibition zone around the agar block. Growth retardation zones were considered after 3 and 10 days of cultivation.

Statistical processing was performed using Microsoft Excel.

RESULTS AND DISCUSSION

The results of studies of the inhibitory activity of bacterial strains against phytopathogenic micromycetes are presented in Table 1.

Table 1. Inhibitory activity of dominant spring barley rhizosphere bacteria

Bacillus methylotrophicus 10 *Do* day 10 (mm)	*Phyllobacterium ifriqiyense* 1 *Do* day 10 (mm)	Phytopathogenic micromycetes (control), *Dk* (mm)		Inhibitory activity *P* (%)	
				Bacillus methylotrophicus 10	*Phyllobacterium ifriqiyense* 1
34 ± 1.6	14 ± 0.8	*Fusarium sporotrichioides Sherb.* 23.2	62 ± 3.8	45.1	77.4
21 ± 2.4	19 ± 1.3	*Alternaria alternata (Fr.) Keissl.* 3.45	57 ± 4.5	63.1	66.6
29 ± 1.4	11 ± 1.9	*Nigrospora oryzae (Berk. & Broome) Petch.* 18.77	83 ± 3.6	65.2	86.7

Note: D_k – diameter of the fungal colony in the control, mm; D_o – diameter of the fungus colony in the experiment, mm; *P* – indicator of inhibition

As a result of the conducted studies, it was identified that bacteria *Bacillus methylotrophicus 10* and *Phyllobacterium ifriqiyense 1* inhibited the growth of phytopathogenic micromycetes *Fusarium sporotrichioides* Sherb. 23.2 – 45.1% and 77.4%, respectively, test cultures *Alternaria alternata* (Fr.) Keissl. 3.45 – 63.1% and 66.6%, *Nigrospora oryzae* (Berk. & Broome) Petch. 18.77 – 65.2% and 86.7%. The conducted studies of antagonistic activity indicate (Fig. 2) that rhizospheric bacterial agents of *Bacillus methylotrophicus 10* and *Phyllobacterium ifriqiyense 1* inhibit the growth of micromycetes, which is evidence of their antifungal activity.

a) b)

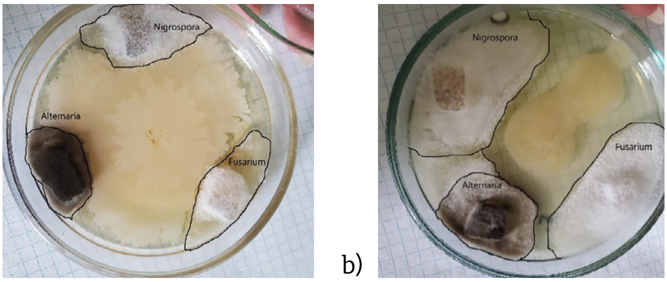

Figure 2. Antagonistic activity of rhizospheric bacterial strains, (day 10)
Note: a) *Bacillus methylotrophicus 10*; b) *Phyllobacterium ifriqiyense 1*

Bacteria *Phyllobacterium ifriqiyense 1* populate the substrate more quickly and use nutrient resources accordingly, while micromycetes lose the ability to grow and do not have the opportunity to populate the substrate further away, and there is a tendency to die. Thus, evidently, the detected antagonistic activity is associated with competition. In natural conditions, antagonism of this type is most often observed in the soil environment of the plant rhizosphere, where there is competition between microorganisms for food sources (root exudates) (Hadzalo, 2015).

The intensity of growth and development of bacteria dominating the rhizosphere of spring barley plants around agar blocks of phytopathogenic micromycetes on days 3 and 10 of the experiment is presented in Table 2.

