

Засновник:

Національний університет біоресурсів і природокористування України

Рік заснування: 2010

*Рекомендовано до друку та поширення
через мережу Інтернет Вченою радою*

Національний університет біоресурсів і природокористування України
(протокол № 4 від 24 листопада 2021 р.)

**Свідоцтво про державну реєстрацію
друкованого засобу масової інформації
серії КВ № 25124-15064 ПР**

Журнал входить до переліку наукових фахових видань України

Категорія «Б». Галузь науки: Сільськогосподарські. Спеціальності:
201 «Агрономія», 203 «Садівництво та виноградарство»
(наказ Міністерства освіти і науки України
від 17 березня 2020 року № 409)

**Журнал представлено у міжнародних наукометричних базах даних,
репозитаріях та пошукових системах:**

Google Scholar, Index Copernicus, Фахові видання України, AGRIS,
НБУ ім. В. І. Вернадського, BASE, Research Bible

Адреса редакції:

Національний університет біоресурсів і природокористування України
03041 вул. Героїв Оборони, 15, м. Київ, Україна,
E-mail: info@agriculturalscience.com.ua
<https://agriculturalscience.com.ua/uk>

Founder:

National University of Life and Environmental Sciences of Ukraine

Year of foundation: 2010

*Recommended for printing and distribution
via the Internet by the Academic Council
of National University of Life and Environmental Sciences of Ukraine
(Minutes No. 4 of November 24, 2021)*

**Certificate of state registration
of the print media**

Series KB No. 25124-15064 PR

The journal is included in the List of Scientific Professional Publications of Ukraine

Category "B". Branch of sciences: Agricultural. Specialties:
201 "Agronomy", 203 "Horticulture and Viticulture"
(order of the Ministry of Education and Science of Ukraine
No. 409, dated March 17th, 2020)

**The journal is presented international scientometric databases, repositories
and scientific systems:**

Google Scholar, Index Copernicus,
Professional publications of Ukraine, AGRIS, VNLU, BASE, Research Bible

Editors Office Address:

National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony, Kyiv, Ukraine
E-mail: info@agriculturalscience.com.ua
<https://agriculturalscience.com.ua/en>

Головний редактор:
Світлана Каленська

доктор сільськогосподарських наук, професор, академік НААН України, Національний університет біоресурсів і природокористування України, Україна

Відповідальний секретар:
Олена Піковська

кандидат сільськогосподарських наук, доцент, Національний університет біоресурсів і природокористування України, Україна

Національні члени редколегії:

Ніна Бісько

доктор біологічних наук, старший науковий співробітник, Інститут ботаніки ім. М.Г. Холодного Національної академії наук України, Україна

Юрій Кравченко

кандидат сільськогосподарських наук, доцент, Національний університет біоресурсів і природокористування України, Україна

Дмитро Літвінов

доктор сільськогосподарських наук, старший науковий співробітник, Національний університет біоресурсів і природокористування України, Україна

Олександр Меньшов

доктор геологічних наук, старший науковий співробітник, Київський національний університет імені Тараса Шевченка, Україна

Наталія Новицька

доктор сільськогосподарських наук, доцент, Національний університет біоресурсів і природокористування України, Україна

Наталія Пасічник

кандидат сільськогосподарських наук, доцент, Національний університет біоресурсів і природокористування України, Україна

Джамал Рахметов

доктор сільськогосподарських наук, професор, Національний ботанічний сад ім. М.М. Гришка, Національний університет біоресурсів і природокористування України, Україна

Семен Танчик

доктор сільськогосподарських наук, професор, член-кореспондент Національної академії аграрних наук України, Національний університет біоресурсів і природокористування України, Україна

Оксана Тонха

доктор сільськогосподарських наук, професор, Національний університет біоресурсів і природокористування України, Україна

Іван Федосій

кандидат сільськогосподарських наук, доцент, Національний університет біоресурсів і природокористування України, Україна

Людмила Шевчук

доктор сільськогосподарських наук, старший науковий співробітник, Національний університет біоресурсів і природокористування України, Україна

Олексій Цюк

доктор сільськогосподарських наук, професор, Національний університет біоресурсів і природокористування України, Україна

Міжнародні члени редколегії:

Міхаел Генрі Бьоме

доктор сільськогосподарських наук, професор, Університет ім. Гумбольта, Німеччина

Хадлей Ренді Катчер

доктор філософії, професор, Саскачеванський університет, Канада

Петер Киверига

доктор філософії, професор, Університет штату Айова, США

Ян Крен

кандидат сільськогосподарських наук, професор, Університет Менделя, Чехія

Чарльз Лі Буррас

доктор філософії, професор, Університет штату Айова, США

Лідія Сас-Паст

професор, Науково-дослідний інститут садівництва, Польща

Лу-Джан Лі

доктор філософії, професор, Північно-східний інститут географії та агроєкології Китайської академії наук, Китай

Віолета Макаревічене

доктор філософії, професор, Інститут навколишнього середовища та екології Університету Вітаутаса Великого, Литва

Кшиштоф Мудрик

доктор наук з агроінженерії, професор, Університет сільського господарства в Кракові, Польща

Онер Четін

доктор філософії, професор, Дікл Університет, Туреччина

Ірина Сметанська

професор, Університет прикладних наук Вайенштефан-Трісдорф, Німеччина

Тенгіз Урушадзе

доктор біологічних наук, професор, Аграрний університет Грузії, Грузія

Editor-in-Chief:

Svitlana Kalenska

Doctor of Agricultural Sciences, Professor, Academician of a NAAS of Ukraine, National University of Life and Environmental Sciences of Ukraine, Ukraine

Executive Secretary:

Olena Pikovska

PhD in Agricultural Sciences, Associate Professor, National University of Life and Environmental Sciences of Ukraine, Ukraine

National Members of the Editorial Board:

Nina Bisko

Doctor of Biological Sciences, Senior Researcher, M.G. Kholodny Institute of Botany National Academy of Sciences of Ukraine, Ukraine

Yuriy Kravchenko

PhD in Agricultural Sciences, Associate Professor, National University of Life and Environmental Sciences of Ukraine, Ukraine

Dmytro Litvinov

Doctor of Agricultural Sciences, Senior Researcher, National University of Life and Environmental Sciences of Ukraine, Ukraine

Oleksandr Menshov

Doctor of Geological Sciences, Senior Researcher, Taras Shevchenko National University of Kyiv, Ukraine

Nataliia Novytska

Doctor of Agricultural Sciences, Associate Professor, National University of Life and Environmental Sciences of Ukraine, Ukraine

Natalia Pasichnyk

PhD in Agricultural Sciences, Associate Professor, National University of Life and Environmental Sciences of Ukraine, Ukraine

Dzhamal Rakhmetov

Doctor of Agricultural Sciences, Professor, Grishko National Botanical Garden of National Academy of Sciences of Ukraine, National University of Life and Environmental Sciences of Ukraine, Ukraine

Semen Tanchyk

Doctor of Agricultural Sciences, Professor, Corresponding Member of the National Academy of Agrarian Sciences of Ukraine, National University of Life and Environmental Sciences of Ukraine, Ukraine

Oksana Tonkha

Doctor of Agricultural Sciences, Professor, National University of Life and Environmental Sciences of Ukraine, Ukraine

Ivan Fedosiy

PhD in Agricultural Sciences, Associate Professor, National University of Life and Environmental Sciences of Ukraine, Ukraine

Liudmyla Shevchuk

Doctor of Agricultural Sciences, Senior Researcher, National University of Life and Environmental Sciences of Ukraine, Ukraine

Oleksiy Tsyuk

Doctor of Agricultural Sciences, Professor, National University of Life and Environmental Sciences of Ukraine, Ukraine

International Members of the Editorial Board:

Michael Henry Boehme

Doctor of Agricultural Sciences, Professor, University of Humboldt, Germany

Hadley Randy Kutcher

PhD, Professor, University of Saskatchewan, Canada

Peter Kyveryga

PhD, Professor, Iowa State University, USA

Jan Kren

PhD in Agricultural Sciences, Professor, Mendel University, Czech Republic

Charles Lee Burras

PhD, Professor, Iowa State University, USA

Lidia Sas-Pasz

Professor, National Institute of Horticultural Research, Skierniewice, Poland

Lu-Jun Li

PhD, Professor, Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, China

Violeta Makareviciene

PhD, Professor, Institute of Environmental Science and Ecology, Vytautas Magnus University, Lithuania

Krzysztof Mudryk

Doctor of Science in Agroengineering, Professor, University of Agriculture in Krakow, Poland

Öner Çetin

PhD, Professor, Dicle University, Turkey

Iryna Smetanska

Professor, University of Applied Sciences Weihenstephan-Triesdorf, Germany

Tengiz Urushadze

Doctor of Biological Sciences, Professor, Agricultural University of Georgia, Georgia

Б. О. Мазуренко, С. М. Каленська, Л. М. Гончар, М. Я. Григоревський Формування елементів продуктивності пшениці озимої за припосівного внесення повільнодіючих комплексних добрив	7
Л. А. Гарбар, Н. В. Кнап Реалізація генетичного потенціалу гібридів соняшнику за впливу умов живлення.....	17
М. П. Соломійчук, М. Й. Піковський Вплив бактерій <i>Pseudomonas fluorescens</i> і речовин стимулюючої природи на продуктивність рослини сої та ураження насіння патогенами.....	28
С. П. Танчик, Н. І. Бабіля, А. І. Бабенко Агрофізичні показники ґрунту за вирощування ячменю озимого в Закарпатті України .37	
О. С. Павлов, А. І. Бабенко, А. С. Андрущенко Біологічна ефективність гербіцидів у посівах пшениці озимої осіннього внесення.....	50
Н. Ф. Шпирка, С. П. Танчик, О. С. Павлов, А. І. Бабенко Вплив систем землеробства та обробітку ґрунту на основних шкідників пшениці озимої .60	
Р. І. Топко, Г. М. Ковалишина, Г. Б. Вологдіна, О. В. Гуменюк Спектральна оцінка сортів та селекційних ліній пшениці озимої у період відновлення весняної вегетації	68
Л. А. Мурашко, Т. І. Муха, Г. М. Ковалишина, Ю. М. Дмитренко Характеристика вихідного матеріалу, стійкого проти фузаріозу колоса та кореневих гнилей, для селекції пшениці озимої	80
С. Ю. Булигін, С. В. Вітвіцький, М. Є. Булигіна, О. І. Вітвіцька Режим зволоження чорнозему звичайного за технології «no-till»	91
Є. Г. Дегодюк, С. Е. Дегодюк, Ю. П. Борко, О. А. Літвінова, Ю. О. Ігнатенко, А. О. Мулярчук Тривалий моніторинг аридизації в землеробстві до змін і за змін клімату в Україні.....	102
В. П. Ковальчук Метод отримання водно-фізичних властивостей ґрунтів за фракціями їхнього гранулометричного складу	115
Н. М. Зеленянська, О. І. Гогулінська, Н. В. Подуст Вплив краплинного зрошення та навантаження суцвіттями на ріст і розвиток маточних кущів винограду	126

B. Mazurenko, S. Kalenska, L. Honchar, M. Hrygirevskiy

Formation of productive elements in winter wheat by seed dressing application with slow-release complex fertilisers 7

L. Garbar, N. Knap

The realisation of the genetic potential of sunflower hybrids under the influence of feeding conditions..... 17

M. Solomiychuk, M. Pikovskyi

The effect of the *Pseudomonas fluorescens* bacteria and substances of a stimulating nature on the productivity of the soybean plant and seed damage by pathogens..... 28

S. Tanchyk, N. Babilia, A. Babenko

Agrophysical indicators of soil for growing winter barley in the Transcarpathia of Ukraine 37

O. Pavlov, A. Babenko, A. Andrushchenko

Biological effectiveness of herbicides in winter wheat crops of autumn sowing 50

N. Shpyrka, S. Tanchyk, O. Pavlov, A. Babenko

Impact of agricultural and tillage systems on the main pests of winter wheat 60

R. Topko, H. Kovalyshyna, G. Vologdina, O. Gymenyk

Spectral assessment of varieties and breeding lines of winter wheat during the restoration of spring vegetation 68

L. Murashko, T. Mukha, H. Kovalyshyna, Yu. Dmytrenko

Characteristics of the source material resistant to Fusarium head blight and root rot for the selection of winter wheat..... 80

S. Bulygin, S. Vitvitskyy, M. Bulygina, O. Vitvitska

Mode of moistening ordinary chernozem using the “no-till” technology 91

E. Dehodyuk, S. Dehodyuk, Yu. Borko, O. Litvinova, Yu. Ihnatenko, A. Mulyarchuk

Long-term monitoring of aridization in agriculture before and after climate change in Ukraine 102

V. Kovalchuk

Method for obtaining water retention properties of soils by fractions of their granulometric composition..... 115

N. Zelenyanska, O. Gogulinska, N. Podust

Effect of drip irrigation and the load of inflorescences on the growth and development of parent vines 126

B.O. Mazurenko*

PhD, Assistant of the Department of Plant Science
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

S.M. Kalenska

Doctor of Agricultural Sciences, Professor Head of the Department
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

L.M. Honchar

Candidate of Agriculture Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

M.Ya. Hrygirevskiy

Master
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

Formation of productive elements in winter wheat by seed dressing application with slow-release complex fertilisers

Abstract. Optimisation of plant nutrition in the initial stages of development is important for the formation of productive elements of the main and additional shoots and grain yield. The study presents the results of examining the effect of slow-release chlorine-free fertilisers in seed dressing application at the rate of 100 kg/ha on the formation of productive elements in winter wheat compared with the zone control – azophoska 16:16:16 and a variant without fertilisers. Field studies were conducted in 2019-2021 on winter bread wheat varieties Bohdana and Samurai. The fertilisers produced by FertinAgro were examined: DuraSOP with the content of NPK(S) – 9:20:12:(15), 10:10:17:(20), and 4:26:12:(10). It is established that the influence of weather conditions on the variability of grain weight per shoot, grain number per shoot, thousand seed weight substantially exceeded the factors under study in both varieties. The formation of productivity elements under the impact of the examined fertilisers depended on the varieties and manifested themselves in different ways in different weather conditions. DuraSOP fertilisers did not have a substantial difference in the effect on grain number and weight per shoot in the Bohdana variety compared to the control in arid conditions, but grain weight from shoot increased to 1.74-1.78 g compared to the application

Suggested Citation:

Mazurenko, B., Kalenska, S., Honchar, L., & Hrygirevskiy, M. (2021). Formation of productive elements in winter wheat by seed dressing application with slow-release complex fertilisers. *Plant and Soil Science*, 12(4), 7-16. doi: 10.31548/agr2021.04.0007.

*Corresponding author



Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (<https://creativecommons.org/licenses/by/4.0/>)

of azophoska, and grain number per shoot varied insubstantially under favourable conditions. Application of DuraSOP fertilisers in the Samurai variety allowed to form 1.17-1.21 g of grain per shoot under the arid conditions and 1.47-1.49 g – in the favourable conditions, which did not differ substantially from the control. The DuraSOP ActiBION increased the number of productive shoots by 8.4% and DuraSOP Phos – by 7.7% in the Bohdana variety, while only DuraSOP Phos substantially affected the productive shoots in the Samurai variety (an increase of 3.8%). Application of slow-release fertilisers allows for obtaining grain yield of 6.58 to 7.03 t/ha in the Bohdana variety and 6.61-6.80 t/ha in the Samurai variety. Fertilisers have higher efficiency in the Bohdana variety, while there was a substantial increase in the Samurai variety only when DuraSOP Phos was applied (0.31 t/ha or 4.8%). The application of slow-release fertilisers also increases the protein content in the grain by 0.3-0.5%. The sensitivity of varieties to different ratios of macronutrients in pre-sowing fertilisers is one of the elements of technology that have a high impact on wheat cultivation, so the use of effective forms can increase yields up to 11.4% compared with typical fertilisers

Keywords: yield, protein content, standing density, variety, thousand seed weight

INTRODUCTION

Growing high and sustainable yields and obtaining quality grain are the basis of profitable grain production in Ukraine. The productivity of cereals has already reached a plateau and its growth rate has slowed substantially compared to the second half of the 20th century. Improving the elements of technology adapted to the variety is the key to increasing wheat productivity in the last decade in Ukraine (Popov *et al.*, 2014). Optimisation of the fertiliser system and some most sensitive elements are the basis for increasing the productivity of cereals at low additional costs (Barabolia *et al.*, 2018).

World experimental data shows that the productivity potential of winter wheat can be extremely high (Hatfield & Beres, 2020). The biological potential of productivity of modern winter wheat varieties reaches 24.6 t/ha, but Ukraine's record for yield in cultivation technology was 13.2 t/ha. Grain yields in the countries with the highest average yields (the United Kingdom, Germany, and France) are only half of the officially registered world records, so the optimisation of cultivation technologies remains the main tool for productivity management (Asseng *et al.*, 2020).

It is necessary to optimise the interaction of the two main components to obtain a high wheat yield: a high genetic productive potential and

growing conditions that can ensure its full realisation (Ghane *et al.*, 2009). The main problems of conventional nitrogen fertilisers include unproductive losses (ammonia weathering for amide fertilisers, leaching for nitrate, denitrification and immobilisation of nitrogen), the discrepancy between the rate of nitrogen consumption by plants and its release from fertilisers, and impossibility (or limited possibility) to implement the differential application of nitrogen (Vozhehova & Serhieiev, 2018; Shiwakoti *et al.*, 2020).

ANALYSIS OF RECENT STUDIES AND PAPERS

The cost of mineral fertilisers is already approaching half the cost of cultivation technology for high-yielding wheat varieties. Fertiliser rates should be determined according to soil conditions, the ability of crops to absorb the elements, and, most importantly, the presence of available moisture (Mazurenko *et al.*, 2020). According to a study by J. Lemon (2007), the dominant group of factors influencing the yield, quality, and protein harvest of winter wheat are soil and climatic conditions, nitrogen fertilisers, crop rotation, and varietal characteristics of plants, which in total causes more than 50% of the variation in this indicator (Behdi *et al.*, 2015). The quality and form of nutrients are less important for

the plant than the total amount, but the product quality can be improved by optimising this element of technology, which will affect the selling price (Karabach, 2020). Common wheat (*Triticum aestivum* L.) forms enough protein in grain with high baking quality at high rates of nitrogen fertilisers with a sufficient number of other macro- and micronutrients in an accessible form (Morgun et al., 2010; Rybalka, 2011).

The grain yield of winter wheat and the formation of its productivity during the growing season largely depend on the gross supply of nitrogen, phosphorus, and potassium (Hartmann et al., 2015). Methods of applying various fertiliser forms and rates are aimed at optimal and most effective use during the growing season to obtain a high yield with appropriate quality by placing them in the adequate depth of soil (Kalenska et al., 2012). The main methods of fertiliser application are scattering before basic tillage with their subsequent earning, locally in rows, or by scattering under pre-sowing cultivation, in rows during sowing and foliar fertilisation (Shyrynian et al., 2006).

Purpose of the study. Establish the influence of sowing ultra-local application of slow-release complex fertilisers on the elements of crop structure and winter wheat productivity.

MATERIALS AND METHODS

The field experiment was conducted during 2

growing seasons of winter crops at a Separated subdivision of the National University of Life and Environmental Sciences of Ukraine “Agronomic Research Station”,

The average air temperature was +8.5°C in the first growing season (2019-2020), but it was +7.2°C in the second (2020-2021), which substantially exceeded the perennial values (+5.8°C). Years were contrasting in terms of moisture because precipitations during the winter wheat vegetation were 213.5 mm in the first year (46.7% of the perennial value) and 504.6 mm (110% of the perennial value) in the second year.

The soil of the experimental field is typical low-humus (humus content is 4.04%). The predecessor crop is peas. Each variant has four replications. The cultivation system is classic fallow. The fertilising system provided the pre-sowing application of 200 kg/ha of diammophos ($N_{20}P_{52}K_{52}$). The application of 200 kg/ha of ammonium nitrate (N_{69}) in tillering stage (BBCH 31-38) was conducted. The sowing rate was 450 pcs/m², the inter-row space was 19 cm, the depth of seed wrapping was 4-6 cm, and the sowing period was the third decade of September. Seeds were treated with Kinto Duo (2.5 l/t). Crop protection included 2 sprayings by fungicide Abacus (1.5 l/ha) and a single application of insecticide Fastak (0.1 l/ha).

The experimental scheme and the characteristics of fertilisers are shown in Table 1.

Table 1. Scheme of the field experiment

Factor A Variety	Factor B Seed dressing, 100 kg/ha physical weight	Fertilise characteristics and nutrient content, %			
		N	P ₂ O ₅	K ₂ O	Other
A1. Bohdana	B1. Without fertilisers	–	–	–	–
	B2. Azophoska (control)	16	16	16	SO ₃ – 6
	B3. DuraSOP ActiBION	9	20	12	SO ₃ – 15
A2. Samurai	B4. DuraSOP Elite	10	10	17	SO ₃ – 20
	B5. DuraSOP Phos	4	26	12	SO ₃ –10

The impact of FertinAgro fertilisers (Spain) on wheat productivity was assessed in comparison with the control of azophoska. FertinAgro fertilisers are made by DuraSOP technology – slow-release chlorine-free fertilisers containing potassium sulfate.

Elements of crop yields were determined by generally accepted methods. Thousand seed weight, grain weight per shoot, and grain yield are calculated based on a moisture content of 14%. The difference between the variants was determined by ANOVA and post-hoc Fisher's LSD₀₅.

RESULTS

It was identified that the form of fertilisers affects certain elements of wheat productivity during research. The effect of fertilisation on the

grain number per shoot, grain weight per shoot, thousand seed weight, and wheat yield were studied.

The grain number per shoot (Fig. 1) is the most variable yield element in the experiment. It was influenced by weather conditions and varietal characteristics, and in some cases, the fertiliser forms. The Bohdana variety formed 26.3 grains/shoot in 2020, but this parameter increased substantially in 2021 (36 grains/shoot). The Samurai variety had a lesser variation of this parameter it formed 28.3 and 32.7 grains per shoot in 2020 and 2021, respectively. From this case, it can be concluded that the Bohdana variety is better adapted to improving growing conditions than the Samurai variety in the "grain number per shoot" parameter.

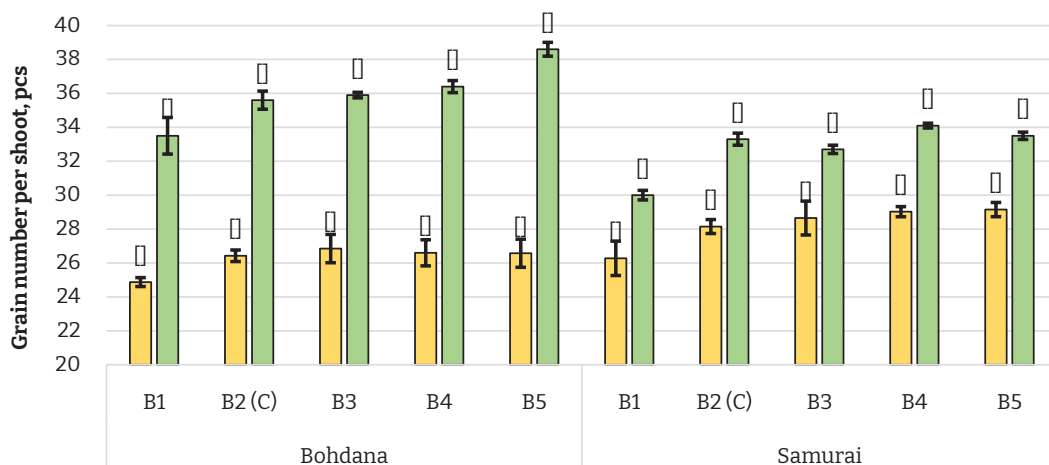


Figure 1. Grain number per shoot

On other hand, all fertilisers had a substantial positive effect on grain number per shoot compared to the variant without their application, but a case of small amounts was better than the control. DuraSOP Elite and DuraSOP Phos substantially increased this parameter in the Sumurai variety in 2020, but DuraSOP fertilisers had not a substantial effect compared to azophoska in the Bohdana variety this year.

The situation changed in 2021 with a sufficient level of precipitations. DuraSOP Phos was

more effective in terms of grain number per shoot than the control in the Bohdana variety, but there was no difference between the fertilisers in cv Samurai in 2021.

Grain weight per shoot (Fig. 2) also varied greatly. According to our research, it was identified that on average over two years the application of DuraSOP fertilisers led to an increase in grain weight per shoot compared to the application of azophoska for seed dressing, but their effectiveness was different in some years and certain varieties.

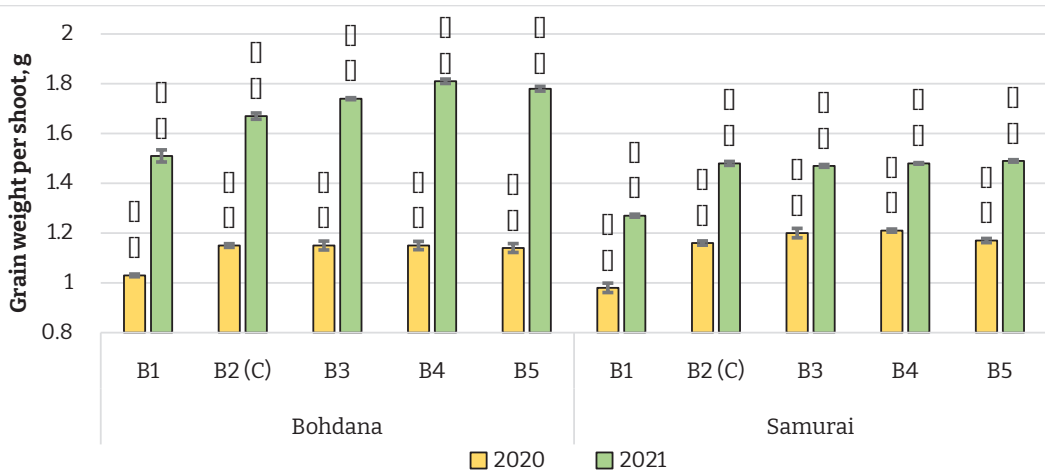


Figure 2. Grain weight per shoot (g) in 2020 and 2021

Grain weight per shoot substantially depended on the weather conditions of the year in both varieties. Notably, there was a tendency for a substantial increase in this parameter in the Bohdana variety with an improvement of the moisture regime in 2021, when this figure averaged 1.70 g against 1.12 g in 2020. The Samurai variety had a lesser gap in grain weight per shoot, it increased from 1.14 to 1.44 g as weather conditions improved.

Sowing without fertilisers led to a decrease in grain weight per shoot compared to the control (azophoska) by 0.15 g (10.6%) in the Bohdana variety and by 0.20 g (15.2%) in the Samurai variety. Application of DuraSOP fertilisers resulted in an increase in the grain weight per shoot

from 2.8 to 5% in the Bohdana variety and from 0.08 to 3% in the Samurai variety on average for two years. Notably, this increase was substantial when using all DuraSOP fertilisers compared to azophoska in the Bohdana variety, but only DuraSOP Elite had a substantial effect on this parameter in the Samurai variety. In both cases, DuraSOP Elite gave the highest increase in grain weight per shoot.

Thousand seed weight (Fig. 3) also differed in varieties, years, and fertiliser forms. Thousand seed weight (TSW) was 42.8 g in the Bohdana variety in 2020, and it was 47.3 g in 2021, while TSW was 40.4 and 43.9 g in the Samurai variety in these years.

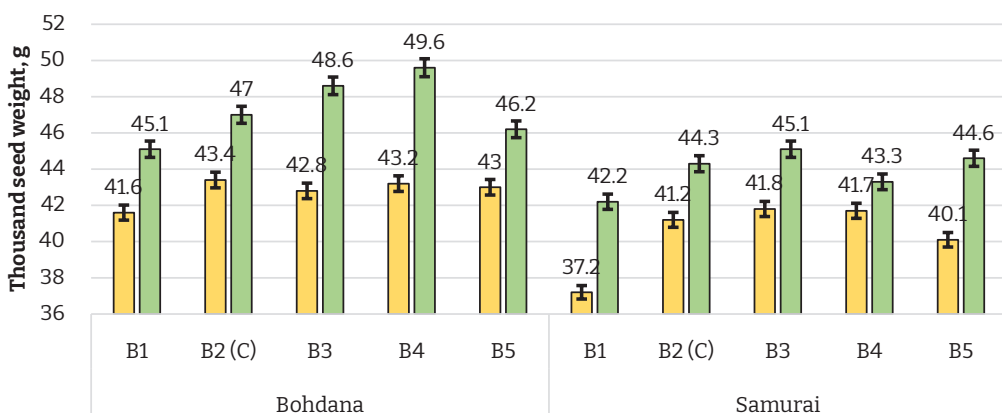


Figure 3. Thousand seed weight in 2020 and 2021 (g)

Fertilisers had a positive effect on thousand seed weight in both years of research. There was no substantial difference between fertilisers in the Bohdana variety in 2020, including azophoska, while DuraSOP ActiBION and DuraSOP Elite increased this figure to 48.6 and 49.6 g, respectively, in 2021, which is substantially more than in the control variant. On another side, these two brands did not have a substantial difference compared with the control in the Samurai variety in 2020, but the application of DuraSOP Phos decreased the thousand seed weight to 40.1 g this year. The difference between the fertilisers in terms of influence on this parameter in 2021 was insubstantial.

Standing density is formed throughout the growing season. The largest number of shoots is observed at the beginning of the jointing phase (BBCH 31), after which weak shoots begin to die off. The number of shoots that formed the grains and those that did not differ insubstantially, but the reduction may occur at the level of formation of the organs in the shoot and fertilisation in the anthesis.

There was no substantial difference in the productivity of the main and side shoots, and the number of low-yielding shoots was insubstantial, so the standing density can be analysed in one array (Table 2).

Table 2. Standing density of winter wheat (shoots/m²)

Variety	Seed dressing	Year		Average per 2020-2021	Increase compared with control	
		2020	2021		t/ha	%
Bohdana	B1. Without fertilisers	417	402	410	-42	-9,3
	B2. Azophoska (c)	477 ^{ab}	427 ^b	452 ^a	0	0
	B3. DuraSOP ActiBION	512 ^{eh}	468 ^c	490 ^{bc}	38	8,4
	B4. DuraSOP Elite	473 ^a	428 ^b	451 ^a	-1	-0,2
	B5. DuraSOP Phos	513 ^{eh}	460 ^c	487 ^{bc}	35	7,7
Samurai	B1. Without fertilisers	490 ^{bcd}	465 ^c	478 ^b	-16	-3,2
	B2. Azophoska (c)	500 ^{de}	488 ^d	494 ^c	0	0
	B3. DuraSOP ActiBION	505 ^{de}	488 ^d	496 ^c	2	0,5
	B4. DuraSOP Elite	498 ^{cde}	487 ^d	493 ^c	-1	-0,2
	B5. DuraSOP Phos	531 ^h	495 ^d	513	19	3,8
LSD ₀₅		10	15	13	-	-

Sowing without fertilisers led to a decrease in the number of productive shoots by 9.3% in the Bohdana variety and 3.2% in the Samurai variety on average for two years. Therewith, the application of DuraSOP fertilisers had almost no effect on the number of productive shoots compared to the variants where azophoska was applied, except for DuraSOP ActiBION and DuraSOP Phos in the Bohdana variety. The increase in the number of shoots in these variants was 7.7-8.4%, while the number of shoots increased substantially in the

Samurai variety only with the application DuraSOP Phos (3.8%). The impact of fertilisers on the standing density was similar in these varieties in 2019 and 2020. The grain yield of winter wheat was formed based on the elements of the crop structure, depending on all factors, including weather conditions. On average, according to the results of the experiment, the Bohdana variety formed 5.39 t/ha of grain in 2020 and 7.46 t/ha in 2021, while the Samurai variety formed 5.77 and 6.97 t/ha, respectively (Table 3).

Table 3. Grain yield of winter wheat

Variety	Seed dressing	Year		Average per 2020-2021	Increase compared with control	
		2020	2021		t/ha	%
Bohdana	B1. Without fertilisers	4.32	6.08	5.20	-1.11	-18.6
	B2. Azophoska (c)	5.47	7.15	6.31	-	-
	B3. DuraSOP ActiBION	5.88	8.17	7.03	0.72	11.4
	B4. DuraSOP Elite	5.44	7.73	6.58	0.27	4.3
	B5. DuraSOP Phos	5.86	8.20	7.03	0.72	11.4
Samurai	B1. Without fertilisers	4.79	5.89	5.34	-1.15	-17.7
	B2. Azophoska (c)	5.79	7.20	6.49	-	-
	B3. DuraSOP ActiBION	6.05	7.19	6.62	0.13	2.0
	B4. DuraSOP Elite	6.02	7.19	6.61	0.11	1.7
	B5. DuraSOP Phos	6.21	7.40	6.80	0.31	4.8
LSD ₀₅		0.34	0.54	0.23	-	-

Grain yield in the Bohdana variety in the control variant (azophoska) was 6.31 t/ha on average for two years, while it was only 5.2t/ha without pre-sowing fertilisation that is 1.11 t/ha less, i.e. yield reduction was 18.6%. Application of DuraSOP fertilisers substantially increased grain yield – by 0.27 t/ha with DuraSOP Elite (an increase of 4.3%) and 0.72 t/ha (an increase of 11.4%) with DuraSOP ActiBION and DuraSOP Phos, respectively. Notably, the application of DuraSOP Elite did not result in a substantial difference compared with the control in 2020, it only slightly exceeded LSD₀₅ in 2021.

The variability of grain yield in the Samurai variety differed from the Bohdana variety under influence of DuraSOP fertilisers. Sowing without fertilisers led to a decrease in yield by an average of 1.15 t/ha (17.7% decrease) compared to the variant with azophoska application, but the application of DuraSOP Elite and DuraSOP ActiBION slightly in-

creased the average yield compared to the control. A substantial increase in grain yield in the Samurai variety was only in a variant with the application of DuraSOP Phos when the increase was 0.31t/ha, i.e. 4.8%, compared with the control.

The protein content of winter wheat in all experimental variants was determined and protein output was calculated (Table 4). It is known that drier conditions contribute to the formation of higher protein content in grains, which is confirmed by the results of the experiment. Application of DuraSOP fertilisers allowed obtaining a high protein content in the grain (14.3-14.5%) in the Bohdana variety in 2020, so according to this indicator it can be classified as the first class, while the Samurai variety formed the grain of the second class in all variants (lesser than 14%), including without fertiliser, but the application of DuraSOP increased the protein content compared with the control variant.

Table 4. The protein content of winter wheat

Variety	Seed dressing	Year	
		2020	2021
Bohdana	B1. Without fertilisers	13.0	12.7
	B2. Azophoska (c)	13.9	13.4
	B3. DuraSOP ActiBION	14.3	13.6
	B4. DuraSOP Elite	14.3	14.1
	B5. DuraSOP Phos	14.5	14.4
Samurai	B1. Without fertilisers	13.0	12.4
	B2. Azophoska (c)	12.7	12.2
	B3. DuraSOP ActiBION	13.2	12.8

Table 4. Continued

Variety	Seed dressing	Year	
		2020	2021
Samurai	B4. DuraSOP Elite	13.0	12.7
	B5. DuraSOP Phos	13.3	12.9
LSD ₀₅		0.5	

Weather conditions in 2021 were more favourable, but the protein content was lower, which is known to be due to the negative correlation between yield and protein content. Therefore, the grain of the first class in the Bohdana variety this year was formed only in the variants of DuraSOP Elite and DuraSOP Phos fertilisers (14.1 and 14.4% of protein, respectively), while the protein content in the Samurai variety corresponded to the second class in the variants with the application of DuraSOP fertilisers. Application of azophoska or sowing without fertilisers contributed to the formation of the grain of the third class (lesser than 12.5% of protein).

CONCLUSIONS

The application of slow-release DuraSOP fertilisers in seed dressing substantially increases

grain weight per shoot and the standing density of plants compared to the application of azophoska in the Bohdana variety. Therewith, only DuraSOP Phos has a substantial effect on increasing yields in the Samurai variety, mainly due to the increase in the density of shoots. This difference is due to the different areas of application and the specific features of the productivity formation in varieties under study as the Samurai variety produces less protein, and its requirements for the fertiliser system and the ratio of nutrients will be different.

Each variety of common winter wheat has its requirements for the ratio of nutrients in the seed dressing application of fertilisers, so further research is relevant given the optimisation of cultivation technologies adapted to the variety.

REFERENCES

- [1] Asseng, S., Guarin, J.R., Raman, M., Monje, O., Kiss, G., Despommier, D.D., ... & Gauthier, P. P. (2020). Wheat yield potential in controlled-environment vertical farms. *Proceedings of the National Academy of Sciences*, 117(32), 19131-19135. doi: <https://doi.org/10.1073/pnas.2002655117>
- [2] Barabolia, O.V., Barat, Yu.M., Kulyk, M.I., & Onoprienko, O. V. (2018). Crop capacity of winter wheat depending on fertilization system and weather conditions of a vegetation period. *Bulletin of Uman National University of Horticulture*, (2), 3-9. doi: <http://dx.doi.org/10.31395/2310-0478-2018-21-3-9>
- [3] Benbi, D.K., Kiranvir, B.R.A.R., & Sharma, S. (2015). Sensitivity of labile soil organic carbon pools to long-term fertilizer, straw and manure management in rice-wheat system. *Pedosphere*, 25(4), 534-545. doi: [https://doi.org/10.1016/S1002-0160\(15\)30034-5](https://doi.org/10.1016/S1002-0160(15)30034-5)
- [4] Ghane, E., Feizi, M., Mostafazadeh-Fard, B., & Landi, E. (2009). Water productivity of winter wheat in different irrigation/planting methods using saline irrigation water. *International Journal of Agriculture and Biology*, 11(2), 131-137.
- [5] Hartmann, T. E., Yue, S., Schulz, R., He, X., Chen, X., Zhang, F., & Müller, T. (2015). Yield and N use the efficiency of a maize-wheat cropping system as affected by different fertilizer management strategies in a farmer's field of the North China Plain. *Field Crops Research*, 174, 30-39. doi: <https://doi.org/10.1016/j.fcr.2015.01.006>
- [6] Hatfield, J. L., & Beres, B. L. (2019). Yield gaps in wheat: path to enhancing productivity. *Frontiers in plant science*, 10, 1603. doi: <https://doi.org/10.3389/fpls.2019.01603>
- [7] Kalenska, S., Kalenski, V., Kachura, I., Gonchar, L., & Matvienko, A. (2012). Role of fertilizers and growth regulators in the improvement of winter wheat resistance to stress and yield. In *Nährstoff- und Wasserversorgung der Pflanzenbestände unter den Bedingungen der Klimaerwärmung: Internationale wissenschaftliche Konferenz* (pp. 65-71).

- [8] Karabach, K. (2020). Yield capacity and quality indicators of winter wheat depending on systems of basic treatment of soil and fertilizer. *Scientific journal "Plant and Soil Science"*, 10(3), 42-48. doi: <http://dx.doi.org/10.31548/agr2019.03.042>
- [9] Lemon, J. (2007) Nitrogen management for wheat protein and yield in the Esperance Port zone. Bulletin 4707, Department of Agriculture and Food, Australia, 1-27.
- [10] Mazurenko, B., Kalenska, S., Honchar, L., & Novytska, N. (2020). Grain Yield Response of Facultative and Winter Triticale for Late Autumn Sowing in Different Weather Conditions. *Agronomy Research*, 18, 183-193. doi: <https://doi.org/10.15159/ar.20.008>
- [11] Morgun, V.V., Schwartz, V.V., & Kiriziy, D.A. (2010). Physiological fundamentals of grain cereals high productivity forming. *Physiology and Biochemistry of Cultivated Plants*, 42(5), 371-392.
- [12] Popov, S. I., Fursova, G. K., & Avramenko, S. V. (2014). Formation of grain yield by intense varieties of winterspiked crops after predecessors sunflower and soybean. *Plant Breeding and Seed Production*, 106, 163-169. doi: <https://doi.org/10.30835/2413-7510.2014.42147>
- [13] Rybalka, O.I. (2011). Yakist pshenytsi ta yii polipshennia: monohrafiia [Wheat quality and its improvement: monograph]. Kyiv: Lohos.
- [14] Shiwakoti, S., Zheljzakov, V.D., Gollany, H.T., Kleber, M., Xing, B., & Astatkie, T. (2020). Macronutrient in soils and wheat from long-term agroexperiments reflects variations in residue and fertilizer inputs. *Scientific reports*, 10(1), 1-9. doi: <https://doi.org/10.1038/s41598-020-60164-6>
- [15] Shyrynian, M., Buhaievskiy, V., Kildiushkyn, V., & Soldatenko, A. (2006). Systema udobrennia ozymykh kolosovykh v enerhozberihaiuchykh tekhnolohiiakh. *Ahronom*, 3, 104-106.
- [16] Vozhehova, R.A., & Serhieiev, L.A. (2018). Formation of elements of seed productivity of winter wheat depending on fertilization and protection of plants in the conditions of the south of Ukraine. *Multiagency subject scientific collection "Irrigated farming"*, 69, 95-99.

Б.О. Мазуренко

Кандидат біологічних наук, асистент кафедри рослинництва
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

С.М. Каленська

Доктор сільськогосподарських наук, професор, завідувач кафедри
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

Л.М. Гончар

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

М.Я. Григоревський

Магістр
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

Формування елементів продуктивності пшениці озимої за приписівного внесення повільнодіючих комплексних добрив

Анотація. Оптимізація живлення рослин на початкових етапах розвитку має важливе значення для формування елементів продуктивності головного та бічних пагонів і врожаю зерна. У статті представлено результати дослідження впливу повільнодіючих безхлорних добрив у приписівне внесення в нормі 100 кг/га на формування елементів продуктивності

пшениці озимої порівняно з зональним контролем – нітроамофоскою 16:16:16. Для вирішення поставлених завдань закладався польовий дослід у 2019-2021 рр. на двох сортах пшениці м'якої озимої – Богдана та Самурай. Вивчалися комплексні повільнодіючі добрива NPK(S) виробництва FertinAgro (Іспанія) марки DuraSOP ActiBION 9:20:12:(15), DuraSOP Elite 10:10:17:(20), DuraSOP Phos 4:26:12:(10). Вплив погодних умов на формування таких елементів продуктивності пшениці озимої, як маса зерна з колоса, кількість зерен у колосі й маса 1000 зерен, суттєво перевищував досліджувані чинники в обох сортів. Формування елементів продуктивності за впливу досліджуваних добрив залежало від сортів і по-різному проявлялося в різних погодних умовах. Добрива DuraSOP не мали суттєвої різниці у впливі на кількість і масу насіння з колосу у сорта Богдана порівняно з контролем у посушливих умовах, але маса насіння з колоса суттєво зростає порівняно з контролем (від 1,67 до 1,74-1,78 г) за сприятливих умов, тоді як кількість зернівок суттєво не різнилася. Форма добрив у припосівне внесення в сорт Самурай немала істотного впливу, оскільки за посушливих умов формувалося 1,17-1,21 г зерна в колосі, а за сприятливих 1,47-1,49 г, що суттєво не відрізнялося від контролю (нітроамофоска). Застосування DuraSOP ActiBION дозволило збільшити кількість продуктивних стебел на момент збирання на 8,4 % порівняно з контролем і на 7,7 % у сорті Богдана у разі застосування DuraSOP Phos. Сорт Самурай слабше реагував на повільнодіючі добрива, тому суттєва різниця була лише у варіанті DuraSOP Phos коли кількість продуктивних стебел. За різностороннього впливу на формування елементів продуктивності всі досліджувані повільнодіючі добрива суттєво впливали на формування врожаю зерна у сорту Богдана – у середньому урожайність на цих варіантах становила від 6,58 до 7,03 т/га (приріст 0,27-0,72 т/га), тоді як на контрольному варіанті формувалося 6,31 т/га зерна. Водночас у сорта Самурай приріст від заміни нітроамофоски на повільнодіючі форми добрив становив 0,11-0,31 т/га, тобто суттєве збільшення урожайності було лише за застосування DuraSOP Phos, що дало можливість отримати 6,80 т/га зерна, тобто приріст становив 4,8 % від контролю (6,49 т/га). Використання повільнодіючих добрив також дало змогу збільшити вміст білка в зерні на 0,3-0,5 %, що загалом є несуттєвим приростом, але в окремих випадках дає змогу підвищити клас зерна під час реалізації. Сортова реакція на різне співвідношення макроелементів у добривах для припосівного внесення є одним з елементів технології, які мають високий вплив на продуктивність пшениці та її розвиток на початкових етапах, тому використання ефективних форм дає можливість підвищити врожайність до 11,4 % порівняно з типовими комплексними добривами

Ключові слова: урожай, вміст білка, густина стояння, сорт, маса 1000 зерен

L.A. Garbar*

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

N.V. Knap

PhD in Agricultural Sciences
Mukachevo Vocational College of the National University of Life
and Environmental Sciences of Ukraine
9600, 32 Tomas Masaryk Str., Mukachevo, Ukraine

The realisation of the genetic potential of sunflower hybrids under the influence of feeding conditions

Abstract. The use of microfertilisers against the background of the main fertiliser helps to increase the efficiency of using nutrients of mineral fertilisers and soil by plants, which ensures an increase in yield and an improvement in the quality indicators of the grown crop. The purpose of the study was to establish the influence of crop nutrition conditions and select highly productive hybrids (NK Diamantis, SI Kupava, NK Neoma) for specific soil and climatic conditions through the formation of their productivity. Field studies were conducted during 2018-2019 on typical low-humus chernozems of the Chernihiv region. The study programme provided for the laying of a three-factor field experiment, in which hybrids (factor A) fertiliser options (Factor B), and foliar top dressing (factor C) were examined in the phases of 4 and 8 sunflower leaves with Ecoline Boron, Nertus Boron, Bast Boron products. Sunflower hybrids under study are NK Diamantis, SI Kupava, and NK Neoma. Studies showed that the most productive was the SI Kupava hybrid with the maximum yield indicator in the option with the application of $N_{36}R_{56}K_{108}S_{28} + N_{23} + \text{Ecoline Boron}$ (in the phases of 4 and 8 leaves of 1 l/ha) – 3.46 t/ha. The fat content in sunflower seeds was determined by the morphobiological features of the hybrid and fertiliser options. The use of foliar top dressing with microelements had a positive effect on the fat content in the seeds of sunflower hybrids, which allowed obtaining the maximum indicator in the option with the application of $N_{36}R_{56}K_{108}S_{28} + N_{23} + \text{Ecoline Boron}$ (5-6 leaves) in plants of the SI Kupava hybrid – 51.1%. The maximum content of oleic acid was identified in the SI Kupava hybrid in the option with added $N_{27}R_{42}K_{81}S_{21} + N_{23} + \text{Ecoline Boron}$ (5-6 leaves) – 77.2%. Due to the use of fertilisers containing boron, the content of this polyunsaturated acid can be increased, improving the quality indicators of sunflower seed oil. The highest oil yield, according to the

Suggested Citation:

Garbar, L., & Knap, N. (2021). The realisation of the genetic potential of sunflower hybrids under the influence of feeding conditions. *Plant and Soil Science*, 12(4), 17-27. doi: 10.31548/agr2021.04.017.

*Corresponding author



Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (<https://creativecommons.org/licenses/by/4.0/>)

calculations performed, was obtained in the option with the application of $N_{36}R_{56}K_{108}S_{28}+N_{23}$ + Ecoline Boron (5-6 leaves) in plants of the SI Kupava hybrid, which amounted to 1.64 tonnes per 1 hectare

Keywords: sunflower; hybrids; nutrients; Boron; Ecoline Boron; Nertus Boron; Bast Boron; yield; fat content; protein content; oleic acid content

INTRODUCTION

Today, sunflower has become a conventional crop for modern agricultural business in Ukraine. This is mainly due to the stable demand of foreign markets for sunflower oil, which led to the formation of attractive purchase prices for producers of the internal market for seeds of the crop, which contributed to the expansion of acreage and the introduction of modern technologies for its cultivation. It is for this reason that the culture remains attractive to producers.

Factors that can ensure the formation of high crop yields include plant nutrition conditions throughout the growing season and technological measures aimed at realising the genetic potential of the crop in certain regions of Ukraine. It is necessary today to thoroughly examine the potential possibilities of hybrids and varieties for cultivating them in different growing conditions to identify their competitiveness and popularise them, which will increase the quality and yield indicators of the crop in general (Eremenko, O., Kalenska, S., & Pokoptseva, L. *et al.*, 2019; Ieremenko, O. & Kalitka, V., 2016).

That is why today much attention is paid to examining the influence of feeding conditions on the formation of productivity of hybrids, both foreign and Ukrainian selection, in specific soil and climatic conditions of Ukraine (Kalenska, Ryzhenko & Novytska *et al.*, 2020; Domaratskiy, Bazaliy *et al.*, 2018).

The efficiency of oilseed production in Ukraine in recent years has led to problems associated with the oversaturation of sunflower crop rotations. An increase in the production of sunflower seeds can be conducted due to the improvement of elements of its cultivation technology, and the rational use of fertilisers is important for it. The effectiveness of applying mineral fertil-

isers on sunflower crops in different agroclimatic zones varies (Havryliuk, 2007; Totskyi, 2014).

ANALYSIS OF RECENT STUDIES AND PAPERS

Recently, a substantial number of sunflower varieties and hybrids with high productivity potential have been added to the State register of plant varieties suitable for distribution in Ukraine. However, the realisation of this potential occurs only partially (Ieremenko, Kalitka & Kalenska, 2017; Bondarenko, Korytnyk & Pysmennyi, 2002).

Technological processes for growing a crop are determined by the characteristics of its variety or hybrid, agrobiological features, which include requirements for growing conditions and information about the influence of the crop on soil properties, depending on the characteristics of biology and agricultural technology.