Table 2. Determination of the growth retardation zone of phytopathogenic micromycetes under the influence of dominant bacteria on days 3 and 10 of the experiment

Phytopathogenic micromycetes (control, mm)		*Bacillus methylotrophicus* 10		*Phyllobacterium ifriqiyense* 1	
		Day 3 (mm)	Day 3 (mm)	Day 3 (mm)	Day 10 (mm)
Fusarium sporotrichioides Sherb. 23.2	62 ± 1.4	3 ± 0.2	1 ± 0.1	9 ± 0.6	2 ± 0.1
Alternaria alternata (Fr.) Keissl. 3.45	57 ± 0.9	11 ± 0.6	3 ± 0.2	13 ± 0.8	5 ± 0.4
Nigrospora oryzae (Berk. & Broome) Petch. 18.77	83 ± 2.2	5 ± .4	2 ± 0.1	11 ± 0.7	7 ± 0.5

Based on the results obtained, bacteria *Bacillus methylotrophicus 10* and *Phyllobacterium ifriqiyense 1* on day 3 of the experiment suppressed the growth and development of phytopathogenic micromycetes, in particular, the zones of growth retardation of micromycetes were as follows: *Fusarium sporotrichioides* Sherb. 23.2 – 3 and 9 mm, respectively, *Alternaria alternata* (Fr.) Keissl. 3.45 – 11 and 13 mm, and *Nigrospora oryzae* (Berk. & Broome) Petch. 18.77 – 5 and 11 mm, respectively. On the 10th day of the experiment bacteria *Bacillus methylotrophicus 10* and *Phyllobacterium ifriqiyense 1* inhibited the growth of fungi *Fusarium sporotrichioides* Sherb. 23.2 – 1 and 2 mm, *Alternaria alternata* (Fr.) Keissl. 3.45 – 3 and 5 mm, and *Nigrospora oryzae* (Berk. & Broome) Petch. 18.77 – 2 and 7 mm, respectively.

Consequently, the antagonistic activity of the bacterial strains dominating the rhizosphere of spring barley was manifested already on the third day of the experiment and increased its influence on the growth and development of phytopathogenic micromycetes during the experiment.

CONCLUSIONS

Rhizospheric bacteria *Bacillus methylotrophicus 10* and *Phyllobacterium ifriqiyense 1,* have antagonistic activity against phytopathogenic micromycetes, and also they have an inhibitory effect on the growth and development of phytopathogenic micromycetes, and therefore the ability to compete with specific plant phytopathogens under study.

Therefore, further research of these bacteria and the search for new effective ones with polyfunctional action are promising for the development of biotechnologies for their use as preparative forms for crop production (alternative ecological technological means for chemical plant protection and mineral fertilisers).

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Антагоністична активність домінантних бактерій, виділених з ризосфери ячменю ярого, щодо фітопатогенних мікроміцетів

Анотація. Метою дослідження було вивчення прояву представниками бактеріального біома, що домінують у ризосфері ячменю ярого, антагоністичної активності щодо фітопатогенних мікроміцетів. Для вивчення антагоністичних властивостей штамів бактерій, що домінують у ризосфері, використовували стандартний дифузний метод подвійного культивування в чашках Петрі. Рівень антагоністичної активності мікроорганізмів оцінювали за показником (%) пригнічення росту і розвитку міцелію мікроміцетів Fusarium sporotrichioides Sherb. 23,2, *Alternaria alternata* (Fr.) Keissl. 3.45, *Nigrospora oryzae* (Berk. & Broome) Petch. 18.77. В результаті проведених досліджень встановлено, що бактерії *Bacillus methylotrophicus* 10 мали інгібуючий вплив на *Fusarium sporotrichioides* Sherb. 23,2 - 77,4%, *Alternaria alternata* (Fr.) Keissl. 3,45 - 66,6% та *Nigrospora oryzae* (Berk. & Broome) Petch. 18,77 - 86,7%, тоді як бактерії *Phyllobacterium ifriqiyense* 1 проявляли активність проти фітопатогенів на 45,1%, 63,1% та 65,0% відповідно. Таким чином, обидва штами домінуючих ризосферних бактерій мають високу антагоністичну активність проти фітопатогенних мікроміцетів, що дає підстави для їх подальшого вивчення

Ключові слова: *Bacillus methylotrophicus* 10, *Phyllobacterium ifriqiyense* 1, антагоністичні властивості, фітопатогенні мікроміцети

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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

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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.