Along with this, preference for growing sunflower seeds is given to hybrids of foreign selection. The advantages of the seed material of these hybrids are the ability to form high crop productivity. However, it should be considered that these hybrids are inferior to the resistance of Ukrainian ones to a number of pathogens characteristic of the climatic conditions of sunflower-growing regions in Ukraine. Features of the formation of productivity of hybrids and varieties of crops, their plasticity and adaptability to soil and climatic conditions are the determining factor in the case of their choice (Alves *et al.*, 2017).

The selection of varieties and hybrids, the features of the formation of reproductive organs of the crop and the quality indicators of the formed seeds are considered (Markova, 2011; Havryliuk *et al.*, 2007).

Auxiliary elements in crop cultivation technologies have now become relevant to increase sunflower productivity, in particular, seed inoculation with microbial-based preparations, and foliar top dressing with biologics and microfertilisers. The preference is often given to complex fertilisers with a full set of nutrients necessary to create optimal conditions for plant nutrition at certain stages of their growth and development (Bailly *et al.*, 2016; Calvo, Nelson, Klopper, 2014; Domaratsky & Dobrovolsky 2018; Yeremenko & Kalytka, 2016; Luhmenev, 2015).

The effectiveness of mineral fertilisers depends both on the ratio of nutrients and on their forms. With the same amount of active substance, different forms of fertilisers provide different results, which is due to the physiological characteristics of fertilisers and plants.

Creating optimal conditions for crop nutrition ensures the formation of an optimal leaf surface area and maximum realisation of the genetic potential of sunflower hybrids and varieties (Kalenska, Gorbatyuk, Garbar, 2020; Helmy & Ramadan, 2009).

The crop fertilisation system is determined considering a number of factors. It should be considered that sunflower plants take substantially higher amounts of nitrogen and phosphorus from the soil compared to other agricultural crops.

Due to the long period of consumption of nutrients, the crop requires a much larger amount of them compared to the group of grain crops.

Notably, sunflowers need a different amount of nutrients at different stages of their growth and development: the overwhelming amount of nitrogen and phosphorus is consumed before the flowering phase and the formation of the leaf apparatus, stems, and root system; after the appearance of baskets, phosphorus absorption decreases sharply; potassium is absorbed by sunflower throughout the growing season.

Food elements have different effects on growth, development, crop formation, and product quality: nitrogen enhances growth processes

and promotes the formation of larger baskets. However, excessive nitrogen nutrition leads to an extension of the growing season, and has a negative impact on the processes of oil accumulation in seeds, while increasing the protein content in it. If there is an excess of nitrogen and a sufficient amount of moisture, there is a possibility of lodging of plants and their damage by pathogens (Phomopsis, white rot, etc.) (Melnyk, Stepanenko, 2000; Shakaliy, 2017).

Sunflowers need phosphorus from germination to flowering. The element accumulates before the flowering phase in the stem and leaves, and later it moves to generative organs. Plants absorb up to 70% of their phosphorus needs during the basket formation period – the end of flowering. The lack of phosphorus has a negative impact on the formation and filling of achenes and limits the productivity of sunflower seeds. Phosphorus increases the drought resistance of plants and the oil content of seeds, ensures the formation of a powerful root system, and promotes the laying of reproductive organs.

Enhanced phosphorous nutrition reduces the water consumption coefficient of sunflower plants (Yeremenko *et al.*, 2017; Buldykova, Sheudzhen & Bondareva, 2015).

The purpose of the study is to establish the influence of factors that were examined on the formation of yield and quality indicators of sunflower hybrid seeds.

MATERIALS AND METHODS

Studies were conducted during 2018-2019 on typical low-humus chernozems in the conditions of the Chernihiv region.

In accordance with this goal, a study programme and a field experiment scheme were developed (Table 1). The scheme of the experiment included the examination of hybrids (factor A), fertiliser options (Factor B), and the use of foliar top dressing of crops (factor C) in the phases of 4 and 8 sunflower leaves.

Table 1. Formation of sunflower productivity elements (experiment scheme)

Hybrids (factor A) / option designation	Fertiliser options (Factor B) / option designation	Foliar use of protective products (factor C) / option designation
1. NK Diamantis, 2. SI Kupava, 3. NK Neoma	1. $N_{27}R_{42}K_{81}S_{21}+N_{23}$; 2. $N_{36}R_{56}K_{108}S_{28}+N_{23}$	1. Ecoline Boron; 2. Nertus Boron; 3. Bast Boron

Microfertiliser Ecoline Boron organic (nitrogen (N-NH₂) boron (B) – 15.5%) is a liquid boron fertiliser for foliar top dressing containing boron in the form of an organic compound. Provides stress and cold resistance for plants. The rate of foliar application is 1-2 l/ha.

Microfertiliser Nertus Boron (150 g/l (boron-ethanolamine) provides an increase in the yield and resistance of the plant to stress, bacterial damage. The rate of foliar application is 1-1.5 l/ha. Bast Boron (B (200 g/L); N (70 g/L) – provides drought resistance of crops, prevents diseases that occur as a result of boron deficiency, increases yield and improves product quality indicators. The rate of foliar application is 1-2 l/ha.

The registered area is 50 m² with a four-fold repetition. The placement of land plots is systematic (Rozhkov, A.O., Puzik, V.K., & Kalenska, S.M., 2016). The seeding rate is 50 thousand germinating seeds/ha. Fertilisers $N_{27}R_{42}K_{81}S_{21}$ and $N_{36}R_{56}K_{108}S_{28}$ were applied during pre-sowing cultivation, N_{23} – during sowing. Top dressing was conducted twice by foliar application of Ecoline Boron, Nertus Boron, and

Bast Boron in phases 4 and 8 leaves at the rate of 1 l/ha. Yield determination was conducted using the accounting method, statistical data processing was conducted using the SAS 9,4 programme.

RESULTS AND DISCUSSION

The study programme included investigating the influence of the factors under study on the formation of elements of productivity of sunflower hybrids. After analysing the results obtained, it is noted that providing sunflower plants with the necessary macro – and micro-nutrients during the entire growing season allows for increasing the yield of the crop.

The level of the yield of sunflower hybrids in the experiment depended on the weather conditions of the years of the study, the morphobiological features of the hybrids under study, and the nutritional conditions created by fertiliser options. The results show that in the options without top dressing, the yield varied in the hybrid NK Diamantis from 2.42 to 2.76 t/ha, SI Kupava from 2.71 to 3.12 t/ha, NK Neoma from 2.59 to 2.89 t/ha (Fig. 1).

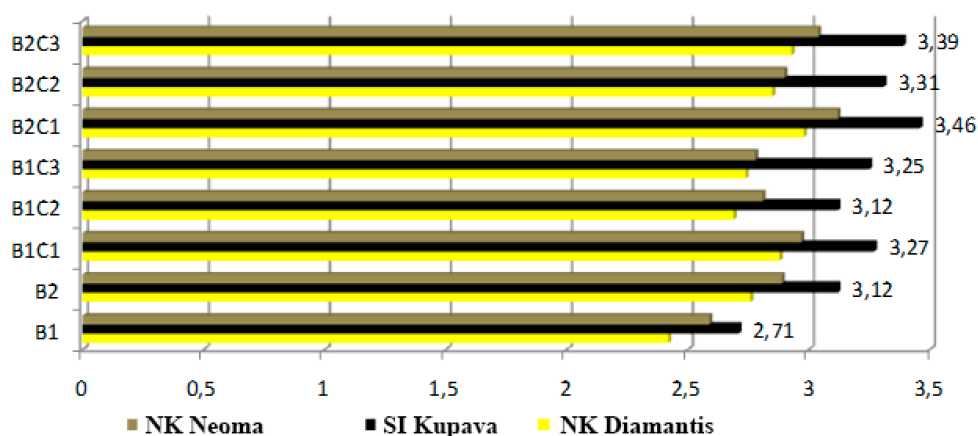


Figure 1. Yield of sunflower hybrids, t/ha

Note: (HIP₀₅ A=0.27; B=0.14; C=0.11; ABC=0.39)

The use of foliar top dressing against the background of the main fertiliser with protective preparations with microelements contributed to an increase in the yield growth to the corresponding options of the main fertiliser from 0.46 to 0.56 t/ha in the hybrid NK Diamantis, from 0.56 to 0.71 t/ha in SI Kupava and from 0.38 to 0.52 t/ha in NK Neoma.

The most productive hybrid was SI Kupava with the maximum yield indicator in the option with the application of $N_{36}R_{56}K_{108}S_{28} + N_{23} + \text{Ecoline Boron}$ – 3.46 t/ha.

The conducted studies allow stating a positive strong correlation $r = 0.93$ in the relationship between the yield of the SI Kupava sunflower hybrid and the fertiliser option (Fig. 2).

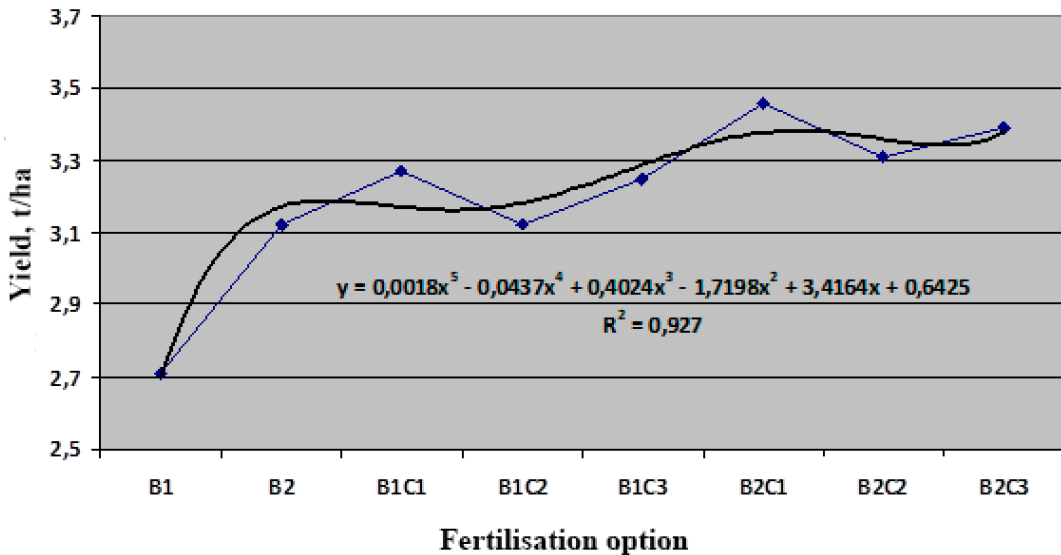


Figure 2. Yield formation model and correlation between yield and fertiliser option of SI Kupava sunflower hybrid

Based on regression analysis, it was identified that yield changes have a polynomial curve type and the yield of a medium-ripened Sunflower hybrid SI Kupava (Y) depending on the fertiliser option (X) can be described by the following equation: $y = 0.0018x^5 - 0.0437x^4 + 0.4024x^3 - 1.7198x^2 + 3.4164x + 0.6425$.

An important element of the characteristics of sunflower products is the quality indicators of oilseeds. The concept of quality covers many indicators of physical and chemical origin. Physical indicators include: pericarp ratio, huskiness, size, and volume mass. Chemical indicators include the fat content in achenes and kernels, the protein content in seeds and meal, the content of oleic acid, the ratio of amino acids, and the acid and iodine numbers of oil. This study in-

cluded the assessment of fat and protein content in sunflower seeds. Determination of these indicators allows for characterising the quality of grown oilseeds.

Sunflower oil, unlike others, has a fatty acid composition with a great advantage of oleic acid over others. Conventional varieties and hybrids of sunflower produce oil with a content of 65-70% of oleic acid, and recently created high-oleic forms have a content of this component in the range of 80-90%. Therefore, the most valuable oil is the one that contains the maximum proportion of oleic acid. Notably, due to fertilisers and protective preparations containing microelements, the oil content in the sunflower seed core can be increased in this way to improve the quality of

raw materials. When introducing new varieties and hybrids into production, it is important to consider not only their yield but also the content and output of oil and protein, and the dynamics of their changes under the influence of growing conditions (Horbatiuk, E.M., 2017). The fat content in the seeds of sunflower

hybrids under study depended both on the morphobiological features of the hybrid and on the conditions created by fertiliser options. Analysis of the results obtained showed that the use of foliar top dressing with microelements had a positive effect on the fat content in sunflower hybrid seeds (Table 2).

Table 2. Fat content in sunflower seeds, % (average for 2018–2019)

Fertiliser option	Hybrid		
	NK Diamantis	SI Kupava	NK Neoma
$N_{27}R_{42}K_{81}S_{21}+N_{23}$ (background 1);	49.7	50.1	50.0
$N_{36}R_{56}K_{108}S_{28}+N_{23}$ (background 2);	49.3	49.2	49.1
Background 1 + Ecoline Boron (5–6 leaves)	50.4	50.7	50.6
Background 1 + Nertus Boron (5–6 leaves)	49.8	49.9	49.8
Background 1 + Bast Boron (5–6 leaves)	50.0	50.4	50.3
Background 2 + Ecoline Boron (5–6 leaves)	50.8	51.1	51.0
Background 2 + Nertus Boron (5–6 leaves)	50.2	50.4	50.3
Background 2 + Bast Boron (5–6 leaves)	50.1	50.8	50.7

The maximum indicator was obtained in the option with the application of $N_{36}R_{56}K_{108}S_{28}+N_{23}$ + Ecoline Boron (5–6 leaves) in plants of the SI Kupava hybrid, which corresponded to 51.1%. The

protein content in sunflower seeds depended more on genetic characteristics than the examined factors (Table 3).

Table 3. Crude protein content in sunflower seeds, % (average for 2018–2019)

Fertiliser option	Hybrid		
	NK Diamantis	SI Kupava	NK Neoma
$N_{27}R_{42}K_{81}S_{21}+N_{23}$ (background 1);	17.6	18.0	17.8
$N_{36}R_{56}K_{108}S_{28}+N_{23}$ (background 2);	18.0	18.6	18.4
Background 1 + Ecoline Boron (5–6 leaves)	18.4	18.9	18.7
Background 1 + Nertus Boron (5–6 leaves)	17.8	18.1	17.9
Background 1 + Bast Boron (5–6 leaves)	18.2	18.4	18.2
Background 2 + Ecoline Boron (5–6 leaves)	18.7	19.0	18.8
Background 2 + Nertus Boron (5–6 leaves)	18.2	18.4	18.2
Background 2 + Bast Boron (5–6 leaves)	18.6	18.7	18.5

In Ukraine, there are no standards regarding the optimal size of seeds and their huskiness in various processing methods. Notably, hybrids, unlike varieties, have small seeds with greater huskiness and lower oil content. Therefore, due to the different quality of oilseeds, it is recommended to process them without preliminary hull separation – by direct extraction.

Sowing with high-quality seeds is one of the main agrotechnical measures aimed at growing high yields of agricultural crops. High-quality seed material allows for ensuring proper plant growth without additional energy costs (fertilisers, pesticides), reducing the negative impact of weeds, diseases, pests, and increasing the

yield and quality of the resulting products on this basis, improving the ecological state of the field.

Sunflower oil is characterised by a fatty acid composition with a substantial advantage of oleic acid over others. The most valuable oil is considered to contain the maximum proportion of oleic acid. The results of studies showed that the highest content of oleic acid was identified in the SI Kupava hybrid in the option with the application of $N_{27}R_{42}K_{81}S_{21}+N_{23}$ + Ecoline Boron (5–6 leaves). Due to fertilisers and protective product, the content of this polyunsaturated acid can be increased and thus improve the quality of oil (Table 4).

Table 4. Percentage of oleic acid in sunflower hybrid oil, % (average for 2018–2019)

Fertiliser option	Hybrid		
	NK Diamantis	SI Kupava	NK Neoma
$N_{27}R_{42}K_{81}S_{21}+N_{23}$ (background 1);	72.7	76.1	74.2
$N_{36}R_{56}K_{108}S_{28}+N_{23}$ (background 2);	72.4	75.2	73.5
Background 1 + Ecoline Boron (5–6 leaves)	74.6	77.2	75.9
Background 1 + Nertus Boron (5–6 leaves)	74.1	75.7	75.5
Background 1 + Bast Boron (5–6 leaves)	73.9	75.4	75.3
Background 2 + Ecoline Boron (5–6 leaves)	73.7	76.9	74.7
Background 2 + Nertus Boron (5–6 leaves)	73.3	75.4	74.4
Background 2 + Bast Boron (5–6 leaves)	73.9	75.2	74.0

The total oil yield is an indicator that, on the one hand, is determined by the fat content, and on the other – by the yield. Consequently, even reducing the fat content of sunflower seeds on fertilised backgrounds generally makes it difficult to achieve an increase in the amount of oil per 1 ha.

The highest oil yield, according to calculations, was obtained in the option with the application of $N_{36}R_{56}K_{108}S_{28}+N_{23}$ + Ecoline Boron (5–6 leaves) in plants of the SI Kupava hybrid, which amounted to 1.64 tonnes per 1 hectare (Table 5). Similar calculations were performed to determine protein output (Table 6).

Table 5. Oil yield from 1 hectare of sunflower, t (average for 2018–2019)

Fertiliser option	Hybrid		
	NK Diamantis	SI Kupava	NK Neoma
$N_{27}R_{42}K_{81}S_{21}+N_{23}$ (background 1);	1.20	1.36	1.30
$N_{36}R_{56}K_{108}S_{28}+N_{23}$ (background 2);	1.36	1.54	1.42
Background 1 + Ecoline Boron (5–6 leaves)	1.45	1.66	1.50

Table 5. Continued

Fertiliser option	Hybrid		
	NK Diamantis	SI Kupava	NK Neoma
Background 1 + Nertus Boron (5–6 leaves)	1.34	1.56	1.40
Background 1 + Bast Boron (5–6 leaves)	1.37	1.64	1.40
Background 2 + Ecoline Boron (5–6 leaves)	1.51	1.77	1.59
Background 2 + Nertus Boron (5–6 leaves)	1.43	1.67	1.46
Background 2 + Bast Boron (5–6 leaves)	1.47	1.72	1.54

Table 6. Protein output from 1 ha of sunflower hybrids, t (average 2018–2019)

Fertiliser option	Hybrid		
	NK Diamantis	SI Kupava	NK Neoma
$N_{27}R_{42}K_{81}S_{21}+N_{23}$ (background 1);	0.43	0.49	0.46
$N_{36}R_{56}K_{108}S_{28}+N_{23}$ (background 2);	0.50	0.58	0.53
Background 1 + Ecoline Boron (5–6 leaves)	0.53	0.62	0.56
Background 1 + Nertus Boron (5–6 leaves)	0.48	0.56	0.50
Background 1 + Bast Boron (5–6 leaves)	0.50	0.60	0.51
Background 2 + Ecoline Boron (5–6 leaves)	0.56	0.66	0.59
Background 2 + Nertus Boron (5–6 leaves)	0.52	0.61	0.53
Background 2 + Bast Boron (5–6 leaves)	0.54	0.63	0.56

The maximum indicator was obtained in the option with the application of $N_{36}R_{56}K_{108}S_{28}+N_{23}$ + Ecoline Boron (5–6 leaves) in the SI Kupava hybrid, which was 0.66 tonnes per hectare.

The weather conditions during the growing seasons under study in 2018 were the most favourable for growing sunflower hybrids.

CONCLUSIONS

The results of the study showed that the use of Ecoline Boron, Nertus Boron, Bast Boron preparations twice in the top dressing in phases 4 and 8 of sunflower hybrid leaves against the background of the main fertiliser provided the crea-

tion of favourable conditions for the formation of hybrid productivity elements and contributed to an increase in yield and seed quality indicators.

The highest effect of applying fertilisers was obtained by applying $N_{36}R_{56}K_{108}S_{28}+N_{23}$ and foliar top dressing of Ecoline Boron to plants of the SI Kupava hybrid.

The complex influence of the factors under study ensured the formation of the yield of the SI Kupava hybrid in the option with the application of $N_{36}R_{56}K_{108}S_{28}+N_{23}$ and foliar top dressing of Ecoline Boron (phases 4 and 8 leaves (0.1 l/ha each) with an indicator of 3.46 t/ha and a fat content of 51.1%.

REFERENCES

- [1] Alves, L., Stark, E., Zonta, E., Fernandes, M., Santos, A., & Souza, S. (2017). Different nitrogen and boron levels influence the grain production and oil content of a sunflower cultivar. *Acta Scientiarum Agronomy*, 39(1), 59-66.

- [2] Bailly C., Benamar, A., Corbineau, F., Come, D. (2000). Antioxidant systems in sunflower (*Helianthus annuus L.*) seeds as affected by priming. *Seed Science Research*, 10, 35-42.
- [3] Bondarenko, M.P., Korytnyk, V.M., Pysmennyi, A.H. (2002). Depending on the nutritional conditions, the incidence of diseases and the productivity of sunflower with different fertilization systems. – *Zakhyst roslyn – Plant protection*, 3, 6-7.
- [4] Buldykova, I.A., Sheudzhen, A.Kh., Bondareva, T.N. (2015). *Mikroelementy na posevakh podsolnechnika* [Trace elements in sunflower crops]. *Nauchnyi zhurnal KubGAU – Scientific Journal of KubSAU*. 107(03). 25-29.
- [5] Calvo, P., Nelson, L., Kloepper, J. W. (2014). Agricultural uses of plant biostimulants. *Plant and Soil*. 383. 3-41. DOI: 10.1007/s11104-014-2131-8.
- [6] Carvalho, M.E.A., Castro, P.R. de C.E, Ferraz Junior, M.V. de C., Mendes, A.C.C.M. (2016). Are plant growth retardants a strategy to decrease lodging and increase yield of sunflower? *Comunicata Scientiae*, 7(1). 154-159. DOI: 10.14295/CS.v7i1.1286.
- [7] Domaratskiy, E.O., Bazaliy, V.V., Domaratskiy, O.O., Dobrovolskiy, A.V., Kyrychenko, N.V., & Kozlova, O.P. (2018). Influence of Mineral Nutrition and Combined Growth Regulating Chemical on Nutri-ent Status of Sunflower. *Indian Journal of Ecology*. 45(1), 126-129.
- [8] Domaratskiy, E.O., & Dobrovolskiy, A.V. (2018). Influence of non-root infusions with complex multifunctional preparations on the level and qualitative composition of the chlorophyll complex in sunflower plants. *Ukrainian Black Sea region agrarian science*, 1, 142-151.
- [9] Eremenko, O., Kalenska, S., Pokoptseva, L. & Todorova, L. (2019). The influence of AKM Growth Regulator on Photosynthetic Activity of Oilseed Flax Plants in the Conditions of Insufficient Humidification of the Southern Stepp of Ukraine. *Modern Development Paths of agricultural production*. 03 July. 703-807. doi: 10.1007/978-3-030-14918-5_78 .
- [10] Havryliuk, M.M. (Ed.). (2007). *Oil crops of Ukraine*. Kyiv: Osnova, 416.
- [11] Havryliuk, M.M., Salatenko, V.N., Chekhov, A.V. et al. (2007). *Oil crops of Ukraine*. Kyiv: Osnova, 416.
- [12] Helmy, A.M., & Ramadan, M.F. (2009). Agronomic performance and chemical response of sunflower (*Helianthus annuus L.*) to some organic nitrogen sources and conventional nitrogen fertilizers under sandy conditions. *Grasas Y Aceites*. 60. 55-67. DOI: 10.3989/gya.032508.
- [13] Horbatiuk, E.M. (2017). Produktivnist posiviv soniashnyku [Productivity of sunflower crops]. *Visnyk Poltavskoi derzhavnoi ahrarnoi akademii – Bulletin of the Poltava State Agrarian Academy*, 3, 23-25.
- [14] Ieremenko, O., & Kalitka, V. (2016). Productivity of sunflower hybrids (*Helianthus annuus L.*) under the effect if AKM plant growth regulator in the conditions low moisture of southern Steppe of Ukraine. *IOSR Journal of Agriculture and Veterinary Science*, 9(9), 59-64. doi: 10.9790/2380-0909015964
- [15] Ieremenko, O.A., Kalitka, V., Kalenska, S. (2017). Sunflower productivity under the effect of AKM plant growth regulator in the conditions of the southern steppe of Ukraine. *Agricultural Science and Practice*, 4(1), 11-19. DOI: 10.15407/agris [in Ukrainian].
- [16] Kalenska, S., Ryzhenko, A., Novytska, N., Garbar, L., Stolyarchuk, T., Kalenskiy, V., & Shytiy, O. (2020). Morphological features of plants and yield of sunflower hybrids cultivated in the Northern part of the Forest-Steppe of Ukraine. *American journal of Plant Science*, 11(8). DOI: 10.4236/ajps.2020.118095.
- [17] Kalenska, S.M., Gorbatyuk, E.M., Garbar, L.A. (2020). The role of sowing parameters in sunflower phytometric indicators formation. *Tavriiskiyi naukoviyi visnyk – Taurida Scientific Herald*. 113. 49-55. DOI: 10.32851/2226-0099.2020.113.7.
- [18] Luhmenev, V.P. (2015). Influence of fertilizers, fungicides and growth regulators on sunflower productivity. *Izvestija Orenburgskogo gosudarstvennogo agrarnogo universiteta – Bulletin of the Orenburg State Agrarian University*, 1(51), 41-46.

- [19] Markova, N.V. (2011). Formation of sunflower hybrids efficiency in depending on terms of sowing and methods of struggle against weeds in the conditions of southern steppe of Ukraine. *Ukrainian Black Sea region agrarian science*, 4, 170-175.
- [20] Melnyk, A.V., & Stepanenko, D.M. (2000). *Influence of nitrogen nutrition on confectionery properties of sunflower*. *Visnyk Sumskoho derzhavnogo ahrarnoho universytetu – Bulletin of Sumy State Agrarian University*. 4, 116-121.
- [21] Rozhkov, A.O. (Ed.). (2016). *Doslidna sprava v ahronomii. Knyha 1. Teoretychni aspekty doslidnoi spravy* [Experimental aspects in agronomy. Vol. 1. Theoretical aspects of a research case]. Kharkiv: Maidan.
- [22] Rozhkov, A.O. (Ed.). (2016). *Doslidna sprava v ahronomii. Knyha 2. Statystychna obrobka rezultativ ahronomichnykh doslidzhen* [Experimental case in agronomy. Book 2. Statistical processing of the results of agronomic research]. Kharkiv: Maidan.
- [23] Shakaliy, S.M. (2017). Formation crop yield and quality of sunflower seeds depending on foliar feeding. *Graincrops*, 1(1), 69-74.
- [24] Totskyi, V.M. (2014). *Influence of fertilizer system and basic tillage on the formation of sunflower productivity*. *Naukovo-tekhnichnyi biuleten Instytutu oliinykh kultur NAAN – Scientific and technical bulletin of the Institute of Oilseeds of NAAS*. No. 20, 204-209.
- [25] Yeremenko, O., Kalenska, S., Kiurchev, S., Rud, A., Chynchyk, O., Semenov, O. (2017). Sunflower (*Helianthus annuus L.*) productivity under the effect of plant growth regulator in the conditions of insufficient moisture. *Scientific achievements in agricultural engineering, agronomy and veterinary medicine: [collective monograph]*. Polish – Ukrainian Cooperation. II. 196-217.
- [26] Yeremenko, O.A., Kalytka, V.V. (2016). Influence of PPP on growth, development and formation of sunflower harvest in the conditions of the Southern Steppe of Ukraine. *NUBiP – naukovi dopovidi (elektronne vydannia)*, 1(58), 11.

Л.А. Гарбар

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

Н.В. Кнап

Кандидат сільськогосподарських наук
Мукачівський аграрний коледж Національного університету біоресурсів і природокористування України
9600, вул. Томаша Масарика, 32, м. Мукачево, Україна

Реалізація генетичного потенціалу гібридів соняшнику за впливу умов живлення

Анотація. Застосування мікродобрив на фоні основного удобрення сприяє підвищенню ефективності використання рослинами поживних елементів мінеральних добрив та ґрунту, що забезпечує зростання урожайності та поліпшення показників якості вирощеного урожаю. Метою проведення досліджень було встановлення впливу умов живлення культури та підбір високопродуктивних гібридів (НК Діамантіс, СИ Купава, НК Неома) для конкретних ґрунтово-кліматичних умов через формування їхньої продуктивності. Польові дослідження проводили впродовж 2018-2019 рр. на чорноземах типових малогумусних Чернігівської області. Програмою досліджень передбачалося закладення трифакторного польового досліду, у якому вивчали гібриди (чинник А) варіанти удобрення (чинник В) та позакореневе підживлення (чинник С) у фазі 4 та 8 листків соняшнику препаратами Еколайн Бор, Нертус Бор, Баст Бор. Гібриди соняшника, що вивчалися, – НК Діамантіс, СИ Купава, НК Неома. Дослідження показали, що найбільш урожайним виявився гібрид СИ Купава з максимальним показником урожайності на варіанті із застосуванням N36P56K108S28 + N23 + Еколайн Бор (у фазі 4 та 8 листків по 1 л/га) – 3,46 т/га. Уміст жиру в насінні гібридів соняшнику визначався морфобіологічними особливостями гібриду та варіантами удобрення. Застосування позакореневих підживлень мікроелементами мало позитивний вплив на вміст жиру в насінні гібридів соняшнику, що дало змогу отримати максимальний показник на варіанті за внесення N36P56K108S28 + N23 + Еколайн Бор (5-6 листків) у рослин гібриду СИКупава – 51,1 %. Максимальний вміст олеїнової кислоти було виявлено в гібриду СИ Купава на варіанті з внесенням N36P56K108S28 +N23 + Еколайн Бор (5-6 листків) – 77,2 %. Завдяки застосуванню добрив, що містять бор, уміст цієї поліненасиченої кислоти можна підвищити, поліпшуючи показники якості олії насіння соняшнику. Найвищий вихід олії, відповідно до проведених розрахунків, було отримано на варіанті з внесенням N36P56K108S28 + N23 + Еколайн Бор (5-6 листків) у рослин гібриду СИ Купава, що становив 1,64 т з 1 гектара

Ключові слова: соняшник; гібриди; елементи живлення; бор; ЕколайнБор; Нертус Бор; Баст Бор; урожайність; уміст жиру; вміст білку; вміст олеїнової кислоти

M.P. Solomiychuk*

PhD in Agricultural Sciences

Ukrainian Scientific-Research Station on Plant Quarantine of Institute of plant protection
of National academy of agrarian sciences of Ukraine
60321, Boyani Vil., Ukraine

M.Y. Pikovskyi

Doctor of Agricultural Sciences, Associate Professor

National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

The effect of the *Pseudomonas fluorescens* bacteria and substances of a stimulating nature on the productivity of the soybean plant and seed damage by pathogens

Abstract. Soybeans are a strategic leguminous crop for global agriculture and play an important role in ensuring food security in many countries. Therewith, biotic factors, in particular, pathogens prevent obtaining a rich and high-quality yield of the crop. Their control is conducted using various methods and techniques. However, with an excessive increase in the use of chemical protective equipment, the environmental situation in agrocenoses becomes more complicated. Therefore, it is important to reduce the pesticide load in crop cultivation technologies. The purpose of the study is to assess the effect of the *Pseudomonas fluorescens* bacteria and stimulating substances on soybean plant productivity and seed damage by pathogens. The experiments were conducted in the conditions of the Ukrainian scientific-research station on plant quarantine of the Institute of Plant Protection of the National Academy of Agrarian Sciences of Ukraine. The soil of the experimental plot is grey forest heavy-loamy. The Ksenia soybean variety was used in the study. Field studies were conducted according to generally accepted methods. Soybean crops were sprayed during the growing season in the following periods: true three-leaf, flowering, and bean formation. For the treatment of soybean plants, a preparation based on the *Pseudomonas fluorescens* bacteria with a titrant of 3×10^9 CFU/cm³ was used with a consumption rate of 5.0 l/ha per use in combinations with substances of stimulating action. Over the years of research, the amount of precipitation (in certain months of soybean vegetation) was higher than the average monthly perennial norm. Pre-harvest desiccation of crops was not conducted. Phytopathological examination of seeds obtained from soybean plants for various treatment options was conducted in accordance with DSTU 4138-2002. Studies show a positive effect of the drug based on *P. fluorescens* and substances of a stimulating nature on biometric

Suggested Citation:

Solomiychuk, M., & Pikovskyi, M. (2021). The effect of the *Pseudomonas fluorescens* bacteria and substances of a stimulating nature on the productivity of the soybean plant and seed damage by pathogens. *Plant and Soil Science*, 12(4), 28-36. doi: 10.31548/agr2021.04.0028.

*Corresponding author



indicators of soybean plants and their productivity. In particular, the weight of 1000 seeds in variants with spraying plants increased in the range from 16 to 66 g. Joint application on soybean crops of *P. fluorescens* together with substances of the group of ammonium salts of dihydropyrimidine and stimulating substances provided an increase in the yield of soybean seeds up to 1.1 t/ha. There was also a decrease in infection of soybean seeds with pathogens of *Fusarium*, *Alternaria* and penicillosis – *Fusarium oxysporum* Schlecht, *Alternaria* spp., and *Penicillium expansum* Link fungi. The investigation of the immunoprotective and stimulating effects of combinations of biocomplexes is promising for the development of environmentally safe measures to increase soybean yield and reduce seed damage by pathogens

Keywords: bacteria; plant productivity; seed infestation; fungi

RELEVANCE

Soy (*Glycine max* (L) Merrill) is a strategic leguminous crop for global agriculture. Its seeds are one of the few complete plant-based protein products with nine essential amino acids (Michelfelder A. J., 2009). Soy plays an important role in the food security of many countries and is used for feed, food, technical, and other purposes (Cherenkov A.V. *et al.*, 2014)

In different countries, soybean acreage has been growing dynamically over the past decades (Babych A.A. Babych-Poberezhna A.A., 2012). The leaders in its production are mainly the countries of South America, in particular, Argentina, Paraguay, and Brazil (De Maria M. *et al.*, 2020). Ukraine is among the top ten leading countries (Berbenets O.V. 2019). Therewith, diseases prevent obtaining a high yield of high-quality soybean grain (Pikovskiy M.I., Kyryk M.M., 2012; Baetsen-Young, A.M., Swinton S.M., Chilvers M.I., 2021; Díaz-Cruz G.A., Cassone B.J., 2021). Their control is conducted using various methods and techniques (Dorrance A.E. *et al.*, 2009; Kurl James, Grau Craig, Oplinger Edward, Mengistu Alemu, 2001; Reznikov S. *et al.*, 2019). However, with an excessive increase in the use of chemical protective equipment, the ecological situation in agrocenoses becomes more complicated due to the violation of natural processes of harmonious coexistence of representatives of natural biota. Therefore, the issue of biologisation of plant protection is relevant (Baranov V.F., Makhonin V.L., 2014).

ANALYSIS OF RECENT STUDIES AND PAPERS

Various methods can be used to prevent, reduce, or control plant diseases, including chemical pesticides that can pollute the environment. Therefore, as an alternative to crop cultivation technologies, there is the development of biological agents (Chandrashekhara K.N. *et al.*, 2020). Studies of the effect of antagonist microbes against soy pathogens are being conducted in different countries of the world. In particular, the activity of the *Rhizobium japonicum* bacteria was evaluated against *Fusarium solani* and *Macrophomina phaseolina* soil pathogens – pathogens of root rot. It was identified that rhizobial culture filtrate caused inhibition of radial growth of phytopathogens *in vitro*. Sowing with seeds treated with bacterial culture (with the introduction of *F. solani* and *M. phaseolina* infection into the soil) substantially increased seed germination and caused a substantial decrease in the intensity of root rot development in the field. These results indicate that *R. japonicum* may be an important element for disease control (Alani Rakib *et al.*, 2012).

Arfaoui *et al.* (2018) evaluated bacteria extracted from rhizosphere soil and rhizoplanes of healthy soybean plants and investigated their antifungal effect against *Phytophthora sojae* soybean isolates. Among those tested, nine bacteria were identified (belonging to *Paenibacillus* and *Streptomyces* sp.), which inhibited the hyphal growth of *P. sojae* *in vitro*. Therewith, the use of

bacterial strain S11 for seed treatment reduced the development of the disease by 57.1% and increased the mass of roots and shoots by 140 and 108%, respectively, compared to the control (Arfaoui A. *et al.*, 2018).

Potential research is also being conducted on *Pseudomonas sp.* as a biocontrol agent for soybean diseases caused by soil pathogens. In particular, *Pseudomonas sp.* CRB suppressed growth of pathogenic fungi (*Sclerotium rolfsii*, *Fusarium oxysporum*, and *Rhizoctonia solani*) *in vitro* by 11.1–60.0%. Therewith, CRB-16, CRB-44, CRB-86, CRB-102, and CRB-109 isolates are promising for the development of biological protection (Susilowati Ari *et al.*, 2013).

Gram-positive bacterium *Paenibacillus* BRF-1, showed strong antifungal activity against the brown stem rot pathogen soy fungus *Phialophora gregata*. Seed treatment also provided better growth of plant shoots (Zhou Keqin *et al.*, 2008).

Against the causative agent of soy anthracnose (*Colletotrichum dematium* fungus (Pres. Ex.Fr.)) antagonism of the *Trichoderma lignorum* and *Trichoderma viride* fungi and the *Bacillus megaterium* and *Bacillus brevis* bacteria was established. They inhibited the linear growth of *C. dematium*, and culture filtrates of the corresponding bioagents inhibited the germination of pathogen spores. Spraying soybean plants with antagonist suspensions or their culture filtrates resulted in a substantial reduction in the development of the disease (Jahan Akida *et al.* 2015). There is also information about the ability of *Trichoderma spp.* to suppress soybean stem rot caused by *Sclerotinia sclerotiorum* (Zhang Fuli *et al.*, 2016).

In the conditions of Ukraine, the effectiveness of preparations of biological origin for growing soybean plants was investigated. It was noted that combinations of Trichodermin (21/t) + Gaubsin (1.51/t) and phytodoctor (1.01/t) + Trichodermin (2 l/t) had the greatest effect on fungal infections (Solomychuk *et al.*, 2020). The positive effect of pre-sowing seed inoculation with the microbial preparation Rizohumin, microfertiliser Reakom, and plant growth stimulator

BioSil was also determined in various combinations. The effectiveness of using microfertiliser and BioSil solutions during the growing season of bactericidal plants on the formation and functioning of legume-rhizobial symbiosis and soybean grain yield was identified (Kabanets, Sobko, Murach, 2017). This indicates the importance of investigating the combinations of bio-complexes with drugs of a stimulating nature to assess their impact on plant yield and pathogen damage.

The purpose of the study is to conduct an assessment of the impact of the *Pseudomonas fluorescens* bacteria and substances of a stimulating nature on the productivity of the soybean plant and seed damage by pathogens.

MATERIALS AND METHODS

The study was conducted during 2019-2020 at the Ukrainian scientific-research station on plant quarantine of the Institute of Plant Protection of the National Academy of Agrarian Sciences of Ukraine. The soil of the experimental plot is grey forest heavy-loamy. Its availability of mobile forms of phosphorus is 148.4 mg/kg, potassium – 185.4 mg/kg, and nitrogen – 83.0 mg/kg. Equilibrium soil density – 1.46 g/cm³. The Ksenia soybean variety was used in the study. Sowing was conducted in the usual rowing way. In June and July 2019, precipitation was 129 and 99 mm, respectively, and in August – 110 mm, which was higher than the average monthly perennial norm. In June and July 2020, they were 130 mm per month at the norm of 75-85 mm. In September 2020, 104 mm of precipitation fell, which exceeded the perennial average. Desiccation of crops was not conducted.

A bacterial-based preparation *Pseudomonas fluorescens* with a titrant of 3x10⁹ CFU/cm³ with a consumption rate of 5.0 l/ha was used in the study. In combinations, the use of a biological product based on the *P. fluorescens* bacteria was combined with succinic acid (ethane-1,2 dicarboxylic acid HOOC(CH₂)₂COOH). Excipients were also examined: dimethyl sulfoxide (DMSO) – a chemical substance with the (CH₃)₂SO formula, which is a bipolar solvent and is used to increase

trans-tissue transport of active substances; dimethylaminoethanol (DMAE), which is an immunoprotector and affects various transmembrane functions.

Field research was conducted according to generally accepted methods (Tribel *et al.*, 2001). Soybean crops were sprayed during the growing season in the following periods: true three-leaf, flowering, and bean formation. During the biometric analysis of plants, the number of formed beans on plants was determined, pcs., the weight of 1000 seeds (g), and yield, t/ha. Phytopathological examination of grain obtained from soybean plants for various treatment options was conducted in accordance with DSTU 4138-2002 (Seeds of agricultural plants. Methods for seeds testing, 2003). Morphological analysis of pathogens was conducted through the creation of microscopic preparations, which were analysed using light microscopy and identified (Kyryk M.M., Pikovskyi M.Y., Azaiki S., 2015).

Statistical processing of experimental data was performed using the Microsoft Office® programme for Microsoft Windows®.

RESULTS

As the results of the study show, spraying soybean plants with a biological product based on the *P. fluorescens* bacteria separately and in combination with substances of the group of ammonium salts of dihydropyrimidine and stimulating substances had a positive effect on the productivity of soybean plants. Thus, the number of beans formed under different spraying schemes increased by 0.4–5.9 pcs./ plant. In particular, in variants with spraying schemes *P. fluorescens*, 5 l/ha + 0.1% xymedone solution + 2 ml DMAE + 2 ml DMSO, *P. fluorescens*, 5 l/ha + 0.2% succinic acid solution + 2 ml DMAE + 2 ml DMSO, and *P. fluorescens*, 5 l/ha + 0.1% xymedone solution + 0.2% succinic acid solution + 2 ml DMAE + 2 ml DMSO the most beans were formed – 11.3-14.2 pcs./plant (Table 1).

Table 1. Soybean productivity depending on the treatment of plants with the *Pseudomonas fluorescens* bacteria in combination with stimulating substances (Ksenia variety, average for 2019-2020)

Options	Number of formed beans per 1 plant, pcs.	Weight of 1000 seeds, g	Yield, t/ha
Control 1 (without treatment);	8.3	105	1.8
Control 2 <i>P. fluorescens</i> , 5 l/ha	8.6	135	2.1
<i>P. fluorescens</i> , 5 l/ha + 2 ml DMAE + 2 ml DMSO	8.7	148	2.2
<i>P. fluorescens</i> , 5 l/ha + 0.2% succinic acid solution + 2 ml DMAE + 2 ml DMSO	12.9	152	2.7
<i>P. fluorescens</i> , 5 l/ha + dihydropyrimidine derivatives (Amine 1 – 0.5% solution + 2 ml DMSO)	10.4	138	2.4
<i>P. fluorescens</i> , 5 l/ha + dihydropyrimidine derivatives (Amine 3 – 0.25% solution + 2 ml DMSO)	10.8	121	2.3
<i>P. fluorescens</i> , 5 l/ha + 0.1% xymedone solution + 2 ml DMAE + 2 ml DMSO	11.3	165	2.4
<i>P. fluorescens</i> , 5 l/ha + 0.1% xymedone solution + 0.2% succinic acid solution + 2 ml DMAE + 2 ml DMSO	14.2	171	2.9
HIP ₀₅	0.1	3.9	0.09

Positive dynamics were also noted regarding the mass of seeds. Thus, the weight of 1000 seeds in variants with spraying plants increased in the range from 16 to 66 g. Joint application *P. fluorescens*, 5 l/ha + 0.2% succinic acid solution + 2 ml DMAE + 2 ml DMSO ensured the formation of seeds by plants, the mass of 1000 of which was 152 g; in the case of use *P. fluorescens*, 5 l/ha + 0.1% xymedone solution + 2 ml DMAE + 2 ml DMSO – the weight of a 1000 seeds reached 165 g and for spraying with *P. fluorescens*, 5 l/ha + 0.1% xymedone solution + 0.2% succinic acid solution + 2 ml DMAE + 2 ml DMSO – 171 g. These were the highest indicators compared to the control (without treatment).

In the end, separate and joint application on soybean crops of *P. fluorescens* together with substances of the ammonium salts of dihydropyrimidine and stimulating substances increased the yield of soybean seeds from 0.3 to 1.1 t/ha. The best result was noted in the version using a preparation based on *P. fluorescens*, 5 l/ha + 0.1% xymedone solution + 0.2% succinic acid solution + 2 ml DMAE + 2 ml DMSO.

Therewith, the soybean yield was 2.9 t/ha, which is 0.8 and 1.1 more than in the control variants (without treatment and with *P. fluorescens*).

According to the results of the phytopathological examination of soybean seeds, selected from various variants of the experiment, the damage by such micromycetes was identified: *Fusarium oxysporum* Schlecht, *Alternaria* spp., and *Penicillium expansum* Link. During germination of seeds infected with the *F. oxysporum* fungus, weak, underdeveloped, deformed seedlings were formed, which later rotted. Seeds affected by *Fusarium* infection could also lose their ability to germinate and become covered with a whitish-pink coating (Fig. 1a). On the surface of soybean seeds affected by *Alternaria* spp. symptoms of the disease initially appeared in the form of a light, later smoky-grey – black coating. In many cases, normal seedlings were formed, but the seeds with severe damage did not germinate (Fig. 1b). *P. expansum* fungi developed on seeds in the form of a mouldy coating of green-blue colour (Fig. 1c).

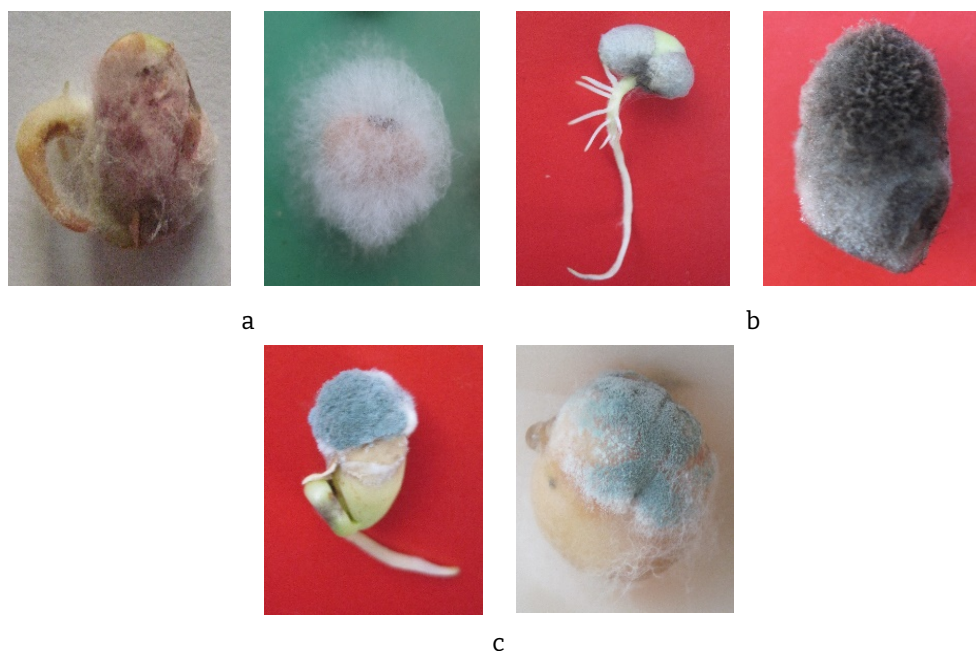


Figure 1. Symptoms of soybean seed diseases with varying degrees of damage: a – *Fusarium*; b – *Alternaria*; c – mould caused by *P. expansum*

Analysis of using the *P. fluorescens* bacteria and their combinations together with substances of ammonium salts of dihydropyrimidine group and stimulating substances showed that all of them provided a reduction in infection of soybean seeds with *F. oxysporum*, *Alternaria spp.*, and *P. expansum* fungi (Table 2). In particular, the number of seeds affected by the causative agent

of *Fusarium* infection ranged from 8.7 to 12% (33.1% in the control). Infection with *Alternaria spp.* was detected in 7.2-10.8% of seeds (29.6% in the control).

Mould caused by the *P. expansum* fungus, infected 1.8-3.2% of soybean crops in various treatment options, while in the control this figure was 14.2%.

Table 2. Effect of treating soybean plants with the *Pseudomonas fluorescens* bacteria in combination with stimulating substances for seed infestation by fungi (Ksenia variety, average for 2019-2020)

Options	Seeds are affected by fungi, %		
		<i>Alternaria spp.</i>	<i>P. expansum</i>
<i>F. oxysporum</i>			
Control 1 (without treatment)	33.1 ± 3.6	29.6 ± 2.8	14.2 ± 2.4
Control 2 <i>P. fluorescens</i> , 5 l/ha	11.2 ± 0.5	10.8 ± 0.5	3.2 ± 0.3
<i>P. fluorescens</i> , 5 l/ha + 2 ml DMAE + 2 ml DMSO	9.8 ± 0.4	10.6 ± 0.3	3.0 ± 0.4
<i>P. fluorescens</i> , 5 l/ha + 0.2% succinic acid solution + 2 ml DMAE + 2 ml DMSO	8.9 ± 0.6	9.7 ± 0.5	2.5 ± 0.4
<i>P. fluorescens</i> , 5 l/ha + dihydropyrimidine derivatives (Amine 1 – 0.5% solution + 2 ml DMSO)	8.9 ± 0.4	9.2 ± 0.3	2.3 ± 0.5
<i>P. fluorescens</i> , 5 l/ha + dihydropyrimidine derivatives (Amine 3 – 0.25% solution + 2 ml DMSO)	12.2 ± 0.7	9.2 ± 0.5	2.6 ± 0.4
<i>P. fluorescens</i> , 5 l/ha + 0.1% xymedone solution + 2 ml DMAE + 2 ml DMSO	10.6 ± 0.5	7.9 ± 0.4	2.1 ± 0.2
<i>P. fluorescens</i> , 5 l/ha + 0.1% xymedone solution + 0.2% succinic acid solution + 2 ml DMAE + 2 ml DMSO	8.7 ± 0.4	7.2 ± 0.3	1.8 ± 0.2

Among the various treatment options for soybean crops, the smallest number of seeds affected by pathogens was noted with the use of *P. fluorescens*, 5 l/ha + 0.1% xymedone solution + 0.2% succinic acid solution + 2 ml DMAE + 2 ml DMSO, which is due to their immunoprotective and stimulating effect.