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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

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Evaluation of parsnip varieties (*Pastinaca sativa* L.) on productivity and adaptability in the conditions of the Right-Bank Forest-Steppe Of Ukraine

Abstract. Commercial products of parsnip were formed in the conditions of the Right-Bank Forest-Steppe of Ukraine within the sum of effective temperatures of 1356 1495°C, precipitation amounts of 171 318 mm, and relative humidity of 57 64%. The yield value had an inverse relationship with the sum of temperatures and a direct relationship with the amount of precipitation, relative humidity, and hydrothermal coefficient. The highest yield in the conditions of the Right-Bank Forest-Steppe of Ukraine is provided by Stymul and Pul's varieties with a total yield of 46.2 and 44.8 t/ha, and a marketability of root crops of 89 and 88%, respectively. Pul's and Stymul varieties had the highest breeding value of genotype in terms of yield (BVGi = 46.2 and 44.8, respectively), high ecological

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stability (Sgi = 3.43 and 1.96, respectively), and plasticity (bi = 1.47 and 0.89%, respectively). The highest indicator of general adaptive ability for plant productivity was observed in the Stymul (GAA= 3.12) and Pul's (GAA= 1.76) varieties. According to the indicator of specific adaptive ability, the Stymul variety (SAA = 2.52) and Pul's (SAA = 0.78) were highlighted. According to the biochemical composition of root crops, the varieties under study did not exceed the control. However, in the Borys variety, the content of dry matter – 25.1%, dry solute – 15.8%, and sugar content – 6.4% was at the control level. All varieties were identified to have a high content of vitamin C – 8.9 10.1 mg/100 g. The varieties did not tend to accumulate nitrates and their content ranged from 67 to 80 mg/kg and was below the maximum allowable level (MAL 250 mg/kg). The highest tasting score of 5.6 points was given by the Pul's variety. It is recommended to grow highly productive varieties of parsnip – Stymul and Pul's to obtain a consistently high yield of root crops (44.8 46.2 t/ha) and their marketability at the level of 88 89% with a high content of basic biochemical components in the conditions of the Right-Bank Forest-Steppe of Ukraine on medium-podzolic coarse-pollinated light loamy turf soil

Keywords: yield, quality indicators, stability, plasticity, breeding value of the genotype

RELEVANCE

Providing the population with high-quality and environmentally safe products is one of the main socio-economic problems of modern times (Engalycheva, I.A. *et al.*, 2021). Parsnip seed is a valuable vegetable crop (Aćimović, M.G., 2017). The chemical composition of parsnip is quite multifaceted and includes a substantial number of biologically active compounds that determine a wide range of its biological properties, which can effectively affect various organs and systems of the body and maintain their health (Shimorova, J.E. *et al.*, 2017)

The problem of selecting and using environmentally plastic variety samples is an important element of adaptive vegetable growing. Its correct solution enables the efficient using material and natural resources and reduces production costs (Gaplaev, M.Sh., 2016).

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Since each variety, depending on the growing conditions, realises its genetic potential differently, it is advisable to choose ones of intensive type that differ in biological characteristics within the same soil and climate zone to reduce the risks associated with weather instability (Gaplaev, M.Sh., 2014; Potapskyi, Y.V., 2015; Khareba, V.V. & Komar, O.O., 2017). Breeding is equally important for product quality. The concept of quality includes various properties, starting from the biochemical composition, which determines the nutritional value, taste properties, and transportability, suitability for storage (Cherkasova, V.K. & Shabetya, O.N., 2014).

Parsnip, as an object of breeding, are characterised by narrow genetic diversity and lower genetic variation in comparison with other root crops (Fedorova, M.I. *et al.*, 2017) Varietal populations and hybrids F_1 of parsnip must have a number of mandatory characteristics, such as high and stable yield of root crops and seeds, improved product quality, good suitability for storage, cold resistance, suitability for mechanised harvesting, high resistance to adverse environmental conditions (Fedorova, M.I. & Stepanov, V.A., 2017; Sokolova, D.V., 2018).

Thus, the most effective and profitable is the widespread introduction of varieties and hybrids with a genetically determined level of adaptation to soilclimatic zones of their cultivation (Komar, O.O. *et al.*, 2020)

The purpose of the study is the selection of the most adapted, high-yielding varieties of parsnip with a high content of basic biochemical components.

MATERIALS AND METHODS

Experimental studies were conducted during 2015-2019 in the field experiment of the Department of Vegetable Crops in the EL "Fruit and vegetable garden" of the National University of Life and Environmental Sciences of Ukraine in the conditions of the Right-Bank Forest-Steppe of Ukraine. The soil of the experimental site is turf-medium-podzolic, coarse-dusty, light loamy. Humus content – 1.8%, total absorbed bases – 6.43 mgEq/100 g of soil, content of easily hydrolysed nitrogen – 42.1 mg/kg, mobile phosphorus – 52 mg/kg, and potassium – 41 mg/kg. The reaction of the soil medium is close to neutral (pH of the salt extract is 6.1).

The following varieties were studied: Petryk (control), Stymul, Borys, and Pul's. The size of the accounting experimental plot was 11.3 m^2, the repetition is fourfold. Variants in the experiment were placed systematically. The predecessor for parsnip was cucumber. Sowing was carried out in the second decade of April according to the 45x10 cm scheme to a depth of 1.52 cm with a seeding rate of 3 kg/ha. In the phase of two true leaves, the final density of plants was formed.

RESULTS

It was established that commercial products of parsnip were formed in the conditions of the Right-Bank Forest-Steppe of Ukraine during the growth period of shootstechnical ripeness during 2015-2019 within the sum of effective temperatures of 13561495°C, precipitation amounts of 171318 mm, and relative humidity of 5764%. The yield value had an inverse relationship with the sum of temperatures and a direct relationship with the amount of precipitation, relative humidity, and hydrothermal coefficient. An increase in the sum of effective temperatures by 1°C provided a decrease in yield in the Borys variety by 6.0 kg, Stymul – 6.3 kg, Pul's – 7.2 kg with a control indicator of 10.5 kg. An increase in the amount of precipitation by 1 mm contributed to an increase in yields in the Stymul variety by 12.2 kg, Borys – 9.1 kg, and Pul's – 8.5 kg with a control indicator of 11.8 kg. An increase in relative humidity by 1% provided an increase in yield in the Stymul variety by 244 kg, Borys – 171 kg, and Pul's – 130 kg with a control indicator of 199 kg. An increase in the hydrothermal coefficient by 0.1 contributed to an increase in yield in the Stymul variety by 327 kg, Borys – 251 kg, and Pul's – 231 kg with a control indicator of 317 kg.

Varietal characteristics affected biometric indicators in parsnip plants (Table 1). In terms of technical ripeness, the largest number of leaves on the plant (9.6 pcs.) were identified in the Petryk variety (control), and the smallest amount – (8.0 pcs.) in the Borys variety, which is 1.6 pcs. less than the control. In the Stymul and Pul's variety, this indicator was 8.7 and 8.3 pcs., which is 0.9 and 1.3 pcs. less than the control, respectively. The height of the plant in the studied varieties ranged from 53.0 cm to 62.7 cm. However, the plant was higher in the Stymul variety, and lower in the Petryk variety (control).

The largest mass of leaves to the total mass of plants was determined in the Stymul (32.6%) and Pul's (30.5%) varieties, which is 3.9% and 1.8% more than the control, respectively. In the Petryk (control) and Borys varieties, this indicator was 28.7% and 29.1%. The largest length of root crops (28.2 cm) was characteristic of the

Petryk variety (control), while the diameter of root crops was 7.6 cm, and the shape index was 3.72. The smallest length of root crops (23.2 cm) was identified in the Borys variety, while the diameter of root crops was 6.8 cm, and the shape index was 3.42.

Table 1. Biometric indicators of parsnip plants in the technical ripeness phase (average for 2015-2019)

Indicator	Variety			
	Petryk (c)*	Stymul	Borys	Pul's
Number of leaves, pcs.	9.6	8.7	8.0	8.3
Plant height, cm	53.0	62.7	55.4	57.6
Leaf weight, g	73	102	78	90
Leaf weight (% of total plant weight)	28.7	32.6	29.1	30.5
Root crop length, cm	28.2	26.5	23.2	24.7
Diameter of root vegetables, cm	7.6	8.5	6.8	9.4
Form index	3.72	3.10	3.42	2.63
Marketability of root vegetables, %	81	89	86	88
Weight of root vegetables, g	181	210	190	205

Note: (c)* – control

Stymul and Pul's varieties were characterised by the highest weight and marketability of root crops, which is 29 g and 24 g, respectively, and 8.0% and 7.0% more than the control.