CONCLUSIONS

Studies showed that the combination of the *P. fluorescens* bacteria with preparations of

a stimulating nature and various derivatives of ammonium salts of dihydropyrimidine for spraying soybean plants provided an increase in the yield of soybean seeds from 0.8 to 1.1 t/ha. In addition, all of them led to a decrease in infection of soybean seeds with the *F. oxysporum*, *Alternaria spp.*, and *P. expansum* fungi. The use of combinations of biocomplexes is promising for further study as environmentally safe measures to increase soybean yield and reduce seed damage by pathogens.

REFERENCES

- [1] Alani Rakib, Adhab Mustafa, Mahdi Haider, Abood Hadi. (2012). Rhizobium japonicum as a Biocontrol Agent of Soybean Root Rot Disease Caused by Fusarium solani and Macrophomina phaseolina. *Plant Protection Science*, 48(4), 149-155. <https://doi.org/10.17221/16/2012-PPS>
- [2] Arfaoui A., Adam L.R., Bezzahou A. *et al.* (2018). Isolation and identification of cultivated bacteria associated with soybeans and their biocontrol activity against *Phytophthora sojae*. *BioControl*, 63, 607-617. <https://doi.org/10.1007/s10526-018-9873-9>
- [3] Babych, A.A, Babych-Poberezhna, A.A. (2012). World and domestic trends in the location of production and use of soybeans to solve the problem of protein. *Kormy i kormovyrobnytstvo*. 71, 12-25.
- [4] Baetsen-Young, A.M., Swinton, S.M., Chilvers, M.I. (2021). Economic Impact of Fluopyram-Amended Seed Treatments to Reduce Soybean Yield Loss Associated with Sudden Death Syndrome. *Plant Disease*, 105(1), 78-86. <https://doi.org/10.1094/PDIS-04-20-0792-RE>
- [5] Baranov, V.F., Makhonin, V.L. (2014). About biological protection of soybean agrophytocenoses from harmful organisms. *Maslichnyye kul'tury*, 1, 152-164.
- [6] Berbenets O.V. (2019). Svitove vyrobnytstvo soyi yak nevycherpnoho dzherela bilkiv roslynnoho pokhodzhennya ta mistse Ukrayiny na svitovomu rynku torhivli neyu [World soybean production as an inexhaustible source of proteins of plant origin and Ukraine 's place in the world market of its trade]. *Ahrosvit*, 10, 41-45. <https://doi.org/10.32702/2306-6792.2019.10.41>
- [7] Chandrashekara, K.N., Manivannan, S., Chandrashekara, C., Chakravarthi, M. (2012). Chapter: 10. Biological Control of Plant Disease. *Eco-friendly Innovative Approaches in Plant Disease Management*. Editors: Vaibhav K. Singh, Yogendra Singh, Akhilesh Singh. Publisher: International Book Distributors, 147-166.
- [8] Cherenkov, A.V. *et al.* (2014). Legumes: modern technologies of cultivation. *Dnipropetrovsk Akcent*. 109 p.
- [9] De Maria M., Robinson E.J.Z., Kangile J.R., Kadigi R., Dreoni I., Couto M., Howai N., Peci J., Fiennes, S. (2020). Global Soybean Trade. The Geopolitics of a Bean. UK Research and Innovation Global Challenges Research Fund (UKRI GCRF) Trade, Development and the Environment Hub. <https://doi.org/10.34892/7yn1-k494>
- [10] Díaz-Cruz G.A., Cassone B.J. (2021). Amplicon Sequencing Reveals Extensive Coinfections of Foliar Pathogens in Soybean. *Plant Disease*, 105(1), 127-133. <https://doi.org/10.1094/PDIS-06-20-1165-RE>
- [11] Dorrance, A.E., Robertson, A.E., Cianzo, S., Giesler, L.J., Grau, C.R., Draper, M.A., Tenuta, A.U., Anderson, T.R. (2009). Integrated management strategies for *Phytophthora sojae* combining host resistance and seed treatments. *Plant Disease*, 93, 875-882.
- [12] Jahan Akida, Jahan Nushrat, Hossain Mohammad, Hossain Muhammed. (2015). Biological control of anthracnose of soybean. *Research in Agriculture Livestock and Fisheries*, 2(3), 419-426. <https://doi.org/10.3329/ralf.v2i3.26164>
- [13] Kabanets, V.M., Sobko, M.H., Murach O.M. (2017). Functioning of symbiosis "Japonicum – soy" and soybean yield under the influence of rhizohumin and physiologically active substances. *Kormy i kormovyrobnytstvo*, 83, 58-66.
- [14] Kurle James, Grau Craig, Oplinger Edward, Mengistu Alemu. (2001). Tillage, Crop Sequence, and Cultivar Effects on Sclerotinia Stem Rot Incidence and Yield in Soybean. *Agronomy Journal*, 93(5), 973-982. <https://doi.org/10.2134/agronj2001.935973x>
- [15] Kyryk, M.M., Pikovskiy, M.Y., Azaiki, S. Diseases of seeds of agricultural crops. Kyiv: CP Kompynt. 2015. 340 s.

- [16] Michelfelder, A.J. (2009). Soy: A complete source of protein. *American Family Physician*, 79(1),43-47.
- [17] Nasinnya sil's'kohospodars'kykh kul'tur. Metody vyznachennya yakosti: DSTU 4138-2002 [Seeds of agricultural plants. Methods for seed testing]. Kyiv: Derzhspozhyvstandart Ukrainy, 2003. 173 s.
- [18] Pikovskyi, M.Y., Kyryk, M.M. (2012). Symptomatyka biloyi hnyli soyi [Symptoms of white mold of soybeans]. *Karantyn i zakhyst roslyn*, 7, 2-5.
- [19] Reznikov, S., De Lisi, V., Claps, P., González, V., Devani, M.R., Castagnaro, A.P., *et al.* (2019). Evaluation of the Efficacy and Application Timing of Different Fungicides for Management of Soybean Foliar Diseases in Northwestern Argentina. *Crop Protection*, 124. <https://doi.org/10.1016/j.cropro.2019.104844>
- [20] Solomiychuk, M.P., Kordulyan, Y.V., Melnyk, A.T., Pikovskyi, M.Y. (2020). Influence of biological complexes and biostimulating material growth and development of soybean plants in the Western Forest-Steppe of Ukraine. *Peredhirne ta hirs'ke zemlerobstvo i tvarynnytstvo*, 67(2), 182-197.
- [21] Susilowati Ari, Wahyudi Aris, Lestari Yulin, Suwanto Antonius, Wiyono Suryo. (2013). Potential *Pseudomonas* Isolated from Soybean Rhizosphere as Biocontrol against Soilborne Phytopathogenic Fungi. *HAYATI Journal of Biosciences*, 18(2), 51-56. <https://doi.org/10.4308/hjb.18.2.51>
- [22] Tribel, S.O. *et al.* (2001). *Methods of testing and application of pesticides*. Kyiv: Svit. 448 s.
- [23] Zhang Fuli, Ge Honglian, Zhang Fan, Guo Ning, Wang Yucheng, Chen Long, Ji Xiue, Li Cheng-Wei. (2016). Biocontrol Potential of *Trichoderma harzianum* isolate T-aloe against *Sclerotinia sclerotiorum* in soybean. *Plant Physiology and Biochemistry*, 100, 64-74. <https://doi.org/10.1016/j.plaphy.2015.12.017>
- [24] Zhou Keqin, Yamagishi Masumi, Osaki Mitsuru. (2008). *Paenibacillus* BRF-1 has biocontrol ability against *Phialophora gregata* disease and promotes soybean growth. *Soil Science & Plant Nutrition*, 54, 870-875. <https://doi.org/10.1111/j.1747-0765.2008.00308.x>

М.П. Соломійчук

Кандидат сільськогосподарських наук
Українська науково-дослідна станція карантину рослин Інституту захисту рослин
Національної академії аграрних наук України
60321, с. Бояни, Україна

М.Й. Піковський

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

Вплив бактерій *Pseudomonas fluorescens* і речовин стимулюючої природи на продуктивність рослини сої та ураження насіння патогенами

Анотація. Соя є стратегічною зернобобовою культурою для світового сільського господарства та має важливу роль у забезпеченні продовольчої безпеки багатьох країн. Водночас отриманню високого і якісного урожаю культури перешкоджають біотичні чинники, зокрема збудники хвороб. Їхній контроль здійснюється за допомогою різних методів і способів. Однак за надмірного збільшення об'ємів застосування хімічних засобів захисту ускладнюється екологічна ситуація в агроценозах. Тому актуальним є зменшення пестицидного навантаження в технологіях вирощування культури. Метою досліджень є проведення оцінки впливу бактерій *Pseudomonas fluorescens* і речовин стимулюючої природи на продуктивність рослини сої та ураження насіння патогенами. Експерименти проводили в умовах Української науково-дослідної станції карантину рослин Інституту захисту рослин НААН. Грунт дослідної ділянки – сірий лісовий важко суглинковий. Для досліджень використовували сорт сої Ксеня. Виконання польових досліджень проводили згідно із загальноприйнятими методиками. Посіви сої обприскували впродовж вегетації у такі періоди: справжній трійчастий листок, цвітіння та формування бобів. Для обробки рослин сої використовували препарат на основі бактерій *Pseudomonas fluorescens* з титром 3×10^9 КУО/см³ з нормою витрати 5,0 л/га за застосування у комбінаціях із речовинами стимулюючої дії. За роки досліджень кількість атмосферних опадів (в певні місяці вегетації рослин сої) була вище середньомісячної багаторічної норми. Передзбиральну десикацію посівів не проводили. Фітопатологічну експертизу насіння отриманого з рослин сої за різних варіантів обробок здійснювали згідно з ДСТУ 4138-2002. У дослідженнях відмічено позитивний вплив препарату на основі *Pseudomonas fluorescens* і речовин стимулюючої природи на біометричні показники рослин сої і їхню продуктивність. Зокрема, маса 1000 насінин у варіантах з обприскуванням рослин збільшувалася в межах від 16 до 66 г. Сумісне внесення на посівах сої *Pseudomonas fluorescens* разом із речовинами групи амонійних солей дигідропірімідину та стимулюючих речовин забезпечувало зростання урожайності насіння сої до 1,1 т/га. Також відмічено зниження інфікування насіння сої збудниками фузаріозу, альтернаріозу та пеніцильозу – грибами *Fusarium oxysporum* Schlecht, *Alternaria* spp. та *Penicillium expansum* Link. Вивчення імунопротекторної та стимулюючої дії комбінацій біокомплексів є перспективним для розробки екологічно безпечних заходів підвищення урожайності сої та зниження ураження насіння патогенами

Ключові слова: бактерії; продуктивність рослин; зараженість насіння; гриби

S.P. Tanchyk*

Doctor of Agricultural Sciences, Professor, Head of the Department
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

N.I. Babilia

Postgraduate Student
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

A.I. Babenko

PhD in Agricultural Sciences, Senior Lecturer
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

Agrophysical indicators of soil for growing winter barley in the Transcarpathia of Ukraine

Abstract. The study presents the values, tasks, and results of various methods of basic tillage for different predecessors on its agrophysical properties for growing winter barley in the Transcarpathia of Ukraine. The soil of the experimental field is sod-podzolic gumbo, which contains 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%. The soil is typical for the area where the study was conducted and is moderately provided with mobile forms of phosphorus, potassium, and nitrogen. A qualitative assessment of the examined soils showed that the soil requires constant use of organic and mineral fertilisers, liming, and the introduction of crop rotations. The soil density is an important indicator of the physical properties of the soil, which affects not only the soil regimes but also the quality of its cultivation, which ultimately affects the yield of the crop and its quality. For the period of sowing winter barley, the most favourable indicators of the volume mass of 0-10 cm of the soil layer were provided by all systems of basic cultivation. The average soil density for the main cultivation options ranged between 1.09-1.17 g/cm³, at $HIP_{0.5} = 0.01$ g/cm³. At a depth of 10-20 cm, the average volume mass of soil during ploughing was 1.14 g/cm³, for chiselling, it was without substantial differences – 1.15 g/cm³. Conducting shallow (12-14 cm) and surface (6-8 cm) cultivation was accompanied by an increase in volume mass indicators to 1.16 and 1.19 g/cm³, respectively. In the soil layer of 20-30 cm, it was similar: with shallow chisel cultivation, the average density was at the level of 1.24 g/cm³, and on the surface – 1.25 g/cm³. The precursors did not substantially affect the change in the

Suggested Citation:

Tanchyk, S., Babilia, N., & Babenko, A. (2021). Agrophysical indicators of soil for growing winter barley in the Transcarpathia of Ukraine. *Plant and Soil Science*, 12(4), 37-49. doi: 10.31548/agr2021.04.0037.

*Corresponding author



Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (<https://creativecommons.org/licenses/by/4.0/>)

density of the tillage layer of the soil. However, after corn for grain and sunflower, there is a tendency to increase the volume mass of the soil after chisel shallow and surface cultivation, especially in the lower layers of the soil. This soil density was at the level of 1.24-1.26 g/cm³, which is within the optimal limit. The soil, loosened by mechanical cultivation, self-compacts during the growing season to an equilibrium density under the influence of its own mass, moisture, and drying. Therefore, during the period of earing and harvesting of winter barley, the soil gradually compacted to natural values. In a 0-10 cm layer of soil, the volume mass varied in the range of 1.20-1.27 g/cm³, in the soil layer of 10-20 cm – from 1.25 to 1.30 g/cm³, and in 20-30 cm – from 1.34 to 1.37 g/cm³. For the effective activity of microorganisms, the growth and development of the root system of plants, and the accumulation of moisture in the soil, density (porosity) is important. It was identified that long-term use of the deep and chisel tillage did not reduce the overall porosity below 50% of the structure of the cultivated layer, which ensured the high productivity of cultivated plants. For the surface and shallow chisel tillage, the total porosity in the lower layers was up to 50% of the structure of the cultivation layer, and in some cases less than 47%. This structure of the cultivation layer negatively affected the water and air regimes of the soil, the growth and development of the root system, and, ultimately, the yield of winter barley. The highest yield of winter barley was obtained after buckwheat, winter rapeseed and soybeans (6.0-6.3 t/ha) during chisel tillage to the depth of 20-22 cm. After corn for grain and sunflower, the yield was 5.1-5.7 t/ha

Keywords: ploughing; chiselling; soil density; porosity

RELEVANCE

Soil fertility is determined by a complex of biological, chemical, and agrophysical properties. In the process of production activity, the farmer modifies these properties and achieves the most favourable conditions for the growth and development of agricultural crops. Human intervention in soil processes should be based on the use of agricultural laws. (Demyatnik *et al.* 2021; Tsyuk & Kirilyuk, 2016; Burtan & Cioroianu, 2020; Shuvar & Grynyk, 2019).

The agrophysical properties of the soil determine the complex of vital conditions for the growth of cultivated plants. Density and porosity are the most important indicators of physical condition that characterise water, nutrient, air, and heat regimes, conditions for the development of root systems, soil microflora, and the formation of agricultural crops. (Shevchenko, 2013; Odachenko & Tanchyk, 2016; Ovsyannikov, 2020; Degodyuk *et al.*, 2020; Kramaryov *et al.*, 2021; Pikovska, 2013).

Thus, the examination of the specific features of growth, development, and formation

of productivity of winter barley in the Transcarpathia of Ukraine is still relevant and led to the choice of the algorithm of the study.

ANALYSIS OF RECENT STUDIES AND PAPERS

The soil, loosened by mechanical cultivation, self-compacts during the growing season to an equilibrium density characteristic of a certain soil cover under the influence of its own mass, moisture, and drying. Thus, for chernozems of medium loamy mechanical composition, it is 1.0-1.3 g/cm³ (Tanchyk & Salnikov, 2014; Uvarenko, 2018), for sod-podzolic gumbo – 1.5-1.6 g/cm³ (Chumbey *et al.*, 2019), for grey forest heavy-loamy – 1.2-1.45 g/cm³ (Korchagin *et al.*, 2015). In most cases, the equilibrium soil density exceeds the optimal one for cultivated plants, and therefore mechanical cultivation is mandatory (Sinchenko *et al.*, 2019).

In the introduction of chisel tillage into production, considerable attention is paid to its theoretical justification and, above all, to its

impact on the agrophysical properties of the soil. Studies in various soil and climatic zones of Ukraine established that the density of the tillage layer of soils with chisel cultivations is higher compared to ploughing to the same depth (Nakloka & Yeshchenko, 2005; Markovska et al., 2020; Chumbey et al., 2018), and reducing the depth of chisel cultivation to 10-12 cm leads to an increase in the density of the entire cultivating (arable) soil layer (Medvedev et al., 2002; Tsylyuryk et al., 2020; Shevchenko et al., 2012; Karpenko & Panchenko, 2014; Tkalich et al., 2011; Reznichenko, 2015; Huang et al., 2015; Weber, Kunz, 2017; Ryken et al., 2018).

In recent years, many studies have been conducted to examine the reaction of agricultural crops to the density of the tillage layer of soil. Now in different soil and climatic zones, soil density parameters for grain crops are established (Berezhnyak, 2015). Regarding winter barley in the Transcarpathia of Ukraine, there are discrepancies in the literature sources, which are explained by soil differences, cultivated varieties of this crop, conditions and methods of scientific research, and many other factors.

The optimal density of the cultivated soil for growing winter barley in conditions of average moisture content of the year on sod-podzolic soils of heavy- and medium-loamy mechanical composition is 1.15 g/cm^3 , on sod-podzolic light- and sandy-loamy mechanical composition – 1.22 g/cm^3 , on chernozems of typical and grey forest soils of heavy- and medium-loamy composition – 1.17 g/cm^3 , on chernozems of typical, southern, and brown soils of heavy-loamy mechanical composition – 1.19 g/cm^3 (Gavrilyuk, 2016; Litvinov, 2015).

The purpose of the study consists in establishing effective mechanical tillage, depending on the predecessor, for growing winter barley in the Transcarpathia of Ukraine. It was planned to solve the following tasks to achieve this goal: establish the influence of different methods of tillage and its depth for different predecessors on changes in the density of the structure, the porosity of the cultivated soil layer, and the 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 different methods of tillage with different predecessors on the productivity of winter barley were conducted during 2018-2020 in the experimental crop rotation of the SSU “Mukachevo Applied College of the National University of Life and Environmental Sciences of Ukraine” in the Transcarpathian region.

The soil of the experimental field is sod-podzolic gumbo, which contains 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 material 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 (by Kirsanov method) – 130-160 mg/kg, mobile potassium (by Kirsanov method) – 120-170 mg/kg. The soil is typical for the area where the studies were conducted and is moderately provided with mobile forms of phosphorus, potassium, and nitrogen. A qualitative assessment of the examined soils showed that the soil requires constant use of organic and mineral fertilisers, liming, and the introduction of crop rotations.

The scheme of the experiment included the analysis of the influence of five predecessors and four tillage types for the cultivation of winter barley:

Predecessor: (A)

1. Soy (control);
2. Winter rapeseed;
3. Buckwheat;
4. Corn for grain;
5. Sunflower.

Tillage: (B) (control)

1. Deep tillage (ploughing) to a depth of 20-22 cm;

2. Chiseling (deep chisel) to a depth of 20-22 cm;
3. Chiseling (discing) to a depth of 12-14 cm;
4. Chiseling (discing) for 6-8 cm.

The climate of the area is moderate with unstable humidity. The average perennial precipitation rate for the year is 618.0 mm. Over the years of the experiment, 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 examined 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 m², accounting plot – 150 m². Land plot placement is randomised. The technology of growing winter barley in the experiment is generally accepted for the zone. In soil samples, the folding density was determined by the Kaczynski cylinder method, and the solid phase density was determined by the Dolgov method. The total porosity was determined by the calculation method.

RESULTS AND DISCUSSION

The soil density is an important indicator of the physical properties of the soil, which affects not only the soil regimes but also the technological properties and quality of tillage, which ultimately affects the yield of the crop and its quality.

It is established that the optimal density of the cultivated soil layer during the growing season of winter barley should be in the range of 1.1-1.3 g/cm³. In experiments, this indicator changed substantially depending on the soil layer, the sampling period, and the factors under study. Thus, during the period of sowing winter barley, the most favourable indicators of the volume mass of 0-10 cm of the soil layer were provided by all systems of basic tillage without a substantial difference. The average soil density for the main cultivation options ranged between 1.09-1.17 g/cm³, at HIP_{0.5} = 0.01 g/cm³ (Table 1). The differences between the main tillage options were more pronounced with increasing sampling depth. At a depth of 10-20 and 20-30 cm, the difference between the main cultivation options was statistically substantial and was manifested in an increase in volume mass in the options with a decrease in the depth of the main cultivation and the predecessor. At a depth of 10-20 cm, the average volume mass of soil during ploughing was 1.14 g/cm³, for chiselling it was not substantially different – 1.15 g/cm³. Conducting shallow (12-14 cm) and surface (6-8 cm) cultivation was accompanied by an increase in volume mass indicators to 1.16 and 1.19 g/cm³, respectively. In the soil layer of 20-30 cm, it was similar: with shallow chisel cultivation, the average density was at the level of 1.24 g/cm³, and on the surface, respectively – 1.25 g/cm³.

Table 1. Influence of the main cultivation and predecessors on the total density of the cultivated soil layer during the cultivation of winter barley, g/cm³ (sowing period, average for of 2018-2020)

Predecessor	Soil layer, cm	Basic tillage			
		Deep tillage (ploughing) to a depth of 20-22 cm (control)	Chiselling (deep chisel) to a depth of 20-22 cm	Chiselling (discing) to a depth of 12-14 cm	Chiselling (discing) to a depth of 6-8 cm
Soy (control)	0-10	1.12	1.14	1.09	1.11
	10-20	1.14	1.15	1.13	1.18
	20-30	1.23	1.21	1.24	1.25
	0-30	1.16	1.17	1.15	1.18
Winter rapeseed	0-10	1.09	1.11	1.10	1.12
	10-20	1.15	1.14	1.14	1.17

Table 1. Continued

Predecessor	Soil layer, cm	Basic tillage			
		Deep tillage (ploughing) to a depth of 20-22 cm (control)	Chiselling (deep chisel) to a depth of 20-22 cm	Chiselling (discing) to a depth of 12-14 cm	Chiselling (discing) to a depth of 6-8 cm
Winter rapeseed	20-30	1.21	1.23	1.24	1.24
	0-30	1.15	1.16	1.16	1.18
Buckwheat	0-10	1.11	1.12	1.10	1.10
	10-20	1.14	1.13	1.13	1.16
	20-30	1.22	1.20	1.22	1.23
Buckwheat	0-30	1.16	1.15	1.15	1.16
Corn for grain	0-10	1.13	1.15	1.17	1.16
	10-20	1.15	1.17	1.19	1.21
	20-30	1.25	1.21	1.26	1.24
	0-30	1.18	1.18	1.21	1.20
Sunflower	0-10	1.12	1.13	1.15	1.14
	10-20	1.14	1.15	1.17	1.23
	20-30	1.23	1.23	1.25	1.26
	0-30	1.16	1.17	1.19	1.21
HIP ₀₅ (A)		0.013	0.014	0.013	0.016
HIP ₀₅ (B)		0.014	0.01	0.01	0.015
HIP ₀₅ (AB)		0.15	0.18	0.7	0.14

Therefore, it can be argued that chisel cultivation leads to some compaction of the soil, which does not exceed the deviation standards for winter barley.

The precursors did not substantially affect the change in the density of the cultivated soil layer. However, after corn for grain and sunflower, there is a tendency to increase the volume mass of the soil after chisel shallow and surface cultivation, especially in the lower layers of the soil. This soil density was at the level of 1.24-1.26 g/cm³, which is within the optimal limit.

Volume mass is a dynamic value during the growing season. It varies depending on the level of soil fertility, the degree of moisture, the conditions for the development of the root system, and soil microflora. The soil, loosened by mechanical cultivation, self-compacts during the growing season to an equilibrium density

characteristic of a certain soil cover under the influence of its own mass, moisture, and drying. Therefore, during the period of winter barley earing, there was a gradual compaction of the soil to natural values. The effect of tillage on its density was substantial, starting from a depth of 10 cm. In the 0-10 cm layer, there was no substantial difference between the main tillage options. The volume mass varied in the range of 1.20-1.27 g/cm³. In the soil depth of 10-20 cm, the average soil density was from 1.25 g/cm³ in the version with ploughing up to 1.30 on areas with surface tillage. Chiselling and shallow cultivation tended to slightly compact the soil to indicators of 1.23 and 1.26 g/cm³, respectively. In the soil layer of 20-30 cm during surface tillage, compaction occurred at the level of 1.30 g/cm³.

During the winter barley harvest period, soil compaction trends continued. The volume mass

in layers of 10-20 and 20-30 cm substantially exceeded the optimal values for all tillage and was maximum for surface chiselling after corn for grain and sunflower and amounted to 1.34-

1.37 g/cm³. That is, for the period of harvesting winter barley, the indicators of soil volume mass acquired natural values inherent in this type of soil (Table 2).

Table 2. Influence of the main cultivation and predecessors on the total density of the cultivated soil layer during the cultivation of winter barley, g/cm³ (harvest period, average for 2018-2020)

Predecessor	Soil layer, cm	Basic tillage			
		Deep tillage (ploughing) to a depth of 20-22 cm (control)	Chiselling (deep chisel) to a depth of 20-22 cm	Chiselling (discing) to a depth of 12-14 cm	Chiselling (discing) to a depth of 6-8 cm
Soy (control)	0-10	1.26	1.25	1.24	1.25
	10-20	1.32	1.31	1.35	1.36
	20-30	1.35	1.34	1.32	1.37
	0-30	1.31	1.30	1.30	1.33
Winter rapeseed	0-10	1.25	1.24	1.25	1.24
	10-20	1.30	1.31	1.33	1.35
	20-30	1.33	1.34	1.35	1.37
	0-30	1.29	1.30	1.31	1.32
Buckwheat	0-10	1.24	1.24	1.23	1.24
	10-20	1.30	1.30	1.34	1.33
	20-30	1.32	1.33	1.36	1.36
	0-30	1.29	1.29	1.31	1.31
Corn for grain	0-10	1.26	1.25	1.27	1.26
	10-20	1.34	1.33	1.35	1.36
	20-30	1.35	1.34	1.36	1.37
	0-30	1.32	1.31	1.33	1.33
Sunflower	0-10	1.25	1.23	1.24	1.25
	10-20	1.33	1.32	1.34	1.35
	20-30	1.36	1.33	1.37	1.36
	0-30	1.31	1.29	1.32	1.32
HIP ₀₅ (A)		0.016	0.018	0.02	0.019
HIP ₀₅ (B)		0.017	0.01	0.019	0.022
HIP ₀₅ (AB)		0.03	0.027	0.025	0.033

The density of the soil does not provide complete information about the structure of the cultivation layer by itself. For the effective activity of microorganisms, the growth and development of the root system of plants, and the accumula-

tion of moisture in the soil, such an indicator of the physical condition of the cultivation layer as density (porosity) is important.

Doyarenko A.G. identified that when the total porosity decreases below 50%, the conditions

for the growth and development of agricultural plants worsen and their yield decreases, while for 55% the latter was the highest.

This study established that long-term use of deep and chisel tillage did not reduce the overall porosity below 50% of the structure of the cultivated layer, which ensured the high productivity of cultivated plants. For the surface and

shallow chisel tillage, the total porosity in the lower layers was up to 50% of the structure of the cultivated layer, and in some cases less than 47% (Table 3, 4). This structure of the cultivated layer negatively affected the water and air regimes of the soil, the growth and development of the root system, and, ultimately, the yield of winter barley.

Table 3. Influence of the main cultivation and predecessors on the total duty cycle of the tillage layer for growing winter barley, % (sowing period, average for of 2018-2020)

Predecessor	Soil layer, cm	Basic tillage			
		Deep tillage (ploughing) to a depth of 20-22 cm (control)	Chiselling (deep chisel) to a depth of 20-22 cm	Chiselling (discing) to a depth of 12-14 cm	Chiselling (discing) to a depth of 6-8 cm
Soy (control)	0-10	57.0	56.2	58.1	57.3
	10-20	56.2	55.8	56.5	54.6
	20-30	53.1	53.5	52.5	52.0
	0-30	55.4	55.0	55.8	54.6
Winter rapeseed	0-10	58.1	57.3	57.7	57.0
	10-20	55.8	56.2	52.5	55.0
	20-30	53.5	53.1	52.5	52.5
	0-30	55.8	55.4	55.4	54.6
Buckwheat	0-10	57.3	57.0	57.7	57.7
	10-20	56.2	56.5	56.5	55.4
	20-30	53.1	53.9	53.1	53.1
	0-30	55.4	55.8	55.8	55.4
Corn for grain	0-10	56.5	55.8	55.0	55.4
	10-20	55.8	55.0	54.2	53.5
Corn for grain	20-30	52.0	53.5	51.5	52.5
	0-30	54.6	54.6	53.5	53.9
Sunflower	0-10	57.0	56.5	55.8	56.2
	10-20	56.2	55.8	55.0	53.1
	20-30	53.1	53.1	52.0	51.5
	0-30	55.4	55.0	54.2	53.5
HIP ₀₅ (A)		0.014	0.014	0.015	0.018
HIP ₀₅ (B)		0.013	0.015	0.017	0.016
HIP ₀₅ (AB)		0.021	0.019	0.025	0.019

Table 4. Influence of the main cultivation and predecessors on the total duty cycle of the tillage layer for growing winter barley, % (harvest period, average for 2018–2020)

Predecessor	Soil layer, cm	Basic tillage			
		Deep tillage (ploughing) to a depth of 20-22 cm (control)	Chiselling (deep chisel) to a depth of 20-22 cm	Chiselling (discing) to a depth of 12-14 cm	Chiselling (discing) to a depth of 6-8 cm
Soy (control)	0-10	51.5	52.0	52.5	52.0
	10-20	49.2	49.6	48.2	47.8
	20-30	48.2	48.5	49.2	47.3
	0-30	49.6	50.0	50.0	48.9
Winter rapeseed	0-10	52.0	52.5	52.0	52.5
Winter rapeseed	10-20	50.0	49.6	48.9	48.2
	20-30	48.9	48.5	48.2	47.3
	0-30	50.4	50.0	49.6	49.2
Buckwheat	0-10	52.5	52.4	53.1	52.5
	10-20	50.0	50.0	48.5	48.9
	20-30	49.2	48.9	47.8	47.8
	0-30	50.4	50.4	49.6	49.6
Corn for grain	0-10	51.5	52.0	51.2	51.5
	10-20	48.5	48.9	48.2	47.8
	20-30	48.2	48.5	47.8	47.3
	0-30	49.2	49.6	48.9	48.9
Sunflower	0-10	52.0	53.1	52.5	52.0
Sunflower	10-20	48.9	49.2	48.5	48.2
	20-30	47.8	48.9	47.3	47.8
	0-30	49.6	50.4	49.2	49.2
HIP ₀₅ (A)		0.016	0.017	0.013	0.018
HIP ₀₅ (B)		0.013	0.015	0.016	0.02
HIP ₀₅ (AB)		0.015	0.018	0.017	0.019

The productivity of winter barley is an integral indicator of the effectiveness of using various predecessors and tillage.

Among the predecessors under study, the highest level of crop yield was obtained for

planting it after buckwheat, winter rapeseed, and soybeans for conducting chisel tillage to a depth of 20-22 cm. On average, for three years in these variants, the yield was from 6.0 to 6.3 t/ha (Table 5).

Table 5. Yield of winter barley depending on its predecessors and main tillage, t/ha

Predecessor (A)	Main tillage (B)	Years			Average for 2018-2020
		2018	2019	2020	
Soy (control)	Deep tillage (ploughing) to a depth of 20-22 cm (control)	6.2	5.7	5.3	5.7
	Chiselling (deep chisel) to a depth of 20-22 cm	6.2	6.1	5.8	6.0
	Chiselling (discing) to a depth of 12-14 cm	5.5	5.3	5.1	5.3
	Chiselling (discing) to a depth of 6-8 cm	5.3	5.2	5.0	5.2
Winter rapeseed	Deep tillage (ploughing) to a depth of 20-22 cm (control)	6.0	5.8	5.4	5.7
	Chiselling (deep chisel) to a depth of 20-22 cm	6.4	5.9	5.8	6.0
	Chiselling (discing) to a depth of 12-14 cm	5.8	5.6	5.5	5.6
	Chiselling (discing) to a depth of 6-8 cm	5.7	5.1	5.3	5.4
Buckwheat	Deep tillage (ploughing) to a depth of 20-22 cm (control)	6.3	5.8	5.7	5.9
	Chiselling (deep chisel) to a depth of 20-22 cm	6.5	6.1	6.2	6.3
	Chiselling (discing) to a depth of 12-14 cm	6.2	5.8	5.5	5.8
	Chiselling (discing) to a depth of 6-8 cm	5.9	5.9	5.3	5.7
Corn for grain	Deep tillage (ploughing) to a depth of 20-22 cm (control)	5.0	4.9	4.8	4.9
	Chiselling (deep chisel) to a depth of 20-22 cm	5.4	5.2	4.8	5.1
	Chiselling (discing) to a depth of 12-14 cm	4.7	4.5	4.6	4.6
	Chiselling (discing) to a depth of 6-8 cm	4.6	4.6	4.3	4.5
Sunflower	Deep tillage (ploughing) to a depth of 20-22 cm (control)	5.4	5.2	5.0	5.2
	Chiselling (deep chisel) to a depth of 20-22 cm	5.9	5.6	5.7	5.7
	Chiselling (discing) to a depth of 12-14 cm	5.0	4.7	4.8	4.8
	Chiselling (discing) to a depth of 6-8 cm	5.1	4.6	4.6	4.8
HIP ₀₅	A	0.248769	0.198605	0.158627	0.248769
	B	0.222506	0.177638	0.14188	0.222506
	AB	0.497538	0.39721	0.317254	0.497538

The lowest yield of winter barley was obtained after corn for grain during shallow and surface tillage. The decrease in yield was from 25 to 29%. The difference between winter barley and sunflower reduced the yield of the crop by 18-20% compared to the reference predecessors.

CONCLUSIONS

In the Transcarpathia of Ukraine, on sod-podzolic soils, minimising tillage leads to an increase in the density of the cultivation layer and a decrease in overall porosity. The soil

density increased from sowing to full ripeness of grain, which did not exceed the optimal one for most agricultural crops, including winter barley (1.30 g/cm³) for ploughing and chiselling to the depth of 20-22 cm. With shallow and surface chisel tillage, the density formed in the range of 1.35-1.37 g/cm³, which exceeded the optimal one for the culture.

The highest yield (6.0-6.3 t/ha) of winter barley was formed when placed after buckwheat, winter rapeseed, and soybeans with chiselling to the depth of 20-22 cm.

REFERENCES

- [1] Berezhnyak, M.F. (2015). Influence of tillage systems on agrophysical properties of southern heavy loam chernozem in the forest. URL: <http://www.sworld.com.ua/konfer39/192.pdf>
- [2] Chumbey, V.V., Tanchik, S.P., Pavlov, O.S. (2018) Stocks of available soil moisture for buckwheat cultivation depending on the main and pre-sowing cultivation in the conditions of Prykarpattia Ukraine. Scientific Bulletin of NULES of Ukraine. Series: Agronomy, 286, 113-120
- [3] Chumbey, V.V., Tanchik, S.P., Pavlov, O.S. (2019) Influence of cultivation on bulk density of sod-podzolic soil for buckwheat cultivation in Prykarpattia of Ukraine. Crop and soil science, 1,27-33 <http://dx.doi.org/10.31548/agr2019.01.027>
- [4] Degodyuk, S., Degodyuk, E., Litvinova, O., Bodnar, Yu., & Buslaeva, N. (2020). Changes in agrophysical parameters of gray forest soil with long-term use of organic and mineral fertilizers. Bulletin of Agrarian Science, 98(1), 19-24. <https://doi.org/10.31073/agrovisnyk202001-03>
- [5] Demyatnik, L.M., Tsilyurik, O.I., Chorna, V.I., Gavryushenko, O.O. (2021). Changes in agrophysical properties of common chernozem under the influence of tillage in crop rotation and on reclaimed lands in the steppe of Ukraine. Cereals, 5(1), 115-124
- [6] Gavrilyuk, Y.V. (2016). Influence of tillage systems on its agrophysical condition. Bulletin of Dnipropetrovsk State Agrarian and Economic University. №3. Pp. 73-77.
- [7] Huang, M., Liang, T., Wang, J., Zhou, C. (2015) Effects of no-tillage systems on soil physical properties and carbon sequestration under long-term wheat-maize double cropping system. Catena, 128, 195-202
- [8] Karpenko V.G., Panchenko O.B. (2014). Change of agrophysical indicators of soil fertility and buckwheat productivity depending on tillage and fertilizer systems. Agrobiology. № 2. Pp. 43-46.
- [9] Korchagin, A.A., Ilyin, L.I., Bibik, T.S., Petrosyan, R.D. (2015) Influence of treatment systems on the water regime of gray forest soil, 8.
- [10] Kramaryov, S.M., Bandura, L.P., Artemenko, S.F., Kramaryov, O.S., Pisarenko, P.V. (2021). Changes in agrophysical properties of common chernozem during long-term land use and economic incentives for their restoration. PDAA Bulletin, 2,93-106 <https://doi.org/10.31210/visnyk2021.02.12>
- [11] Lavinia Burtan , Denis Țopa, Gerard Jităreanu , Anca Elena Calistru, Lucian Răus, Irina Gabriela Cara , Carmen Sîrbu , Traian Cioroianu (2020) The influence of conservative tillage systems on physico-chemical properties and yield under a cambic chernozem from northeastern part of Romania. *Romanian agricultural research*, 37, 141-149
- [12] Litvinov, D.V. (2015) Formation of soil water regime in the system of short-rotation crop rotations. *Visnyk ahrarnoyi nauky*, 11(753), 13-18

- [13] Markovska, O.E., Malyarchuk, M.P., Isakova, G.M. Tomnytsky, A.V. (2020) Cultivation productivity under different systems of basic tillage in the conditions of the southern Steppe of Ukraine under irrigation. *Irrigation agriculture. Collection of scientific works*, 74, 53-59. <https://doi.org/10.32848/0135-2369.2020.74.8>
- [14] Medvedev, V.V., Lipets, E., Lindina, T.E. (2002). Influence of soil density on the assimilation of nutrients by crops. *Bulletin of Agricultural Science*, 5, 11-15
- [15] Nakloka, Y.I., Yeshchenko, V.O. (2005) Soil density depending on the methods and depths of the main cultivation under spring barley after winter wheat. *Scientific works of Poltava GAA*. Poltava, 4(23), 261-265
- [16] Odachenko, O.M., Tanchyk, S.P. (2016). Influence of shelf and zero tillage on the soil structure in the field of spring barley of the Right-Bank Forest-Steppe of Ukraine. *Agrobiology* №1: 36-41.
- [17] Ovsyannikov, R.O. (2020). Peculiarities of the influence of winter wheat precursors and methods of basic tillage on agrophysical indicators of common chernozem in the conditions of research NSC DDAEU.
- [18] Pikovska, O.V. (2013). Influence of minimization of tillage on the structural condition of ordinary chernozem. *Scientific Bulletin of the National University of Life and Environmental Sciences of Ukraine. Series: Agronomy*, 183(2), 193-197. URL: [http://nbuv.gov.ua/UJRN/nvnau_agr_2013_183\(2\)_35](http://nbuv.gov.ua/UJRN/nvnau_agr_2013_183(2)_35)
- [19] Reznichenko, N.D. (2015) Influence of methods of basic tillage and “direct sowing” on the water-physical properties of the soil and the yield of winter barley on irrigated lands in southern Ukraine. *Tavriya Scientific Bulletin*, 91, 406 p.
- [20] Ryken, N., Vanden Nest T., Al-Barri B., Blake, W. (2018) Oct all soil erosion rates under diferent tillage practices in central Belgium: New perspectives from a combined approach of rainfall simulations and be measurements. *Soil and Tillage Research*, 179, 29-37.
- [21] Shevchenko, M.V. (2013). Changes in the water-physical condition of the soil and the yield of spring barley with long-term use of basic tillage methods. *Proceedings of the international scientific-practical Internet conference “Directions of development of modern farming systems”, dedicated to the 110th anniversary of the birth of Professor SD Lysogorova: scientific publication*. Kherson: VC “Kolos”, 176-181.
- [22] Shevchenko, M.V., Budyonny, V.Yu., Kolos, M.O. (2012). Water-physical properties of chernozem soils and productivity of grain crops depending on cultivation technologies. *Bulletin of the Dokuchaev Kharkiv National Agrarian University. Series: Soil Science, Agrochemistry, Agriculture, Forestry, Soil Ecology*, 132-135.
- [23] Shuvar, I.A., Hrynyk, S.I. (2019). Influence of the method of basic tillage and fertilizer on agrophysical properties of sod-podzolic soil of Precarpathia for growing spring wheat. *Scientific journal «Crop and Soil Science»*, 10(2), 38-47. <http://dx.doi.org/10.31548/agr2019.02.028>
- [24] Sinchenko, V.V., Tanchik, S.P., Litvinov, D.V. (2019) Influence of different tillage methods on the structural aggregate composition of chernozem typical of the Right-Bank Forest-Steppe of Ukraine, 3(79) <http://dx.doi.org/10.31548/dopovidi2019.03.013>
- [25] Tanchyk, S.P., Salnikov, S.M. (2014). Influence of agricultural systems on water-physical properties of soil at cultivation of sugar beets in the conditions of the right-bank Forest-steppe of Ukraine. *Scientific reports of the National University of Life and Environmental Sciences of Ukraine. №4*. http://www.irbis-nbuv.gov.ua/cgi-bin/irbis_nbuv/cgiirbis_64.exe?C21COM=2&I21DBN=UJRN&P21DBN=UJRN&IMAGE_FILE_DOWNLOAD=1&Image_file_name=PDF/Nd_2014_4_13.pdf
- [26] Tkalich, I.D., Oleksyuk, O.M., Tkalich, Y.I., Kulik, A.O. (2011). Basic tillage for field crops. *Bulletin of the Institute of Agriculture of the steppe zone*, 1, 15-20. URL: http://nbuv.gov.ua/UJRN/bisg_2011_1_5//http://www.institut-zerna.com/library/pdf1/3.pdf

- [27] Tsilyuryk, O.I., Shapka, V.P. (2014). Efficiency of shelfless tillage for growing spring barley in the northern steppe. *Bulletin of the Poltava State Agrarian Academy*, 1, 25-29
- [28] Tsylyuryk, O.I., Chorna, V.I., Desyatnyk, L.M., Gorshchar, V.I. (2020). Influence of methods of basic tillage on the dynamics of productive moisture reserves in spring barley crops in the Northern Steppe of Ukraine *Cereals*, 4(2), 339-352 <https://doi.org/10.31867/2523-4544/0143>
- [29] Tsyuk, O.A., Kirilyuk, V.I. (2016). Influence of agricultural systems on changes in agrophysical indicators of soil. *Scientific reports of the National University of Life and Environmental Sciences of Ukraine*, (4). <http://surl.li/kwnpb>
- [30] Uvarenko, K.Yu. (2018) Assimilation of nutrients by different varieties of spring barley depending on the density of the soil structure. *Collection of scientific works of Uman National University of Horticulture*, 92, Part 1: agricultural sciences, 223-230.
- [31] Weber, J.F., C Kunz, G.G. (2017) Peteinatos. Weed control usieng conventional tillage, reduced tillage, no-tillage and cover crops in orgnic soybean. *Agriculture*, 43(7) <https://doi.org/10.3390/agriculture7050043>.

С.П. Танчик

Доктор сільськогосподарських наук, професор, завідувач кафедри
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

Н.І. Бабіля

Аспірант
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

А.І. Бабенко

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

Агрофізичні показники ґрунту за вирощування ячменю озимого в Закарпатті України

Анотація. У статі подані значення, завдання та результати різних способів основного обробітку ґрунту за різних попередників на агрофізичні його властивості за вирощування ячменю озимого в Закарпатті України. Ґрунти дослідного поля – дернові опідзолені оглеєні, які містять у гумусовому горизонті в середньому 2,6 % гумусу. З глибиною кількість перегною зменшується дуже поступово й на глибині 100-130 см він досягає ще 1,0-1,7 %. Ґрунт є типовим для зони проведення досліджень, середньо забезпечений рухомими формами азоту, фосфору та калію. Якісна оцінка обстежених ґрунтів показала, що ґрунти потребують постійного застосування органічних і мінеральних добрив, проведення вапнування та впровадження сівозмін. Щільність ґрунту є важливим показником фізичних властивостей ґрунту, який впливає не лише на ґрунтові режими, а й на його якість обробітку, що в підсумку впливає на урожайність культури та її якість. На період сівби ячменю озимого найбільше сприятливі показники об'ємної маси 0-10 см шару ґрунту забезпечували всі системи основного обробітку. Щільність ґрунту в середньому по варіантах основного обробітку коливалася в межах 1,09-1,17 г/см³, за НІР0,5

0,01 г/см³. На глибині 10-20 см середня об'ємна маса ґрунту за оранки становила 1,14 г/см³, за чизельного обробітку вона була без істотних відмінностей – 1,15 г/см³. Проведення мілкого на 12-14 см та поверхневого на 6-8 см супроводжувалося підвищенням показників об'ємної маси до, відповідно, 1,16 і 1,19 г/см³. У шарі ґрунту 20-30 см була аналогічною: за мілкого безполицевого обробітку середня щільність була на рівні 1,24 г/см³, а за поверхневого – 1,25 г/см³. Попередники суттєво не впливали на зміну щільності оброблювального шару ґрунту. Проте, після кукурудзи на зерно та соняшника спостерігається тенденція до підвищення об'ємної маси ґрунту після безполицевого мілкого та поверхневого обробітку, особливо в нижніх шарах ґрунту. Ця щільність ґрунту була на рівні 1,24-1,26 г/см³, що не виходила за межі оптимальної. Розпушений у процесі механічного обробітку ґрунт упродовж вегетаційного періоду під впливом сили власної маси, зволоження і висихання самоущільнюється до рівноважної щільності. Тому на період колосіння і збирання врожаю ячменю озимого відбулося поступове ущільнення ґрунту до природних значень. У 0-10 см шарі ґрунту об'ємна маса варіювала в межах 1,20-1,27 г/см³ у шарі ґрунту 10-20 см – 1,25-1,30 г/см³ і 20-30 см – 1,34-1,37 г/см³. Для ефективної діяльності мікроорганізмів, росту й розвитку кореневої системи рослин та нагромадження вологи в ґрунті важливе значення має щільність (пористість). Встановлено, що тривале застосування полицевих і безполицевих обробіток ґрунту не знижувало загальної щільності нижче 50 % будови оброблюваного шару, що забезпечило високу продуктивність культурних рослин. За безполицевих поверхневого та мілкого обробітку ґрунту загальна щільність у нижніх шарах становила до 50 % будови оброблювального шару, а в деяких випадках менш як 47 %. Така будова оброблювального шару негативно впливала на водний та повітряний режими ґрунту, на ріст і розвиток кореневої системи і, у кінцевому результаті на урожайність ячменю озимого. Найвища урожайність ячменю озимого отримана після гречки, ріпаку озимого та сої (6,0-6,3 т/га) за проведення безполицевого чизельного обробітку ґрунту на 20-22 см. Після кукурудзи на зерно і соняшнику урожайність становила 5,1-5,7 т/га

Ключові слова: часник; сорт; Любаша; Дюшес; Угорський; урожайність; поліморфізм

O. Pavlov*

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

A. Babenko

PhD in Agricultural Sciences
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

A. Andrushchenko

1st Year Master's Degree
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

Biological effectiveness of herbicides in winter wheat crops of autumn sowing

Abstract. An effective measure for controlling the most harmful wintering and winter weed species, such as *Apera spica-venti*, *Galium aparine*, *Veronica persica*, *Consolida regalis*, *Capsella bursa-pastoris*, *Descurainia Sophia*, *Vicia villosa*, etc. in winter wheat crops is the autumn application of herbicides, especially in the early stages of crop development, starting from the seed germination stage, when it is most sensitive to their presence. The study presents the results of two-year studies on the biological effectiveness of applying the herbicide Pledge 50, WP in different stages of development of winter wheat (BBCH 00, 11, 12, 14, and 16) independently and in a mixture with herbicides partners: Zenkor Liquid 600, SC, Marathon, SC, Granstar Gold 75, WG, Grodil Maxi 375, OD, and adjuvant Skaba, EC. As a result, it is identified that the biological effectiveness of the drugs under study against *Apera spica-venti* and other winter and wintering weeds substantially differed depending on the phase of development of winter wheat during the period of herbicide application. Pre-emergence application of herbicides does not ensure proper control of *Apera spica-venti* and other winter and wintering weeds. In particular, during the spring resumption of vegetation, the control of *Apera spica-venti* with the use of 0.1 kg/ha Pledge 50, WP was 69.0%, with an overall efficiency of 68.0%. Application of 0.4 l/ha Sencor Liquid 600, CS provided indicators of 66.1 and 71.4%, respectively. The introduction of 0.1 kg/ha of Pledge 50, WP in the BBCH 11 development phase provided high efficiency in controlling *Apera spica-venti* and all weeds in general with indicators of 91.2 and 87.6%, respectively. The use of a reduced rate of 0.08 kg/ha Pledge 50, WP in the BBCH 12 phase did not reduce both the overall

Suggested Citation:

Pavlov, O., Babenko, A., & Andrushchenko, A. (2021). Biological effectiveness of herbicides in winter wheat crops of autumn sowing. *Plant and Soil Science*, 12(4), 50-59. doi: 10.31548/agr2021.04.050.

*Corresponding author



Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (<https://creativecommons.org/licenses/by/4.0/>)

effectiveness against weeds – 87.4%, and *Apera spica-venti* in particular – 93.1%. The use of Pledge 50, WP (0.1 kg/ha) in the BBCH 16 phase had a worse, but acceptable effect with efficiency indicators of 84.2% against *Apera spica-venti* and 83.6% overall. The best control of *Apera spica-venti* and all weeds, in general, was obtained by using a mixture of Pledge 50, WP + Granstar Gold 75, WG + adjuvant Skaba, EC (0.06 kg/ha + 0.025 l/ha + 0.05 l/ha) in the BBCH 14 phase – 97.5 and 99.2%, which is at the level of Sencor Liquid 600, SC + Grodil Maxi 375, OD (0.35 l/ha + 0.11 kg/ha). The highest yield of winter wheat in the experiment was obtained by applying a mixture of Pledge 50, WP + Granstar Gold 75, WG + adjuvant Skaba, EC (0.06 kg/ha + 0.025 l/ha + 0.05 l/ha) in the BBCH 14 phase – 7.56 t/ha, which is 59.8% better than the control

Keywords: winter wheat; herbicides; biological efficiency; *Apera spica-venti*; Galium Aparine; *Veronica persica*; *Consolida regalis*; *Capsella bursa-pastoris*; *Descurainia Sophia*; *Vicia villosa*; yield

RELEVANCE

As is known, the main and most harmful weeds in winter grain crops are winter and wintering species, such as: common windgrass (*Apera spica-venti*), cleavers (*Galium Aparine*), bird-eye speedwell (*Veronica persica*), field larkspur (*Consolida regalis*), shepherd's purse (*Capsella bursa-pastoris*), flaxweed (*Descurainia Sophia*), winter vetch (*Vicia villosa*) *et al.* These weeds are a serious competitor to the crop for moisture and light, reduce the effectiveness of fertilisers applied. Therefore, an effective method of controlling wintering and winter weeds in winter wheat crops can be the autumn application of herbicides, especially in the early stages of crop development, starting from the stage of seed germination, when it is most sensitive to their presence.

ANALYSIS OF RECENT STUDIES AND PAPERS

According to Soltani *et al.* (2006), the constant expansion of the area under no-till and the injudicious use of glyphosate group herbicides in predecessor crops led to an increase in the presence of winter annual, biennial, and perennial weeds in winter wheat agrocenoses. According to Curran *et al.* (2017), winter wheat yields declined with increasing biomass of weeds such as winter vetch. Therefore, the autumn post-emergence application of herbicides was a priority to reduce competition with this weed during the autumn and early spring growing seasons. Therewith,

the most effective and safe active ingredients for the culture were 2,4-D amine salt, mesosulfuron-methyl, tribenuron-methyl, and tifensulfuron-methyl. According to Storchous I.M. (2019), the optimal time for the use of herbicides in the autumn period in winter wheat crops is the phenological phase of crop development of 1-2 leaves, while the use of a mixture of active substances tribenuronmethyl, 562.5 g/kg and tifensulfuron-methyl, 187.5 g/kg provided one hundred per cent effectiveness against weeds. Studies by Kochyk G. and Melnychuk A. (2013) proved an increase in the yield of winter wheat by 20.1% with the autumn application of a combination of tribenuron-methyl and metsulfuron-methyl in contrast to spring.

Many studies confirm the high harmfulness of common windgrass in winter grain crops, especially in cases where their share in the structure of sown areas was more than 60%. Researcher Bartels (2004) indicates a loss of 3 t/ha of winter wheat grain yield in areas where the number of *Apera spica-venti* averaged 200 pcs./m² compared to the areas where this weed was controlled. Danish researchers Andreasen & Stryhn (2008) and Melander *et al.* (2008) also indicate an increase in the proportion of broom infestation of winter crops. *Apera spica-venti* ranked fifth in the ranking of the 15 most important weed species identified in 26 European countries in winter grain crops (Schroeder *et al.*, 1993). Latvian researchers identified that in winter wheat

fields, where *Apera spica-venti* was the dominant weed with a share of 70-80% of the total weed biomass, the spring application of herbicides did not ensure proper control of this weed. Autumn post-emergence application of crop protection products resulted in satisfactory control over *Apera spica-venti* up to the harvest time of the next year (Vanaga *et al.*, 2010).

There are also no unambiguous results regarding the effectiveness of the pre-emergence application of herbicides in winter wheat crops. According to Streit *et al.* (2003), the effectiveness of weed control with insurance herbicides was generally better than the effectiveness of the pre-emergence application of the protective products, regardless of the intensity of tillage. However, Johnson *et al.* (2018) indicate that the effective control of grass weeds, in particu-

lar, *Bromus* spp. and the highest yield of winter wheat is due to the pre-emergence use of herbicides based on piroxasulfone in combination with flumioxazine.

Purpose of the study. Establish the biological effectiveness of herbicides against cereal and dicotyledonous annual winter and wintering weeds in winter wheat crops with pre-emergence and post-emergence application during the various phases of crop development.

MATERIALS AND METHODS

The study was conducted during 2018-2021 in the conditions of the Separated subdivision of the National University of Life and Environmental Sciences of Ukraine "Agronomic Research Station", Pshenychne village, Vasylkivsky district, Kyiv region, according to the scheme shown in Table 1.

Table 1. Scheme of the experiment on the examination of the biological effectiveness of herbicides

No.	Experiment options	Active ingredient	Drug consumption rates l/ha, kg/ha	BBCH
1	Control		-	-
2	Pledge 50, WP	flumioxazine, 511 g/kg	0.08	00
3	Sencor Liquid 600, SC	metribuzin (250 g/l)	0.40	
4	Pledge 50, WP	flumioxazine, 511 g/kg	0.08	12
5	Marathon, SC	pendimethalin, 250 g/l, isoproturon, 125 g/l	4.00	
6	Pledge 50, WP + Granstar Gold 75, WG + adjuvant Skaba, EC	flumioxazine, 511 g/kg + tribenuron-methyl, 562.5 g/kg, tifensulfuron-methyl, 187.5 g/kg + polyalkylene oxide modified with heptamethyltrisiloxane, 21%, and a complex of nonionic surfactants 79%	0.06 + 0.025 + 0.05	14
7	Sencor Liquid 600, SC + Grodil Maxi 375, OD	metribuzin, 600 g/l + iodosulfuron, 25 g/l, amidosulfuron, 100 g/l, mefenpir-diethyl (antidote), 250 g/l	0.35 + 0.11	
8	Granstar Gold 75, WG + adjuvant Skaba, EC	tribenuron-methyl, 562.5 g/kg, tifensulfuron-methyl, 187.5 g/kg + polyalkylene oxide modified heptamethyltrisiloxane, 21%, and a complex of nonionic surfactants 79%	0.025 + 0.05	
9	Pledge 50, WP	flumioxazine, 511 g/kg	0.1	11
10	Pledge 50, WP	flumioxazine, 511 g/kg	0.1	16

Experiment area is 1200 m². The area of each experiment variant is 120 m² (4 repetitions of 30 m² each). The working fluid flow rate is 300 l/ha. The placement of variants and repetitions in the experiment is randomised. The method of applying herbicides is spraying with a Jacto pjb-16C satchel sprayer. The ground cover at the station is typical medium-loamy chernozem. The humus content in the arable soil layer is 4.38-4.53%, the pH of the salt extract is 6.9-7.3; the absorption capacity is 32 mg-eq./100 g of soil. The humus Reserve in the meter thickness is 404-448 t/ha. Such soil declination is typical for the forest-steppe zone, covering 54.6% of its territory. Groundwater is at a depth of 5-6 m.

The total moisture capacity of the soil of the experimental field in the 0-30 cm layer is 38.4%, in the 30-45 cm layer – 42.75%. The field moisture capacity of this soil in a layer of 0-30 cm reaches 28.2%, capillary rupture humidity – 19.7%, maximum hygroscopicity – 74.6%, moisture inaccessible to plants – 10%, total porosity at equilibrium – 52-55%.

In the experiment, the winter wheat variety Linus was sown. The seeding rate is 3.8 million seeds/ha, seeding depth is 4 cm, row spacing width – 19 cm, predecessor – peas.

Agricultural techniques for growing winter wheat in the experiment are generally accepted for the conditions of the Right-Bank Forest-Steppe of Ukraine. Protection against pests and diseases is the same for all areas of the experiment.

Visual evaluation of the effectiveness of the drugs was determined on days 7, 14, and 28 after treatment and in the spring after the

resumption of vegetation. Species composition of weeds on control and experimental options: before treatment (except for the use of pre-emergence), on the 7th, 14th, and 28th day after treatment and in the spring after the resumption of vegetation.

Determination of the biological effectiveness of herbicides was conducted according to the method of Tribel S.O. et al. (2001). Research methods: observation, analysis, and synthesis in combination with special methods (field, quantitative-weight, mathematical-statistical). Statistical analysis of experimental data – using Excel software from MS Office 365 and Statistica 10.

RESULTS

Visual assessment of the effect of the protective products under study was performed separately for each type of weed. In variants with the post-emergence application of drugs, the first record of the number of weeds was conducted immediately before their use. During the period of these records, 6 main types of winter and wintering weeds were present in winter wheat crops. The number of weeds in the control and experimental variants substantially differed depending on the period of application of the drugs. *Apera spica-venti* was the dominant species in winter wheat crops among cereal weeds. Dicotyledonous weeds were represented by five species with approximately equal numbers of each (Table 2). The first records of weeds in variants with pre-emergence use of herbicides were conducted 7 days after their application.

Table 2. Species composition and number of weeds in variants with the post-emergence application of herbicides before their application, pcs./m²

Experiment variant	Types of weeds						Total
	<i>Apera spica-venti</i>	<i>Galium aparine</i>	<i>Veronica persica</i>	<i>Consolida regalis</i>	<i>Capsella bursa-pastoris</i>	<i>Descurainia Sophia</i>	
BBCH 11							
Control	6.25	4.75	5.5	3.75	4.75	4.25	29.3
9. Pledge 50, WP	4.75	5.25	5.75	5.25	5.25	3.75	30

Table 2. Continued

Experiment variant	Types of weeds						
	Apera spica-venti	Galium aparine	Veronica persica	Consolida regalis	Capsella bursa-pastoris	Descurainia Sophia	Total
BBCH 12							
Control	13.25	4.75	8	5.5	6	6.25	43.8
4. Pledge 50, WP	13.5	6.5	6.75	7.25	6.75	5.0	45.8
5. Marathon, SC	9.25	6	7	5.25	6.5	5.0	39.0
BBCH 14							
Control	13.25	4.75	8	5.5	6	4.25	41.8
6. Pledge 50, WP + Granstar Gold 75, WG + adjuvant Skaba, EC	12.25	6.75	5.75	6.25	5.75	5	41.8
7. Sencor Liquid 600, SC + Grodil Maxi 375, OD	14.75	7.75	4.5	5.75	4.75	5.75	43.8
8. Granstar Gold 75, WG + adjuvant Skaba, ke	10.75	8.75	7.75	6	6.5	4.5	44.8
BBCH 16							
Control	13.25	7.5	8.5	8	12.5	6.0	55.8
10. Pledge 50, WP	10.25	8.25	5.25	5.5	6	5.8	41.0

The biological effectiveness of the drugs under study expressed in % for each type of weed was calculated to assess the effectiveness of the drugs under study. The biological effectiveness of the preparations for pre-emergence application was in the range of 57.0% against common windgrass and 58.5% in general against all types of weeds for the application of Pledge 50, WP (0.08 kg/ha) and, respectively, 52.6 and 57.0% for the use of Sencor Liquid 600, CS (0.4 l/ha). Such indicators are insufficient and are caused

by unfavourable conditions that have developed during the period of their application (low soil moisture).

The introduction of Pledge 50, WP after germination of the crop in different phases of development showed high efficiency in controlling Apera spica-venti and other winter and wintering weeds. The introduction of this herbicide at a rate of 0.1 kg/ha in the development phase of winter wheat BBCH 11 provided reliable control of Apera spica-venti at the level of 93.7%,

with an overall efficiency of 88.1%. Reduction of the norm of Pledge 50, WP to 0.08 kg/ha in the BBCH 12 phase of crop development, efficien-

cy decreased by 3.5 percentage points to 90.2% against *Apera spica-venti* and to 86.2% overall (Table 3).

Table 3. Biological effectiveness of herbicides, %

Option No.	Types of weeds													
	Apera spica-venti		Galium aparine		Veronica persica		Consolida regalis		Capsella bursa-pastoris		Descurainia Sophia		Total	
	a	s	a	s	a	s	a	s	a	s	a	s	a	s
BBCH 00														
2.	57.0	69.0	36.3	53.5	67.9	67.1	57.3	64.3	54.2	75.7	78.5	78.5	58.5	68.0
3.	52.6	66.1	44.2	41.8	63.8	75.4	51.0	79.1	42.7	78.3	87.7	87.7	57.0	71.4
BBCH 11														
9.	93.7	91.2	80.4	74.7	83.8	84.8	95.4	90.3	82.8	91.9	92.5	92.5	88.1	87.6
BBCH 12														
4.	90.2	93.1	85.8	80.6	83.7	84.0	86.0	89.3	88.0	88.5	83.8	88.8	86.2	87.4
5.	94.5	89.3	72.8	68.8	63.4	59.9	93.3	92.6	90.1	90.3	91.4	95.0	84.3	82.7
BBCH 14														
6.	97.5	97.5	100.0	100.0	91.9	100.0	97.9	97.9	100.0	100.0	100.0	100.0	97.9	99.2
7.	96.9	94.6	98.3	94.9	73.5	75.6	100.0	100.0	96.4	96.1	100.0	100.0	94.2	93.5
8.	73.1	77.7	90.3	82.3	93.0	92.9	81.4	82.9	100.0	100.0	92.5	92.5	88.4	88.1
BBCH 16														
10.	70.5	84.2	82.3	78.5	84.5	97.0	81.6	83.9	89.6	79.4	78.7	78.7	81.2	83.6
HIP₀₅	12.2	9.9	16.9	21.2	23.0	24.6	15.8	14.3	17.4	9.4	16.9	10.3	7.1	7.5

Note: a – accounting in autumn 28 days after the introduction of herbicides, s – accounting for the period of spring restoration of vegetation of the crop

The highest efficiency of control of *Apera spica-venti* and other weeds in the experiment was recorded for the introduction of a mixture of Pledge 50, WP + Granstar Gold 75, WG + adjuvant Skaba, EC (0.06 kg/ha + 0.025 l/ha + 0.05 l/ha) – 97.5 and 97.9% in the BBCH 14 phase, which is reliable at the level of the Sencor Liquid 600, SC + Grodil Maxi 375, OD (0.35 l/ha + 0.11 kg/ha) – 96.4 and 94.2% composition. The use in the same phase of only Granstar Gold 75, WG + adjuvant Scaba, EC (0.025 kg/ha + 0.05 l/ha) provided mediocre effectiveness against *Apera spica-venti* – 73.1% against the

background of sufficient control of dicotyledonous weeds. Notably, the Sencor Liquid 600, SC + Grodil Maxi 375, OD (0.35 l/ha + 0.11 kg/ha) composition provided insufficient control of *Veronica persica* – 73.5% (Table 3).

The introduction of 0.1 kg/ha Pledge 50, WP in the BBCH 16 phase provided control of *Apera spica-venti* with an efficiency of 70.5% and other weeds – 81.2%, which in general did not substantially differ from Granstar Gold 75, WG + adjuvant Scaba, EC (0.025 kg/ha + 0.05 l/ha).

One of the best in control of *Apera spica-venti* was the option with the introduction

of the BBCH 12 marathon phase, SC at a rate of 4.0 l/ha – 94.5%, however, it did not provide reliable control of *Veronica persica* – only 63.4%, which is the lowest indicator in the experiment.

The last accounting conducted for the period of spring vegetation restoration (SVR) of winter wheat did not show substantial changes in the species composition and number of weeds in the cultivated areas. The biological effectiveness of the preparations for the spring renewal of winter wheat vegetation was higher compared to the last autumn records, which is mainly due to an increase in the number of weeds in the areas of the control variant and a decrease in their number in some herbicidal variants.

The effectiveness of soil herbicides against *Apera spica-venti* was 69.0% of the application of 0.08 kg/ha Pledge 50, WP and 68.0% in general against winter and wintering weeds, which is at the level of 0.4 l/ha Sencor Liquid 600, SC (Table 3).

Statistically, the same effectiveness against *Apera spica-venti* and other weed species was provided by the use of Pledge 50, WP (0.1 kg/ha) in the BBCH 11 phase – 91.2 and 87.6% and Pledge

50, WP (0.08 kg/ha) in the BBCH 12 phase – 93.1 and 87.4%.

The highest efficiency against these weeds was when using a mixture of Pledge 50, WP + Granstar Gold 75, WG + adjuvant Skaba, ke (0.06 kg/ha + 0.025 l/ha + 0.05 l/ha) in the BBCH 14 phase – 97.5 and 99.2%, which is at the level of Granstar Gold 75, WG + adjuvant Skaba, EC + Grodil Maxi 375, OD (0.35 l/ha + 0.11 kg/ha).

The use of Pledge 50, WP (0.1 kg/ha) in the BBCH 16 phase had a worse, but acceptable effect in controlling broom and other weeds in general – 84.2 and 83.6% compared to the use of this herbicide in earlier phases of winter wheat development (Table 3).

The crop yield in the control variant averaged 4.73 t/ha. All herbicidal variants had substantially higher yields, which is confirmed by dispersion analysis. The introduction of soil preparations in the second and third variants provided an increase in yield by 36.8% relative to the control over the use of Pledge 50, WP (0.1 kg/ha), which is at the level of Sencor Liquid 600, CS (0.4 l/ha) – 34.2% (Table 4).

Table 4. Winter wheat yield depending on the herbicide protection options under study

Experiment variant	Yield, t/ha	+/- to control, %
1. Control	4.73	
BBCH 00		
2. Pledge 50, WP	6.48	36.8
3. Sencor Liquid 600, SC	6.35	34.2
BBCH 11		
9. Pledge 50, WP	7.31	54.5
BBCH 12		
4. Pledge 50, WP	7.03	48.5
5. Marathon, SC	7.14	50.8
BBCH 14		
6. Pledge 50, WP + Granstar Gold 75, WG + adjuvant Skaba, EC	7.56	59.8
7. Sencor Liquid 600, SC + Grodil Maxi 375, OD	7.43	56.9
8. Granstar Gold 75, WG + adjuvant Skaba, ke	7.1	50.1
BBCH 16		
10. Pledge 50, WP	6.96	47.1
HIP ₀₅	0.21	3.1

Applying 0.1 kg/ha of Pledge 50, WP in the BBCH 11 phase provided a substantially higher yield by 54.5% than using the same drug, but 0.08 kg/ha in the BBCH 12 phase – 48.5% and 0.1 kg/ha in the BBCH 16 phase – 47.1%.

The highest yield in the experiment was formed by applying a tank mixture of Pledge 50, WP + Granstar Gold 75, WG + adjuvant Skaba, EC (0.06 kg/ha + 0.025 l/ha + 0.05 l/ha) in the BBCH 14 phase – 7.56 t/ha, which is 59.8% better than the control (Table 4).

CONCLUSIONS

The biological effectiveness of the drugs under study against common windgrass and other winter and wintering weeds substantially differed depending on the phase of development of winter wheat for the use of herbicides.

Pre-emergence application of herbicides does not ensure proper control of *Apera spica-venti* and other winter and wintering weeds. In particular, during the SVR, the control of *Apera spica-venti* for the use of 0.1 kg/ha Pledge 50, WP was 69.0%, with an overall efficiency of 68.0%. Application of 0.4 l/ha Sencor Liquid 600, CS provided indicators of 66.1 and 71.4%, respectively.

Application of Pledge 50, WP after germination of the crop in the development phases of winter wheat BBCH 11-12 showed high efficiency in controlling *Apera spica-venti* and all weeds in general with the following indicators:

- Pledge 50, WP (0.1 kg/ha) in the BBCH 11 – phase 91.2 and 87.6%;

- Pledge 50, WP (0.08 kg/ha) in the BBCH 12 phase – 93.1 and 87.4%.

The use of Pledge 50, WP (0.1 kg/ha) in the BBCH 16 phase had a worse, but acceptable effect with efficiency indicators of 84.2 and 83.6%.

The highest effectiveness against *Apera spica-venti* and all weeds, in general, was for the use of a mixture of Pledge 50, WP + Granstar Gold 75, WG + adjuvant Skaba, EC (0.06 kg/ha + 0.025 l/ha + 0.05 l/ha) in the BBCH 14 phase – 97.5 and 99.2%, which is at the level of Sencor Liquid 600, SC + Grodil Maxi 375, OD (0.35 l/ha + 0.11 kg/ha).

The highest yield of winter wheat in the experiment was obtained by applying a mixture of Pledge 50, WP + Granstar Gold 75, WG + adjuvant Skaba, EC (0.06 kg/ha + 0.025 l/ha + 0.05 l/ha) in the BBCH 14 phase – 7.56 t/ha, which is 59.8% better than the control.

REFERENCES

- [1] Andreassen, C. & Stryhn, H. (2008). Increasing weed flora in Danish arable fields and its importance for biodiversity. *Weed Research*, 48(1), 1-9 <https://doi.org/10.1111/j.1365-3180.2008.00603.x>.
- [2] Bartels M. (2004) Ungräser sollten Sie im Herbst beseitigen. *Top Agrar* 9, 50-55.
- [3] Curran, W.S., Wallace, J.M., Mirsky, S., Crockett, B. (2017). Effectiveness of Herbicides for Control of Hairy Vetch (*Vicia villosa*) in Winter Wheat. Cambridge University Press, 29(3) <https://doi.org/10.1614/WT-D-14-00139.1>.
- [4] Johnson, E.N., Wang, Z., Geddes, C. M., Coles, K., Hamman, B., Beres B.L. (2018). Pyroxasulfone Is Effective for Management of *Bromus* spp. in Winter Wheat in Western Canada. *Weed Technology*, 32, (6), 739-748 <https://doi.org/10.1017/wet.2018.70>
- [5] Kochyk, H., Melnychuk, A. (2013). Khimichniy zakhyst ozymoi pshenytsi pisliashkodovymy herbitsydamy varto perenosyty z vesny na osin [Chemical protection of winter wheat with post-emergence herbicides should be transferred from spring to autumn]. *Grain and bread*, 4, 46-48 http://irbis-nbuv.gov.ua/cgi-bin/irbis_nbuv/cgiirbis_64.exe?C21COM=2&I21DBN=UJRN&P21DBN=UJRN&IMAGE_FILE_DOWNLOAD=1&Image_file_name=PDF/Zikh_2013_4_18.pdf.
- [6] Melander, B., Holst, N., Jensen, P.K., Hansen, E.M. & Olesen, J.E. (2008). *Apera spica-venti* population dynamics and impact on crop yield as affected by tillage, crop rotation, location and herbicide programs. *Weed Research*, 48(1), 48-57 <https://doi.org/10.1111/j.1365-3180.2008.00597.x>.

- [7] Soltani, N., Shropshire, C., Sikkema, P.H. (2006). Responses of winter wheat (*Triticum aestivum* L.) to autumn applied post-emergence herbicides. *Crop Protection*, 25(4), 346-349. <https://doi.org/10.1016/j.cropro.2005.05.012>
- [8] Storchous, I.M. (2019). Comparative evaluation of herbicides for autumn and spring use in winter wheat crops in the Forest-Steppe zone of Ukraine. *Plant protection and quarantine*, 65, 165-190. <https://doi.org/10.36495/1606-9773.2019.65.175-190>.
- [9] Streit, B., Rieger, S. B., Stamp, P., Richner, W. (2003). Weed populations in winter wheat as affected by crop sequence, intensity of tillage and time of herbicide application in a cool and humid climate. *Weed Research*, 43(1), 20-32 <https://doi.org/10.1046/j.1365-3180.2003.00310.x>
- [10] Trybel, S.O., Siharova, D.D., Sekun, M.P., Ivashchenko, O.O. et al. (2001). Methods of testing and application of pesticides. Kyiv, Ukraine: Svit, 448.
- [11] Vanaga, I., Mintale, Z. and Smirnova, O. (2010). Control possibilities of *Apera spica-venti* (L.) P. Beauv. in winter wheat with autumn and spring applications of herbicides in Latvia. *Agronomy Research (Special Issue II)*, 493-498.

О.С. Павлов

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

А.І. Бабенко

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

А.С. Андрущенко

1-й рік навчання, магістр
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

Біологічна ефективність гербіцидів у посівах пшениці озимої осіннього внесення

Анотація. Ефективним заходом контролювання найбільш шкодочинних зимуючихта озимих видів бур'янів, таких як: *Apera spica-venti*, *Galium aparine*, *Veronica persica*, *Consolida regalis*, *Capsella bursa-pastoris*, *Descurainia Sophia*, *Vicia villosa* та ін. у посівах пшениці озимої є осіннє внесення гербіцидів, особливо на ранніх стадіях розвитку культури, починаючи від стадії проростання насіння, коли вона найбільш чутлива до їхньої присутності. У статті наведено результати дворічних досліджень щодо біологічної ефективності внесення гербіциду Пледж 50, ЗП е різні строки розвитку пшениці озимої (ВВСН 00, 11, 12, 14 і 16) самостійно та в суміші з гербіцидами партнерами: Зенкор Ліквід 600, КС, Марафон, КС, Гранстар Голд 75, ВГ, Гроділ Максі 375, Од та ад'ювантом Скаба, КЕ. У результаті встановлено, що біологічна ефективність досліджуваних препаратів проти *Apera spica-venti* й інших озимих та зимуючих бур'янів суттєво відрізнялася залежно від фази розвитку пшениці озимої на період внесення гербіцидів. Досходове внесення гербіцидів не забезпечує належного контролювання *Apera spica-venti* та інших озимих і зимуючих бур'янів. Зокрема, на період весняного відновлення

вегетації контроль *Apera spica-venti* за використання 0,1 кг/га Пледж 50, ЗП становив 69,0 %, за загальної ефективності 68,0 %. Внесення 0,4 л/га Зенкор Ліквід 600, КС забезпечувало показники відповідно 66,1 та 71,4 %. Внесення 0,1 кг/га Пледж 50, ЗП у фазу розвитку культури ВВСН 11 забезпечило високу ефективність контролювання *Apera spica-venti* та загалом усіх бур'янів із показниками, відповідно, 91,2 та 87,6 %. Використання зменшеної норми 0,08 кг/га Пледж 50, ЗП у фазу ВВСН 12 не знижувало як загальну ефективність проти бур'янів – 87,4 %, так і *Apera spica-venti*, зокрема – 93,1 %. Використання Пледж 50, ЗП (0,1 кг/га) у фазу ВВСН 16 мало гірший, проте прийнятний ефект із показниками ефективності 84,2 % проти *Apera spica-venti* та 83,6 % загалом. Найкращий контроль *Apera spica-venti* та загалом усіх бур'янів отримано за використання суміші Пледж 50, ЗП + Гранстар Голд 75, ВГ + ад'ювант Скаба, КЕ (0,06 кг/га + 0,025 л/га + 0,05 л/га) у фазу ВВСН 14 – 97,5 і 99,2 %, що на рівні Зенкор Ліквід 600, КС + Гроділ Максі 375, ОД (0,35 л/га + 0,11 кг/га). Достовірно найвищу урожайність пшениці озимої в досліді отримано за внесення суміші Пледж 50, ЗП + Гранстар Голд 75, ВГ + ад'ювант Скаба, КЕ (0,06 кг/га + 0,025 л/га + 0,05 л/га) у фазу ВВСН 14 – 7,56 т/га, що на 59,8 % краще контролю

Ключові слова: пшениця озима; гербіциди; біологічна ефективність; *Apera spica-venti*; *Galium aparine*; *Veronica persica*; *Consolida regalis*; *Capsella bursapastoris*; *Descurainia Sophia*; *Vicia villosa*; урожайність

N. Shpyrka*

Postgraduate Student

National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

S. Tanchyk

Doctor of Agricultural Sciences, Professor

National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

O. Pavlov

PhD in Agricultural Sciences, Senior Lecturer

National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

A. Babenko

PhD in Agricultural Sciences, Senior Lecturer

National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

Impact of agricultural and tillage systems on the main pests of winter wheat

Abstract. The intensification of agriculture has some adverse consequences, and the preservation of land resources during their active exploitation is a vital issue today, given the ever-increasing need to increase food supply. The world practice of organic farming shows limited regulation of the number of pests of agricultural crops. Artificially increasing natural enemies and altering the landscape to enhance biological control is not a popular solution and has controversial effectiveness. The number of winter wheat entomocomplex was monitored according to generally accepted methods on 48 plots, where 12 variants were placed in 4 repetitions during 2019-2021. This paper presents the results of a study indicating a substantial impact of agricultural systems on the main pests of winter wheat and the ability to control their numbers according to the ecological system at the level of the economic threshold of harmfulness. Tillage variants did not regulate the number of *Schizaphis graminum* R., *Eurygaster integriceps* R. and *Oulema melanopus* L., while chisel tillage at 20-22 cm regulated the number of *Anisoplia austriaca* N. and *Haplothrips tritici* Kurd at the level of the control (ploughing) in all years of observations. In the case of surface cultivation of the soil to a depth of 6-8 cm, the number of these pests increased substantially, and was on average at 2.0 and

Suggested Citation:

Shpyrka, N., Tanchyk, S., Pavlov, O., & Babenko, A. (2021). Impact of agricultural and tillage systems on the main pests of winter wheat. *Plant and Soil Science*, 12(4), 60-67. doi: 10.31548/agr2021.04.0060.

*Corresponding author



Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (<https://creativecommons.org/licenses/by/4.0/>)

14.4 specimens/m², respectively. Thus, the highlighted data confirm the effectiveness of reducing the multiplicity of insecticidal treatments of winter wheat in the ecological system without increasing the risks of crop loss due to pest damage to plants in combination with chisel tillage

Keywords: phytophages; chisel; ploughing; disking; ecological cultivation of winter wheat

RELEVANCE

According to the UN forecast, by 2050, population growth will lead to an increase in demand for food, including cereals, up to 46% (M.C. Hunter *et al.* 2017). The productivity of winter wheat depends on the use of modern intensive cultivation technology, where one of the determining factors is the management of the dynamics of harmful organisms and the use of modern plant protection products. However, the choice of intensive tillage and application of insecticides can adversely affect the functional diversity of soil communities and their abundance (J.G. Zaller *et al.*, 2016.)

Given the tendency to minimize the main tillage and reduce the use of pesticides, there is a need to find new, balanced approaches to solving the problem of protecting winter wheat from pests and increasing its productivity.

ANALYSIS OF RECENT STUDIES AND PUBLICATIONS

The difficulty in making decisions regarding the protection of crops from pests lies in the lack of monitoring and the uneven understanding of the economic threshold of harmfulness (ETH) according to different phenological phases of plant development, the effectiveness of preparations and various natural zones (V.M. Chaika *et al.*, 2014). According to some data (S. Stankevich, 2016), the ETH of cereal aphid on winter wheat in the earing phase is 5-10 pcs./stem, and according to others – 20-25 specimens/ear (V.P. Omelyuta, 1986). The economic threshold of harmfulness of the imago of a sunn pest in the phase of stem elongation in these authors also ranges from 1 to 4 specimens/m². Therefore, agricultural producers often introduce insecticides in response to any potential economic threat, rather

than as a last resort. The intensity and excessive use of chemical plant protection products creates adverse consequences for the environment, including the destruction of beneficial entomofauna. According to the authors (Sabluk *et al.*, 2021), the number of the latter in the sowing of crops under the organic farming system was substantially higher than in the industrial system, which ensured that the pest population was reduced by half. Many field studies on the effectiveness of the implementation of the practice of intercropping flowering plants to create a shelter and additional food source for entomophages and, as a result, increase their number and regulation of phytophages showed somewhat inconsistent and sometimes inconclusive results (Schipanski *et al.*, 2014; Gontijo *et al.*, 2018). Researchers (Buchanan & Hooks, 2018) found that mixed cover crops of barley and clover did not attract entomophages and did not regulate pest populations, while increasing the abundance of the *Carabidae* family in organic farming systems did not provide sufficient regulation of phytophagous populations (Birkhofer *et al.*, 2008). Research in organic crop rotation at PE “Agroecology” shows a reduction in winter wheat crop losses from *Heteroptera* bugs and *Anisoplia austriaca* due to sowing with spring wheat, the grain of which is used for fodder (V.M. Pysarenko *et al.* 2020).

The results of some studies show that often the authors do not correlate the increase in the number of natural enemies with the decrease in damage to plants by phytophages (Cloyd, 2020). The study results regarding the influence of the depth and method of soil cultivation as a factor that can reduce the number of phytophages are equally ambiguous. The study (O.M. Yakovenko, 2017) showed that the population of *Elateridae*

under the conventional tillage system was 5.2 specimens/m², under systems with mini-till elements – 8.0 specimens/m², while the conservation tillage system reduced the number of phytophages to 4.6 specimens/m².

An analysis of 30 publications from 1990 to 2017 (Rowen *et al.*, 2020), despite the expectation that soil pests would be particularly sensitive to habitat change, did not reveal any considerable differences in pest numbers in systems with different methods and depth of tillage, even using no-till technology. An interesting fact is that pests whose life cycle does not pass in the soil and most of which are r-strategists were considerably inferior in numbers in systems with low intensity of cultivation and increased the population in conventional systems.

Understanding the specific features of the biology of winter wheat pests allows identifying the optimal and critical stages of their development, which, together with crop rotation, tillage, and greening of agriculture, enables effective regulation of their number.

The purpose of this study was to establish the impact of minimizing the main tillage under various farming systems on the number of main phytophagous winter wheat.

MATERIALS AND METHODS

The study was conducted during 2019–2021 in the conditions of the stationary field of the Detached Division of the National University of Life and Environmental Sciences of Ukraine “Agronomic Research Station”. The species composition and number of pests of *Linus* winter wheat

were determined according to generally accepted entomological methods (V.P. Omelyuta, 1986; S. Stankevich, 2016) according to species. Scheme of a two-factor experiment: factor A – three farming systems: industrial, ecological, and biological. Factor B – variants of the main tillage of the soil: ploughing at 20–22 cm (control), tillage without shelves (chiselling at 20–22 cm), shallow tillage at 10–12 cm (disc harrow), surface tillage at 6–8 cm (disc harrow).

The insecticide “Pirinex Super” (chlorpyrifos, 400 g/l + bifenthrin, 20 g/l) was applied in the BBCH phase 31 (first node) and BBCH 53 (30% of inflorescence emerged) at the rate of 1 l/ha under the industrial farming system, marginal spraying with the preparation of plots under ecological conditions – 0.8 l/ha. The biological system of agriculture did not make provision for the introduction of chemical protection preparations.

The soils of the experimental plots are typical medium-loamy chernozem. The content of humus in the arable layer of the soil is 4.38–4.53%, the pH of the salt extract ranges from 6.9 to 7.3.

The experiment was based on the method of split areas. There were 48 sections in total, where 12 variants were placed in 4 repetitions. The total area of the experimental plot is 93.6 m², and the accounting plot is 75 m².

The typicality of the weather conditions of the northern Forest-Steppe of Ukraine is determined by three elements, such as the sum of active temperatures (SAT), the amount of precipitation, and a general indicator – the hydrothermal coefficient (HTC) (Table 1).

Table 1. Distribution of key weather conditions indicators, 2019–2021

Indicator	2019	2020	2017	Average over the years of the experiment	Average multi-year rate
SAT, >10 °C	3,090.0	3,099.3	2,897.3	3,028.8	3,007.5
Total precipitation, mm	352	326	299	325.6	310.3
HTC	1.14	1.05	1.03	1	1.04

RESULTS

Entomocomplexes of winter wheat are constantly in a dynamic state depending on the average annual temperature indicators, precipitation, farming systems, crop rotation, etc. The analysis of HTC according to the adequacy indicator (K_i) showed that the years of experiment differed substantially in terms of monthly values. Specifically, the spring months of 2019 were excessively wet ($K_i = 1.7$ and 0.8), which is not typical of multi-year data, while June and August were dry ($K_i = -0.2$), which is optimal for this period. April and May 2020 were excessively wet, while $K_i = 0.9$ and $K_i = 2.0$ were substantially and extremely different from the long-term norm. The summer months were tendentially dry ($K_i = -0.4; -0.3; -0.5$).

The beginning of the growing season of 2021 according to HTC indicators was comparable with 2019 with an extremely wet April ($K_i = 4.2$), June is tendentially dry ($K_i = -0.9$), while July

and August showed optimal conditions to multi-year indicators ($K_i = 0.0$ and 0.2).

The rate of development of the sunn pest depends on the hydrothermal conditions of the spring-summer period, dry summer months can lead to the death of 75-95% of the eggs of the *Anisoplia austriaca*, therefore the analysis of weather conditions is an essential factor in preventing outbreaks of pests.

The species composition of phytophages can vary due to migration from other biotypes and vary depending on the phase of wheat development, so for the choice of chemical protection, it is primarily important to identify constant and dominant species that cause considerable crop losses. According to the study results, the main pests of winter wheat in the spring and summer period were identified as follows: wheat aphids (*Schizaphis graminum* R.), sunn pest (*Eurygaster integriceps* R.), cereal leaf beetle (*Oulema melanopus* L.), *Anisoplia austriaca* N. and *Haplothrips tritici* Kurd. (Fig. 1).

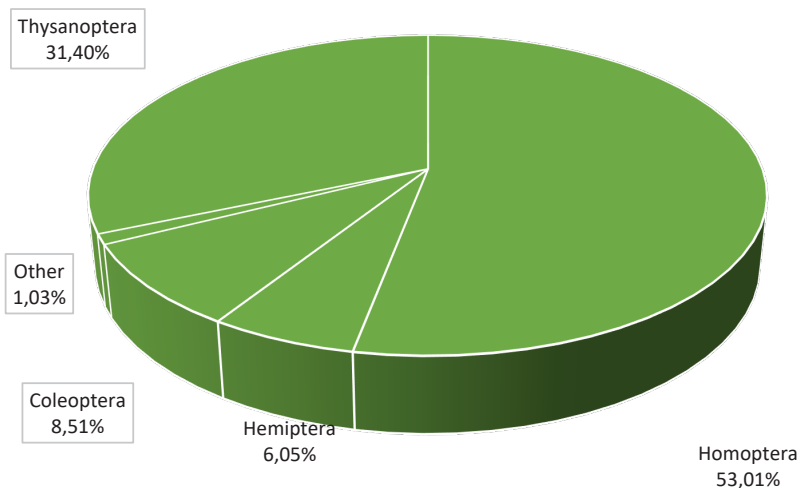


Figure 1. The structure of the entomocomplex of the main pests of winter wheat in the Detached Division of NULES of Ukraine “Agronomic Research Station”, 2019-2021

The analysis of the species composition of pests shows that, in percentage terms, the main number of phytophages belonged to the orders *Homoptera* and *Thysanoptera* – 53.01% and 31.4%, respectively. Representatives of the *Coleoptera* order were less numerous – 8.51%,

specifically 53.47% of the order was accounted for by *Oulema melanopus*, the rest by *Anisoplia austriaca*. The smallest number over the years of observation was the sunn pest of the *Hemiptera* order – 6.05%. Such phytophages as *Cephus pygmeus* and *Zabrus tenebrioides* were sparsely

present in winter wheat crops and did not pose a threat to the crop.

It is generally accepted that the main tillage has a considerable impact on the regulation of the number of pests of agricultural crops, and tillage, as an independent agrotechnical method of controlling winter wheat phytophages, is not used in modern crop cultivation technology. However, farmers introduce insecticides in response to any potential economic threat, and not as a last resort, and systematically work to prevent exceeding the threshold of harmfulness. Statistical analysis of the obtained data showed

that the number of all pests was significantly affected by agricultural systems (factor A). The industrial model turned out to be the best farming system in terms of its impact on the number of pest populations. The biological system showed the inability to effectively control the population of winter wheat phytophages (Table 2). According to the authors' observations, populations of natural enemies without increasing the availability of flowering plants, landscape diversity or the use of cover crops are incapable of effective regulation of insect pests, which confirms the data of other researchers (McGuire, 2017).

Table 2. Total pest density of winter wheat under various farming systems (2019-2021)

Agriculture system (Factor A)	Main tillage variants (Factor B)	Aphid count, specimens/plant	Number of <i>Heteroptera</i> , specimens/m ²	Number of <i>Oulemas</i> , specimens/m ²	Number of beetles, specimens/m ²	Number of <i>Thysanoptera</i> , specimens/m ²
Industrial (c)	Ploughing at 20-22 cm (control)	2.4	0.6	0.2	0.1	0.8
	Chiselling at 20-22 cm	2.8	1.0	0.3	0.0	0.7
	Shallow 12-14 cm	2.5	0.8	0.3	0.1	1.0
	Surface area 6-8 cm	3.4	1.3	0.2	0.2	1.4
Ecological	Ploughing at 20-22 cm (control)	17.4	1.6	1.2	0.6	6.3
	Chiselling at 20-22 cm	16.8	1.9	0.9	0.8	7.8
	Shallow 12-14 cm	16.6	1.8	1.2	0.8	10.6
	Surface area 6-8 cm	18.7	2.2	1.0	1.3	11.5
Biological	Ploughing at 20-22 cm (control)	28.7	3.1	3.1	2.3	13.2
	Chiselling at 20-22 cm	32.9	3.1	3.0	2.4	13.0
	Shallow 12-14 cm	29.6	2.9	3.4	2.4	25.6
	Surface area 6-8 cm	34.5	3.3	3.1	4.4	30.2
LSD ₀₅ (A)		3.2	0.6	0.7	0.6	2.8

Table 2. Continued

Agriculture system (Factor A)	Main tillage variants (Factor B)	Aphid count, specimens/plant	Number of <i>Heteroptera</i> , specimens/m ²	Number of <i>Oulemas</i> , specimens/m ²	Number of beetles, specimens/m ²	Number of <i>Thysanoptera</i> , specimens/m ²
	LSD ₀₅ (B)	F _f <F ₀₅	F _f <F ₀₅	F _f <F ₀₅	0.7	3.2
	LSD ₀₅ (AB)	F _f <F ₀₅	F _f <F ₀₅	F _f <F ₀₅	1.2	5.6

There was a significant influence of the main tillage options on limiting the number of beetles and Thysanoptera, while the number of Aphidoidea, *Heteroptera*, and cereal leaf beetles for all tillage options was within random deviations. On average, over the years of the experiment, the number of *Anisoplia austriaca* increased substantially on the variant of disc tillage at 6-8 cm, while the variants of chiselling and disc tillage at 10-12 cm limited its number to 1.1 specimens/m², which is at the control level, with slight deviation towards increase.

The numerical advantage of aphids and *Heteroptera* for surface cultivation at 6-8 cm, without a statistically significant difference, is explained by the increase in the mass of weeds in this variant, which serve as a reservoir of diseases and an added habitat for pests.

Analysis of data on the influence of Factor B on the population size of *Haplothrips tritici* Kurd. shows that reducing the depth of tillage in shallow and surface tillage variants substantially increases the average pest population to 12.4 and 14.4 specimens/m² (LSD₀₅ = 3.2). The use of chisel tillage proved the absence of a statistically significant difference compared to ploughing (control) and ensured the

regulation of the phytophagous population at 7.1 specimens/m².

CONCLUSIONS

According to the present study, the main tillage considerably affects the number of *Thysanoptera* and *Anisoplia austriaca* H., whose females lay eggs to the depth of the arable layer, and the larvae of the *Anisoplia austriaca* H. can penetrate the soil to a depth of 80 cm. Variants of chiselling at 20-22 cm and shallow cultivation at 12-14 cm showed the result at the control level, and reducing the depth of cultivation to 6-8 cm substantially increased the number of *Anisoplia austriaca* H. to 2.0 specimens/m². The distribution of Thysanoptera in the Right-Bank Forest-Steppe zone of Ukraine was substantially affected only by the chiselling variant, with an average pest population of 7.1 specimens/m². Modern farming lies in controlling the number of pests at a level that does not lead to a substantial decrease in the yield of winter wheat, and not at a level close to zero. It is due to the reduction of the rate of insecticide application and merely marginal treatment of the plots that the ecological farming system appears as the best variant in terms of the numbers of all pests below the levels of ETH.

REFERENCES

- [1] Birkhofer, K., Fließbach, A., Wise, D.H., & Scheu, S. (2008). Generalist predators in organically and conventionally managed grass-clover fields: implications for conservation biological control. *Annals of applied biology*, 153(2), 271-280. doi:10.1111/j.1744-7348.2008.00257.x.

- [2] Buchanan, A.L., & Hooks, C.R. (2018). Influence of winter cover crop mulch on arthropods in a reduced tillage cucurbit system. *Environmental entomology*, 47(2), 292-299. DOI: 10.1093/ee/nvy004.
- [3] Chaika V.M., Havei I.V., Neverovska T.M. (2014). Dynamika chyselnosti shkidnykiv pshenytsi ozymoi Lisostepu Ukrainy v movakh zmin klimatu [Dynamics of the number of winter wheat school students] *Zakhyst i karantyn Roslyn*, 60, 444-451.
- [4] Cloyd, R.A. (2020). How Effective Is Conservation Biological Control in Regulating Insect Pest Populations in Organic Crop Production Systems?. *Insects*, 11(11), 744. <https://doi.org/10.3390/insects11110744>.
- [5] Gontijo, L.M., Saldanha, A.V., Souza, D.R., Viana, R.S., Bordin, B.C., & Antonio, A.C. (2018). Intercropping hampers the nocturnal biological control of aphids. *Annals of Applied Biology*, 172(2), 148-159. <https://doi.org/10.1111/aab.12407>.
- [6] Hunter, M.C., Smith, R.G., Schipanski, M.E., Atwood, L.W., Mortensen, D.A. (2017). Agriculture in 2050: recalibrating targets for sustainable intensification. *BioScience*. 2017;67(4):386-391. <https://doi.org/10.1093/biosci/bix010>.
- [7] McGuire, A.M. (2017), Agricultural Science and Organic Farming: Time to Change Our Trajectory. *Agricultural & Environmental Letters*, 2: 170024. <https://doi.org/10.2134/ael2017.08.0024>.
- [8] Omeliuta V.P., Hryhorovych I.V., Chaban V.S. (1986). Za red. Omeliuty V.P. Kyiv: Urozhai.
- [9] Pysarenko V.M., Kovalenko N.P., Pospelova H.D., Pishchalenko M.A., Melnychuk V.V., Sherstiuk O.L. (2020) Ekolohizatsiia zemlerobstva yak pershyi krok do orhanichnoho vyrobnytstva roslynnytskoi produktsii [Greening of agriculture as the first step to organic production of crop products.]. *Visnyk PDAA*, 3, 109-117.
- [10] Rowen, E.K., Regan, K.H., Barbercheck, M.E., & Tooker, J.F. (2020). Is tillage beneficial or detrimental for insect and slug management? A meta-analysis. *Agriculture, Ecosystems & Environment*, 294, article number 106849. <https://doi.org/10.1016/j.agee.2020.106849>.
- [11] Sabluk, V.T., Hryshchenko, O.M., & Omelianovych, R.V. (2021) Formation of harmful and useful entomofauna in agrocenoses under different farming systems, (27), 31-38. <https://doi.org/10.47414/np.27.2019.211094>
- [12] Schipanski, M.E., Barbercheck, M., Douglas, M.R., Finney, D.M., Haider, K., Kaye, J.P., ... & White, C. (2014). A framework for evaluating ecosystem services provided by cover crops in agroecosystems. *Agricultural Systems*, 125, 12-22. <https://doi.org/10.1016/j.agsy.2013.11.004>
- [13] Stankevych, S. *Monitorynh shkidnykiv silskohospodarskykh kultur navchalnyi posibnyk* [Monitoring of agricultural pests] Kharkivskiy natsionalnyi ahrarniy universytet im. V.V. Dokuchaieva.
- [14] Yakovenko, O.M., & Novokhatskyi, M.L. (2017) Vplyv riznykh system osnovnoho obrobittku hruntu na formuvannya populiatsii kovalykyv (Coleoptera, Elateridae) v ahrotsenozakh zernovoi sivozminy [influence of different systems of basic tillage on formation populations of kovalik (coleoptera, elateridae) in agrocenoses of grain crop changes] *Bila Tserkva*, 14.
- [15] Zaller, J.G., König, N., Tiefenbacher, A. et al. (2016). Pesticide seed dressings can affect the activity of various soil organisms and reduce decomposition of plant material. *BMC Ecol* 16, 37. <https://doi.org/10.1186/s12898-016-0092-x>.