A substantial amount of dry matter was accumulated in the varieties under study – 24.725.4% (Table 2). Root crops of the Petryk variety (control) accumulated the most dry matter – 25.4%. Borys root crops were characterised by a high dry matter content (25.1%), which is within the control range. The content of dry solute in the varieties under study ranged from 14.4% to 16.5%. The highest sugar content (6.7%) was observed in the Petryk variety (control), and the lowest in the Stymul variety (6.0%). The content of vitamin C in root vegetables was highest in the Petryk variety (control) – 10.1 mg/100 g. Thus, in the Borys, Stymul, and Pul's varieties, the vitamin C content was 8.9 mg/100 g, 9.2 mg/100 g, and 9.6 mg/100 g, respectively, which is substantially less than the control.

Table 2. Main biochemical parameters and tasting assessment of parsnip root crops (average for 2015-2019)

Variety	Content					Tasting score, units
	dry matter, %		sugars (sum), %	vitamin C, mg/100 g	nitrates, mg/kg	
	general	soluble				
Petryk (c)*	25.4	16.5	6.7	10.1	75	4.7
Stymul	24.7	14.4	6.0	9.2	60	5.1
Borys	25.1	15.8	6.4	8.9	80	5.4
Pul's	24.9	15.0	6.1	9.6	67	5.6
HIP_{05}	*0.43*	*0.13*	*0.39*	*0.37*	*2.31*	

Note: (c)* – control

Among the safety indicators of fresh vegetable products, special attention is paid to the content of nitrates in them. At the same time, the presence of nitrates in the plant and their accumulation in food organs is a biological necessity for the nutrition and photosynthetic activity of plants.

Parsnip roots of the Stymul variety were characterised by the lowest nitrate content – 60 mg/kg, the Borys variety had the highest (80 mg/kg). The nitrate content in the varieties under study was below the maximum allowable level (MAL 250 mg/kg). According to organoleptic parameters, the best among the studied assortment was the Pul's variety, which received the highest score of 5.6 points during the tasting. The Petryk (control), Stymul, and Borys varieties also scored a high tasting score of 4.7, 5.1, and 5.4 points, respectively.

A substantial variation in the yield of parsnip by year (2015-2019) was identified in the Stymul and Petryk varieties. Over the years of research, it was 8.6% or 4.2 t/ha and 6.3% or 2.6 t/ha, respectively. In the Pul's and Borys varieties, this indicator reached 5.6% or 2.6 t/ha and 5.3% or 2.3 t/ha, respectively (Table 3).

Table 3. Parameters of adaptive capacity, ecological stability, and plasticity of parsnip varieties by yield (average for 2015-2019)

Variety	Yield, t/ha			Variation range (v), t/ha	Adaptive ability		Stability (Sgi)	Plasticity (bi), %	Breeding value (BVGi)
	min	max	$\bar{X}$		GAA (Vi)	SAA (CACi)			
Petryk (c)*	38.4	41.0	39.6	2.6	-3.42	0.65	2.03	0.81	22.6
Stymul	44.7	48.9	46.2	4.2	3.12	2.52	3.43	1.47	46.2
Borys	40.8	43.1	41.6	2.3	-1.45	0.71	2.03	0.83	41.6
Pul's	43.9	46.5	44.8	2.6	1.76	0.78	1.96	0.89	44.8
HIP_{05}			2.62						

Note: (c)* – control

During 2015-2019, a substantial difference in yield was identified in Stymul (46.2 t/ha) and Pul's (44.8 t/ha) varieties, which is 6.6 t/ha or 16.7% and 5.2 t/ha or 13.1% more than the control, respectively. The yield of the Borys variety was at the control level and amounted to 41.6 t/ha.