Н.Ф. Шпирка

Аспірантка

Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна**С.П. Танчик**

Доктор сільськогосподарських наук, професор

Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна**О.С. Павлов**

Кандидат сільськогосподарських наук, старший викладач

Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна**А.І. Бабенко**

Кандидат сільськогосподарських наук, старший викладач

Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна**Вплив систем землеробства та обробітку ґрунту на основних шкідників пшениці озимої**

Анотація. Інтенсифікація сільського господарства має низку негативних наслідків, а збереження земельних ресурсів за їхньої активної експлуатації є важливим питанням сьогодення, з огляду на дедалі більшу потребу в збільшенні продовольства. Світова практика ведення органічного землеробства показує обмеженість в регулюванні чисельності шкідників сільськогосподарських культур. Штучне збільшення природних ворогів та зміна ландшафту для підсилення біологічної боротьби не є популярним рішенням та має суперечливу ефективність. Моніторинг чисельності ентомокомплексу пшениці озимої проводився згідно із загальноприйнятими методиками на 48 ділянках, де розміщено 12 варіантів у 4 повторностях упродовж 2019-2021 рр. У статті наведені результати дослідження, що свідчать про істотний вплив систем землеробства на основних шкідників пшениці озимої та здатність до контролю їхньої чисельності за екологічної системи на рівні економічного порогу шкідливості. Варіанти обробітку ґрунту не регулювали чисельність *Schizaphis graminum* R., *Eurygaster integriceps* P. та *Ouleta melanopus* L., тоді як чизельний обробіток на 20-22 см забезпечував регуляцію кількості *Anisoplia austriaca* H. та *Haplothrips tritici* Kurd на рівні контролю (оранка) у всі роки спостережень. За поверхневого обробітку ґрунту на глибину 6-8 см чисельність цих шкідників істотно збільшувалась, та була в середньому на рівні 2,0 та 14,4 екз./м². Отже, висвітлені дані підтверджують ефективність зменшення кратності інсектицидних обробок пшениці озимої за екологічної системи без підвищення ризиків втрати врожаю через пошкодження рослин шкідниками в поєднанні з чизельним обробітком ґрунту

Ключові слова: фітофаги; чизель; оранка; дискування; екологічне вирощування пшениці озимої

R.I. Topko*

3rd Year Postgraduate Student

Myroniv Wheat Institute named after V.M. Remesla of the National Academy of Sciences
08853, 68 Tsentralnaya Str., Tsentralnye, Ukraine

H.M. Kovalyshyna

Doctor of Agricultural Sciences, Professor

National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

G.B. Vologdina

PhD in Agricultural Sciences, Senior Researcher at the Laboratory

Myroniv Wheat Institute named after V.M. Remesla of the National Academy of Sciences
08853, 68 Tsentralnaya Str., Tsentralnye, Ukraine

O.V. Gymenyk

PhD in Agricultural Sciences, Head of the Laboratory

Myroniv Wheat Institute named after V.M. Remesla of the National Academy of Sciences
08853, 68 Tsentralnaya Str., Tsentralnye, Ukraine

Spectral assessment of varieties and breeding lines of winter wheat during the restoration of spring vegetation

Abstract. The development of new and implementation of existing methods of field assessment of winter wheat genotypes is one of the key tasks of modern breeding. The use of modern screening methods in breeding allows the breeder to get a more objective assessment, as well as to increase the volume of the studied samples several times. The time of spring vegetation recovery (TSVR) is one of the key stages of the vegetation period of winter wheat. Biometric and spectral assessment of winter wheat with the onset of the TSVR allows establishing how plants of a certain genotype overwintered, as well as the state of their growth and development before the start of the second growing season. The purpose of this study was to determine the characteristics of plant growth and development of modern varieties and promising breeding lines of winter wheat of The V.M. Remeslo Myronivka Institute of Wheat (MIP) from sowing to the restoration of spring vegetation. The hydrothermal conditions of the seedling-TSVR period had diverse effects on the reproductive process of the genotypes of winter wheat under study. According to the study results, abnormally dry conditions of the period from sowing to the end of the autumn growing

Suggested Citation:

Topko, R., Kovalyshyna, H., Vologdina, G., & Gymenyk, O. (2021). Spectral assessment of varieties and breeding lines of winter wheat during the restoration of spring vegetation. *Plant and Soil Science*, 12(4), 68-79. doi: 10.31548/agr2021.04.068.

*Corresponding author



Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (<https://creativecommons.org/licenses/by/4.0/>)

season in 2019 adversely affected the condition of winter wheat plants that were in BBCH Phase 10-13, autumn tillering did not take place. Regardless of the genotype, plants were more developed during the first sowing period. According to biometric and spectral parameters, at the time of spring vegetation recovery, the following varieties turned out better than the Podolyanka standard variety (NDVI = 0.52): MIP Dnipryanka (NDVI = 0.58), MIP Lada (NDVI = 0.56), Balada Myronivska (NDVI = 0.56) and lines Lutescens 37519 (NDVI = 0.55) and Erythrospermum 55023 (NDVI = 0.58). During the second sowing period, the variety MIP Dnipryanka (NDVI = 0.45) and the selection lines Lutescens 37519 (NDVI = 0.44) and Erythrospermum 55023 (NDVI = 0.43) were selected. The standard Podolyanka variety had an NDVI index value of 0.43. MIP Lada and Balada Myronivska varieties react more sensitively to the timing of sowing and need a longer period of autumn vegetation to accumulate more dry matter and better pass the winter rest period.

Keywords: soft winter wheat; varieties; breeding lines; spring vegetation recovery time; NDVI index; biometric analysis; morphophysiological analysis

RELEVANCE

Among the most important grain crops, winter wheat takes the first place in Ukraine in terms of cultivated area and is the main food crop. Over the past three years, the sown area of this crop reached approximately 6.8-7 million ha, which is a quarter of the entire arable land of Ukraine.

One of the factors of agricultural intensification in Ukraine is the collection and evaluation of remote sensing spectral data. Presently, the use of satellite monitoring during the growing season of agricultural crops is becoming the norm in the production activities of most agricultural enterprises.

The introduction of the latest scientific and technical achievements in breeding practice not only improves the quality of evaluation of the source material, but also increases the volume of samples studied. The spectral assessment of winter wheat plants in a complex, considering the data of morphological and biological analysis, allows identifying the reaction of the genotype to environmental conditions, the level of which depends on such properties as cold and frost resistance, drought resistance, resistance to pathogens, etc.

The development and implementation of a comprehensive method for field assessment of winter wheat genotypes based on spectral and morphobiological analysis will improve the

quality of selection of initial forms and enable a more comprehensive investigation of the created varieties and breeding lines.

ANALYSIS OF RECENT STUDIES AND PUBLICATIONS

The time of spring vegetation recovery plays a noticeable role in the life of wintering plants, since the intensity and duration of solar radiation considerably affects their growth and development (V.D. Medynets, 2014.; V.D. Medynets, 1974.; O.Ye. Medynets, 2014; V.D. Medynets, 2001).

An increase in the average daily air temperature contributes to the gradual restoration of all physiological and biochemical processes in the plant. The ecological effect of the spring growing season recovery time allows predicting the ontogenesis of winter wheat in the second half of the growing season with high reliability. To a large extent, the final productivity of the crop is not influenced by the starting conditions of the TSVR (nature and quality of solar radiation), but by a more stable indicator – the duration of vegetation from its recovery to earing. The longer this period, the better plants use the energy of the Sun's rays during photosynthesis.

The essence of this natural phenomenon is related to the radiation regime, duration, intensity, and qualitative composition of sunlight, its

exceptional role in the life of a plant organism. During the early recovery of the spring growing season, the intensity of blue-violet rays of the solar spectrum is quite low, and during the late recovery period, it increases and the intensity of red rays prevails. The later the vegetation of winter wheat resumes, the more total radiation enters the surface of crops. Therefore, in years with a late spring, plants grow and develop in conditions of higher air temperature and more solar energy. In the case of early spring, the vegetation of winter wheat occurs at lower temperatures and their slow growth, which is more favourable for the regeneration of damaged organs, plant growth, and the course of all growth processes (V.D. Medynets, 1974; V.D. Medynets, 2001; Yu.F. Tereshchenko, 2014).

Currently, methods of phenotyping winter wheat are the principal methods of breeding this crop in leading breeding institutions of developed countries of the world. All spectral studies are carried out using the basic NDVI index (Normalized Difference Vegetation Index, B.J. Rouse *et al.*, 1973). Recent studies indicate a close correlation between the NDVI index obtained during winter wheat flowering and yield results (T. Duan, S.C. Chapman, Y. Guo, B. Zheng, 2017).

Given that the UAV image acquisition operation is less time-consuming and with higher accuracy than previously used imageless proximal sensing, airborne UAV-based multispectral sensing is expected to increase the efficiency of high-throughput phenotyping (M. Maimaitijiang, A. Ghulam, P. Sidike, S. Hartling, M. Maimaitiyiming, K. Peterson, E. Shavers, J. Fishman, J. Peterson, S. Kadam *et al.*, 2017; M. Tattaris, M. P. Reynolds, S.C. Chapman, 2016).

The purpose of this study was to establish the features of plant growth and development of modern varieties and promising selection

lines of winter wheat of MIP selection from sowing to the time of spring vegetation recovery using spectral and biometric evaluation.

MATERIALS AND METHODS

The study was conducted during the 2018/19-2020/21 growing seasons in the selective crop rotation of the winter wheat breeding laboratory at the V.M. Remeslo Myronivka Institute of Wheat (MIP) of the National Academy of Agrarian Sciences of Ukraine. Sowing was carried out after the soybean predecessor in two terms: 2018 – September 25 and October 5; 2019 and 2020 – October 5 and 15. Placement of land plots was systematic, four-fold repetition, accounting area – 10 m². Seeding rate – 5 million germinating seeds per 1 ha. The Podolyanka variety was used as a standard. Agricultural cultivation techniques were generally accepted for the Forest-Steppe zone. The study was conducted according to the “Methodology of the Field Experiment” (B. A. Dospekhov, 1979), phenological observations and records – according to the “Methodology of the State Variety Trial” (V.V. Volkodav, 2003). The main method of research is field-based, supplemented by analytical studies, measurements, calculations, and observations.

Spectral evaluation of winter wheat varieties and breeding lines was performed using a Mavic Zoom 2 UAV using a Parrot Sequoia multispectral camera. Pix4Dcapture and Pix4Dmapper software were used to form the orthophotoplan. Photo recording was performed with a multispectral camera at 30 m above the level of the object under study to improve the quality of the orthophotoplan, with an overlap of 80% of the images and with a time interval of two seconds. The NDVI index (Normalized Difference Vegetation Index) was calculated using the formula (“Measuring Vegetation”. NASA Earth Observatory, 2000-08-30.):

$$NDVI = \frac{NIR-RED}{NIR+RED}, \quad (1)$$

where NIR is a reflection in the near-infrared region of the spectrum; RED is the reflection in the red region of the spectrum.

The years of the study were contrasted with the hydrothermal regime, with an uneven distribution of precipitation over the months, which allowed for objective data. Meteorological conditions were analysed using data from a private stationary weather station connected to the Meteoblue global system (Basel, Switzerland), located within a radius of 6 km from the fields where the study was conducted.

Biometric analysis was conducted according to the method of F.M. Kuperman (F.M. Kuperman, 1977), as well as according to the scientific publications of the MIP (V.T. Koliuchyi, V.A. Vlasenko, H.Yu. Borsuk, 2007).

RESULTS AND DISCUSSION

It is known that the rapid growth and development of winter wheat plants in autumn are incompatible with high winter hardiness (V.V. Volkodav, 2003). Plants are characterized by wide leaves, develop rapidly at all stages, especially during the tillering period, which adversely affects the course of hardening processes to the action of low temperatures. They are characterized by a rapid rate of development since the resumption of spring vegetation, have a large ear and large grain, and under conditions of favourable wintering can form a high yield. In natural conditions, plant growth and development depend on a complex of factors: soil, nutrients, light, moisture, heat, etc. A favourable combination of these factors enhances growth processes, and in case of their lack or excess, the weakening of plant development is noted (A.V. Cherenkov, A.D. Hyrka, O.O. Pedash, O.I. Dubovyi, 2009). Long-term observations and practice prove that in years when full-fledged sprouts are obtained in time, crops in the autumn develop well and have a

strong root system and, as a rule, provide a high yield of grain even under adverse weather conditions in the summer months. Weakly developed and thinned autumn crops are almost always low-yielding (<https://propozitsiya.com/sroki-poseva-ozimoy-pshenicy>). The autumn period of 2018 was excessively wet (HTC = 1.76), the rest – dry (HTC = 0.005–0.27). The temperature regime of the growing season over the years of the study was slightly higher than the annual average (over the past 30 years).

Weather conditions in 2019 were unfavourable for seedlings: the amount of precipitation from August to the end of October was 28.7 mm (long-term average – 163.2 mm). The air temperature for August–October 2019 exceeded the long-term average values by 0.4–2.7°C. The increased temperature regime was observed in December 2019 and February 2020 – 8.1°C, with an average long-term value of 5.9°C over the past 30 years. Sharp changes in air temperature did not help winter crops to complete the hardening phase necessary for overwintering and to accumulate sufficient sugars in the nodes of the shoots. Their value was at 20% or lower, which is insufficient to counteract the adverse factors of wintering. This sugar content and the lack of snow cover during the winter led to the complete or partial death of winter crops, especially in the plots during the second sowing period. Such weather conditions created a natural background for selecting shapes with high adaptive capacity.

According to weather conditions, the 2018/2019 growing year was the most favourable for the growth and development of winter wheat plants. Thus, according to the amount of daily precipitation during the autumn–winter period until the time of vegetation recovery (March 4) in the spring, the year was quite wet, with repeated precipitation of more than 5 mm, which were productive (Fig. 1).

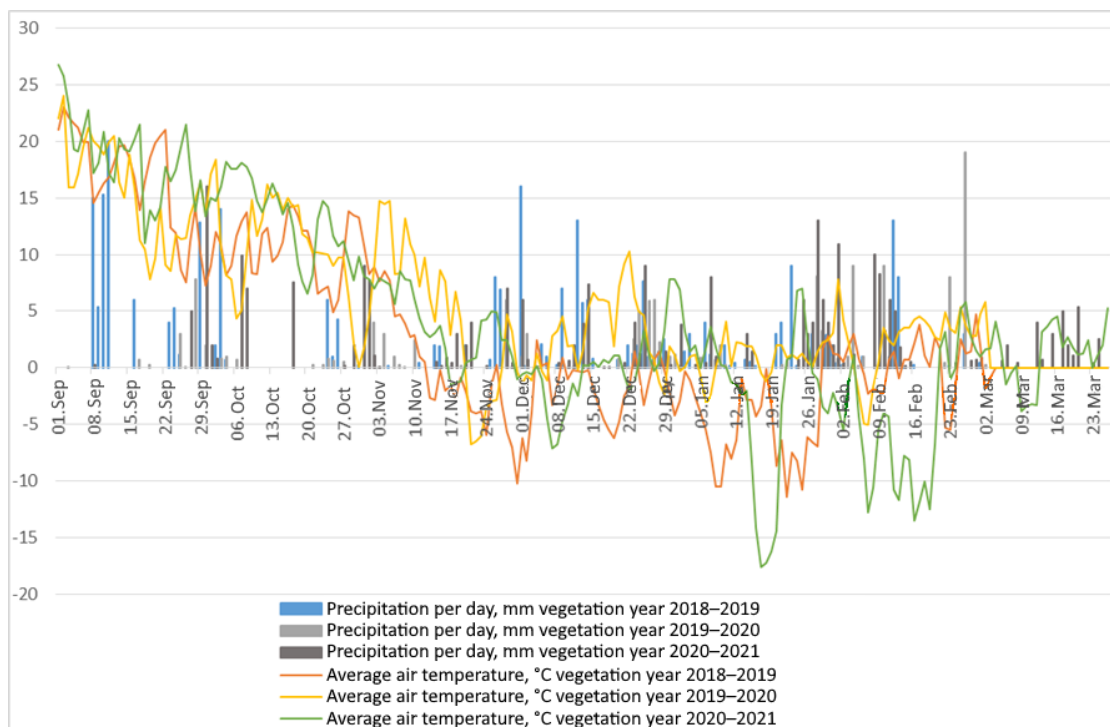


Figure 1. Climatogram of the autumn – TSVR period for 2018-2021, MIP

In the specified period of 2019/2020, the vast majority of precipitation did not exceed 5 mm, so it can be considered abnormally dry for the Forest-Steppe zone of Ukraine. During the resumption of the spring vegetation in 2020 (March 2), two rains of approximately 8 and 18 mm of rainfall were recorded, but this was insufficient to successfully establish the root system, the number of leaves and productive shoots.

In the autumn of 2020, four cases of productive precipitation (over 7 mm) were observed, as well as a substantial amount of precipitation during the period of winter dormancy. In general, moisture accumulation in the soil was more than sufficient for high-quality plant fertilization and successful restoration of spring vegetation (March 26).

The average air temperature during the autumn – TSVR period of the 2018/2019 growing year turned out to be more than optimal for the normal growth and development of winter

wheat plants. A gradual decrease in the air temperature towards negative values positively affected the biochemical and physiological processes during the hardening of plants. This temperature regime positively affects the hardening of plants (Pirych, Bulavka, Kovalyshina, Derhachev, Humeniuk, 2018).

November 2019 was relatively warm and dry, but with sharp drops in air temperature to minus 5-7°C. The average value of the indicator in the winter period of the 2019/2020 growing year was mainly within 0-+3°C and only sometimes passed to a negative value, which indicates an almost complete absence of winter dormancy in winter wheat plants.

The autumn period of 2020 was satisfactory for the development and growth of winter wheat plants. In the pre-sowing period, two rainy days were noted with precipitation of 18 mm (out of a total of 24.1 mm for the entire period), which allowed for sowing in moist soil. The total amount

of precipitation in autumn was 68.6 mm, which ensured good shoots and normal growth processes.

The heat requirement of plants is characterized by the sum of the average daily temperatures after their passage through the biological minimum for a certain growing season. It is known that during the autumn vegetation, winter wheat plants from sowing to stable transition at +5°C must undergo the second stage of organogenesis, form two to four stems and harden. For this, they need to collect the sum

of effective temperatures of 450-550°C, provided that there is sufficient moisture (Tanchyk, Mokriienko, Motorny, 2014). Under such conditions, plants accumulate a sufficient amount of plastic substances for the overwintering period, which allows them to better withstand the harsh conditions of both the winter and spring-summer growing seasons. In the fall of 2020, winter wheat plants of the second sowing period, during the period from sowing to a stable transition through +5°C, gained the minimum amount of active temperatures (Table 1).

Table 1. Characteristics of the weather conditions of the pre-sowing period, autumn vegetation and the TAVC-TSVR period, (2018/19-2020/2021, MIP)

Year	Interphase period	Date	Precipitation, mm		Sum of active temperatures, °C	
			sowing period		sowing period	
			I	II	I	II
2018/2019	Pre-sowing	01.09.18-24.09/04.10.18	71.0	101.7	439.1	537.9
	Sowing-TAVC*	25.09/05.10.18-05.11.18	37.7	7.0	427.3	328.5
	TAVC-TSVR**	06.11.18-04.03.19	160.4		-234.8	
2019/2020	Pre-sowing	01.09.19-04/14.10.19	14.8	16.5	533.2	639.5
	Sowing-TAVC	05/15.10.19-19.11.19	15.2	13.5	443.0	336.7
	TAVC-TSVR	20.11.19-02.03.20	115.9		175.1	
2020/2021	Pre-sowing	01.09.20-04/14.10.20	24.1	41.0	617.9	780.3
	Sowing-TAVC	05/15.10.20-10.11.20	44.5	27.6	418.5	256.1
	TAVC-TSVR	11.11.20-26.03.21	190.8		-142.0	

Note: * – time of autumn vegetation cessation, ** – time of spring vegetation recovery

A value of 418.5°C was recorded for the first and 256.1°C for the second sowing period. In percentage terms, the difference in the sum of the average daily temperature between the sowing periods was 38.8%, and in 2018 and 2019 – 23.1% and 25.0%, respectively.

The autumn period of 2018 was the wettest and warmest, which was a prerequisite for the good development of winter wheat plants during both sowing periods: over 107 mm of precipitation (a sixth of the long-term average for this zone); 18 days with an average air temperature of +10°C for plants of the first sowing period and 14 days – for the second period.

During the above period, 30 mm of precipitation fell in 2019, of which only two productive rains can be distinguished, which fell almost at the end (03.11.19 and 11.11.19, respectively) of the autumn growing season (4.0 and 2.4 mm). Under such conditions, at the time of termination of

the growing season, winter wheat plants were in a development phase that varied between phases 10-13 according to the international BBCH classification, no autumn tillering occurred. Notably, the winter dormancy period until the resumption of spring vegetation was abnormally warm: the average daily air temperature ranged from 0°C to +1.6°C, and its repeated excess of +5°C was noted. The average value of the indicator for winter dormancy in the 2019/2020 growing year was +1.68°C, while in 2018/2019, 2020/2021 – -1.97°C and -1.04°C, respectively.

Consequently, the hydrothermal conditions of the germination period had different effects on the reproduction process of the winter wheat genotypes under study. Regardless of the genotype, plants were more developed during the first sowing period. Indicators of phytocenosis: the number of stems and leaves, the height of the plant and its weight are presented in Table 2.

Table 2. Biometric and spectral indicators of winter wheat plants of the first sowing period during the resumption of spring vegetation (average for 2018/2019-2020/2021 growing years, MIP)

Variety, breeding line	Quantity per 1 plant, pcs.		Plant height, cm	Weight of one plant, g	NDVI index
	stems	leaves			
MIP Assol	2.49	8.06	19.24	0.86	0.54
Balada MYR*	2.66	8.88	17.45	0.99	0.56
Hratsiia MYR	2.47	8.03	16.31	0.92	0.54
MIP Yuvileyna	2.37	8.21	17.31	1.00	0.53
MIP Lada	2.62	7.89	19.65	1.08	0.56
MUP Dnipryanka	3.10	9.12	18.69	1.04	0.58
Erythrospermum 55023	2.50	8.35	16.84	1.07	0.58
Lutescens 55198	2.43	8.28	17.13	0.93	0.52
Lutescens 37519	4.09	8.37	17.77	1.02	0.55
Lutescens 60049	2.24	7.79	16.23	0.81	0.53

Table 2. Continued

Variety, breeding line	Quantity per 1 plant, pcs.		Plant height, cm	Weight of one plant, g	NDVI index
	stems	leaves			
Lutescens 60107	2.87	8.12	17.99	0.95	0.52
Podolyanka St	2.62	8.14	16.98	0.77	0.52

Note: * MYR – Myronivka

Biometric analysis data, combined with the NDVI Index, allows for a more objective assessment of the condition of plants after overwintering and provides insight into how they develop, simulate the relative yield of a certain genotype. The implementation of NDVI index accounting in the selection process improves the efficiency of winter wheat plant state accounting during the growing season: the time for inspecting crops is reduced by 5-6 times and the dependence on weather conditions is reduced; the number of tested samples increases and the quality of the obtained results improves substantially. The breeder has time to interpret the data. Chlorophyll is known to absorb red waves: as a result, photosynthesis occurs, i.e., the plant grows and develops well, and the cell structure reflects near-infrared light. Therefore, there is a correlation between the value of the NDVI index and biometric indicators of aboveground biomass. The use of both methods of determining

the state of winter wheat plants in a certain growing season allows establishing the reliability of the observed differences and obtaining the necessary information regarding valuable raw material for selection for high productivity and adaptability.

Varietal characteristics affected the level of development of winter wheat plants during the growing season. The best varieties and breeding lines of winter wheat in terms of the main biometric indicators included: MIP Dnipryanka, MIP Lada, Balada Myronivska, Lutescens 37519, and Erythrospermum 55023. They also had the highest NDVI index value.

During the second sowing period, the MIP Dnipryanka variety and the Lutescens 37519 and Erythrospermum 55023 breeding lines were selected. Varieties MIP Lada and Balada Myronivska were at the level or dominated in some morphological and spectral indicators the Podolyanka standard variety (Table 3).

Table 3. Biometric and spectral indicators of winter wheat plants of the second sowing period during the resumption of spring vegetation (average for 2018/2019–2020/2021, MIP)

Variety, breeding line	Quantity per 1 plant, pcs.		Plant height, cm	Weight of one plant, g	NDVI index
	stems	leaves			
MIP Assol	2.10	6.53	15.98	0.59	0.43
Balada MYR	2.18	6.20	15.58	0.54	0.44
Hratsiia MYR	2.01	5.87	12.99	0.55	0.43
MIP Yuvileyna	2.27	6.28	13.88	0.51	0.42

Table 3. Continued

Variety, breeding line	Quantity per 1 plant, pcs.		Plant height, cm	Weight of one plant, g	NDVI index
	stems	leaves			
MIP Lada	1.86	5.69	14.37	0.55	0.43
MUP Dnipryanka	2.53	6.94	16.74	0.67	0.45
ErythrospERMum 55023	1.96	5.98	16.00	0.64	0.43
Lutescens 55198	1.96	5.87	14.89	0.54	0.42
Lutescens 37519	3.29	6.75	13.18	0.51	0.44
Lutescens 60049	2.22	6.27	13.99	0.58	0.43
Lutescens 60107	2.23	6.47	14.48	0.49	0.43
Podolyanka St	2.34	6.63	15.01	0.57	0.43

Note: * MYR – Myronivka

These varieties react more sensitively to the timing of sowing and need a longer period of autumn vegetation to accumulate more dry matter and better pass the winter rest period.

Thus, the conducted studies allowed establishing the features of plant growth and development of modern varieties, and promising selection lines of winter wheat of MIP selection from sowing to the time of spring vegetation recovery using spectral and biometric evaluation. The selected genotypes have a well-developed aboveground mass, are resistant to unfavourable conditions for growth and development, and can form high productivity.

CONCLUSIONS

The hydrothermal conditions of the seedling-TAVC-TSVR period had diverse effects on the reproductive process of the genotypes of winter wheat under study. According to the study results, abnormally dry conditions of the period from sowing to the end of the autumn growing season in 2019 negatively affected the condition of winter wheat plants that were in BBCH Phase 11-13, autumn tillering did not take place.

Regardless of the genotype, plants were more developed during the first sowing period. According to biometric and spectral parameters, at the time of spring vegetation recovery, the following varieties turned out better than the Podolyanka standard variety (NDVI = 0.52): MIP Dnipryanka (NDVI = 0.58), MIP Lada (NDVI = 0.56), Balada Myronivska (NDVI = 0.56), Lutescens 37519 (NDVI = 0.55), and ErythrospERMum 55023 (NDVI = 0.58). During the second sowing period, the variety MIP Dnipryanka (NDVI = 0.45) and the selection lines Lutescens 37519 (NDVI = 0.44) and ErythrospERMum 55023 (NDVI = 0.43) were selected. MIP Lada and Balada Myronivska varieties react more sensitively to the timing of sowing and need a longer period of autumn vegetation to accumulate more dry matter and better pass the winter rest period.

The use of biometric analysis methods with the NDVI index to determine the condition of winter wheat plants in a certain growing season allows establishing the reliability of the observed differences and obtaining the necessary information regarding valuable raw material for selection for high productivity and adaptability.

REFERENCES

- [1] "Measuring Vegetation". NASA Earth Observatory. 2000-08-30.
- [2] Cherenkov, A.V., Hyrka, A.D., Pedash, O.O., Dubovyy, O.I. (2009). Vplyv strokiv sivby ta azotnykh pidzhyvlen' na rist i rozvytok roslyn ozymoyi pshenytsi vprodovzh vesnyano-litn'oho periodu vechetatsiyi. *Byuleten' Instytutu zernovoho hospodarstva*, 37, 86-93.
- [3] Dospikhov, B.A. (1979). Textbooks and textbooks for higher agricultural educational institutions. *Yzd. 4-oe, pererab. y dop. Moskva : Kolos*, 1979. 416 s., yl. (Uchebnyky y ucheb. posobyia dlya vyssh s.-kh. ucheb. zavedenyy).
- [4] Duan, T., Chapman, S.C., Guo, Y., Zheng, B. (2017). Dynamic monitoring of NDVI in wheat agronomy and breeding trials using an unmanned aerial vehicle. *Field Crops Research*, 210, 71-80.
- [5] Kolyuchuy, V.T., Vlasenko, V.A., Borsuk, H.YU. (2007). Influence of sowing dates and nitrogen fertilization on the growth and development of winter wheat plants during the spring-summer growing season. *Kyiv: Ahrarna nauka*, 800.
- [6] Kuperman, F.M. (1977). Breeding, seed production and technologies for growing grain crops in the forest-steppe of Ukraine. 3-e yzd. *Moskva: Vysshaya shkola*, 287.
- [7] Maimaitijiang, M., et al. (2017). Unmanned Aerial System (UAS)-based phenotyping of soybean using multi-sensor data fusion and extreme learning machine. *ISPRS J. Photogramm. Remote. Sens*, 134, 43-58.
- [8] Medynets, O.YE. (2014). Energy factors for the development of winter wheat diseases. Abstracts of scientific practice. conference dedicated to the 90th anniversary of Dr. s.-g. Sciences Medinets Vasily Dmitrovich. *Poltava*, 2014, 9-72.
- [9] Medynets, V.D. (1974). Influence of ecological conditions and time of resumption of spring vegetation of plants on a ratio of bodies and productivity of winter wheat, their value for varietal agrotechnics and selection: votref. dis. ... Doctor of agricultural sciences Sciences. *Kharkov*, 1974, 48.
- [10] Medynets, V.D. (2001). Management of plant ontogenesis (agroecological direction)]. *Poltava: Verstka*, 2001. 86.
- [11] Medynets, V.D. (2014). The role of time of restoration of spring vegetation in ontogenesis, phylogeny and selection of wintering plants. Abstracts of scientific practice. conference dedicated to the 90th anniversary of Dr. s.-g. Sciences Medinets Vasily Dmitrovich. *Poltava*, 2014, 4-6.
- [12] Piryck, A.V., Bulavka, N.V., Kovalyshyna, H.M., Derhachov, O.L., Humenyuk, O.V. (2018). Peculiarities of plant growth and development in the early stages in a number of Myronov varieties of soft winter wheat and their connection with frost resistance and yield. *Naukovi dopovidi NUBiP Ukrayiny*, 5(75). *Rezhym dostupu: [http://dx doi.org/10.31548/dopovidi.2018.05.013/](http://dx.doi.org/10.31548/dopovidi.2018.05.013/)*.
- [13] Riznyk, O.I., Sayko, V.F., Lobas, M.H. (1994). Cereals, legumes, cereals and corn in agroecosystems K.: *Urozhay*, 1994, 41-54.
- [14] Tanchyk, S.P., Mokriyenko, V.A., Motorny, V.A. (2014). Produktyvnist' pshenytsi ozymoyi zalezno vid strokiv sivby. [Productivity of winter wheat depending on sowing dates]. *Naukovi dopovidi Natsional'noho universytetu bioresursiv i pryrodokorystuvannya Ukrayiny*, 2. *Rezhym dostupu: http://nbuv.gov.ua/UJRN/Nd_2014_2_9*.
- [15] Tattaris, M., Reynolds, M.P., Chapman, S.C. (2016). A Direct Comparison of Remote Sensing Approaches for High-Throughput Phenotyping in Plant Breeding. *Front. Plant Sci*, 7, 61.

- [16] Tereshchenko, YU.F. (2014). Elucidation of the ecological effect of CHVVV in textbooks for agricultural universities. Abstracts of scientific practice. conference dedicated to the 90th anniversary of Dr. s.-g. Sciences Medinets Vasily Dmitrovich. Poltava, 2014, 35-37.
- [17] Volkodav, V.V. (2003). Methodology for the examination of the sovereign varieties and the testing of varieties of cereal roslin, cereals and leguminous crops. Kyiv: Alefa, 2(3), 241.

Р.І. Топко

Аспірант 3-го року навчання

Миронівський інститут пшениці імені В.М. Ремесла НААН України
08853, вул. Центральна, 68, смт. Центральне, Україна

Г.М. Ковалишина

Доктор сільськогосподарських наук, професор

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

Г.Б. Вологдіна

Кандидат сільськогосподарських наук, старший науковий співробітник лабораторії

Миронівський інститут пшениці імені В.М. Ремесла Національної академії наук України
08853, вул. Центральна, 68, смт. Центральне, Україна

О.В. Гуменюк

Кандидат сільськогосподарських наук, завідувач лабораторії

Миронівський інститут пшениці імені В.М. Ремесла Національної академії наук
08853, вул. Центральна, 68, смт. Центральне, Україна

Спектральна оцінка сортів та селекційних ліній пшениці озимої у період відновлення весняної вегетації

Анотація. Розробка нових та впровадження наявних методів польової оцінки генотипів пшениці озимої є одним із ключових завдань сучасної селекції. Застосування сучасних методів скринінгу в селекції дає можливість селекціонеру дістати більш об'єктивну оцінку, а також у разі збільшити обсяги досліджуваних зразків. Час відновлення весняної вегетації (ЧВВВ) є одним із найважливіших етапів вегетаційного періоду пшениці озимої. Біометрична та спектральна оцінка пшениці озимої із настанням ЧВВВ дає змогу встановити, як перезимували рослини певного генотипу, а також стан їх росту та розвитку перед початком другого періоду вегетації. Метою дослідження було встановлення особливостей росту та розвитку рослин сучасних сортів і перспективних селекційних ліній пшениці озимої селекції Миронівського інституту пшениці імені В.М. Ремесла (МІП) від сівби до відновлення весняної вегетації. Гідротермічні умови періоду сходи-ЧВВВ по різному впливали на репродукційний процес досліджуваних генотипів пшениці озимої. За результатами досліджень аномально посушливі умови періоду від сівби до часу припинення осінньої вегетації у 2019 р. негативно вплинули на стан рослин пшениці озимої, які знаходились у фазі 10-13 за міжнародною класифікацією ВВСН, осіннього кушіння не відбулось. Незалежно від генотипу більш розвинутими були рослини за першого строку сівби. На час відновлення весняної вегетації за біометричними та спектральними показниками кращими за сорт стандарт Подольянку (NDVI = 0,52) виявилися:

сорта МІП Дніпрянка (NDVI = 0,58), МІП Лада (NDVI = 0,56), Балада миронівська (NDVI = 0,56) та лінії Лютесценс 37519 (NDVI = 0,55) й Еритроспермум 55023 (NDVI = 0,58). За другого строку сівби виділили сорт МІП Дніпрянка (NDVI = 0,45) та селекційні лінії Лютесценс 37519 (NDVI = 0,44) й Еритроспермум 55023 (NDVI = 0,43). Сорт стандарт Подолянка мав значення індексу NDVI на рівні 0,43. Сорти МІП Лада та Балада миронівська більш чутливо реагують на строки сівби та потребують тривалішого періоду осінньої вегетації для накопичення більшої кількості сухих речовин і кращого проходження періоду зимового спокою

Ключові слова: пшениця м'яка озима; сорти; селекційні лінії; час відновлення весняної вегетації; індекс NDVI; біометричний аналіз; морфофізіологічний аналіз

L.A. Murashko*

Researcher at the Winter Wheat Breeding Laboratory
Myroniv Wheat Institute named after V.M. Remesla of the National Academy of Sciences
08853, 68 Tsentralnaya Str., Tsentralnye, Ukraine

T.I. Mukha

Researcher at the Winter Wheat Breeding Laboratory
Myroniv Wheat Institute named after V.M. Remesla of the National Academy of Sciences
08853, 68 Tsentralnaya Str., Tsentralnye, Ukraine

H.M. Kovalyshyna

Doctor of Agricultural Sciences, Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

Yu.M. Dmytrenko

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

Characteristics of the source material resistant to Fusarium head blight and root rot for the selection of winter wheat

Abstract. Diseases of winter wheat considerably reduce the yield and quality of grain. Losses of the gross grain harvest from them annually amount to 20-30%, and in epiphytotic years – 50%. An effective measure to limit the development of winter wheat diseases is the introduction of varieties that are resistant to their damage. Successful development of breeding work in this area is impossible without the use of a gene pool of stable forms. Among the genetic resources of wheat, there are genotypes described by resistance against several pathogens at the same time, and therefore have special value as sources of group resistance. There is a constant need to identify new sources and donors of resistance against pathogens, the search for which is an urgent area of research and requires constant screening of the gene pool. In the V.M. Remeslo Myronivka Institute of Wheat, work is constantly being carried out to create the initial breeding material of winter wheat, resistant to the main pathogens, which will be used by breeders in the future. According to the selection program for resistance against fusarium head blight and root rot, the following lines were created: Lutescens

Suggested Citation:

Murashko, L., Mukha, T., Kovalyshyna, H., & Dmytrenko, Yu. (2021). Characteristics of the source material resistant to Fusarium head blight and root rot for the selection of winter wheat. *Plant and Soil Science*, 12(4), 80-90. doi: 10.31548/agr2021.04.080.

*Corresponding author



Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (<https://creativecommons.org/licenses/by/4.0/>)

F. g. 163/19, ErythrospERMUM F. g. 164/19, ErythrospERMUM F. g. 166/19, ErythrospERMUM S. h. 177/19, ErythrospERMUM S. h. 175/19, which are used by breeders of the institute and have been transferred to the National Centre for Plant Genetic Resources of Ukraine. The line ErythrospERMUM F. g. 164/19 was selected according to the “duration of the growing season” indicator, with a growing season of 238 days, which is 3 days less than the Podolyanka standard variety. It belongs to the group of early-maturing forms. High TGW indicators were noted in the lines ErythrospERMUM F. g. 164/19 – 50.6 g, ErythrospERMUM F. g. 166/19 – 49.3 g, ErythrospERMUM F. g. 163/19 – 46.5 g, and ErythrospERMUM C. h. 177/19 – 47.3 g. In terms of productivity, the following lines exceeded the standard: Lutescens F. g. 163/19 – by 38.8 g/m², ErythrospERMUM C. h. 177/19 – by 39.6 g/m², ErythrospERMUM C. h. 175/19 – by 26.7 g/m². Lines ErythrospERMUM F. g. 166/19 and ErythrospERMUM C. h. 177/19 were distinguished by their high-protein content – 16.5% and 15.8%, respectively. The highest level of gluten content in grain was recorded in the line ErythrospERMUM F. g. 166/19 – 41.2%. The best lines in terms of sedimentation are: Lutescens F. g. 163/19 – 70 ml, ErythrospERMUM F. g. 164/19 – 67 ml, ErythrospERMUM F. g. 166/19 – 71 ml. It was established that the Lutescens line F. g. 163/19 showed elevated resistance against the causative agent of powdery mildew (damage – 1.0%) and septoria leaf blotch (damage – 3.0%). Fusarium head blight damage did not exceed 5.0%. ErythrospERMUM F. g. 166/19 was resistant to two pathogens (fusarium head blight, powdery mildew), while ErythrospERMUM F. g. 164/19 was resistant to fusarium head blight and septoria leaf blotch. The lines created under the program of resistance against root rot ErythrospERMUM C. h. 177/19 and ErythrospERMUM C. h. 175/19 showed relative resistance to this pathogen – 10.0% and 10.5% damage, respectively, and had high resistance to powdery mildew – 2.0% damage

Keywords: lines; diseases; damage; resistance; lodging; plant height; yield; grain quality

RELEVANCE

Grain crops during the growing season are affected by many types of pathogens, but there are some that occur very frequently. Diseases of winter wheat considerably reduce the yield and quality of grain. Losses of the gross grain harvest from diseases annually amount to 20-30%, and in epiphytotic years – 50% (S. V. Retman, 2009). An effective measure to limit diseases of winter wheat is the introduction of varieties that are resistant to their damage (Taranova *et al.*, 2020). Under favourable conditions for the development of diseases, such varieties do not reduce the yield of the crop. Chemical treatment of crops is not carried out or is used in small quantities. It is especially necessary to give preference to those varieties that have a comprehensive resistance to limiting major diseases. Selection from among the recommended varieties, relatively resistant or hardy against a complex of diseases, which are of economic importance.

The creation of sustainable varieties is recognized worldwide, the most effective,

economically justified and environmentally safe method from the standpoint of environmental protection. Successful development of breeding work in this area is impossible without the gene pool of stable forms. Recently, against the background of the increase in the price of fungicidal preparations, on the one hand, and the ecological crisis of the biosphere, on the other hand, the search for new effective sources of resistance to diseases has become especially important (Kholod *et al.*, 2015; Lyfenko, 1988). Among the genetic resources of wheat, there are genotypes described by resistance against several pathogens at the same time, and therefore have special value as sources of group resistance (Kovalyshyna, 2012).

ANALYSIS OF RECENT STUDIES AND PUBLICATIONS

Pathogens of diseases that affect winter wheat plants in the early stages of development include root rot, specifically common fusarium,

ophiobolus, cercosporiosis; diseases of the wintering period – snow mould and sclerotiniosis; diseases that appear and intensively develop in the period from germination to milky grain maturity – powdery mildew, septoria; diseases of the stem elongation period – milky-wax grain ripeness – brown rust; flowering period – milky-wax grain ripeness – fusarium head blight, alternariosis, helminthosporiosis, volatile and hard soot, olive mould, black spot and basal bacteriosis (Retman, 2009; Trybel *et al.*, 2010).

Fusarium head blight (*Fusarium graminearum* Schwabe) manifests itself in the earing phase and develops before harvesting. The disease is widespread, especially damaging in years with wet weather and moderate temperatures after the earing phase. The harmfulness of Fusarium pathogens largely depends on the phase of wheat plant development in which the damage occurs. Deep infection is especially dangerous, when the pathogen reaches the seed embryo due to damage to the ear in the early phases of development during the flowering period and before the grain is milky. In this case, the mycelium completely penetrates the grain, the seeds lose their germination. In spikes infected during this period, slender whitish grains are formed, often with a visible coating of mycelium on the surface of the grain. Such seeds almost completely lose their germination. At a late stage of infection, the affected grains, as a rule, do not differ in appearance from healthy ones, but carry a latent form of infection. Such grain stays in the batch of commercial grain and poses the greatest threat, since it is a source of infection for healthy seeds during storage. Damage to the ear leads to infection of grain, as a result of which the crop shortage reaches 45-73%, the sowing qualities of seeds deteriorate: the energy of germination and seedling can decrease by 24%, the TGW – by 39-72%. The empty ears of the affected spikelets sometimes reach 60%. In the affected grain, gluten density worsens, and the amount of protein decreases. In the presence of Fusarium grain during grinding, the quality of flour deteriorates, baked bread

loses volume and porosity. Cracks appear in it, and the crumb has a brown tint. Grain affected by pathogens such as *F. sporotrichiella* and *F. graminearum* release strong mycotoxins and can cause poisoning in humans and animals (T. Yu. Gagkaeva *et al.*, 2011).

Several types of root rot can be distinguished on winter wheat: helminthosporium (causing agent *Helminthosporium sativum* Pamel., King Bakkel), fusarium (causing agents *Fusarium culmorum* Sacc., *Fusarium avenaceum* Sacc., *Fusarium oxysporium* Schlecht, *Fusarium sporotrichiella* Bilai, *Fusarium graminearum* Schwabe), ophiobolus (causing agent *Ophiobolus graminis* Sacc.), rhizoctonia (*Rhizoctonia cerealis* Vander Hoeven), cercosporiosis root rot (causing agent *Pseudocercospora herpotrichoides* Fron), etc. Some of them can destroy a third, half, or even more of the winter wheat crop. They are one of the most widespread and harmful diseases of cereals. The area of their distribution almost coincides with the area of cultivation of ear crops. Root rot refers to ecological parasitic diseases. Their causative agents are facultative pathogens that affect plants weakened by unfavourable growing conditions (Kriuchkova, & Hrytsyuk, 2014).

Infectious root rots are caused by phytopathogenic microorganisms, which can be divided into three groups according to the type of nutrition: 1) specific, the causative agents of which are organisms inherent to a certain culture or this type of disease (phytophthora, ophiobolus, common root rot of cereals). Such diseases are usually primary. According to the method of nutrition, the causative agents of primary root rots can be biotrophs and necrotrophs or have a mixed type of nutrition; 2) non-specific, the causative agents of which are accompanying microorganisms – bacteria, nematodes, etc. These parasites enter the roots through various damages and their toxic secretions further weaken the plants, causing widespread neurotization of the roots and stem. Such fungi include representatives of the genera *Penicillium*, *Aspergillus*, *Cladosporium*, etc.; 3) mixed infections, when after damage to the

root system by specific phytopathogens, it becomes possible for other types of fungi to penetrate them (fusarium-helminthosporium root rot of cereals). Infectious root rot is characterized by uneven spread of the disease. If crop rotations are saturated with repeated crops that are susceptible to diseases of crops, soil contamination progresses, which leads to frequent epiphytotics (Novokhatka, 1990).

Due to the harmfulness of diseases, one of the vital tasks in the selection of soft winter wheat is to create a breeding material that is resistant to diseases. The main and necessary condition for any breeding work is the presence of sources and donors of the trait used for breeding. A distinctive feature of disease-resistant breeding is that genotypes identified as donors can quickly lose this property. This occurs due to changes in the virulence of pathogens and their overcoming of plant resistance genetic systems, i.e., there is a loss of effectiveness of known resistance genes (Kovalyshyna et al., 2020a; Kovalyshyna et al., 2020b). Therefore, there is a constant need to identify new sources and donors of resistance against pathogens, the search for which is an urgent area of research and requires constant screening of the gene pool.

The purpose of this study was to create a new selection material with group resistance against the main pathogens for use in selection work.

MATERIALS AND METHODS

The study was conducted under artificial inoculation with pathogens in field infectious nurseries of the Department of Plant Protection at the V.M. Remeslo Myronivka Institute of Wheat (MIP) of the National Academy of Agrarian Sciences of Ukraine according to generally accepted methods (Babayants et al., 1988; Volkodav et al., 2000; Trybel et al., 2010; DSTU 3768:2010).

The artificial background of the causative agent of cercosporiellosis was created as a result of spraying wheat plants in early spring in the budding phase with a mycelium sus-

pension, for the development of which strains of the local population of the causative agent were used according to the generally accepted method (Grigorev, 1976). MV-EMESE variety was used as the susceptibility standard.

An artificial infectious background of fusarium head blight was created as a result of spraying winter wheat plants in the flowering phase with a suspension of spores isolated from the local population of the pathogen, according to the generally accepted method (L.T. Babayants et al., 1988). The susceptible Natula variety was used as the susceptibility standard.

Experiments on the evaluation of varieties and collection samples of wheat for resistance to diseases, using artificial inoculation, were laid according to the schemes used in the system of state variety testing of agricultural crops (Volkodav et al., 2000). The resistance of winter wheat plants against the causative agents of fusarium and cercosporiellosis was assessed dynamically to determine the growth of the disease according to generally accepted methods (Trybel et al., 2010). The main assessment is during the period of maximum development of diseases.

RESULTS AND DISCUSSION

Over 100 hybrid populations were investigated for resistance against causative agents of cercosporiellosis root rot and Fusarium head blight in breeding nurseries F_3 - F_5 . The most resistant descendants were selected in combinations created with the participation of the following sources of resistance: against Fusarium head blight – Catalon, Co 75-50-71, TAM 139482/79, Nobeoka Bozu; root rot – Cappelle despres, Cartago, Roason.

According to the results of the study of constant lines of winter wheat of the selection nursery, twenty lines were transferred to the National Centre for Plant Genetic Resources of Ukraine (NCPGRU) in 2019, 5 of them were created under the selection program for resistance to Fusarium head blight and root rot: Lutescens F. g. 163/19, Erythrospermum F. g. 164/19 Eryth-

rospermum F. g. 166/19, ErythrospERMum S. h. 175/19, ErythrospERMum S. h. 177/19.

These lines are superior to the Podolyanka standard variety in terms of resistance against the main pathogens, TGW and grain yield from the plot.

One of the key signs used to evaluate the material of winter wheat is the duration of the growing season. This indicator determines not only the yield level of the variety, but also its re-

sistance to drought, diseases, and other stressful factors. The value of the “germination – maturation” period of samples of the breeding nursery of winter wheat was within 238-245 days. The duration of the growing season in the line ErythrospERMum F. g.164/19 was 238 days, which is 5-7 days less than in the vulnerable varieties MV-EMESE (HUN), Natula (POL) and 3 days less than in the Podolyanka standard variety (Table 1).

Table 1. Characterization of lines of breeding nursery of soft winter wheat selection of MIP according to valuable economic traits, MIP, 2019.

Line or variety name	Growing season duration, days	Plant height, cm	TGW, g	Yield from the plot, g/m ²	± to standard, g/m ²
Resistant to fusarium head blight					
Natula (susceptible variety)	245	105.0	41.6	461.5	-53,0
Podolyanka (standard)	241	95.0	42.5	514.5	-
Lutescens F. g. 163/19	241	95.0	46.5	553.3	+38.8
ErythrospERMum F. g. 164/19	238	85.0	50.6	522.1	+7.6
ErythrospERMum F. g. 166/19	246	95.0	49.3	508.4	- 6,1
Resistant to root rot					
MV-EMESE (susceptible variety)	243	95.0	40.9	412.7	-101,8
Podolyanka (standard)	241	95.0	42.5	514.5	-
ErythrospERMum C. h. 177/19	241	90.0	47.3	554.1	+39.6
ErythrospERMum C. h. 175/19	242	80.0	43.6	541.2	+26.7
LSD ₀₅			1.37	33.45	

An important feature of most winter grain samples is the presence of a link between plant height and lodging resistance. As the world breeding practices show, short-stemmed winter wheat samples with a plant height of 70.0-90.0 cm are sufficiently resistant to lodging, almost regardless of the thickness of the stem, and forms with a plant height of 90.0-100.0 cm have an average resistance to lodging. In terms

of plant height, winter wheat lines created in the plant protection department are characterized by considerable variability (80.0-95.0 cm). According to the results of studying the material by plant height, 1 sample (ErythrospERMum C. h. 175/19) with a plant height of 80 cm (semi-dwarf forms) was found, and 4 samples were included in the medium-sized group (85-95 cm). The stem height of 105 cm (tall forms) was in-

herent in the susceptible variety Natula (POL) (Table 1).

The TGW is an essential indicator of productivity, as well as a sign that characterizes increased drought resistance and heat resistance. The formation of grain with a high absolute mass is the resulting indicator of the formation of high and stable yields (Kyrpa, 2013). Growing conditions, precipitation, and temperature during the grain filling period, as well as biological features of the variety, are of decisive importance in the formation of grain with a high TGW. In experiments for this study, the average TGW of winter wheat samples was 44.9 g. According to the "grain size" indicator, the standard varieties had the following parameters: Podolyanka – 42.5 g, Natula – 41.6 g, MV-EMESE – 40.9 g. The largest grain was in the line distinguished by its resistance to fusarium head blight – ErythrospERMUM F. g. 164/19 – 50.6 g, a high TGW index was also noted in the line ErythrospERMUM C. h. 177/19 – 47.3 g. The TGW in other lines of winter wheat was also higher than that of the Podolyanka standard variety (Table 1).

According to yield data, the Lutescens F. g. 163/19, ErythrospERMUM C. h. 177/19 and ErythrospERMUM C. h. 175/19 significantly exceed the Podolyanka standard variety – by 38.8, 39.6, and 26.7 g/m², respectively.

The key features limiting the production of high-quality grain were and still are its protein and gluten content (B. Belderok et al., 2000; K.A. Larchenko & B.V. Morgun, 2010). These indicators are closely related to each other, having a high (0.765) correlation coefficient (P. I. Bukrieva et al., 2004). The protein and gluten content in

grain characterize its quality, which is a crucial indicator when determining the price of grain. According to the current standard in Ukraine, the food grain can be attributed to those in which the protein content exceeds 10.5%, and gluten – 18% (DSTU 3768:2010).

One of the most informative parameters for determining the quality of wheat grain is the level of gluten content in it. Gluten is essential in the production of pasta, performing two main functions: it is a plasticizer, and it is also a substance that binds starch grains into a single mass. The former property of gluten contributes to the formation of the dough, while the latter preserves the shape given to the dough (H.P. Zhemela et al., 2020). Factors such as the predecessor in the cultivation of the crop and the genotype of the variety have a substantial influence on the mass share of raw gluten (I.V. Pravdziva, et al. 2020).

A low percentage of protein content was found in the variety susceptible to fusarium head blight – Natula – 11.7%, and in the variety susceptible to root rot – MV-EMESE – 12.6%. These varieties also had a low level of gluten – 27.7% and 29.6%, respectively. A prominent protein content was found in the lines ErythrospERMUM F. g. 166/19 – 16.5% and ErythrospERMUM C. h. 177/19 – 15.8%, protein content at 14.9% was found in the grain of the lines ErythrospERMUM F. g. 164/19 and ErythrospERMUM C. h. 175/19. The highest level of gluten content in grain was recorded in the winter wheat line resistant to fusarium head blight – ErythrospERMUM F. g. 166/19 – 41.2%. In other lines, the content of the gluten indicator was at the standard level (Table 2).

Table 2. Results of incomplete technological analysis of winter wheat samples resistant to pathogens, MIP, 2019

Line or variety name	Protein content, %	Sedimentation rate, ml	Raw gluten content, %
Resistant to fusarium head blight			
Natula (susceptible variety)	11.7	52	27.7
Podolyanka (standard)	13.3	71	32.6
Lutescens F. g. 163/19	14.0	70	34.4
ErythrospERMUM F. g. 164/19	14.9	67	35.7

Table 2. Continued

Line or variety name	Protein content, %	Sedimentation rate, ml	Raw gluten content, %
ErythrospERMUM F. g. 166/19	16.5	71	41.2
Resistant to root rot			
MV-EMESE (susceptible variety)	12.6	59	29.6
Podolyanka (standard)	13.3	71	32.6
ErythrospERMUM C. h. 177/19	15.8	51	38.0
ErythrospERMUM C. h. 175/19	14.9	61	36.4

The index of sedimentation (swelling) is a complex indicator that judges the strength of grain (flour) (V. T. Koljuchyj, 2011). According to the data of this study, this indicator in winter wheat samples varied from 51 to 71 ml. The best lines in terms of this indicator (the sedimentation indicator is at 60-71 ml) are the lines resistant to fusarium head blight – *Lutescens* F. g. 163/19, *ErythrospERMUM* F. g. 164/19, *ErythrospERMUM* F. g. 166/19, and the line *ErythrospERMUM* C. h. 175/19, created under the root rot resistance program. In winter wheat varieties, which are standards of susceptibility to pathogens, a low sedimentation rate was found: *Natula* – 52%, *MV-EMESE* – 59%.

Determination of the sedimentation rate allows selecting promising material in the primary links of the breeding process and successfully conducting selection for grain quality, without increasing the volume of the source material. This indicator substantially depends on the genotype of the original forms and their combinational ability (L. M. Kononiuk *et al.*, 2014).

In nature, the plant is usually affected by several diseases at once, so there is a need to create varieties with group resistance. Evaluating the lines created under the resistance program against the pathogens of fusarium head blight, it was established that the line *Lutescens* F. g. 163/19 showed high resistance against the pathogen of powdery mildew (damage – 1.0%) and septoriosiS of leaves (damage – 3.0%), but the damage from brown rust was 30.0%. Damage by fusarium head blight did not exceed 5.0%. The *ErythrospERMUM* F. g. 166/19 line was distinguished by resistance against two pathogens (fusarium head blight, powdery mildew), while *ErythrospERMUM* F. g. 164/19 – against fusarium head blight and septoria leaf blotch (Table 3).

Two best winter wheat lines, *ErythrospERMUM* C. h. 177/19 and *ErythrospERMUM* C. h. 175/19, were selected on an artificial infectious background of cercosporiellosis root rot, which were relatively resistant to this pathogen (damage – 10.0% and 10.5%, respectively) and had high resistance to powdery mildew – damage 2.0%.

Table 3. Immunological characteristics of winter wheat samples for resistance against pathogens, MIP, 2019

Line or variety name	Disease damage, %				
	Fusarium head blight	root rot	powdery mildew	brown rust	septoria leaf blotch
Resistant to fusarium head blight					
<i>Natula</i> (susceptible variety)	15.0	-	15.0	70.0	10.0
<i>Podolyanka</i> (standard)	15.0	-	3.0	60.0	5.0
<i>Lutescens</i> F. g. 163/19	5.0	-	1.0	30.0	3.0

Line or variety name	Disease damage, %				
	Fusarium head blight	root rot	powdery mildew	brown rust	septoria leaf blotch
ErythrospERMum F. g. 164/19	1.0	-	10.0	60.0	3.0
ErythrospERMum F. g. 166/19	3.0	-	3.0	80.0	30.0
Resistant to root rot					
MV-EMESE (susceptible variety)	-	34.0	3.0	60.0	5.0
Podolyanka (standard)	-	34.0	3.0	60.0	5.0
ErythrospERMum C. h. 177/19	-	10.0	2.0	80.0	20.0
ErythrospERMum C. h. 175/19	-	10.5	2.0	30.0	40.0

CONCLUSIONS

According to the results of the study of constant lines of winter wheat from the breeding nursery, 5 lines created under the selection program for resistance against hard soot, fusarium head blight, and root rot were transferred to the National Centre for Plant Genetic Resources of Ukraine: *Lutescens* F. g. 163/19, *ErythrospERMum* F. g. 164/19, *ErythrospERMum* F. g. 166/19, *ErythrospERMum* C. h. 175/19, *ErythrospERMum* C. h. 177/19.

The line *ErythrospERMum* F. g. 164/19 was selected according to the "duration of the growing season" indicator, with a growing season of 238 days, which is 3 days less than the *Podolyanka* standard variety. It belongs to the group of early-maturing forms.

High TGW indicators were established in the lines *ErythrospERMum* F. g. 164/19 – 50.6 g and *ErythrospERMum* C. h. 177/19 – 47.3 g.

In terms of yield, the standard was exceeded by the lines *Lutescens* F. g. 163/19 – by 38.8 g/m², *ErythrospERMum* C. h. 177/19 – 39.6 g/m², *ErythrospERMum* C. h. 175/19 – 26.7 g/m².

The lines *ErythrospERMum* F. g. 166/19 and *ErythrospERMum* C. h. 177/19 stood out with high-protein content – 16.5% and 15.8%,

respectively. The highest level of gluten content in grain was recorded in the line *ErythrospERMum* F. g. 166/19 – 41.2%.

The best lines in terms of sedimentation are: *Lutescens* F. g. 163/19 – 70 ml, *ErythrospERMum* F. g. 164/19 – 67 ml, *ErythrospERMum* F. g. 166/19 – 71 ml.

Based on the resistance against diseases on artificial infectious backgrounds of their pathogens, the following lines were selected: *Lutescens* F. g. 163/19 line with high resistance against the causative agent of powdery mildew (damage – 1.0%) and septoria leaf blotch (damage – 3.0%), damage from fusarium head blight did not exceed 5.0%. The *ErythrospERMum* F. g. 166/19 line was distinguished by resistance against two pathogens (fusarium head blight, powdery mildew), while *ErythrospERMum* F. g. 164/19 – against fusarium head blight and septoria leaf blotch. The lines created under the program of resistance against root rot, *ErythrospERMum* C. h. 177/19 and *ErythrospERMum* C. h. 175/19, showed relative resistance to this pathogen – 10.0% and 10.5% damage, respectively, and had high resistance to powdery mildew – 2.0% damage.

REFERENCES

- [1] Babayants, L.T., Meshterkhazi, A., Vekhter, F. (1988). *Metody selektsii i otsenki ustoychivosti pshenitsy i yachmenya k boleznyam v stranakh-chlenakh SEV* [Methods for breeding and assessing the resistance of wheat and barley to diseases in the CMEA member countries]. Praga, 321.

- [2] Belderok, B., Mesdag, J., Mesdag, H., & Donner, D.A. (2000). *Bread-making quality of wheat: A Century of Breeding in Europe*. Springer Science & Business Media. (No. 641.815 BEL. CIMMYT).
- [3] Bukrieva, P.I., Neudachin V.P., Donchenko V.I. (2004). Correlation of technical indicators of grain of winter soft wheat in the conditions of Krasnodar. *Krasnodar*, 10, 223-228.
- [4] DSTU 3768: 2010. Wheat. Specifications. Kyiv, 14 p. (National standard of Ukraine).
- [5] Gagkaeva, T.Yu., Gavrilova, O.P., Levitin, M.M, & Novozhilov, K.V. (2011). Fusarium wilt of cereals. *Plant protection and quarantine*, 5(69), 69-120.
- [6] Grigorev, M.F. (1976). *Metodicheskie ukazaniya po izucheniyu ustoychivosti zernovykh kultur k kornevym gnilyam* [Guidelines for the study of the resistance of crops to root rot]. Leningrad: VIR, 59.
- [7] Kholod, S.M., Illichev, Yu.H., & Vyskub, R.S. (2015). Potential of geographically distant samples of winter wheat from 18TH FAWWON-SA nursery in the southern Forest-Steppe of Ukraine. *Scientific works of the Institute of Bioenergy Crops and Sugar Beets*. (23), 117-123.
- [8] Koljuchyj, V.T. (2011). Winter wheat breeding for grain quality in the Forest-Steppe of Ukraine. *Plant Breeding and Seed Production*, 100, 160-171. <https://doi.org/10.30835/2413-7510.2011.66545>
- [9] Kononiuk, L.M., Korsun, S.G., & Davydiuk, G.V. (2014). Yield and quality of winter wheat grain depending on the technology of cultivation in the Right Bank Forest-Steppe. *Collection of scientific works of the National Research Center Institute of Agriculture NAAS*, 4, 46-54.
- [10] Kovalyshyna, H., Dmytrenko, Y., Makarchuk, O., Slobodyanyuk, N. & Mushtruk, M. (2020a). The donor properties of resources resistance against the exciter of wheat rust wheat. *Potravinarstvo Slovak Journal of Food Sciences*, 14, 821-827. <https://doi.org/10.5219/1427>
- [11] Kovalyshyna, H., Dmytrenko, Y., Tonkha, O., Makarchuk, O., Demydov, O., Humenyuk, O., Kozub, N., Karelov, A., Sozinov, I. & Mushtruk, M. (2020b). Diversity of winter common wheat varieties for resistance to leaf rust created in the V. M. Remeslo Myronivka Institute of Wheat. *Potravinarstvo Slovak Journal of Food Sciences*, 14, 1001-1007. <https://doi.org/10.5219/1447>
- [12] Kovalyshyna, H.M. (2012). Immunological aspects of creation of initial forms of winter wheat with increased resistance against fungal diseases and substantiation of protective measures in the Forest-Steppe of Ukraine (Doctoral dissertation, senior doctor of agricultural sciences: special 06.01.11 – “Phytopathology” / H. M. Kovalyshyna).
- [13] Kriuchkova, L.O., & Hrytysuk, N.V. (2014). The distribution of winter wheat root rots in Northern Forest-Steppe of Ukraine. *Quarantine and Plant Protection*, 2, 9-12.
- [14] Kyrpa, M.Ya. (2013). Size and sowing qualities of winter wheat seeds. *Plant breeding and seed production*, (103), 178-186. <https://doi.org/10.30835/2413-7510.2013.54091>
- [15] Larchenko, K.A. & Morgun, B.V. (2010). Wheat grain quality traits and methods of their improvement. *Physiology and biochemistry of cultivated plants*, 42 (6), 463-474. <http://dspace.nbuv.gov.ua/bitstream/handle/123456789/66321/01-Larchenko.pdf?sequence=1>
- [16] Lyfenko, S.F. (1988). Breeding winter wheat varieties of intensive type in the conditions of the south of Ukraine. Dis. Doctor of Agricultural Sciences (in the form of scientific reports). Odesa. VSGI.
- [17] Novokhatka, V.G., Doroshenko, N.V, & Zabolotnaya, V.A (1990). Distribution of root and root rot of winter wheat in the USSR. *Mycology and Phytopathology*, 24 (4), 352-357.
- [18] Pravdziva, I.V., Demydov, O.A., Hudzenko, V.M., & Derhachov, O.L. (2020). Evaluation of yield and stability of bread winter wheat genotypes (*Triticum aestivum* L.) depending on predecessors and sowing dates. *Plant Varieties Studying and Protection*, 16(3), 291-302. <https://doi.org/10.21498/2518-1017.16.3.2020.214923>
- [19] Retman, S.V. (2009). Wheat spots in the Forest-Steppe of Ukraine and conceptual bases of protection (Doctoral dissertation, senior doctor of agricultural sciences: special 06.01.11 – “Phytopathology” / S.V. Retman).

- [20] Taranova, T.Yu., Kincharov, A.I., Demina, E.A., & Mullayanova, O.S. (2020). Sources of resistance to fungal diseases for selection of spring soft wheat. *The Agrarian Scientific Journal*, 12, 45-49. <https://doi.org/10.28983/asj.y2020i12pp45-47>
- [21] Trybel, S.O., Hetman, M. V., Stryhun, O.O., Kovalyshyna, H.M. & Andriushchenko, A.V. (2010). *Metodolohiia otsiniuvannia stiikosti sortiv pshenytsi proty shkidnykiv i zbudnykiv khvorob* [Methodology of evaluation of resistance of wheat varieties to pests and pathogens], Ukraine, Kyiv: Kolobih, 392.
- [22] Volkodav, V.V., Andriushchenko, A.V., Pilkevych, A.V. (2000). *Metodyka derzhavnoho sortovuyprobuvannia silskohospodarskykh kultur* [Method of state sorting of agricultural crops]. Ukraine, Kyiv, 100.
- [23] Zhemela, H.P., Barabolia, O.V., Tatarko, Yu.V., & Antonovskiy, O.V. (2020). Vplyv sortovykh osoblyvostei na yakist zerna pshenytsi ozymoї. *Visnyk Poltavskoi Derzhavnoi Ahrarnoi Akademii*, 3, 32-39. <https://doi.org/10.31210/visnyk2020.03.03>

Л.А. Мурашко

Науковий співробітник лабораторії селекції озимої пшениці
Миронівський інститут пшениці імені В.М. Ремесла НААН
08853, вул. Центральна, 68, м. Центральне, Україна

Т.І. Муха

Науковий співробітник лабораторії селекції озимої пшениці
Миронівський інститут пшениці імені В.М. Ремесла Національної академії наук
08853, вул. Центральна, 68, м. Центральне, Україна

Г.М. Ковалишина

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

Ю.М. Дмитренко

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

Характеристика вихідного матеріалу, стійкого проти фузаріозу колоса та кореневих гнилей, для селекції пшениці озимої

Анотація. Хвороби пшениці озимої значно знижують урожайність та якість зерна. Втрати валового збору зерна від них щорічно становлять 20-30 %, а в епіфітотійні роки – 50 %. Ефективним заходом для обмеження розвитку хвороб пшениці озимої є впровадження стійких проти їхнього ураження сортів. Успішний розвиток селекційної роботи в цьому напрямку неможливий без використання генофонду стійких форм. Серед генетичних ресурсів пшениці є генотипи, що характеризуються стійкістю проти кількох збудників одночасно, а тому мають особливу цінність як джерела групової стійкості. Постійно існує потреба у виявленні нових

джерел та донорів стійкості проти збудників хвороб, пошук яких є актуальним напрямом досліджень і потребує постійного скринінгу генофонду. У Миронівському інституті пшениці імені В. М. Ремесла постійно ведеться робота зі створення вихідного селекційного матеріалу пшениці озимої, стійкого проти основних збудників хвороб, які надалі використовуються селекціонерами. За програмою селекції на стійкість проти фузаріозу колосу та кореневих гнилей створені лінії: Лютесценс F. g. 163/19, Еритроспермум F. g. 164/19, Еритроспермум F. g. 166/19, Еритроспермум С. h. 177/19, Еритроспермум С. h. 175/19, які використовують селекціонери інституту і їх передано до НЦГРРУ. За показником тривалість вегетаційного періоду виділено лінію Еритроспермум F. g. 164/19 у якої вегетаційний період становив 238 днів, що на 3 доби менше, ніж у стандартного сорту Подолька. Її віднесено до групи ранньостиглих форм. Високі показники маси 1000 зерен відмічені в лінії Еритроспермум F. g. 164/19 – 50,6 г, Еритроспермум F. g. 166/19 – 49,3 г, Еритроспермум F. g. 163/19 – 46,5 г та Еритроспермум С. h. 177/19 – 47,3 г. За урожайністю стандарт перевищували лінії Лютесценс F.g. 163/19 – на 38,8 г/м², Еритроспермум С. h. 177/19 – на 39,6 г/м², Еритроспермум С. h. 175/19 – на 26,7 г/м². З високим вмістом білка вирізнялися лінії Еритроспермум F. g. 166/19 – 16,5 % і Еритроспермум С. h. 177/19 – 15,8 %. Найвищий рівень вмісту клейковини в зерні зафіксовано в лінії Еритроспермум F. g. 166/19 – 41,2 %. Кращими за показником седиментації виділені лінії: Лютесценс F.g. 163/19 – 70 мл, Еритроспермум F.g. 164/19 – 67 мл, Еритроспермум F. g. 166/19 – 71 мл. Встановлено, що лінія Лютесценс F. g. 163/19 проявила високу стійкість проти збудника борошнистої роси (ураження – 1,0 %) та септоріозу листя (ураження – 3,0 %). Ураження колосу фузаріозом не перевищувало 5,0 %. Стійкістю проти двох збудників (фузаріоз, борошнеста роса) вирізнялася лінія Еритроспермум F.g. 166/19, а проти фузаріозу й септоріозу листя – Еритроспермум F. g. 164/19. Лінії, створені за програмою стійкості проти кореневих гнилей Еритроспермум С. h. 177/19 і Еритроспермум С. h. 175/19, проявили відносну стійкість проти цього збудника – ураження 10,0 та 10,5 %, та мали високу стійкість проти борошнистої роси – ураження 2,0 %

Ключові слова: лінії; хвороби; ураження; стійкість; вилягання; висота рослин; урожайність; якість зерна

S.Yu. Bulygin*

Doctor of Agricultural Sciences, Professor, Academician
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

S.V. Vitvitsky

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

M.E. Bulygina

Junior Researcher
National Research Centre "Institute of Mechanisation and Electrification of Agriculture"
08631, 11 Vokzalna Str., Hlevakha, Ukraine

O.I. Vitvitska

Senior Researcher
National Scientific Center
"Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine"
08163, 2B Mashinobudivnikiv Str., Chabany, Ukraine

Mode of moistening ordinary chernozem using the "no-till" technology

Abstract. Studies of the influence of different technologies of conventional chernozem cultivation on the reserves of productive moisture for the cultivation of maize over grain and winter wheat in the Steppe zone of Ukraine were carried out. The parameters of productive moisture in the technology of growing field crops using "no-till" soil treatment in relation to shelf ploughing were determined. It was established that the "no-till" system substantially reduces moisture loss due to unproductive evaporation with a high coefficient of precipitation assimilation and provides reliable protection of the soil from erosion. If the soil surface is covered close to 100% in the summer under maize, the reserves of productive moisture in the root layer are over 1.5 times higher than the corresponding reserves under conventional technology; in the absence of mulch, the moistening regime for no-till technologies is more intense compared to the conventional one. The mode of moistening the soil under winter wheat over maize for silage is preferable according to the "no-till" technology, but

Suggested Citation:

Bulygin, S., Vitvitsky, S., Bulygina, M., & Vitvitska, O. (2021). Mode of moistening ordinary chernozem using the "no-till" technology. *Plant and Soil Science*, 12(4), 91-101. doi: 10.31548/agr2021.04.091.

*Corresponding author



Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (<https://creativecommons.org/licenses/by/4.0/>)

there was no substantial difference between the variants on average for 3 years. In a winter with little snow, the height of the snow cover was 3.2 times higher with the “no-till” technology with mulch compared to the conventional technology. It was found that a prerequisite for growing crops without tillage in the zone of insufficient moisture is the creation of a powerful layer of mulch due to the non-commodity share of the crop, which stays on the soil surface in crushed form. Projective mulch coverage of 100% or close to this level is the key to the widespread introduction of technologies for growing without tillage in arid Steppe conditions

Keywords: reserves of productive moisture, ordinary chernozem, maize over grain, winter wheat, “no-till” system

RELEVANCE

Growing maize in the steppe is a risky endeavour. A.H. Shevchenko (1996) classifies the level of favourability of the natural and climatic resources of this zone for the cultivation of most crops, including maize, as unfavourable. V.V. Medvedev *et al.*, based on numerous studies in various soil and climatic zones, consider the Steppe, including the Donbas, to be an acceptable zone for growing maize, but suboptimal (Medvedev, 1997). The primary limiting factor of the yield level is moisture reserves, which are insufficient for optimal growth and development of maize.

It is the preservation and rational use of moisture that is one of the principal tasks of steppe agriculture. Therefore, investigating the regime of chernozem hydration in the development and implementation of innovative technologies for growing agricultural crops is a mandatory condition.

Such studies are especially necessary in the areas of water and wind erosion, which include the Donetsk region, since fluctuations in soil moisture reserves cause not only a substantial change in crop yields, but also a noticeable erosion resistance of the soil.

The most effective technique for accumulating and preserving moisture is mulching the soil surface with plant remains (Bulyhin *et al.*, 2016).

The “no-till” system allows successfully applying this method during the cultivation of all agricultural crops and maize specifically. The study by V.V. Medvedev and others has shown that the soils of Ukraine are generally favourable for the introduction of minimal and no-till cultivation.

Soils were classified according to the possibility of applying minimal and no tillage by classes and area: I – optimal (8.46% or 2.54 mln ha); II – favourable (40.57% or 12.17 mln ha); III – satisfactory (41.2% or 12.36 mln ha). Along with reducing costs for soil cultivation, increasing its fertility, their use contributes to the additional accumulation of moisture by 30-50 mm, which ensures stable harvests, especially in conditions of severe droughts, which are most inherent in the Steppe zone (Kosolap & Krotinov, 2011).

ANALYSIS OF RECENT STUDIES AND PUBLICATIONS

The transition to the no-till system is not just a replacement of the tillage system, but factually a new farming system. In the world, the area on which this system is used is approximately 105 mln ha, of which 87 mln ha are in the USA, Canada, Brazil, Argentina, and Australia, and annually the area under such a system grows by approximately 1 mln ha. In Europe, including its eastern part, the volume of implementation of no-till technology is 2.5-3% of the global application (Medvediev *et al.*, 2017; Bulyhin *et al.*, 2019).

Considerable attention of Ukrainian scientists is devoted to the search for optimal soil cultivation systems, their adaptation to the cultivation of various agricultural crops in the conditions of changing climatic conditions, which substantially determine the level of productivity.

It was found that the use of minimal and no tillage of ordinary chernozem for the cultivation

of maize for silage provided the highest reserves of productive moisture in a metre-thick soil during the growing season compared to ploughing, and the indicators of deflation resistance increased considerably (Pikovska, 2020).

The advantage of shallow cultivation with slitting to a depth of 38-40 cm over shelf ploughing for growing maize over grain in the growing conditions of southern Ukraine is evidenced by the data of R.A. Vozhehova *et al.* (2019) and V.Kh. Kiver *et al.* (2019), which established a high efficiency of minimization of tillage and fertilization on ordinary chernozems for maize grain production.

The widespread use of chemicals, the elevated energy saturation of conventional technologies can cause environmental pollution, the development of erosion processes, and increase costs per unit of production. Therefore, one of the main areas of eliminating or mitigating these adverse factors is to reduce the anthropogenic load and switch to less expensive technologies with maximum use of plant growing by-products.

NSC "Institute of Agriculture of the National Academy of Agrarian Sciences" (2015) developed resource-saving technologies for growing maize over grain and winter wheat according to the no-till system, which achieves the highest return on spent resources with the obtained products, renews soil fertility.

The advantage of "no-till" technology in preserving soil fertility and, specifically, soil moisture, which determines the productivity of crops, is also evidenced by data obtained by foreign researchers. R. Derpsh, A. Calagari (1992) established that during shelf cultivation in the arable layer, moisture loss amounted to 18.3 mm, during no tillage – 4.1 mm, and the subsoil layer lost 9.7 mm and 3.5 mm, respectively. An analysis of numerous studies on no-tillage by Y. Li, Z. Li,

S. Cui & Q. Zhang (2020) showed that it is climatic conditions that determine its effectiveness, and therefore research on such tillage systems is important, especially in arid zones.

The purpose of this study was a systematic investigation of sowing seeds without tillage, which is the basis of the "no-till" technology of growing crops in the understanding of American scientists.

MATERIALS AND METHODS

The study was conducted in the conditions of a stationary field experiment, established on the territory of the experimental farm of the Donetsk region, on ordinary low-humus light loamy chernozem. The repetition of the experiment was threefold. The area of the sown plot was 1.7 ha, the accounting plot area was 100 m². The research was conducted in a 9-field crop rotation, entering the crop rotation was carried out with four fields. Furthermore, separate options include the unchanged sowing of maize over grain (monoculture) with a natural projective coverage and the option of monoculture of maize with an artificially created 100% projective coverage of the soil surface with a layer of mulch, which is obtained from crushed maize stalks. The obtained data were subjected to statistical processing according to the variance method (Dospikhov, 1985), and analysed by non-parametric statistics using quantile analysis (Blahoveshchenskyi, Samsonova, Dmitriev, 1987).

RESULTS AND DISCUSSION

Under crops in crop rotation, the projected coverage of the soil surface with plant residues did not exceed 25%, it was insufficient for a substantial increase in moisture in the soil, and therefore under the "no-till" technology, the moisture reserves were slightly higher compared to the conventional technology (Table 1).

Table 1. Dynamics of productive moisture reserves when growing maize over grain (average for 3 years)

Variants	Soil layers, cm	Stock, mm				
		Exit from winter	Sowing	Sprouts	Flowering	Harvesting
Shelf ploughing – control	0-20	35	33	33	15	16
	0-50	91	80	71	36	39
	0-100	168	143	140	76	75
	0-150	233	207	198	127	118
“No-till”	0-20	41	37	29	17	18
	0-50	98	84	73	39	42
	0-100	176	150	131	80	77
	0-150	244	212	185	129	119

Only before sowing, the moisture reserves under the “no-till” technology of growing monoculture maize over grain were substantially higher than under the conventional technology, and even then, only in the 0-50 cm soil layer. Furthermore, during germination, the moisture reserves in the soil layer of 0-20 cm using “no-till” technology were substantially less than using conventional one (shelf ploughing). In general, the sowing-germination period turned out to be critical for the “no-till” technology with a small amount of plant residues on the soil surface. This was most pronounced in May 2011, when the reserves of available moisture at the time of germination of monoculture maize over grain using “no-till” technology

were only 8 mm in a 0-10 cm layer, which is too insufficient. At the same time, through sowing to a depth of 5 cm, maize seeds were found in the over-dried upper layer of soil. Currently, the shoots of monoculture maize over grain using conventional technology have risen by 100%, while using “zero” technology – only by 60%. maize – a monoculture over grain under “no-till” technology – rose only on June 9 and continued to fall behind in development.

Considering the experience of 2011, a micro-field experiment was created with 100% coverage of maize plant residues and in 2013 the authors received data on moisture reserves under the maize monoculture for grain with 100% projected coverage (Table 2).

Table 2. Dynamics of reserves of productive moisture when growing maize over grain, 2013

Variants	Soil layers, cm	Stock, mm			
		Exit from winter	Sowing	Flowering	Harvesting
Shelf ploughing – control	0-20	34	38	7	1
	0-50	92	93	29	7
	0-100	174	170	69	14
	0-150	222	229	118	36

Table 2. Continued

Variants	Soil layers, cm	Stock, mm			
		Exit from winter	Sowing	Flowering	Harvesting
"No-till", projective coverage – 100%	0-20	42	44	23	5
	0-50	109	108	66	15
	0-100	193	186	132	31
	0-150	259	238	174	62

2013 was a dry year, and therefore the difference between the variants was striking. In almost every soil layer, at each selection period, the moisture reserves under mulch were substantially higher compared to conventional technology. Additionally, the moisture reserves under the "no-till" technology with a projective mulch coverage < 30% at the end of winter were insignificantly lower compared to the projective mulch coverage of 100%; however, in the subsequent sampling periods, the moisture reserves under the "no-till" technology

with a small amount of mulch were significantly smaller (see Table 1). During flowering (in the period critical for maize), the reserves of moisture in the soil for "no-till" technology with mulch exceeded the reserves for other technologies in the 0-20 cm soil layer by 3.2 times, in the 0-50 cm soil layer – by 2, 3 times, in the 0-100 cm layer – by 1.9 times, and in the 0-150 cm layer – by 1.5 times. N.F. Tsupenko (1990) compiled a scale for evaluating the suitability of productive moisture reserves for maize based on generalized data (Table 3).

Table 3. Scale for assessing the compliance of productive moisture reserves in the soil with the requirements of maize in different growing seasons

Soil layer, cm	Phases of plant development	Stock, mm	Assessment of moisture reserves
0-20	Sowing – seedlings	< 10	Insufficient
		11-20	Satisfactory
		21-30 >	Good
0-20	Flowering	< 10	Insufficient
		11-20	Satisfactory
		21-30 >	Good
0-50	Flowering	< 20	Insufficient
		30-50	Satisfactory
		60-70	Optimal

Consequently, the initial conditions for maize growth and development were equal (Figs. 1 and 2). But in July, when, according to M.I. Volodarskii, maize needs the largest amount of available moisture, its median reserves according to

conventional technology (comparable data were obtained using "no-till" technology for 25% coverage of the soil surface with plant remains) were insufficient both in the soil layer 0-20 cm (Fig. 1) and in the 0-50 cm layer (Fig. 2).

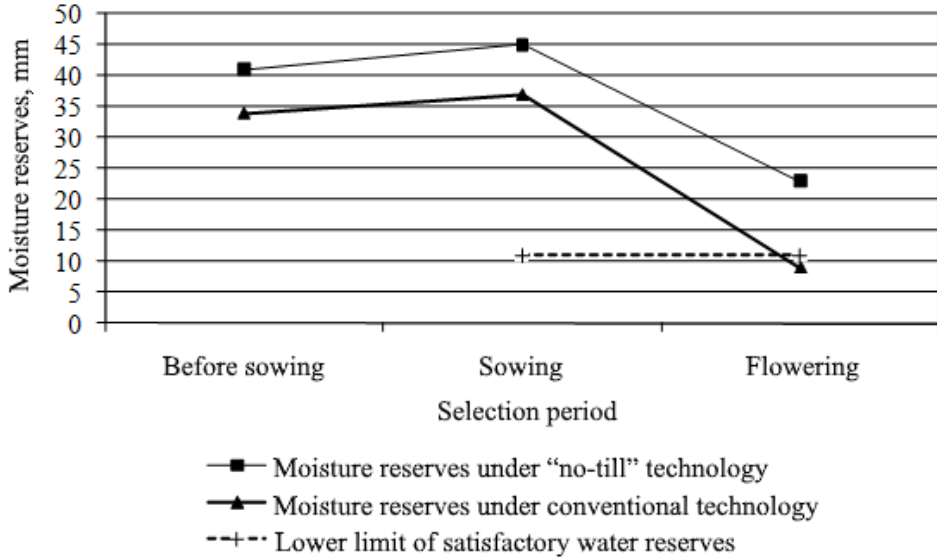


Figure 1. Median values of productive moisture reserves in the 0-20 cm layer under maize over grain

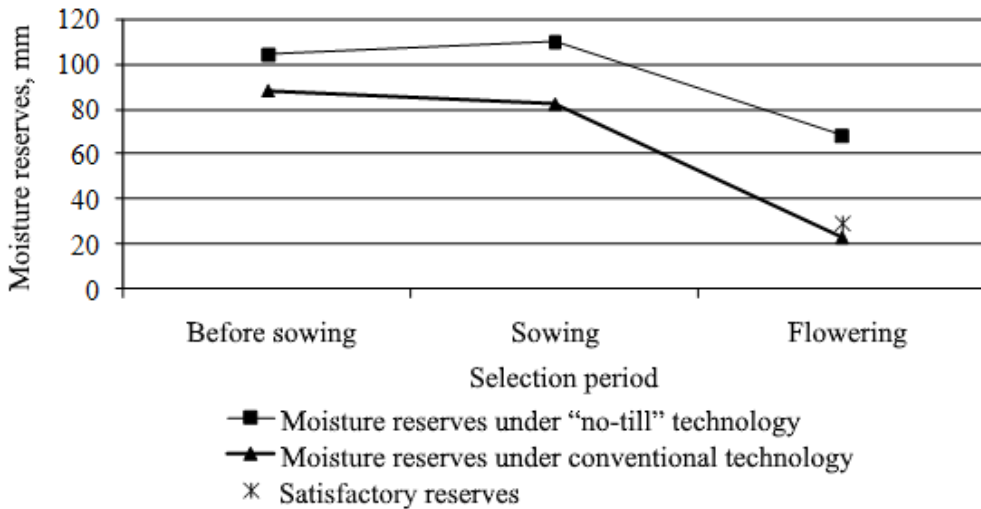


Figure 2. Median values of productive moisture reserves in the 0-50 cm layer under maize over grain

The authors of this study deliberately took the median values because they are statistically “more stable” than the average. When using “no-till” technology with 100% mulch coverage during flowering, available moisture reserves were optimal, both in the 0-20 cm soil layer and in the 0-50 cm soil layer.

The use of mulch, admittedly, is prescribed over a fairly long period of time, as a result of which it is possible to accumulate moisture in the deep layers of the soil from year to year. A certain trend was already visible in 2013. Thus, the average moisture content of the soil layer when using conventional technology in a 100-150 cm layer at the time of exit from winter was 21%, and when using no-till – 23.5%.

It is known that mulch, by lowering the temperature on the soil surface and separating the soil surface from the atmosphere, sharply reduces the intensity of steam entering the air from the soil surface, reduces unproductive evaporation of water from the soil. However, the question arises as to how the soil surface retains moisture without a mulch of plant residues. On June 3, 2013, in the seedling phase of maize under the “no-till” technology, the authors of this study noticed that the upper, 0-3 cm layer of the soil is much looser than the rest of the soil. B.H. Rozanov claims that soils with a heavy granulometric composition have a tendency to self-mulching. The authors of the present study believe that this is precisely what happened. According to V.V. Medvediev (1988), the differentiation of the upper layer of the soil by density (the upper loose layer changes to a denser one at 5-10 cm) helps to reduce evaporation, increases the condensation of moisture vapour, while at the same time there are

no substantial additional obstacles to the entry of atmospheric moisture into soil. Clearly, mulch created by fine soil is not as effective as mulch created by plant residues. In the flowering phase, when using the “no-till” technology without mulch and when using the conventional technology, the humidity in the 0-3 cm layer was 8% and 7%, respectively, and 13% against 10% in the 3-10 cm layer, while when using the “no-till” technology with 100% coverage with plant remains – 18% in the 0-3 cm layer and 23% in the 3-10 cm layer.

It is known that in the chernozem zone of insufficient moisture, the productive moisture in the soil is the first limiting factor in the yield level of agricultural crops. Using evidence from 2013, it can be argued that mulch practically solves the problem of a guaranteed high maize yield in conditions of insufficient moisture in the chernozem zone.

In addition, there is a tendency for changes in some characteristics of the soil climate. A.A. Shulgin (1972) gives a quantitative description of the amplitude of soil moisture reserves in a metre-long soil layer during the warm period (the so-called moisture turnover): uniform – under 50 mm, uneven – 50–100 mm, very uneven – over 100 mm. Evidently, at least up to and including flowering, the amplitude of soil moisture reserves under the “no-till” technology with mulch was considered uneven – 61 mm, and under the conventional technology, as very uneven – 105 mm.

The mode of moistening the soil under winter wheat for maize over grain is preferable when using “no-till” technology, but there was no substantial difference between the options on average for 3 years (Table 4).

Table 4. Dynamics of productive moisture reserves for winter wheat cultivation (average for 3 years)

Variants	Soil layers, cm	Stock, mm			
		Sowing	Restoration of vegetation	Flowering	Harvesting
Shelf ploughing – control	0-20	12	25	16	18
	0-50	35	64	34	34
	0-100	73	116	65	48
	0-150	116	173	111	78

Table 4. Continued

Variants	Soil layers, cm	Stock, mm			
		Sowing	Restoration of vegetation	Flowering	Harvesting
“No-till”	0-20	19	25	21	18
	0-50	44	66	41	35
	0-100	83	119	76	53
	0-150	129	175	119	81

This can be explained by the contrasting weather conditions in 2011 compared to 2012 and 2013. Considering each year separately, it turns out that in 2011, during sowing, reserves of available moisture in the 0-20 cm layer when using “no-till” technology amounted to 39 mm, against 29 mm when using the conventional one. During sowing in 2012, the moisture reserves using the “no-till” technology were 2.4 times higher compared to conventional technology, respectively, 12 mm against 5 mm. In 2013, the driest year at this point, the moisture reserves for both technologies were practically the same: 3 mm for the conventional one, 5 mm for the “no-till” one. Thus, when sowing winter wheat using “no-till” technology, the starting conditions are better than upon using conventional technology. The fact is that the “no-till” technology contributes to more efficient consumption of moisture for physical evaporation, and therefore the highest content of moisture is stable in the soil during sowing. Both in 2012 and 2013, using the “no-till” technology, full shoots were observed in the autumn, while upon using the conventional technology, only in the spring of the following year.

It is known that in the Steppe zone, moisture accumulation occurs during the cold period of the year. In winter, precipitation falls in the form of snow, sleet (snow with rain) and rain. The average snow cover height is 6-11 cm. Due to

frequent thaws, the snow cover is unstable. The value of the hydrothermal coefficient for Donbas (0.8-0.9) shows that evaporation in the warm period of the year exceeds this amount. Therefore, in the practice of agriculture, it is necessary to apply all methods of moisture accumulation in the autumn and winter period.

During ploughing, due to the uneven “corrugated” surface, the snow is blown off the ridges, and the surface of the soil without plant remains freezes and prevents the infiltration of water into the soil. The presence of a mulch layer on the surface of the soil also affects its hydrothermal regime in winter, reducing soil freezing and creating more favourable conditions for replenishing water reserves during snow melting, during thaws and in spring, and considerably reduces the risk of water erosion. On February 24, 2013, the soil temperature in the 0-5 cm and 0-10 cm layers upon using the “no-till” technology with mulch was the same and equal to +1.5°C. Using conventional technology – -1.5°C in the 0-5 cm layer and -0.7°C in the 0-10 cm layer.

Apart from affecting the freezing of the soil, mulch, by increasing the aerodynamic roughness of the surface, retains and accumulates snow, protecting it from wind blowing. This is especially evident in low-snow winters, in heavy-snow winters without blizzard redistribution of snow, the difference in its reserves on the field slightly decreases (Table 5).

Table 5. Snow cover thickness in various hydrothermal winter conditions, cm

Crop	Technology	February 2, 2011	February 2, 2013
Winter wheat	Conventional	25.8	13.3
	No-till	25.8	7.7

Table 5. Continued

Crop	Technology	February 2, 2011	February 2, 2013
Maize – monoculture	Conventional	24.7	8.2
	No-till (projective coverage < 30%)	24.7	16.1
	No-till (projective coverage > 85%) No-till	-	26.1
Stubble of winter wheat (predecessor for sunflower)	Conventional	24.7	8.1
	No-till	24.7	6.2
LSD _{0.05} S _x %		2.8	
		4.9	

As this table suggests, in the snowy winter of 2011, the height of the snow cover was almost the same for all technologies. In a winter with little snow, the advantage of “no-till” technology was evident. This is especially noticeable for the use of “no-till” technology with mulch, where the height of the snow cover was 3.2 times higher compared to the conventional technology. The “no-till” technology of growing corn without mulch also contributed to the accumulation of snow cover – twice as much as the conventional technology.

The relatively small height of the snow cover on the stubble of winter wheat is explained by the low cut of the straw during wheat harvesting. However, when using conventional technology, the surface area without snow occupied up to 15%, and when using “no-till” technology, 100% snow coverage of the soil surface was noted for all cultures.

CONCLUSIONS

In the world and in Ukraine, the use of agrotechnical techniques is becoming increasingly important. These techniques ensure a substantial reduction of moisture loss caused by unproductive evaporation with a high rate of assimilation

of (melt) water and rain, which, among other things, provides reliable protection of the soil from erosion.

The “no-till” technology most fully meets these requirements with 100% or close to this level of projective covering with mulch from plant residues, which is considered a prerequisite for the wide implementation of cultivation technologies without tillage in the arid conditions of the Steppe.

If the soil surface is covered close to 100% in the summer under maize, the reserves of productive moisture in the root layer are over 1.5 times higher than the corresponding reserves when using conventional technology; in the absence of mulch, the moistening regime when using no-till technologies is more intense compared to the conventional technology.

The mode of moistening the soil under winter wheat over maize for silage is preferable when using the “no-till” technology, but there was no substantial difference between the variants on average for 3 years.

In a winter with little snow, the height of the snow cover was 3.2 times higher when using the “no-till” technology with mulch compared to the conventional technology.

REFERENCES

- [1] Agroecological assessment of the lands of Ukraine and the placement of agricultural crops. (1997) pod red. akad. UAAN V.V. Medvedeva. - Kiyev: Agrarnaya nauka. 163 p.
- [2] Blagoveshchenskiy, YU.N. Samsonova, V.P. Dmitriyev, Ye.A. (1987). Nonparametric methods in soil research. M: Nauka, 96p.
- [3] Bulyhin S.YU., Velychko V.A., Demydenko O.V. (2016). Agrogenesis of chernozem. K. Ahrarna nauka. 356 p.
- [4] Bulyhin, S.YU., Vitvits'kyi, S.V., Antonyuk, D.O. (2019). Direct sowing No-till: agrophysical examination of the transition stage. *Visnyk ahrarnoyi nauky*, 6, 13-20. doi.org/10.31073/agrovisnyk201906-02
- [5] Derpsh, R., Calegari, A. (1992). Plantas para adupacao verde de inverno. IAPAR, Londrina, Circular, Nº73. 80 p.
- [6] Dospikhov, B.A. Field experiment technique. (1985). M.: Agropromizdat, 351.
- [7] Kiver, V.KH., Onopriyenko, D.M. (2019). Energy-saving agrotechnology of corn grain production on irrigated lands. *Visnyk ahrarnoyi nauky*, 4. 74-81. DOI: <https://doi.org/10.31073/agrovisnyk201904-11>
- [8] Kosolap, M.P., Krotinov, O.P. (2011). No-till farming system Kyiv. “Lohos”. 350.
- [9] Li, Y., Li, Z., Cui, S., & Zhang, Q. (2020). Trade-off soil pH, bulk density and other soil physical properties under global no-tillage agriculture. *Geoderma*, 361 doi:10.1016/j.geoderma.2019.114099
- [10] Medvedev, V.V. (1988). Optimization of the physical properties of chernozems. M: Agropromizdat, 158 p.
- [11] Medvedyev, V.V., Bulyhin, S.YU., Bulyhina, M.YE. (2017). Modern farming systems the problem of tillage. *Ahroekolohichnyy zhurnal*, 55, 127-134.
- [12] Pikovs'ka, O.V (2020). Preservation of fertility of common chernozems in terms of climate legalization. *Plant and Soil*, 11/1, 62-68. DOI : <https://doi.org/10.31548/org2020.01.062>
- [13] Scientific bases of effective development of agriculture in agrolandscapes of Ukraine. (2015). Za red.. V.F. Kamins'koho. K.: “Edel'veys”, 428 p.
- [14] Shevchenko, A.H. (1996). Agrometeorological resources and their rational use. *Zemlya i lyudy Ukrainy*, 4-5, 23-28. 45-52.
- [15] Shul'gin, A.A. (1972). Soil climate and its regulation. L.: Gidrometeoizdat, 343 p.
- [16] Tsupenko, N.F. (1990). *Agronomist's Handbook of Meteorology*. K.: Urozhay, 240 p.
- [17] Vozhehova, R.A, Malyarchuk, M.P, Malyarchuk, A.S., Markovs'ka, O.YE. (2019). Formation of humus condition and nutrient regime of soil for corn for grain in crop rotation under irrigation. *Visnyk ahrarnoyi nauky*, 9, 12-20, DOI : <https://doi.org/10.31073/agrovisnyk201909-02>

С.Ю. Булигін

Доктор сільськогосподарських наук, професор, академік
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

С.В. Вітвіцький

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

М.Є. Булигіна

Молодший науковий співробітник
Національний науковий центр
«Інститут механізації та електрифікації сільського господарства»
08631, вул. Вокзальна, 11, м. Глеваха, Україна

О.І. Вітвіцька

Старший науковий співробітник
Національний науковий центр
«Інститут землеробства Національної академії аграрних наук України»
08163, вул. Машинобудівників, 2Б, м. Чабани, Україна

Режим зволоження чорнозему звичайного за технології «no-till»

Анотація. Проведені дослідження впливу різних технологій обробітку чорнозему звичайного на запаси продуктивної вологи за вирощування кукурудзи на зерно та пшениці озимої у степовій зоні України. Визначені параметри продуктивної вологи при технології вирощування польових культур за «нульового обробітку» ґрунту («No-till») щодо полицевої оранки. Встановлено, що система «No-till» сприяє суттєвому зменшенню втрат вологи на непродуктивне випаровування за високого коефіцієнта засвоєння атмосферних опадів, забезпечує надійний захист ґрунту від ерозії. У разі вкриття поверхні ґрунту близькому до 100 % влітку під кукурудзою запаси продуктивної вологи в кореневмісному шарі в 1,5 і більше рази перевищують відповідні запаси за традиційної технології; у разі відсутності мульчі режим зволоження за технології без обробітку ґрунту складається більш напружений у порівнянні з традиційною. Режим зволоження ґрунту під озимою пшеницею по кукурудзі на силос кращий за «нульовою» технологією, але суттєвої різниці між варіантами в середньому за 3 роки не виявлено. У малосніжну зиму за «нульової» технології з мульчею висота снігового покриву була в 3,2 рази вищою у порівнянні з традиційною технологією. Виявлено, що обов'язковою умовою вирощування культур без обробітку ґрунту в зоні недостатнього зволоження є створення потужного шару мульчі завдяки нетоварній частці врожаю культур, яка в подрібненому вигляді залишається на поверхні ґрунту. Проективно покриття мульчею у 100 % або близьким до цього рівня є запорукою широкого впровадження технологій вирощування без обробітку ґрунту в посушливих умовах Степу

Ключові слова: запаси продуктивної вологи; чорнозем звичайний; кукурудза на зерно; пшениця озима; система «No-till»

E.H. Dehodyuk*

Doctor of Agricultural Sciences, Professor, Academician
National Scientific Center

“Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine”
08163, 2B Mashinobudivnikiv Str., Chabany, Ukraine

S.E. Dehodyuk

Doctor of Agricultural Sciences, Senior Researcher
National Scientific Center

“Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine”
08163, 2B Mashinobudivnikiv Str., Chabany, Ukraine

Yu.P. Borko

PhD in Agricultural Sciences
National Scientific Center

“Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine”
08163, 2B Mashinobudivnikiv Str., Chabany, Ukraine

O.A. Litvinova

PhD in Agricultural Sciences, Senior Researcher
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

Yu.O. Ihnatenko

Postgraduate Student
National Scientific Center

“Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine”
08163, 2B Mashinobudivnikiv Str., Chabany, Ukraine

A.O. Mulyarchuk

Postgraduate Student
National Scientific Center

“Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine”
08163, 2B Mashinobudivnikiv Str., Chabany, Ukraine

Long-term monitoring of aridization in agriculture before and after climate change in Ukraine

Suggested Citation:

Dehodyuk, E., Dehodyuk, S., Borko, Yu., Litvinova, O., Ihnatenko, Yu., & Mulyarchuk, A. (2021). Long-term monitoring of aridization in agriculture before and after climate change in Ukraine. *Plant and Soil Science*, 12(4), 102-114. doi: 10.31548/agr2021.04.102.

*Corresponding author



Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (<https://creativecommons.org/licenses/by/4.0/>)

Abstract. This paper presents the results of systematic monitoring in Ukraine for manifestations of aridity according to the method of summarizing spring, summer, and autumn droughts conducted by I. Ye. Buchynskiy for 1872-1969 and authors' meteorological generalizations according to weather types (1951-1984) and clearly expressed zonal climate changes (1985-2006) and statistical and local signs of climate aridization at the meteorological station in the northern part of the Forest Steppe ("Chabany") – 2006-2020, covering a total of 150 years of historical time. According to the spatial distribution of droughts, determined according to a unified methodology, starting from 1872 and ending in the late 1960s, the defining indicator is the gradual spatial distribution of seasonal local droughts with the recurrence of spring droughts after 2 years, summer droughts after 4 years, and autumn droughts, mainly in the south of Ukraine, after 2 years. The number of moderate and large droughts since the beginning of the 20th century (11-30% of the distribution area) are typical for the summer period, and they are repeated in the south after 4-5 years. Abnormal droughts (over 50%) are inherent in large areas for every tenth year, which, starting from the last quarter of the 19th century and until the 1950s, ended with famine for the population (especially the droughts of 1891, 1921, and 1947). Subsequent droughts of 1963 and 1968 were determined by abnormal weather conditions, but without the manifestation of a food crisis, which is associated with the beginning of chemicalization and an increase in agricultural culture. Meteorological indicators of six stations in diverse natural and climatic zones for 1951-1981 and 1985-2008 indicate a zonal systematic increase in positive air temperatures with a decrease in precipitation, the deficit of which is compensated by a farming system with a moderate saturation of organic and mineral fertilizers, which have a stabilizing effect in extreme years. Since the last quarter of the 20th century, climate changes have been identified that are associated not only with the greenhouse effect, but also with a periodicity that depends on the ecliptic of the globe. Climate changes in recent decades are particularly noticeable, which is accompanied by a systematic increase in air temperature and an increase in climate aridity and requires new technical and technological solutions from humanity

Keywords: seasonal droughts; air temperature; precipitation; agriculture; fertilizers; productivity; systematicity

RELEVANCE

The term "arid climate" (from Latin – dry) refers to the climate of semideserts and deserts with a small amount of precipitation (100-150 mm per year) with sharp fluctuations in day and night temperatures. Climate aridization is determined by human influence on nature, especially in the era of global warming with the transformation of large areas into steppes, semideserts, and deserts.