The Stymul (GAA = 3.12) and Pul's (GAA = 1.76) varieties were characterised by the highest general adaptive ability (GAA), reflecting the preservation of genotype traits under various environmental conditions. The lowest GAA is noted in the varieties Borys (GAA = 1.45) and Petryk (control) (GAA = 3.42).

According to the indicator of specific adaptive ability (SAA), which indicates the plasticity of the variety, i.e. adaptability to individual conditions, the Stymul (SAA = 2.52) and Pul's (SAA = 0.78) varieties had better stability. The worst varieties in this parameter were Borys (SAA = 0.71) and Petryk (control) (SAA = 0.65).

The relative stability index ranged from 1.96 to 3.43. Thus, all the varieties of parsnip under study can be attributed to a highly stable group. It was identified that the Petryk (control) and Borys varieties had the lowest sensitivity to growing conditions. Thus, with an increase in the average yield level by 1 t/ha, the increase in root crops was 0.81 and 0.83 t/ha, respectively. The changes in the growing conditions affected the Stymul and Pul's varieties the most (with an increase in the average yield level by 1 t/ha, the increase in root crops was 1.47 and 0.89 t/ha, respectively).

By BVG_i indicator, the best in descending order were parsnip varieties of seed Stymul, Pul's, Borys, and Petryk (control).

CONCLUSIONS

It is recommended to grow highly productive varieties of parsnip – Stymul and Pul's to obtain a consistently high yield of root crops (44.846.2 t/ha) and their marketability at the level of 8889% with a high content of basic biochemical components in the conditions of the Right-Bank Forest-Steppe of Ukraine on medium-podzolic coarse-pollinated light loamy turf soil. In connection with the forecast of experts on climate aridification, it is promising to create varieties that are comprehensively resistant to drought, extreme temperatures, acidity, salinity, and other environmental stress factors.

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Оцінка сортів пастернаку (*Pastinaca sativa* L.) за продуктивністю та адаптивністю в умовах Правобережного Лісостепу України

Анотація. Товарна продукція пастернаку формувалася в умовах Правобережного Лісостепу України в межах суми ефективних температур 1356 1495 °С, кількості опадів 171 318 мм та відносної вологості повітря 57 64%. Величина врожайності мала обернену залежність від суми температур і пряму залежність від кількості опадів, відносної вологості повітря та гідротермічного коефіцієнта. Найвищу врожайність в умовах Правобережного Лісостепу України забезпечили сорти Стимул і Пульс із загальною врожайністю 46,2 і 44,8 т/га та товарністю коренеплодів 89 і 88% відповідно. Сорти Пульс і Стимул мали найвищу селекційну цінність генотипу за врожайністю (BVGi = 46,2 і 44,8 відповідно), високу екологічну стабільність (Sgi = 3,43 і 1,96 відповідно) та пластичність (bi = 1,47 і 0,89% відповідно). Найвищий показник загальної адаптивної здатності за продуктивністю рослин спостерігався у сортів Стимул (GAA = 3,12) та Пульс (GAA = 1,76). За показником специфічної адаптивної здатності виділилися сорти Стимул (SAA = 2,52) та Пульс (SAA = 0,78). За біохімічним складом коренеплодів досліджувані сорти не перевищували контроль. Проте у сорту Борис вміст сухої речовини – 25,1%, сухих розчинних речовин – 15,8% та цукрів – 6,4% був на рівні контролю. Всі сорти характеризувалися високим вмістом вітаміну С – 8,9 10,1 мг/100 г. Сорти не були схильні до накопичення нітратів, їх вміст коливався від 67 до 80 мг/кг і був нижчим за максимально допустимий рівень (МДР 250 мг/кг). Найвищу дегустаційну оцінку 5,6 бала отримав сорт Пульс. Рекомендовано вирощувати високопродуктивні сорти пастернаку – Стимул і Пульс для отримання стабільно високої врожайності коренеплодів (44,8 46,2 т/га) та їх товарності на рівні 88 89% з високим вмістом основних біохімічних компонентів в умовах Правобережного Лісостепу України на середньопідзолистому крупнопилуватому легкосуглинковому дерновому ґрунті

Ключові слова: урожайність, показники якості, стабільність, пластичність, селекційна цінність генотипу

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