The process of climate change, which has become noticeable since the last quarter of the 20th century, is associated exclusively with the anthropogenic factor, mainly with the greenhouse effect, as a result of industrial emissions of carbon dioxide (CO₂), methane (CH₄), nitrogen oxide (N₂O), ozone (O₃) and water vapour. If the concentration of greenhouse gases in the atmosphere doubles, the average glob-

al temperature will likely increase from 1.5 to 4.5°C. Other causes of warming were as follows: changes in solar activity, increasing tropospheric ozone concentration, atmospheric electricity that depends on solar activity, etc. The results of instrumental observations and the materials of paleogeographical reconstructions indicate that the global climate is changing, and these changes are accompanied by adverse consequences for the economy and living conditions of humankind (M.I. Budyko, 1980; Lipinskii, 2003; V.F. Martizanova, O.K. Ivanova, 2010; O.O. Vrublevska, H.P. Katerusha, 2005; R.L. William *et al.*, 2010). This is attributed to an increase in air temperature of 1°C per century, whereas previously this happened in 1,000 years. This simplified approach to planetary changes is predictable but does not reveal the

underlying nature of these changes. The planet Earth is not a stationary system, but one that is in constant motion and changes its ecliptic relative to the sun, and solar activity also has its patterns. As a result of the influence of cosmic factors in the Cenozoic era, ice ages occur with systematic periodicity, lasting an average of 100 thousand years, and the warming time between them is on average 10 thousand years; at the same time, the onset, and disappearance of a glacier occurs rapidly – over hundreds of years. The last Valdai (Würm) glaciation began 110,000 years ago, preparing for the planet the Holocene period – an interglacial period with an optimum temperature regime of air and humidity, which ensured the flourishing of the green world, and with it the fauna and human civilization. Presently, the post-Holocene period has arrived, which marks the approach of a new ice age, which must come after the maximum warming, which will bring it closer due to the cooling of oceanic warm currents and the change of the Earth's ecliptic to the Sun. In nature, everything happens naturally, according to the established cosmic and planetary cycles.

The climate changes that occur are not uniform in time and space, and therefore it is necessary to investigate climate fluctuations in various regions, considering the characteristics of a particular region and the dependence of these fluctuations on atmospheric circulation.

ANALYSIS OF RECENT STUDIES AND PUBLICATIONS

Planetary climate change is the most pressing issue of modern times, attracting the attention of the scientific and public community. They pose threats to environmental security, require forecasting and feedback on the prevention of real threats, especially for agriculture as an open-air workshop. Famous works on climate change by US scientists, namely Fred Kempe, Berry Pavel (US Atlantic Council), Brent Scowcroft, David Mitchell, English scientists of the Royal Institute of International Relations – Bernes Lee, Jonathan Parris and many others (Shevchenko, 2017).

Considerable attention in foreign literature is paid to the dynamics of human development

in conditions of climate change (Bondarenko *et al.*, 2018; Parri, 2019; Snakin, 2019;), adaptation of farming to climate change (Brouder & Volenec, 2008; Sanderson *et al.*, 2018), problems of microbiology in these conditions (Hutchins *et al.*, 2019) and preservation of soil fertility (Haasnoot *et al.*, 2018; Pikovska, 2020); threats to natural biodiversity and natural ecosystems (Pugnaire *et al.*, 2019; Turner *et al.*, 2020).

A considerable contribution to the theory and practice of climate change has been made by Ukrainian scientists, the results of which are presented in publications of professional journals and materials of numerous conferences covering this topical issue (Baliuk *et al.*, 2018; Vozhegova & Kokovikhin, 2018; Zatula & Zatula, 2020; Dehodiuk and Dehodiuk, 2008; Petrychenko *et al.*, 2018; Pysarenko *et al.*, 2019; Polovyi *et al.*, 2017; Kholiavchuk & Shkaieva, 2021; Loboda *et al.*, 2010).

The purpose of this study was to generalize a 150-year period of the distribution patterns of seasonal and zonal droughts on the territory of Ukraine, to systematize their recurrence, the causes of catastrophic droughts and climate changes since the last quarter of the 20th century, to determine the decisive role of agriculture and fertilization systems in stabilizing crop yields under extreme weather conditions.

MATERIALS AND METHODS

During systematization of spatial, zonal, and local climatic conditions over the past 150 years in Ukraine, the methods adopted in meteorology and agrochemistry were applied – monographic and systematic analysis, statistical, statistical-logical, graphic methods regarding the patterns of distribution of extreme weather conditions and climate changes in Ukraine based on monographic generalizations and own research.

RESULTS AND DISCUSSION

Monitoring of spatial droughts in Ukraine in 1872-1969 It is known that the Holocene had an amplitude of oscillation from warming to small ice ages (13th-19th centuries). According to the information of I.Ye. Buchynskiy (1970), according to

literary sources, in the 10th-11th centuries, 14 dry years were registered on the territory of modern Ukraine, in the 14th century – 10 droughts, in the 15th-17th centuries – 17 anomalous phenomena, of which a third with an onrush of locusts, during the 18th century there were 28 dry years, of which 9 were marked by an onrush of locusts.

According to I.Ye. Buchynskiy (1970), the year 1872, when the meteorological service was introduced on the territory of Ukraine, should be considered the starting point of the modern meteorological era. Almost 100 years of monitoring (1872-1969) determined, using a single method, the spatial distribution of spring, summer, and autumn droughts according to the characteristics of local (1-10% of the covered territory), moderate (10-20%), large (21-30%), massive (31-50%) and catastrophic (> 50% of the territory of Ukraine).

The authors of this study conducted a quantitative analysis of the drought phenomena identified by I.Ye. Buchynskiy, indicating that during almost a century of observation, absolutely favourable weather conditions throughout the territory of Ukraine during spring droughts amounted to 16 years, summer droughts – 11 years, and autumn droughts – 17 years. Or, on average, it can be assumed that approximately 85% of growing seasons were extreme for agriculture in a certain way. In the spring and autumn periods, local droughts were most common (61% and 57%) of the total number, and in the summer – half as many. The proportion of moderate droughts is almost evenly distributed between seasons – 17% each in spring and autumn, and 23% in summer. Large and massive droughts accounted for 19% in spring, 43% in summer, and 26% in autumn, indicating that the threat of summer droughts is twice as high as that of other growing seasons. The largest spring droughts in the 19th century occurred in 1872 (40% of the territory), in the 20th century – 1934 (80%), 1946 (60%), 1957 (33%), 1968 (52%). The most noticeable are the summer droughts, which covered 50-55% of the territory for 8 years (1876, 1895, 1900, 1903, 1904, 1923, 1952, 1953) and over 60% of the affected territory for 3 years

(1874, 1890, 1909). Therefore, over a period of almost a hundred years, 10% falls on an unfavourable type of weather, of which the coincidence of spring and summer droughts is particularly dangerous, which caused the complete death of crops and hunger among the population. Abnormal drought was recorded in 1891, which covered 40% of the territory of the east and south of Ukraine, then the amount of precipitation at the weather station in Kherson city was 21 mm, or 4 times less than normal, and at the Odesa station – 18 mm. Severe droughts in 1921 engulfed the South, Centre, and part of territory in the east of Ukraine. Then in the southern regions for 6 months (X-XII, I-III) less than 10% of precipitation fell compared to the norm, and the air temperature in May and June was 31.5°C and 34.5°C, respectively, at the norm up to 20°C. Spring droughts in 1932 and 1933 were not recorded, the summer drought in 1932 was at the level of moderate distribution (16.2% of the territory), and in 1933 – local (4.5%). The drought of 1947 covered 46% of the territory of Ukraine, except for parts of the centre and northwest, when the air temperature in the south exceeded the norm in May and June by 3.3°C and 5.1°C, respectively, and the amount of precipitation was 6 mm above the norm of 72 mm.

Subsequent droughts of 1950 (21%), 1952 (53%), 1953 (52.3%), 1962 (43.1%), 1963 (36.1%), 1967 (55%) were severe but not as damaging as previous ones. The explanation for this lies in the weakening of spring droughts and the fact that with the growth of technical equipment with the use of fertilizers, the stability of agriculture against adverse conditions of the growing seasons increased.

The spread of autumn droughts was mostly local in nature, intensifying the effects of subsequent or previous droughts in certain periods. The largest of them were defined in 1883 – 46.9% of the territory of Ukraine, 1942 – 27.9%, 1949 – 42.5%, 1963 – 38.8%, 1967 – 38.1%. Local autumn droughts for almost a hundred years covered 57% of the territory of Ukraine, moderate and severe – 17% each, and very severe – 10% (Fig. 1).

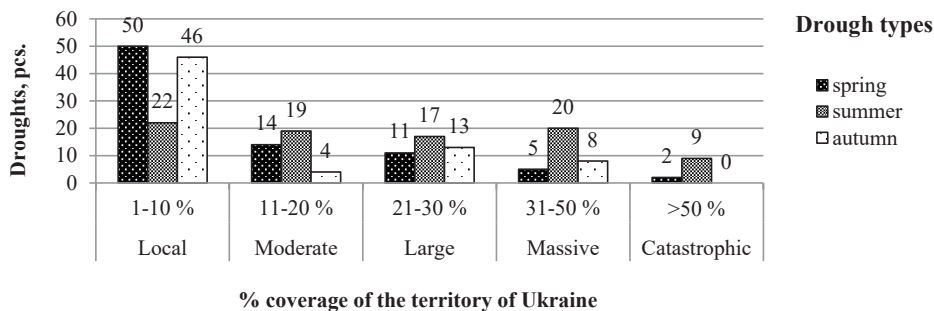


Figure 1. Summary data of age-related changes in seasonal aridity of climate on the territory of Ukraine for 1872-1969 (according to I.Ye. Buchinskyi, 1970)

The age-old amplitude of dry phenomena in Ukraine is associated with the invasion of Ukrainian territory by cold air from the north, northwest, and west, and the formation of a powerful anticyclone behind the cold front, in which high pressure, weak wind, and sunny weather with high dryness and heat are formed in summer. Anticyclones move slowly, sometimes almost without movement, sometimes replacing each other. They move clockwise, while the northern ones move along the southern periphery to the eastern and south-eastern ones, creating an impression of the desert origin of droughts (I.Ye. Buchinskyi, 1970).

Zonal features of weather conditions formation in 1951-1984 The authors of this study monitored the amount of precipitation and air temperature during the specified period according to the data of weather stations located in characteristic points of the soil and climate zones of Ukraine – Polissia (Chernobyl, Teteriv, Makariv

weather stations); Prykarpattia (Ternopil); Western Forest-Steppe (Khmelnyskyi) and Central Forest-Steppe (Bila Tserkva); Eastern (Kirovohrad (currently Kropyvnytskyi)); Steppe (Bashtanka, Mykolaiv region).

The systematization of meteorological indicators determined during this time three types of weather – favourable, dry, overmoistened, and cold (E. H. Dehodiuk, 1993). According to the amount of precipitation in favourable years up to 585 mm, the difference between the northern and southern meteorological stations was 85 mm and 52 mm, respectively, in dry years – 416 mm and 61-95 mm, respectively. In wet and cold growing seasons, the average amount of precipitation at 6 weather stations was 462 m with a deviation of 30 mm at the Ternopil weather station and 101 mm at the Bash-tanka weather station, which indicates a high differentiation of moisture depending on the type of weather (Figs. 2, 3).

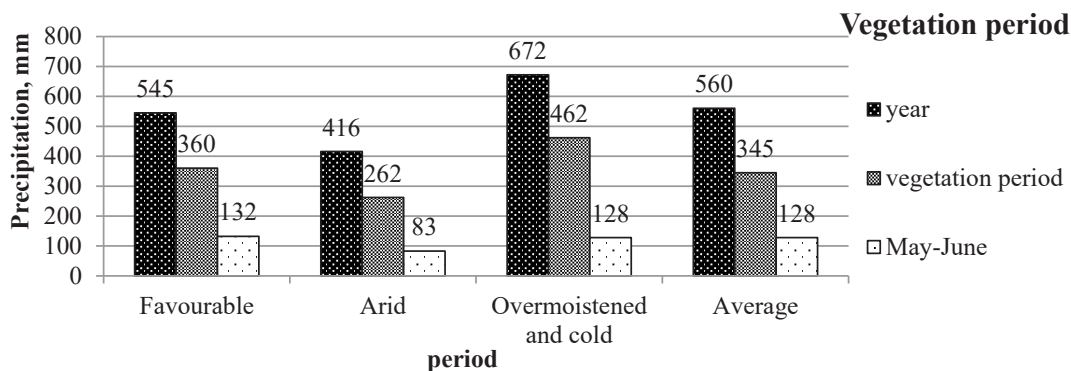


Figure 2. Precipitation on average according to 6 observation stations in the main soil and climatic zones of Ukraine for 1951-1984 (according to E.H. Dehodiuk, 1993)

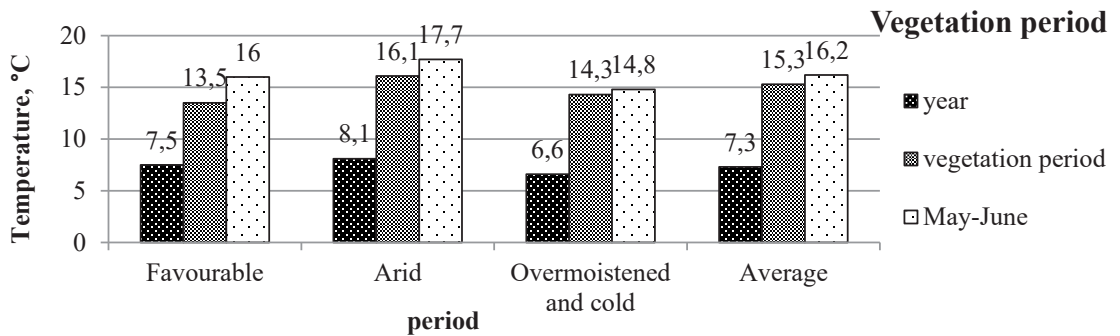


Figure 3. Average air temperature according to data from 6 observation stations in the main soil and climate zones of Ukraine for 1951-1984 (according to E.H. Dehodiuk, 1993)

The average air temperature for the year came close to the average statistical values – 7.3°C, but in dry years its temperature increased by 11%, and in wet and cold years it also decreased by 11%. On a zonal level, the annual temperature difference between the south and the north reached 23% in favourable years, 34% in dry years, and 21% in wet and cold years.

During the monitoring period, the number of favourable years in the Polissia zone was 52%,

60% – in the Forest-Steppe and 46% – in the Steppe, 24% and 25% of dry and overmoistened years in the Polissia and Forest-Steppe, respectively, and 44% – in the Steppe zone.

During monitoring, the authors of this study summarized over 40 field experiments with fertilizers conducted in the research network of Ukraine on crops – winter wheat, maize, barley in variants without fertilizers and with their application in optimal doses and for each crop (Table 1).

Table 1. Yield of agricultural crops and their increments under dry weather in the main zones of Ukraine, average for 1965-1984, t/ha

Crop	Average fertilizer doses	Polissia			Forest-Steppe			Steppe		
		Harvest without fertilizers	Increment from fertilizers	%	Harvest without fertilizers	Increment from fertilizers	%	Harvest without fertilizers	Increment from fertilizers	%
Winter wheat (grain)	Manure aftereffect (25 t/ha) + N ₇₀ P ₇₀ K ₇₀	2.13	1.58	74	2.25	1.2	53	2.16	0.61	28
Spring barley (grain)	Manure aftereffect (30 t/ha) + N ₆₀ P ₈₀ K ₇₀	1.04	1.5	144	3.09	1.29	48	1.28	0.12	9
Grain maize	Manure 30 t/ha + N ₆₀ P ₅₀ K ₅₅	2.71	1.93	71	3.29	1.79	54	2.92	0.36	12
Maize for silage, green mass	Manure 20 t/ha + N ₁₄₀ P ₉₀ K ₁₀₀	18.0	17.8	98	27.6	12.2	44	16.5	14.5	87
Mean				97			50			34

In dry summers during 1965-1984, with the application of fertilizers, the stabilization effect on these crops, compared to the control without fertilizers, in Polissia ranged from 71% to 144% (an average of 97%), in the Forest-Steppe zone – 26-53% (an average of 50%), and in the Steppe by grain group – 34%, which indicates the importance of irrigation in this zone. The average amount of precipitation for May-June for 1951-1984 here was 83 mm, or 65% of the average annual norm, which noticeably stabilized the harvest in those years.

Monitoring of weather conditions for climate change in the post-Chernobyl period. The next

zonal monitoring was conducted within the previous 6 weather stations for 1985-2006, conventionally named as “post-Chernobyl”, which covers 21 years (1985-2006) and is defined as the period of the beginning of climate changes (S.E. Dehodiuk, E.H. Dehodiuk, 2008). This is evidenced by a comparison of the temperature regime and precipitation with the previous period (1951-1984). During this period, decisive is the onset of a new type of weather that did not exist before – mixed, when overmoisturization and cooling occur in one growing season, changing to aridity – heat and rainlessness. And all this against the background of increasing air temperatures (Fig. 4, 5).

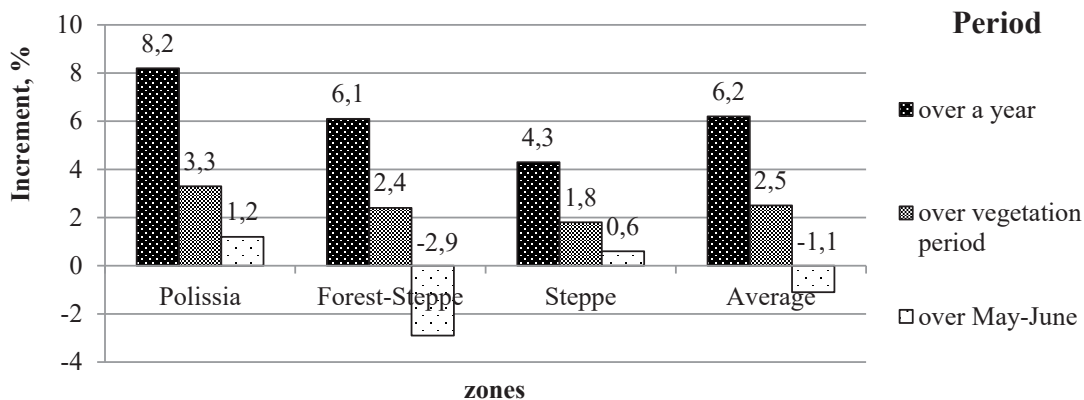


Figure 4. Temperature increment for the second round of observations (1985-2006) compared to the previous period (1954-1984), % (Dehodiuk & Dehodiuk, 2008)

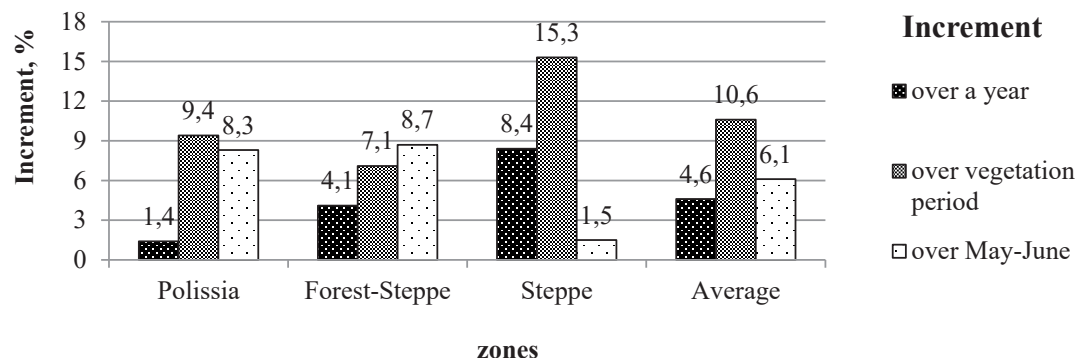


Figure 5. Precipitation increment for the second round of observations (1985-2006) compared to the previous period (1954-1984), mm (Dehodiuk & Dehodiuk, 2008)

On average for the year during the second stage of observations, the greatest warming was determined in the Polissia zone – +8.2% compared to the previous period, in the Forest Steppe – +6.1%, and in the Steppe – +4.3%. In May, the average temperature in the Forest-Steppe was 2.6% lower compared to the previous study period. A tendency to increase the average annual temperature regime up to 9.5%, during the growing season – up to +2.5%, upon signs of cooling in May (-1.1%), upon an increase in the average annual amount of precipitation – by +5%, during the growing season – +10% and in May-June – up to +6%. This shows that in a historically short period of time within the 54-year cycle from the second part of it, trends emerged that are not explained by changes in the distribution of weather between cyclones and anticyclones (Figs. 4, 5). After all, a considerable part of Polissia has acquired the characteristics of a forest-steppe in terms of temperature, and the hu-

midification of the northern part of the Steppe has approached the Forest-Steppe in terms of precipitation, while the regions of the southern Steppe experienced aridization.

Local monitoring of climate changes on the model of the Chabany weather station (NSC “Institute of Agriculture of the National Academy of Agrarian Sciences”) for 2006-2020. The progressive increase in air temperature over the past decades has increased the evaporation of water from the world’s oceans and the disturbance of air masses, which expand arid zones in some places, while in others an excess of atmospheric moisture leads to weather anomalies.

The monitoring carried out at the Chabany weather station indicates that over the past 15 years, with each five-year period, there has been a progressive increase in temperature locally with a one-time decrease in the amount of precipitation, in contrast to the 1985-2006 period (Table 2).

Table 2. Dynamics of changes in air temperature and precipitation at the Chabany weather station for 2006-2020

Period, years	Air temperature, °C				Precipitation, mm			
	Per year		During vegetation		Per year		During vegetation	
	°C	% to normal	°C	% to normal	mm	% to normal	mm	% to normal
2006-2010	9.4	21	17.3	10.1	629	95	60	95
2011-2015	9.7	24	17.8	13.3	657	99	50	79
2016-2020	11.2	32	18.3	16.5	153	70	35	56

Note: the long-term average annual air temperature is 7.8°C, during vegetation – 15.7°C, the average annual precipitation is 659 mm, during the growing season – 63 mm per month

The progressive increase in annual air temperature from 21% to 32% per year and from 10% to 16.5% during vegetation, with the average annual temperature for 2016-2020 – 11.1°C, indicates that the thermal regime of Kyiv is approaching that of Odesa in the middle of the 20th century with the sign of the steppe zone with the amount of precipitation for 2019, 2020, 399 and 389 mm, respectively. In 2006-2010, the amount

of precipitation was 95%, the next period – 79%, and the last five years – 56% of normal. It is characteristic that during local monitoring in May-June, an average of 68 mm of precipitation fell, compared to the norm of 88 mm, or 72% of it. Such a situation necessitates the adaptation of agricultural technologies to climate variability, where not only fertilization systems play a stabilizing role in agriculture, but also there is a

need for purposeful selection work, agricultural techniques for soil cultivation, adaptation of crop rotations to stressful conditions, and optimization of fertilization systems. Therefore, to obtain planned yields and scientifically sound placement of agricultural crops, along with a detailed assessment of agroclimatic resources, it is necessary to investigate the temporal variability of yields in different agroclimatic zones (Adamenko, 2004; Polovyi, 2005, 2007).

Another feature of this period is the absence of such a type of weather as “cold and overmoistened”. After all, for 15 years, the air temperature during the growing season exceeded the norm by an average of 13%, and the amount of precipitation in 2008 and 2013 alone was higher than 700 mm compared to the average annual norm of 659 mm, and in 11 years out of 15 it was less than the norm (from 3% to 40%). This gives reason to define these years as dry-mixed, which ensured the formation of non-critical crop levels even during the dry growing seasons of 2015,

2019, and 2020, when the amount of precipitation was below 400 mm.

In 2016-2020, there was an increase in air temperature by 18.3% and a decrease in precipitation to 56%, compared to the norm of the growing season, which created unfavourable conditions for the growth and development of agricultural crops. The results of field studies in a short-term 5-field crop rotation (winter wheat, maize over grain, spring barley, buckwheat, peas) planted on Alfisols found that, compared with extensive crop rotation (without fertilizers), the greatest stabilization effect was obtained with organic-mineral fertilizer system – 70%, with an organic system, due to limited resources – 37%, with the introduction of straw with a biodestructor – 11%. It is promising to use a new generation of organic-mineral bioactive fertilizers (OMBF), which provided an increase in yield compared to the control without fertilizers when applying 1 t/ha of 4-4-4 OMBF at 57%, and 2 t/ha of 0-0-0 (organic farming) – at 44% (Table 3).

Table 3. Productivity of crops of 5-field crop rotation in a long-term experiment on Alfisols of the NSC “Institute of Agriculture of the National Academy of Agrarian Sciences” under different fertilization systems in the conditions of an arid-mixed climate for 2016-2020

Fertilizer systems	Fertilizers					Productivity	Increment	%
	Manure	Straw	Mineral resources, kg/ha					
	t/ha		N	P	K	t/ha		
Without fertilizers (control 1)	-	-	-	-	-	3.05	-	-
Straw (control 2)	-	3	-	-	-	3.23	0.18	6
Organic	12	3	-	-	-	4.42	1.19	37
	-	3+ biodestructor	-	-	-	3.6	0.37	11
Mineral	-	-	40	60	60	4.80	1.78	53
	-	-	60	90	90	4.93	1.91	63
Organic-mineral	12	-	40	60	60	5.13	2.11	70
	6	-	40	60	60	3.97	0.95	31
OMBF 4-4-4	0.5	-	40	-	-	4.75	1.73	57
OMBF 0-0-0	2.0	3	-	-	-	4.66	1.43	44

Therefore, in the context of climate change, it is necessary to abandon the unsystematic management of agriculture and bring it closer to a scientifically sound direction with clear observance of crop rotation, water-saving systems of soil cultivation, fertilization and plant protection, which will be accompanied by nature-restoring measures in the basins of small rivers with cultural and technical works, agro-, chemo-, bio-, and phytomeliorations.

CONCLUSIONS

Data of meteorological observations for 150 years (1872-2020) with manifestations of seasonal dry phenomena were systematized and the beginning of climate changes from the last quarter of the 20th century, which continue to this day, were recorded. During the 100-year period (1872-1969), it was found that only 16 years of spring droughts had favourable growing season conditions in all territories of Ukraine, 11 years of summer droughts, and 17 years of autumn droughts.

Local droughts are most inherent in spring and summer droughts – 72% and 61%. Large and massive droughts (21-30% and 31-50%) prevailed in the summer and covered 43% of the territory of Ukraine. Abnormal droughts (50% of the territory) occurred due to the coincidence of autumn, spring, and summer droughts with an average frequency of 10 years.

The droughts of 1891, 1922, and 1947 ended in crop failure without recurrence in the future due to the disappearance of spring droughts and the improvement of agriculture.

The zonal monitoring of weather conditions for 1954-1984 was determined by 4 types of weather – favourable, dry, overmoistened, and cold with a noticeable increase in temperature in summer by 0.6°C, in winter – up to 2°C, and an increase in the amount of precipitation – per year up to 4.6 mm, during the growing season – up to 11 mm. Repeated monitoring of zonal weather conditions for 1986-2006 determined an added mixed type of weather, with a further noticeable increase in the temperature regime and a slight increase in the amount of precipitation.

Local weather monitoring at the weather station of the National Scientific Centre “Institute of Agriculture of the National Academy of Agrarian Sciences” established a constant increase in the annual air temperature to 20-21% per year and 10-17% during the growing season with a decrease in the amount of precipitation from 95% to 50% during vegetation, which indicates an increase in climate aridity.

The study established the stabilization effect in the formation of the productivity of agricultural crops due to the improvement of the technical equipment of agriculture and the use of fertilizers.

REFERENCES

- [1] Adamenko, T.I. (2004). Numerical experiments to assess the impact of agrometeorological conditions on photosynthetic productivity of maize crops. *Interdepartmental. Science. zb. Of Ukraine: Meteorology, climatology and hydrology*. Vip. 48, 213-218.
- [2] Baliuk, S.A., Nosko, B.S., & Vorotyntseva, L.I. (2018). Regulation of fertility of soils and efficiency of fertilizers in conditions of climate fluctuations. *Bulletin of Agricultural Science*, 96(4), 5-12. doi: 10.31073/agrovisnyk201804-01.
- [3] Bondarenko, L.V., Maslova, O.V., Belkina, A.V., & Sukhareva, K.V. (2018). Global climate changing and its after-effects. *Vestnik of the Plekhanov Russian University of Economics*, 2, 84-93. doi: 10.21686/2413-2829-2018-2-84-93.
- [4] Brouder, S.M. & Volenec, I.I. (2008). Impact of climate change on crop nutrient and water use efficiencies. *Physiologia plantarum*, 1133, 705-724. doi: 10.1111/j.1399-3054.2008.01136.x.
- [5] Buchinsky, I.E. (1970). Droughts, dry winds, dust storms in Ukraine and the fight against them. Kiev: The Harvest.
- [6] Budyko M.I. (1980). Climate in the past and in the future. L.: Gidrometeoizdat, 351 p.
- [7] Climate of Ukraine. (2003). For ed. Lipinsky. Kyiv: Raevsky Publishing House, 343 p. 10.

- [8] Degodyuk, E.G. (1993). The role of the fertilizer system in stabilizing crop yields. Sustainability of agriculture: problems and solutions (pp. 113-149). Kiev: The Harvest.
- [9] Degodyuk, S.E. & Degodyuk, E.G. (2008). Specialization of agriculture in the country depending on climate change. Collection of scientific works of NSC "Institute of Agriculture of NAAS". Special issue, 69-77.
- [10] Haasnoot, M., van't Klooster, S., & Van Alphen, J. (2018). Designing a monitoring system to detect signals to adapt to uncertain climate change. *Global Environmental Change*, 52, 273-285. doi: 10.1016/j.gloenvcha.2018.08.003.
- [11] Hutchins, D.A., Jansson, J.K., Remais, J.V., Rich, V.I., Singh, B.K., & Trivedi, P. (2019). Climate change microbiology - problems and perspectives. *Nature Reviews Microbiology*, 17(6), 391-396. doi: 10.1038/s41579-019-0178-5.
- [12] Kholiavchuk, D.I. & Shkaieva, D.I. (2021). Dynamics of human development in Ukraine under the global climate change. *Scientific Notes of Sumy State Pedagogical University. Geographical Sci.* 2(2), 124-142. doi: 10.5281/zenodo.4782633.
- [13] Loboda, N.S., Korobchinskaya, A.A., Rudnik, A.A. (2010). Climate change and its impact on the rivers of Ukraine. *Ukrainian Hydrometeorological Journal*. Heads. ed. S.M. Stepanenko, 6, 199-204.
- [14] Martazinova, V.F., & Ivanova, O.K. (2010). The modern climate of the Kiev region. K.: ABEPC 70.
- [15] Parry, M.L. (2019). Climate change and world agriculture. Bristol: Longdun Press.
- [16] Petrychenko, V., Korniiichuk, O., Veklenko, Yu. (2018). Sustainable development of grassland forage production in conditions of climate change. *Bulletin of Agrcultural Science*, 96(6), 25-32. doi: 10.31073/agrovisnyk201806-04.
- [17] Pikovska, O. (2020). Conservation of fertility of chernozem ordinary in the condition of climate aridization. *Plant and soil science*, 11(1), 62-68. doi: 10.31548/agr2020.01.062/
- [18] Polovyi, A.M. (2007). Modeling of hydrometeorological regime and productivity of agroecosystems. K.: CNT 344 p.
- [19] Polovyi, A.M., Bozhko, L. Yu., & Barsukova, O.A. (2017). The impact of climate change on the agro-climatic conditions of the growing season of major crops. *Ukrainian Hydrometeorological Journal*, 20, 61-70.
- [20] Polovyi, A.M., Kulbida, M.I., Trofimova, I.T., Adamenko, T.I. (2005). The impact of climate change on agriculture in southern Ukraine. *Interdepartmental. Science. zb. Of Ukraine: Meteorology, climatology and hydrology*. K.: KNT, 49, 252-260.
- [21] Pugnaire, F.I., Morillo, J.A., Peñuelas, J., Reich, P.B., Bardgett, R.D., Gaxiola, A. & Van Der Putten, W.H. (2019). Climate change effects on plant-soil feedbacks and consequences for biodiversity and functioning of terrestrial ecosystems. *Science advances*, 5(11), eaaz1834. doi: 10.1126/sciadv.aaz1834.
- [22] Pysarenko, V.M., Pysarenko, P.V., & Pysarenko, V.V. (2019). Directions of adaptation of agriculture to climate change. Collection of abstracts II International scientific-practical conf. "Climate change and agriculture. Challenges for agricultural science and education", April 10-12, 2019. Kyiv - Mykolaiv - Kherson: State Institution NMC "Agroosvita", 9-22.
- [23] Sanderson, M.R., Bergtold, J.S., Stamm, J.L.H., Caldas, M.M., Ramsey, S.M., & Aistrup, J. (2018). Climate change beliefs in an agricultural context: what is the role of values held by farming and non-farming groups? *Climatic Change*, 150(3), 259-272. doi:10.1007/s10584-018-2283-2
- [24] Shevchenko, O.V. (2017). The challenge of global climate change in the aspect of international security. Actual problems of international relations. Release, 130, 24-38. doi: 10.17721/apmv.2017.130.0.24-38

- [25] Snakin, V.V. (2019). Global Climate Changes: Forecasts and Reality. *The life of the earth*, 41(2), 148-164. doi: 10.29003/m649.0514-7468.2019_41_2/121-246.
- [26] Turner, M.G., Calder, W.J., Cumming, G.S., Hughes, T.P., Jentsch, A., LaDeau, S.L., & Carpenter, S.R. (2020). Climate change, ecosystems and abrupt change: science priorities. *Philosophical transactions of the royal society*, 375(1794), 20190105. doi: 10.1098/rstb.2019.0105.
- [27] Vozhegova, R. & Kokovikhin, S. (2018). Irrigation farming – the guarantor of food safety of Ukraine in conditions of climate fluctuations. *Bulletin of Agricultural Science*, 96(11), 28-34. doi: 10.31073/agrovisnyk201811-04.
- [28] Vrublevska O.O., Katerusha G.P. (2005). Applied climatology: Summary of 622 lectures. Dnepropetrovsk: Economy 131 p.
- [29] William, R.L. Anderegg, James W. Prall, Jacob Harold, and Stephen H. Schneider (2010). Expert credibility in climate change. doi: <https://doi.org/10.1073/pnas.1003187107>.
- [30] Zatula, V.I. & Zatula, N.I. (2020). Aridization of Ukraine's climate and its impact on agriculture. Collection of abstracts II International scientific-practical conf. "The impact of climate change on the spatial development of the earth's territories: consequences and solutions", June 11-12, 2020. Kherson: State Institution NMC "Agroosvita", 121-124.

Є.Г. Дегодюк

Доктор сільськогосподарських наук, професор, академік
Національний науковий центр
«Інститут землеробства Національної академії аграрних наук України»
08163, вул. Машинобудівників, 2Б, м. Чабани, Україна

С.Е. Дегодюк

Доктор сільськогосподарських наук, старший науковий співробітник
Національний науковий центр
«Інститут землеробства Національної академії аграрних наук України»
08163, вул. Машинобудівників, 2Б, м. Чабани, Україна

Ю.П. Борко

Кандидат сільськогосподарських наук
Національний науковий центр
«Інститут землеробства Національної академії аграрних наук України»
08163, вул. Машинобудівників, 2Б, м. Чабани, Україна

О.А. Літвінова

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

Ю.О. Ігнатенко

Аспірант
Національний науковий центр
«Інститут землеробства Національної академії аграрних наук України»
08163, вул. Машинобудівників, 2Б, м. Чабани, Україна

А.О. Мулярчук

Аспірант
Національний науковий центр
«Інститут землеробства Національної академії аграрних наук України»
08163, вул. Машинобудівників, 2Б, м. Чабани, Україна

Тривалий моніторинг аридизації в землеробстві до змін і за змін клімату в Україні

Анотація. Наведено результати систематичного моніторингу в Україні за проявами посушливості методом узагальнення весняних, літніх і осінніх посух, проведених І.Є. Бучинським за 1872-1969 рр. та наших метеорологічних узагальнень за типами погоди (1951-1984 рр.) і чітко виражених зональних змін клімату (1985-2006 рр.) та статистично-локальних ознак аридизації клімату по метеорологічній станції в північній частині Лісостепу («Чабани») – 2006-2020 рр., охоплюючи загалом історичний проміжок часу в 150 років. За просторовим поширенням посух, визначених за єдиною методикою, починаючи із 1982 р. і до кінця 60-х рр. XX ст., визначальним показником є поступове просторове поширення сезонних локальних посух із повторенням весняних через 2 роки, літніх – через 4 і осінніх, переважно на півдні України, через 2 роки. Кількість помірних і великих посух із початку XX ст. (11-30 % площі поширення), характерні для літнього періоду і вони повторюються на півдні через 4-5 років. Аномальні посухи (понад 50 %) характерні для великих територій для кожного десятого року, які, починаючи з останньої чверті XIX ст. і до 50-х рр. XX ст. закінчувалися голодом для населення (особливо посухи 1891, 1921, 1947 рр.). Наступні посухи 1963, 1968 рр. визначались аномальними погодними умовами, але без прояву продовольчої кризи, що пов'язано з початком хімізації й підвищення культури землеробства. Метеопоказники шести станцій у різних природно-кліматичних зонах за 1951-1981 і 1985-2008 рр. вказують на зональне систематичне наростання позитивних температур повітря зі зменшенням кількості опадів, дефіцит яких компенсується системою землеробства з помірним насиченням органічними й мінеральними добривами, які мають стабілізуючий ефект в екстремальні роки. З останньої чверті XX ст. визначено зміни клімату, які пов'язані не тільки з парниковим ефектом, а й із періодичністю, що залежить від екліптики земної кулі. Особливо помітні кліматичні зміни останніх десятиліть, що супроводжується систематичним підвищенням температури повітря й наростанням аридності клімату і вимагає від людства нових технічних і технологічних рішень

Ключові слова: сезонні посухи; температура повітря; опади; землеробство; добрива; продуктивність; систематичність

V.P. Kovalchuk*

Doctor of Technical Sciences, Chief Researcher
Institute of Water Problems and Land Reclamation
of the National Academy of Sciences of Ukraine
03022, 37 Vasytkivska, Kyiv, Ukraine

Method for obtaining water retention properties of soils by fractions of their granulometric composition

Abstract. This paper presents the method of obtaining water retention properties of soils (water retention curve (WRC) and water conductivity functions) is presented. These properties, or functions, allow describing the vertical movement of water in unsaturated soils as one of the components of the water balance expenditure item. They are widely used during the substantiation of water reclamations and during modelling of water transfer in the soil. The method is based on laboratory studies of soil samples taken in the field for granulometric composition. Currently, the results of laboratory analyses in Ukraine are obtained according to the Kachynskiy method with two components, the percentage of clay and sand. They are transformed graphically, using integral (cumulative) curves, into data corresponding to the international classification – with three components: the content of sand, dust, clay. The world community of soil scientists uses the latter fractional distribution. Therefore, using data on the content of sand, dust, clay, thanks to the open access computer program “Rosetta” USDA (United States Department of Agriculture), water retention properties are found in the form of water constants (total water content, minimum hygroscopic water content, filtering coefficient), coefficients of the equations of Van Genuchten’s mathematical model. This paper provides examples of calculating the water retention properties of soils using the method of dark chestnut soils and ordinary chernozems. The advantages of the proposed method include the low complexity of experimental studies, the availability of analyses and the presence of many experimental studies of the granulometric composition of soils, including in literature sources. As a development of the research area, the author showed the application of the obtained dependencies for modelling water transfer during water reclamation (irrigation in irrigation control systems). As for future research areas, the publication suggests comparing the accuracy of obtaining water retention properties of soils according to various methods, as well as obtaining an important water constant – the minimum soil water capacity (MSWC)

Keywords: Soil properties; integral (cumulative) distribution curves of soil fractions; USDA “Rosetta” computer program; total water capacity; minimum hygroscopic water capacity; filtration coefficient

Suggested Citation:

Kovalchuk, V. (2021). Method for obtaining water retention properties of soils by fractions of their granulometric composition. *Plant and Soil Science*, 12(4), 115-125. doi: 10.31548/agr2021.04.115.

*Corresponding author



Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (<https://creativecommons.org/licenses/by/4.0/>)

RELEVANCE

Water retention properties of soils are a fundamental characteristic during hydraulic reclamation. Today, there are many methods for their determination: they are given in literary sources and DSTU state standards, but their direct determination faces difficulties with the lack of appropriate laboratory equipment, the duration, and laboriousness of research. The availability of analyses and the availability of many experimental studies of the granulometric composition of soils, including in literary sources, on the one hand, the presence of studies on the connection of granulometric composition with water properties of soils prompted the author to use these scientific assets. Therefore, the idea of this paper was to develop a scientifically sound convenient methodological tool for obtaining water retention properties of soils (WRP) based on data on the granulometric composition of the soil.

ANALYSIS OF RECENT STUDIES AND PUBLICATIONS

Research in theoretical (Van Genuchten, 1980; "Soil-hydrophysical maintenance", 1987; Schaap *et al.*, 2001; Kovalchuk & Kolomiets, 2007), field (DSTU B V.2.1 -24:2009), and laboratory (ISO 11274:1998; M.I. Romashchenko *et al.*, 2019) determination of water retention properties of soils was initiated quite a long time ago and has been covered extremely widely in the scientific literature, and a number of DSTUs were developed for this purpose (ISO 11274: 1998; DSTU ISO 11276:2001; DSTU B V.2.1-24:2009). These properties, the water retention curve (WRC) and the function of moisture conductivity, are used to substantiate hydraulic meliorations (Shang Songhao *et al.*, 2004; Kovalchuk *et al.*, 2008; Vozhegova *et al.*, 2013; Zeleke, 2019; Gadzalo *et al.*, 2019; Markovska, 2021), for scientific research during mathematical modelling of moisture transfer in soils (Ahmad *et al.*, 2018; Salugin, 2018; Ryzhova *et al.*, 2019; Silva Ursulino *et al.*, 2019; "System Modelling and Management", 2019). A substantial obstacle is the duration and complexity of field and laboratory studies to determine WRP.

To avoid the mentioned shortcomings in the determination of WRP, this paper proposes to use the results of analyses of the granulometric composition, according to the standardized method (DSTU ISO 11277: 2005; ISO 11277: 1998), of soil samples taken in the field. In the west, laser diffractometers are used for particle size analysis (Budanova *et al.*, 2013).

Since the results of laboratory analyses are obtained according to the Kachynskiy method, they can be transposed to the international classification according to a graphical method using graphical interpolation based on the obtained cumulative curves of the granulometric composition of soils. This method for determining the content of sand-dust-clay fractions in the soil is proposed in publications (Baboshkina *et al.*, 2016; Zamin, *et al.*, 2020).

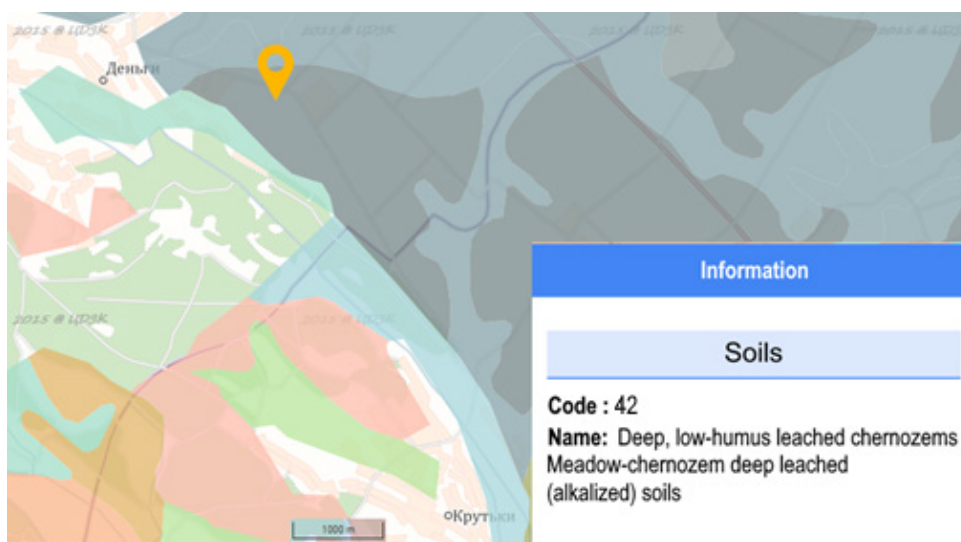
According to the content of sand-dust-clay fractions in the soil, based on the USDA (United States Department of Agriculture) open access software "Rosetta" (Schaap *et al.*, 2001; "Rosetta v. 1.0"), there are water retention properties in the form of water constants – total water capacity, minimum water retention capacity, filtration coefficient and coefficients of equations of Van Genuchten's mathematical model (Van Genuchten, 1980).

Therefore, the purpose of this study was to develop a method for calculating the coefficients of the equations of Van Genuchten's mathematical model and water constants: total water retention (TWR), minimum water retention content (MWRC), and filtration coefficient, for scientific and practical use for substantiation of hydrotechnical reclamation. Such a method will be developed based on the graphical transformation of the results of laboratory analyses according to the Kaczynski method to the international soil classification and using the USDA "Rosetta" open access computer program. The main tasks of this paper were to present the essence of the method with an illustration of it using the example of several soils. At the same time, the comparison of different methods was not the task of this paper.

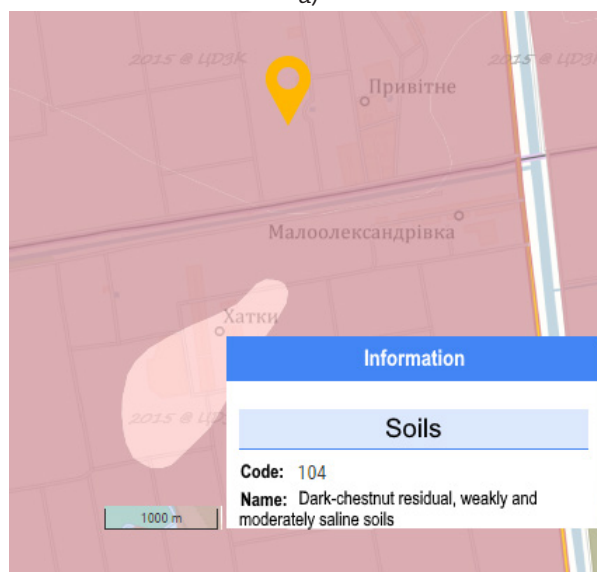
MATERIALS AND METHODS

As for the objects of the study (Fig. 1), on the example of dark-chestnut soils of the village Pryvitne of the left-bank Kherson Oblast, at the State Enterprise “Experimental Farm “Brylivske” of the Institute of Water Problems and Land Reclamation of the National Academy of Agrarian Sciences of Ukraine and chernozems of

deep low-humus soils in a complex with meadow-chernozem soils of the village of Denhy, Zolotonskyi District of Cherkasy Oblast, the study will illustrate the calculation of water-physical properties according to the proposed and described method. Soil samples were taken from several horizons of the soil profile: arable, sub-arable, and the horizon of the parent rock (Table 1).



a)



b)

Figure 1. Location of experimental plots and soil sampling points (according to the public cadastral map): a) chernozems, Denhy village; b) dark chestnut soils of Pryvitne village

Table 1. Results of laboratory analysis of soil samples according to granulometric composition

No.	Place of selection	Selection depth, cm	Diameter of fractions (in mm) and their content (in %) by weight of dry soil						Soil classification by granulometric composition	
			1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	< 0.001	> 0.01 mm	< 0.01 mm
			1	village of Denhy	10-25	0.20	22.28	50.88	6.53	6.12
2	village of Denhy	36-61	0.12	14.00	61.65	3.79	8.36	12.08	75.77	24.23
3	village of Denhy	71-93	0.38	15.41	56.02	4.73	8.81	14.65	71.81	28.19
4	village of Pryvitne	0-20	30.2	38.5	9.64	5.12	6.76	9.76	78.36	21.64
5	village of Pryvitne	20-35	25.85	37.15	6.44	6.40	9.6	14.56	69.44	30.56
6	village of Pryvitne	75-85	15.2	43.72	4.6	15.92	0.16	20.40	63.52	36.48

Soil dispersion is characterized by a granulometric composition, the relative content of particle fractions of different sizes in the soil. Therefore, laboratory studies using standardized methods (DSTU ISO 11277 : 2005; ISO 11277:1998) established the percentage of the size of soil

particles according to Kachynski's classification (Table 1). Grapho-analytical studies were methodically applied, USDA "ROSETTA" open access software was used, and water-physical properties of soils were found in the form of Van Genuchten formula coefficients (Van Genuchten M. T., 1980):

$$\frac{\theta - \theta_0}{\theta_{TWC} - \theta_0} = \left(\frac{1}{1 + (\alpha\psi)^n} \right)^{1-\frac{1}{n}} \text{ or } \psi = \left(\left(\frac{\theta - \theta_0}{\theta_{TWC} - \theta_0} \right)^{-\frac{1}{1-\frac{1}{n}}} - 1 \right)^{\frac{1}{n}} \quad (1)$$

$$k = k_{\psi} \sqrt{\left(\frac{\theta - \theta_0}{\theta_{TWC} - \theta_0} \right) \left(1 - \left(1 - \left(\frac{\theta - \theta_0}{\theta_{TWC} - \theta_0} \right)^{\frac{n}{n-1}} \right)^{\frac{n-1}{n}} \right)^2} \quad (2)$$

where θ , θ_{TWC} , θ_0 – bulk soil moisture, total water content, minimum possible moisture content, fractions 1; ψ is the water framework potential; k , k_ϕ are water conductivity and filtration coefficients, respectively, *cm/day*; n , α are coefficients.

The granulometric composition for determining the parameters of the Van Genuchten model can be found in the laboratory or in the Atlas of soils of Ukraine (Atlas of soils of the Ukrainian SSR, 1979) for approximately 70 soil profiles.

RESULTS AND DISCUSSION

As a result of the *sand/clay* gradation, which underlies Kachynskyi's classification, some soil types were obtained according to the granulometric composition (Tsytsiura *et al.*, 2020): loose sand, cohesive sand, loamy sand, sandy loam, medium loam, clay loam, light clay, medium clay, heavy clay. It does not fully show the real

diversity of soils in terms of granulometric composition. Especially due to the failure to consider the role of dust (swelling and subsidence, substantial influence on the anisotropy of moisture conductivity, etc.) in the formation of the physical properties of the soil, the classification is still far from reality.

Since the vast majority of Ukrainian laboratories provide the results of analysis on the granulometric composition of soil in the form of the Kachynskyi's classification, there is a need to transform these experimentally obtained results into the FAO international classification. The international classification consists of 12 soil classes according to granulometric composition, where three fractions are distinguished – sand, dust, and clay (Table 2). The translation of class names is taken according to the monograph of L.M. Globus (1987).

Table 2. Distribution of soils into structural classes according to granulometric composition

English (USDA)	Designation	Cyrillic (according to L. M. Globus)
1. Clay	C	Глина
2. Clay Loam	CL	Важкий суглинок
3. Loam	L	Суглинок
4. Loamy Sand	LS	Супісок
5. Sand	S	Пісок
6. Sandy Clay	SC	Опісчана глина
7. Sandy Clay Loam	SCL	Опісчаний важкий суглинок
8. Sandy Loam	SL	Легкий суглинок
9. Silt	Si	Пилуватий (мулистий) ґрунт
10. Silty Clay	SIC	Пилувата глина (лучний ґрунт)
11. Silty Clay Loam	SICL	Пилуватий важкий суглинок
12. Silty Loam	SIL	Пилуватий суглинок

Therefore, the next step in implementing the method is to construct integral curves of the

distribution of soil particles by fractions based on laboratory analysis data (Fig. 2).

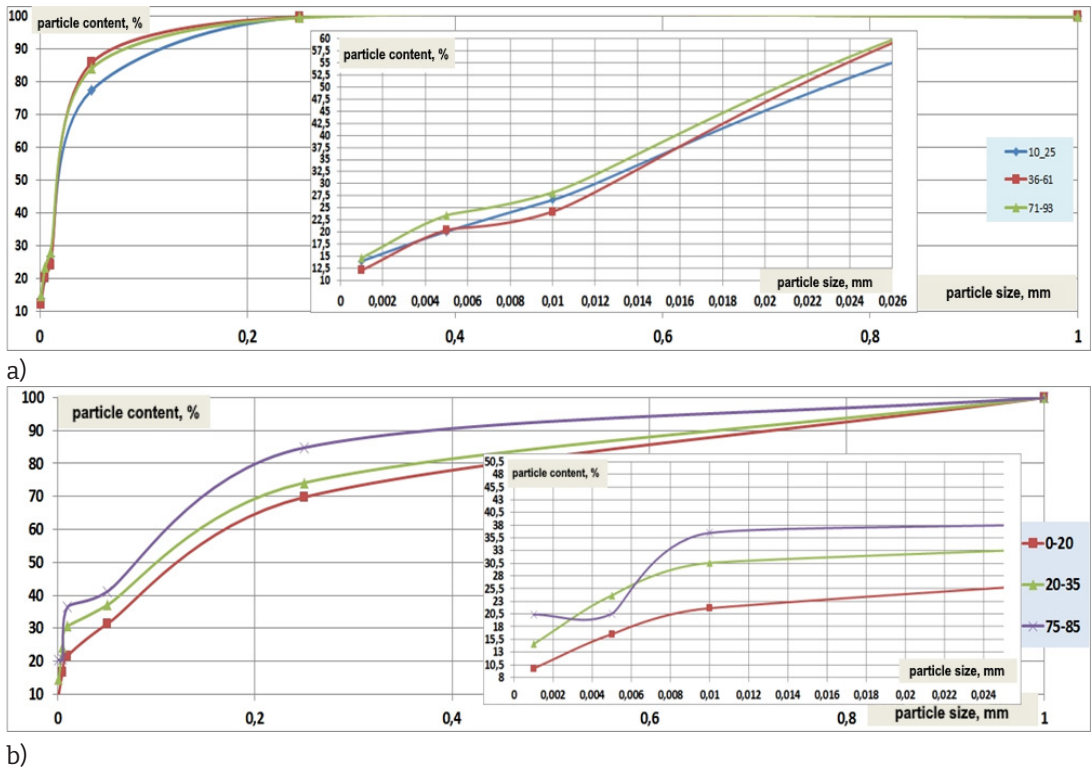


Figure 2. Integral curves of the distribution of soil particles of experimental plots by size and fractions: a) chernozem, Denhy village; b) dark chestnut, Pryvitne village

New values of the content of fractions of particles of different sizes (sand, dust, clay) in the soil are obtained from the integral curves. The margins of sand, dust, and clay fractions according to the USDA classification are as follows:

- between fractions of sand and dust, the marginal particle size is 0.05 mm;
- between fractions of dust and clay, the

marginal particle size is 0.002 mm.

Thus, for the objects of this study, the soils of experimental sites, the fractional composition according to the international classification is obtained, which is presented in Table 3. Thus, according to the international classification, chernozem soil from the Cherkasy region is silty loam (Class 12), and soil from the Kherson region is sandy loam (Class 8) (Fig. 3).

Table 3. Distribution of soils of experimental plots into structural classes according to granulometric composition according to the international classification

No.	Selection location, horizon	Sand (%)	Dust (%)	Clay (%)	Soil class according to granulometric composition	Density, g/cm ³
1	Denhy village, 10-25 cm	22.48	62.32	15.2	silty loam	1.35
2	Denhy village, 36-61	14.12	71.18	14.7	silty loam	1.36

Table 3. Continued

No.	Selection location, horizon	Sand (%)	Dust (%)	Clay (%)	Soil class according to granulometric composition	Density, g/cm ³
3	Denhy village, 71-93	15.79	67.71	16.5	silty loam	1.4
4	Pryvitne village, 0-20	68.7	19.8	11.5	sandy loam	1.6
5	Pryvitne village, 20-35	63	20	17	sandy loam	1.7
6	Pryvitne village, 75-85	58.92	21.08	20	sandy loam	1.7

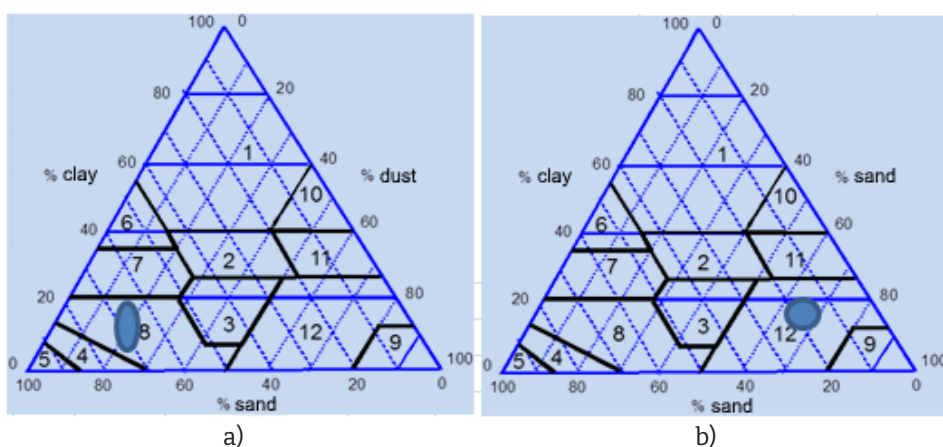


Figure 3. Diagram of the classification of the soils of the experimental plots according to the granulometric composition: a) dark-chestnut, Pryvitne village; b) chernozem, Denhy village

The “ROSETTA” program allows obtaining hydraulic properties – the water retention curve $\psi = f(\theta)$, and the water conductivity correlation $k = f(\theta)$ proposed by Van Genuchten (M.T. Van Genuchten, 1980), water constants *TWR* and *MWRC* at different levels of input information about soils:

- by soil type according to granulometric composition – these are the most generalized water retention functions that can be used in the preliminary evaluation calculations of Table 2;
- presence of granulometric composition and soil density (Table 3) allows obtaining adequate water retention functions of the soils under study;
- presence of granulometric composition and density of the soil, supplemented by refer-

ence points of the main water retention characteristic $\psi = f(\theta)$ at pressures of 300 and 1500 kPa, give the most accurate water retention correlations according to the “ROSETTA” program.

For the soils of the experimental plots, the results of the calculations of water constants and curve coefficients are presented in Table 4 (parts 1 are converted to % volume by multiplying by 100%). There are also data from (Atlas of Soils of the Ukrainian SSR, 1979) for somewhat comparable soils (meadow-chernozem soil on loess-like loams and dark-chestnut saline soils on loess). As the data in Table 4 show, in general, each soil is unique in terms of water retention properties, since the properties change during agricultural use. That is why the proposed method is useful and will help accurately determine them.

Table 4. Results of calculations of water retention properties of soils of study objects and their comparison with data from literature sources

No.	Selection location, horizon	θ_{TWR}	θ_o	α	n	k_ϕ	θ_{MSWC}	θ_{TWR}	θ_{MSWC}
		parts 1	parts 1	-	-	cm/day	parts 1	parts 1	parts 1
1	Denhy village, 10-25 cm	0.385	0.060	0.0057	1.638	14.22	0.254	0.565	0.282
2	Denhy village, 36-61 cm	0.427	0.065	0.0049	1.689	29.26	0.198	0.563	0.32
3	Denhy village, 71-93 cm	0.419	0.067	0.0051	1.672	21.18	0.217	53.2	0.29
4	Pryvitne village, 0-20 cm	0.311	0.040	0.3825	1.238	35.96	0.258	0.55	0.305
5	Pryvitne village, 20-35 cm	0.331	0.047	0.3547	1.251	10.71	0.252	0.5	0.275
6	Pryvitne village, 75 cm	0.368	0.059	0.2879	1.372	8.2	0.270	0.44	0.268

Notably, the fundamental constant, the *minimum soil water capacity* (MSWC), is determined according to the method proposed in the study (T.H. Barros *et al.*, 2017) using the authors' proposed method of calculating water retention properties (Table 4). The authors of the present paper will present these studies in further publications.

In this publication, the authors did not set a task and did not investigate the question of the accuracy of WRP calculations according to the described method, since this is the subject of further studies, where several methods will be compared.

The reliability of the results obtained according to the described method is confirmed by the use of granulometric composition data according to standardized methods, transformation of laboratory analysis results into an international classification according to the tested method, further calculation of water retention properties according to a computer program recommended by the US Department of Agriculture. Notably, the empirical results that form the basis of the program are based on the analysis of over 6 thousand soil samples. Van Genuchten's correlation has been well known for many years. Its use is confirmed by many studies that are described in many publications, and is used in FAO software (AquaCrop, CROPWAT). The correlation is convenient for modelling the water regime of soils.

Therefore, having obtained water retention properties, it is possible to model water transport in the soil (Ahmad *et al.*, 2018; Salugin, 2018; Ryzhova *et al.*, 2019; Silva Ursulino *et al.*, 2019; "System Modelling and Management", 2019), calculate irrigation rates, watering times based on smart systems, as in (Kovalchuk *et al.*, 2008; Gadzalo *et al.*, 2019), or based on programs AquaCrop, CROPWAT, etc., recommended by FAO, as it is done in publications (Vozhegova *et al.*, 2013; Zeleke, 2019; Markovska, 2021).

CONCLUSIONS

This paper presented a new method of determining water retention properties of the soil, based on the laboratory determination of the granulometric composition of the soil. The method combines a number of international standardized and widely known methods, computer programs for calculating the water retention properties of soil with Ukrainian methods for determining the granulometric composition. The method allows determining the TWR, MSWC, MWRC, soil filtration coefficient, coefficients of the Van Genuchten model. This method is very useful for substantiation water reclamation, as it increases the accuracy of calculations of irrigation regime parameters. The further development of this line of research will be a comparison of the accuracy of the obtained water constants and correlation coefficients according to several laboratory and field methods.

REFERENCES

- [1] Ahmad, M., Chakraborty, D., Aggarwal, P., Bhattacharyya, R., & Singh, R. (2018). Modelling soil water dynamics and crop water use in a soybean-wheat rotation under chisel tillage in a sandy clay loam soil. *Geoderma*, 327, 13-24. <https://doi.org/10.1016/j.geoderma.2018.04.014>.
- [2] AquaCrop, the crop-water productivity model. Retrieved from <https://www.fao.org/aquacrop>. Accessed May, 2018.
- [3] Atlas of soils of the Ukrainian SSR (Pod red.: N.K.Krupskoho, N.Y. Polupana). (1979). Kyiv: Urogray, 159p.
- [4] Baboshkina, S.V., Puzanov, A.V., Elchininova, O.A., & Rozhdestvenskaya, T.A. (2016). Water-physical properties and modeling of the process of moisture movement in the southern chernozems of the Kansk intermountain basin (basin of the Charysh River, northwestern Altai). *Bulletin of Altai State Agrarian University*, (3(137)).
- [5] Barros, T.H., Farias, A.J., de Almeida, A.M., FRAGA JUNIOR, E.F., & Coelho, R.D. (2017). Field Capacity estimation from the inflection point of the soil moisture retention curve. In *IV INOVAGRI-Institute International Meeting, Fortaleza. Anais... Fortaleza*. <https://doi.org/10.7127/iv-inovagri-meeting-2017-res0250268>.
- [6] Budanova, T.E., Ozmidov, O.R., & Ozmidov, I.O. (2013). Modern methods of studying the granulometric composition of soils. *Engineering survey*, (8), 66-70.
- [7] CROPWAT: a decision support tool. Retrieved from <https://www.fao.org/land-water/databases-and-software/cropwat/en/>. Accessed May, 2018.
- [8] DSTU B V.2.1-24:2009. Soils. Field permeability test methods.
- [9] DSTU ISO 11276: 2001. Soil quality. Determination of pore water pressure. Method using a tensiometer.
- [10] DSTU ISO 11277: 2005. Soil quality. Determination of particle size distribution of soil mineral material. Sedimentation sieving method.
- [11] Gadzalo, Ya., Romashchenko, M., Kovalchuk, V., Matiash, T., & Voitovich O. (2019). Using smart technologies in irrigation management. *International Commission on Irrigation and Drainage: 3rd World Irrigation Forum (WIF3)*. Bali, Indonesia: WIF3, 178. Retrieved from: https://www.icid.org/wif3_bali_2019/wif3_abst_vol.pdf.
- [12] Globus, A.M. (1987). Soil and hydrophysical support of agroecological mathematical models. Leningrad:Gidrometeoizdat, 427.
- [13] ISO 11274:1998. Soil quality. Determination of water retention characteristics. Laboratory methods.
- [14] ISO 11277: 1998. Soil quality. Determination of particle size distribution.
- [15] Kovalchuk, P.I., Matiash, T.V., Kovalchuk, V.P., Demchuk, O.S., Balykhina, H.A., Herus, A.V., Pendak, N.V. (2019). System modeling and management of water and land use. Kyiv: Ahrarna nauka, 608p.
- [16] Kovalchuk, P.I., Pendak, N.V., Kovalchuk, V.P., & Voloshyn, M.M. (2008). System optimization of water use during irrigation. Monograph. Rivne: Vydavnytstvo NUVGP.
- [17] Kovalchuk, V.P. & Kolomiets, S.S. (2007). Simulation modeling of hydrophysical properties of soils when performing agro-ameliorative measures. *Taurian Scientific Bulletin. Collection of scientific works of KSAU*, 53. Kherson: Ailant, 397-405.
- [18] Markovska, O.Ye. (2021). Modeling of irrigation modes of different varieties of rice using the information and software complex AquaCrop. *Taurian Scientific Bulletin*, 119. DOI <https://doi.org/10.32851/2226-0099.2021.119.30>.
- [19] Puzanov, A.V., Baboshkina, S.V., Rozhdestvenskaya, T.A., & Balykin, S.N. (2014). Comparative analysis of the main hydrophysical characteristics of steppe and mountain-forest soils of Altai, reconstructed by calculation methods. *Bulletin of Altai State Agrarian University*, (12(122)).

- [20] Romashchenko, M.I., Kolomiets, S.S., & Bilobrova, A.S. (2019). System of laboratory diagnostics of water-physical properties of soils. *Land Reclamation and Water Management*, (2), 199-208. <https://doi.org/10.31073/mivg201902-193>.
- [21] Rosetta Version 1.0 (Free downloaded program). U.S.Salinity Laboratory ARSUSDA; Retrieved from: <http://www.usssl.ars.usda.gov>. Accessed 10 Sep 2017.
- [22] Ryzhova, T.A., Melikhova, E.V., & Rogachev, A.F. (2019). Computer modeling and determination of the main hydrophysical characteristics on the example of light chestnut soils of the Lower Volga region. *Bulletin of the Nizhnevolzhsky agro-university complex: science and higher professional education*, (3(55)). DOI: 10.32786/2071-9485-2019-03-49.
- [23] Salugin, A.N. (2018). Primeneniye osnovnykh gidrofizicheskikh kharakteristik dlya modelirovaniya vertikalnogo dvizheniya vlagi v zone aeratsii. [Application of basic hydrophysical characteristics for modeling the vertical movement of moisture in the aeration zone]. *Bulletin of the Nizhnevolzhsky agro-university complex: science and higher professional education*, (1 (49)). DOI: 10.32786/2071-9485-2018-01-58-65.
- [24] Schaap, M.G., Leij, F.J., & Van Genuchten, M.T. (2001). Rosetta: A computer program for estimating soil hydraulic parameters with hierarchical pedotransfer functions. *Journal of hydrology*, 251(3-4), 163-176. [https://doi.org/10.1016/S0022-1694\(01\)00466-8](https://doi.org/10.1016/S0022-1694(01)00466-8)
- [25] Shang, Songhao & Li, Xichun & Mao, Xiaomin & Lei, Zhidong. (2004). Simulation of water dynamics and irrigation scheduling for winter wheat and maize in seasonal frost areas. *Agricultural Water Management*, 68, 117-133. <https://doi.org/10.1016/j.agwat.2004.03.009>.
- [26] Silva Ursulino, B., Maria Gico Lima Montenegro, S., Paiva Coutinho, A., Hugo Rabelo Coelho, V., Cezar dos Santos Araújo, D., Cláudia Villar Gusmro, A., ... & Angulo-Jaramillo, R. (2019). Modelling soil water dynamics from soil hydraulic parameters estimated by an alternative method in a tropical experimental basin. *Water*, 11(5), 1007. <https://doi.org/10.3390/w11051007>.
- [27] Tsytsiura, Ya.H., Polishchuk, M.I., & Bronnikova, L.F. (2020). Soil science with the basics of geology. Part II. Genesis, classification and properties of soils. Tutorial. Vinnytsia: TOV "Druk plus".
- [28] Van Genuchten, M.T. (1980). A closed-form equation for predicting the hydraulic conductivity of unsaturated soils 1. *Soil science society of America journal*, 44(5), 892-898.
- [29] Vozhehova, R.A., Kokovikhin, S.V., Shepel, A.V., & Boiarkina, L.V. (2013). Application of information technologies for assessment of climatic conditions and calculation of alfalfa water consumption. *Taurian Scientific Bulletin. Issue*, 86, 49-52.
- [30] Zamin, B., Nasir, H., Mehmood, K., & Iqbal, Q. (2020). Field-Obtained Soil-Water Characteristic Curves of KPK Expansive Soil and Their Prediction Correlations. *Advances in Civil Engineering*, article number 4039134. <https://doi.org/10.1155/2020/4039134>.
- [31] Zeleke, K.T. (2019). AquaCrop calibration and validation for faba bean (*Vicia faba* L.) under different agronomic managements. *Agronomy*, 9(6), 320. <https://doi.org/10.3390/agronomy9060320>.

В.П. Ковальчук

Доктор технічних наук, головний науковий співробітник
Інститут водних проблем і меліорації Національної академії наук України
03022, вул. Васильківська, 37, м. Київ, Україна

Метод отримання водно-фізичних властивостей ґрунтів за фракціями їхнього гранулометричного складу

Анотація. Представлено метод отримання водно-фізичних властивостей ґрунтів (основної гідрофізичної характеристики (ОГХ) і функції вологопровідності). Ці властивості, або функції дають можливість описати вертикальний рух вологи в ненасичених вологою ґрунтах, як одну зі складових частин видаткової статті водного балансу. Вони широко застосовуються під час обґрунтування водних меліорацій і під час моделювання вологоперенесення в ґрунті. А в основу методу покладено лабораторні дослідження зразків ґрунту, що відбираються в полі, на гранулометричний склад. Результати лабораторних аналізів натепер в Україні зазвичай отримуються за методом Качинського з двома складовими, процентний вміст глини й піску. Вони графічним методом, за допомогою інтегральних (кумулятивних) кривих перетворюються в дані, відповідні до міжнародної класифікації – з трьома складовими: вміст піску, пилу, глини. Останній пофракційний розподіл використовує світова спільнота ґрунтознавців. Тому з використанням даних про вміст піску, пилу, глини, за допомогою комп'ютерної програми з відкритим доступом «Rosetta» USDA (United State Department of Agriculture) знаходяться водно-фізичні властивості у вигляді водних констант (повної вологоємності, найменшої гігроскопічної вологоємності, коефіцієнта фільтрації), коефіцієнтів рівнянь математичної моделі Ван Генухтена. У публікації наведено приклади розрахунку водно-фізичних властивостей ґрунтів представленим методом темно-каштанових ґрунтів і чорноземів звичайних. До переваг запропонованого методу варто віднести невелику трудомісткість експериментальних досліджень, доступність аналізів і наявність великої кількості експериментальних досліджень гранулометричного складу ґрунтів, у т.ч. у літературних джерелах. Як розвиток напрямку досліджень, автор показав застосування отриманих залежностей для моделювання вологоперенесення за водних меліорацій, (зрошенні в системах керування зрошенням). Щодо напрямів майбутніх досліджень, публікація пропонує провести порівняння точності отримання водно-фізичних властивостей ґрунтів за різними методами, а також отримання важливої водної константи – найменшої вологоємності (НВ)

Ключові слова: ґрунтові властивості; інтегральні (кумулятивні) криві розподілу фракцій ґрунту; комп'ютерна програма «Rosetta» USDA; повна вологоємність; найменша гігроскопічна вологоємність; коефіцієнт фільтрації

N.N. Zelenyanska*

Doctor of Agricultural Sciences, Deputy Director
National Scientific Center "Institute of Viticulture and Winemaking named after V.E. Tairov"
65496, 27 40th anniversary of Victory Str., Tairove, Ukraine

O.I. Gogulinska

PhD in Agricultural Sciences, Senior Researcher
National Scientific Center "Institute of Viticulture and Winemaking named after V.E. Tairov"
65496, 27 40th anniversary of Victory Str., Tairove, Ukraine

N.V. Podust

PhD in Agricultural Sciences, Senior Researcher
National Scientific Center "Institute of Viticulture and Winemaking named after V.E. Tairov"
65496, 27 40th anniversary of Victory Str., Tairove, Ukraine

Effect of drip irrigation and the load of inflorescences on the growth and development of parent vines

Abstract. The high yield of grafted grape seedlings and their quality depend on many factors, including the quality of the grafting and rootstock components, which is also determined by proper care of the parent grafted and rootstock vines. Their agricultural techniques should be aimed at better growth and maturation of shoots. The technological technique of breaking off the shoots is mandatory on parent vines, partial removal of inflorescences is not so common in the agrotechnics of parent vines, but it has a positive effect on the overall development of plants. Parent plantings should be irrigated, if possible, since insufficient moisture supply adversely affects the condition of vines throughout the growing season and wintering. This paper investigated the effect of partial removal of inflorescences (inflorescence load of 100%, 75%, and 50% of their total number) on parent vines and the effect of different irrigation regimes (pre-irrigation soil water levels of 90%, 80%, and 70% of the minimum water content) on the state of parent vines were investigated, specifically on physiological, biochemical, and biometric indicators of plants. It was shown that irrigation of vines and reducing the load of inflorescences to 50% and 75% of their total number stimulated the accumulation of chlorophyll in the leaves of parent plants, improved the watering of leaf tissues, and contributed to an increase in the intensity of respiration during active growth and development of grapes. A positive effect of irrigation and a reduction in the load of vines with inflorescences up to

Suggested Citation:

Zelenyanska, N., Gogulinska, O., & Podust, N. (2021). Effect of drip irrigation and the load of inflorescences on the growth and development of parent vines. *Plant and Soil Science*, 12(4), 126-137. doi: 10.31548/agr2021.04.126.

*Corresponding author



Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (<https://creativecommons.org/licenses/by/4.0/>)

50% and 75% on the agrobiological indicators of parent vines was noted. The highest values of the total length of the shoots and the degree of their maturation were found in the vines of the variants with PSWL 90% MWRC 50% inflorescences, 80% MWRC 50% inflorescences, 70% MWRC 50% and 75% inflorescences. Therefore, effective irrigation regimes and reducing the load of vines with inflorescences contributed to the growth of medium and strong full-fledged shoots, which are more productive.

Keywords: grafted grape rootstocks; pre-irrigation soil water level; number of inflorescences; watering of leaf tissues; respiration intensity; pigment content; agrobiological indicators of vines

RELEVANCE

Viticulture is a promising area of agricultural production in Ukraine. Long-term fertile grape plantations ensure stable and full-fledged development of the industry. High-quality, certified grafted grape seedlings should be used for planting industrial vineyards. During their production, special attention is paid to the quality of grafting and rootstock components. Studies indicate that the prominent yield of grafted grape seedlings and their quality depend on many factors, including proper care of royal plantings of grafted and rootstock vines (Vlasov, 2015).

Rootstocks of grafted grape vines are specially created plantations of promising zoned table and technical varieties, the vines of which are used to produce grafted grape seedlings. Parent plantings should be distinguished by the purity of vines, the absence of diseases, elevated productivity and durability, and their agricultural technology should be aimed at better growth and maturation of shoots (Dikan, 2001). Usually, the size of the berry harvest on the mother grape bushes is regulated, preventing the bushes from being overloaded with the harvest. On such bushes, the technological method of breaking off the shoots, but not removing the inflorescences, is mandatory, as this requires additional labour costs (Mykytenko *et al.*, 1990). Studies indicate that normalizing the number of inflorescences per vine after establishing the optimal number of shoots contributes to a substantial increase in the leaf surface area of the vine and its overall development

(Kozhukharenko, 2013). Considering the possibility of obtaining more high-quality grafting vines of grapes, the method of partial removal of inflorescences on parent vines is relevant and requires detailed investigation.

Parent plantings should be irrigated, if possible, since insufficient moisture supply adversely affects the condition of vines throughout the growing season and wintering. One of the main elements of irrigation technology is the irrigation regime – a combination of the amount, timing, and norms of irrigation, which substantially depends on the yield of plantations. The basis of forming the vineyard irrigation regime is the support of the optimal range of humidity in the soil layer, where the main part of the root system of plants is located. For industrial plantings of table and technical grape varieties, the National Standard of Ukraine defines irrigation regimes, according to which the level of pre-irrigation moisture of the root layer of the soil (PSWL), depending on the phase of development and water retention properties of the soil, should be 70-80% of the minimum water retention capacity (MWRC) for table grape varieties and 65-75% MWRC for technical varieties. It is recommended to carry out 7-12 waterings during the growing season of technical varieties, 10-15 waterings during the growing season of table varieties (DSTU 7595:2014, 2015). Since there are no practical results regarding the determination of optimal modes of drip irrigation on rootstocks of grafted vines, this issue requires further investigation.

ANALYSIS OF RECENT STUDIES AND PUBLICATIONS

Today, for the cultivation of high-quality grafting material of grapes, it is generally accepted to use short pruning and to regulate the load of the vines with buds and shoots, which allows using the growth of the bushes to the maximum for harvesting grape stalks (Ursu, 1989). When determining the load of vines with shoots, their growth strength, soil and climatic conditions and the level of agrotechnics of plantings are considered (Perstnev, 2001; Feitosa *et al.*, 2018; Almanza-Merchán *et al.*, 2014). Other authors believe that the load of vines with shoots should be determined by the amount of annual growth of vines for the previous year or by the amount of phytomass of growth of one-year shoots per vine (Chulkov, Mukhortova, 2018; Kumar *et al.*, 2017). The practice of partial removal of inflorescences on parent vines is not so common in the agrotechnics of parent vines. However, it was established that vines, in which the inflorescences were completely or partially removed in the previous 1-2 years, develop better, become more uniform in growth strength, store a larger amount plastic substance (Ursu, 1989).

As for the irrigation of vineyards, different methods of irrigation are used in Ukraine and the world, but it is drip irrigation that keeps the optimal moisture regime in the local soil layer, reduces water consumption, and increases the yield of grapes (Shevchenko, 2019).

It was confirmed that watering grape plantations while maintaining soil moisture within 80-90% MWRC in the period after the end of flowering and before the beginning of ripening of berries creates favourable conditions for increasing the volume of the root system, the development of leaf and productive mass of plants (Kudryasheva, 2006). Using the example of the technical grape variety Aligoté, it is shown that with drip irrigation of plantings and their load of 110 thousand shoots/ha, the total water consumption is 5,070 m³/ha, provided that the humidity in the metre layer of the soil is kept at 100-85% MWRC (4-7 irrigations rate of 110-130 m³/ha, the irrigated rate was 460-900 m³/ha).

Under such conditions, the optimal parameters of winter resistance of cells, development of the root system and one-year growth, fertility of shoots, size of berries and clusters were obtained (Kyrychenko, 2003).

It was established that, depending on the phase of development, table grape varieties should be irrigated at the rate of 90 m³/ha (phase of bud break – flowering), 120-130 m³/ha (phase of berry growth – ripening of berries), 150 m³/ha (period of the greatest biomass increment) (Pavelkivska, 2013). There is information that during drip irrigation of parent plantations of table grapes of the Rannii Magarach variety with different loads of vines with buds and shoots, soil moisture was kept within 70-100% MWRC, the irrigated rate, including moisture-charging irrigations, averaged 630-800 m³/ha per year (Mykytenko *et al.*, 1990).

The purpose of this study was to develop effective modes of drip irrigation and load rates of parent vines with inflorescences to obtain high-quality graft components based on physiological, biochemical, and biometric indicators of growth and development of parent vines.

MATERIALS AND METHODS

The work was carried out in the department of nursery and propagation of grapes of the NSC “V.Ye. Tairov Institute of Viticulture and Wine-making” during 2017-2020. The research was conducted on the early ripening Augustyn table grape variety, the vines of which were planted according to the scheme of 2.0×2.5 m in the spring of 2010. The formation of the vines is a horizontal two-stem border with a stem height of 70 cm, the load of shoots is 26-28 shoots per vine. The soil of the experimental site is southern medium-loamy chernozem.

Three experiments were included in the research scheme, which differed in PSWL and the load of vines with inflorescences. Experiment 1 – PSWL 90% MWRC during the entire vegetation period of plants; experiment 2 – PSWL 80% MWRC during the entire vegetation period of plants; experiment 3 – PSWL 70% MWRC during the entire vegetation period of the plants. In

each experiment, there were 3 variants in which a different number of inflorescences were left on the vines. Variants 1.1, 2.1, 3.1 – 100% load of vines with inflorescences (30-33 inflorescences/vine); variants 1.2, 2.2, 3.2 – 75% load of vines with inflorescences (24-25 inflorescences/vine); variants 1.3, 2.3, 3.3 – 50% load of vines with inflorescences (15-16 inflorescences/vine). The control variants were those where soil moisture was natural, the load of vines with inflorescences was comparable to the experimental variants (variants 4.1, 4.2, 4.3). In each variant, there were 5 accounting vines in 4 repetitions.

Drip tubes with a diameter of 16 mm with integrated water outlets every 45 cm and a water flow rate of 1.5 dm³/h were used to irrigate the vineyards, which were suspended from the crop wire. Soil moisture was controlled according to the thermostatic weight method once a week in the 0-80 cm soil layer. The timing of irrigation and the duration of the inter-irrigation period were determined based on the dynamics of the moisture reserves of the root layer of the soil and the distribution of precipitation. The basis for maintaining PSWL 90% MWRC, 80% MWRC, 70% MWRC was the minimum soil water capacity, which was determined in undisturbed soil according to the method of flooding sites. The value of the irrigation rate was calculated according to the formula of O.M. Kostyakov. It was established that in the 0-80 cm layer, the MWRC is equal to 27.03% of the dry soil mass.

On average, over the years of studies in experiment 1, where the PSWL was kept at 90% of the MWRC, 5.3 irrigations were carried out (from 4 to 8 irrigations per season), the irrigation rate was 81.9 m³/ha, the irrigated rate was 504.0 m³/ha. In experiment 2 with PSWL 80% MWRC, the average number of waterings was 3.7 (from 2 to 5 waterings per season) with an irrigation rate of 91.3 m³/ha, the irrigated rate was 414.0 m³/ha. In experiment 3, with PSWL 70% MWRC, an average of 2 irrigations were carried out (from 1 to 4 irrigations per season), the irrigation rate was equal to 99.2 m³/ha, and the irrigated rate was 157.5 m³/ha. In the control, soil moisture was natural.

During the growing season (monthly, from June to September), the main physiological and biochemical indicators of plants were determined in leaf tissues (total moisture content, pigment content according to T.M. Godnev, respiration intensity according to the P. Boyesen-Jensen method) (Tretyakov, 1990). At the end of the growing season, biometric indicators of plant development were measured (Avidzba, 2004). The obtained results were processed using the ANOVA program and the Microsoft Excel application package.

RESULTS

Sufficient soil moisture during the growing season has a positive effect on the development of the leaf apparatus, as evidenced by the intensive course of physiological processes. Physiological indicators of the water regime of grape plants most fully indicate their need for water, depending on particular environmental conditions (I. V. Shevchenko, 2019).

The change in the level of hydration of leaf tissues has a protective nature against the influence of adverse environmental factors during the growing season and tends to decrease from July to August (Stoev, 1984). This is also confirmed by the authors' studies. Thus, it was established that the water content in the leaves of irrigated grape plants ranged from 70.1% to 76.8%, reaching the highest values in June in the variants with PSWL 90 and 80% MWRC 75% inflorescences and in the version with PSWL 70% MWRC 50% inflorescence. In July, in all experimental variants with PSWL 70%, 80%, and 90% of MWRC, this indicator slightly decreased (67.5-75.5%). On the other hand, the water content in the leaves of the control plants was 64.9-71.1%. In September, with the beginning of the leaf ageing period, the water content of the leaf tissues decreased to 60.6-69.6%.

One of the key processes of living organisms is the respiration of their tissues, since it provides metabolic and energy processes, considerably affects the growth and accumulation of plant biomass (Keller, 2020). The conducted studies revealed that the intensity of leaf tissue

respiration in June was at 0.34-0.50 mg CO₂/g, in July it increased to 0.47-0.71 mg CO₂/g, in August it reached maximum values of 0.51-0.97 mg CO₂/g, in September it decreased to 0.34-0.46 mg CO₂/g (Fig. 1). In general, the most significant difference with the control according to this indicator was in July, at the beginning of

the phase of ripening of berries – in the vines under irrigation with a load of 100% of the inflorescence, a decrease in the intensity of respiration by 18.3-33.8% was noted. If the load of inflorescences was reduced to 50-75%, the intensity of leaf respiration in vines during irrigation decreased by 20.3-26.9%.

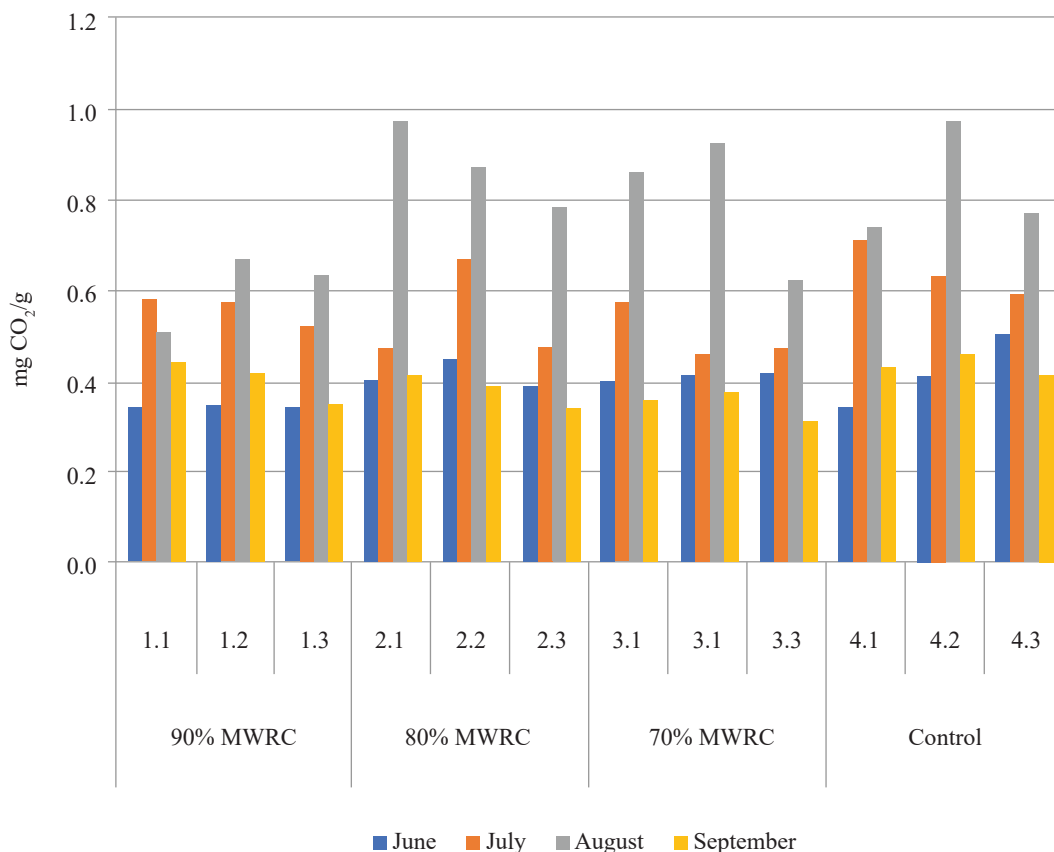


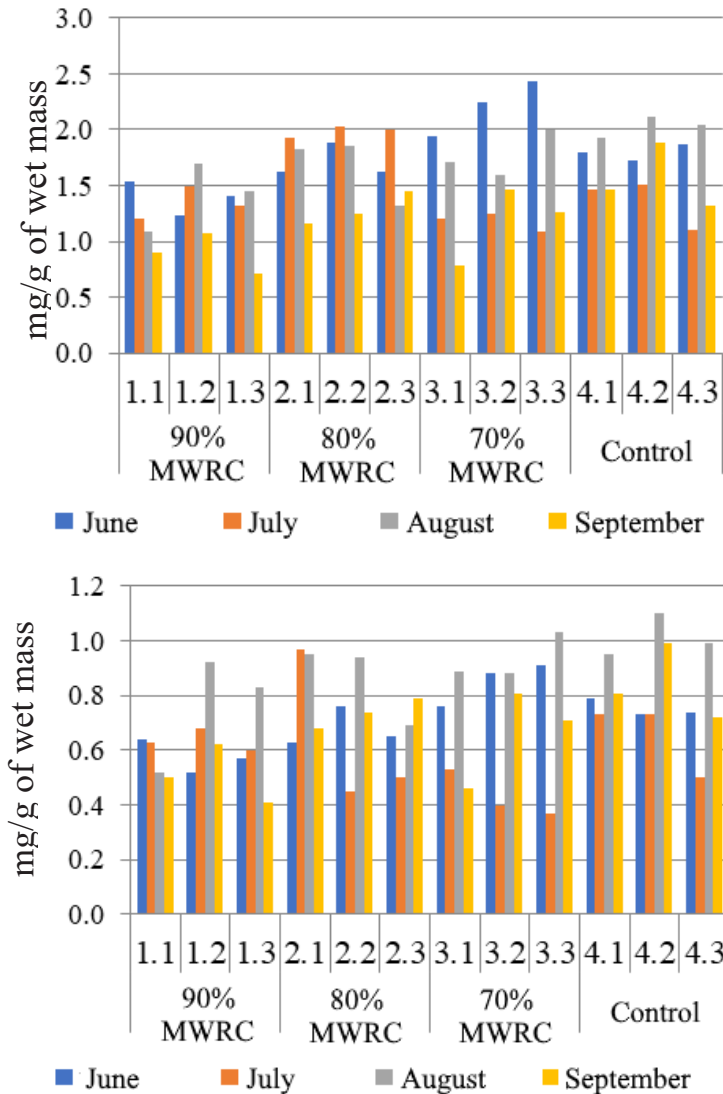
Figure 1. Intensity of tissue respiration of leaves of Augustyn grape plants under different PSWL and load of inflorescences (average for 2017-2020)

The study of the state of the photosynthetic apparatus, primarily the content of pigments, can provide information about the state of the plant because even in conditions of short-term water stress, accelerated disintegration of pigments is noted. It was found that under moisture deficiency, the content of chlorophylls, especially chlorophyll A, decreases, and the amount of carotenoids increases (Stoev, 1984).

It was determined that in June and July, the largest amount of chlorophyll A was in the tissues of plant leaves in the variants with irrigation of 70% MWRC 50, 75, 100% inflorescences and 80% MWRC 75% inflorescences (by 9.3-30.8% more compared to the control variants) (Fig. 2). In June-July, the content of chlorophyll A in the leaf tissues of all control vines was at 1.72-1.87 mg/g of wet mass, while in August, it in-

creased by 7.8-23.3% compared to previous data, probably due to the high adaptability of the Augustyn variety to soil moisture deficit. In August, the amount of chlorophyll A in irrigation plants decreased by 5.7-29.3%. In September, at the beginning of the period of senescence of leaves, active ripening of vines and outflow of metab-

olites from leaves, the amount of chlorophyll A decreased to 1.07-1.88 mg/g of wet mass. In June, the amount of carotenoids was higher in the tissues of the leaves of the control vines (0.73-0.79 mg/g of wet weight), except for the variant 70% MWRC 75-50% inflorescences, where this indicator exceeded the control by 20.5-23.0% (Fig. 2).



chlorophyll A carotenoids

Figure 2. The content of pigments in the tissues of the leaves of Augustyn grape plants under different PSWL and load of inflorescences (average for 2017-2020)

During further records, this trend was maintained, the content of carotenoids in plant tissues of control variants mostly exceeded this indicator in vines under irrigation, reaching maximum values in August – 0.95-1.10 mg/g of wet mass.

It is known that with insufficient moisture supply, the growth period of grape shoots is shorter, and the growth intensity weakens, and the yield of vines decreases. The size of internodes decreases, as a result of which the average number of leaves along the length of the shoot increases (Stoev, 1984). The present study confirms that irrigation certainly has a positive effect on the growth and development of grape plants. In general, the average values of the number and diameter of leaves on experimental vines (on irrigation) and on control vines (without irrigation) did not significantly differ from each other and were within 328.1-438.8 pcs./vine and 14.8-7.5 cm, respectively (Table 1). The leaf surface area of the plants of the 80%, 70% MWRC 50% inflorescence and 70% MWRC 75% inflorescence variants was the largest (858.7-896.4 dm²) and exceeded the control values by 12.0-20.4%.

The leafiness of the shoots was the greatest in the control variants with a load of inflorescences of 75 and 100%, in vines with irrigation of 90% PSWL this indicator was lower by 16.8-31.3%, 80% PSWL– by 9.6-17.3%, 70% PSWL – by 13.9-28.7% compared to the control.

Ensuring the good development of the growth of shoots of a standard diameter and their timely ripening on the parent vines allows obtaining high-quality grafted grape vines. With this in mind, the authors of this study recorded the development of one-year shoots of parent vines. It was found that the total length of the shoots of parent vines under irrigation with different levels of PSWL with 100% load of inflorescences exceeded this indicator in control vines (without irrigation) by 5.3-26.3%, and the longest shoots – 161.44 cm – were in the vines of the variant with PSWL 70% MWRC (Table 1). In the case of a decrease in the load of the vines with inflorescences, it was noted that the longest shoots were in the vines of the variants with a load of 50% of the inflorescences, this indicator was 176.2-191.1 cm, which is 8.5-17.7% more than in the control vines.

Table 1. Agrobiological indicators of vines of the Augustyn variety under different PSWL and load of inflorescences (average for 2017-2020)

Variant	Number of leaves, pcs.	Leaf diameter, cm	Area of leaves per vine, dm ²	Leafiness of the shoot, cm ³	Shoot length, cm	Length of the mature part of the shoot		Shoot diameter, mm
						cm	%	
90% MWRC								
100% inflorescences	369.1	14.8	646.8	18.8	134.6	93.6	69.5	7.09
75% of inflorescences	372.9	15.2	669.9	14.3*	183.7*	135.0*	73.5	7.41
50% of inflorescences	328.1	17.5	794.0	15.8	191.1	161.4*	84.5	7.48
80% MWRC								
100% inflorescences	383.6	15.4	716.2	18.7	146.9	111.5	75.9	7.11

Table 1. Continued

Variant	Number of leaves, pcs.	Leaf diameter, cm	Area of leaves per vine, dm ²	Leafiness of the shoot, cm ³	Shoot length, cm	Length of the mature part of the shoot		Shoot diameter, mm
						cm	%	
75% of inflorescences	390.2	15.9	774.2	18.8	157.2	153.9*	97.9	7.15
50% of inflorescences	406.7	16.4	858.7	18.3	181.9	156.6*	86.1	7.82
70% MWRC								
100% inflorescences	370.1	15.2	664.3	15.9*	161.4*	120.0	74.3	7.31
75% of inflorescences	438.8	15.7	866.1	17.9	186.9*	156.5*	83.8	7.84
50% of inflorescences	419.3	16.5	896.4*	19.7	176.2	164.7*	93.5	7.51
Control								
100% inflorescences	373.0	16.0	747.4	22.6	127.8	123.6	96.7	7.51
75% of inflorescences	399.8	15.5	773.6	20.8	144.1	100.2	69.5	7.59
50% of inflorescences	382.7	15.9	744.4	17.7	162.4	111.7	68.8	7.53
LSD ₀₅	58.0	1.8	119.4	6.3	28.9	32.1		0.48

Note: * – the difference with the control is statistically significant

The Augustyn variety is characterized by an early termination of growth processes and an early onset of shoot maturation, according to average annual indicators, it belongs to the group with satisfactory maturation of one-year shoots (at least 2/3 of the total length, or 65-80%). The authors of this study found that the degree of shoot maturation was the best in vines irrigated with PSWL 70% MWRC 50% inflorescences and 80% MWRC 75% inflorescences and was 93.5% and 97.9% of the total length (Table 1).

In control vines, which were cultivated without irrigation with a load of inflorescences of 100%, the degree of shoot maturation was also high – 96.7%. In general, shoot maturation was worse (62.1-73.5%) in the variants with the most intensive irrigation of 90% MWRC at 100% and

75% inflorescence load, probably due to excessive soil moisture. In control vines (without watering) with a load of 75% and 50% of inflorescences, the maturation of shoots was satisfactory (68.8-69.5%). In all variants with irrigation in the case of a load of 50% inflorescences, the length of the mature part of the shoots was 40.1-47.4% longer compared to the control, the difference is reliable. When loaded with inflorescences of 75%, the length of the mature part of the shoots decreased, but was greater than in the control variant of 75% inflorescences by 34.8-56.3%. The average diameter of the mature part of the shoots in vines on irrigation was 7.1-7.8 mm, in vines without irrigation (control) –

7.5-7.6 mm, the difference between the variants is not significant.

The study also analysed the number of shoots of different length on the vines, since a higher yield of the standard grafted vine can be obtained thanks to the development of medium and strong shoots (Table 2). Thus, in the control variant with 100% load of inflorescences, shoots with a length over 150 cm accounted for 40.8% of their total number, and in the variant with 90% MWRC irrigation, there were more such shoots – 42.8%, in the 80% MWRC variants – 51.7%, and 70% MWRC – 59.4%. In

the case of a decrease in the load of vines with inflorescences, the share of long shoots (over 150 cm) increased to 73.9-74.4% (PSWL 90% of MWRC), 57.7-71.6% (PSWL 80% of MWRC) and 63.4-72.6% (PSWL 70% MWRC), while the proportion of long shoots in control plants was 49.3-71.1%. The total growth (total length of all shoots) of vines of experimental variants is significantly higher than in the control. For instance, in the variant with PSWL 90% MWRC, if the load of inflorescences was reduced to 50-75%, the total growth of shoots was greater compared to the control by 19.5-29.5%.

Table 2. Influence of drip irrigation and loading of vines with inflorescences on the growth of annual shoots of Augustine grapes (average for 2017-2020)

Variant 0-50		Shoot length, cm				Total growth of shoots	
		51-100	101-150	>150	cm	% to control	
90% MWRC 100% inflorescences	cm	7.0	573.8	1,175.0	1,313.4	3,069.2	130.1
	% of total growth	0.2	18.7	38.3	42.8		
90% MWRC 75% of inflorescences	cm	31.8	196.8	907.4	3,219.2	4,355.2	129.5
	% of total growth	0.7	4.5	20.8	73.9		
90% MWRC 50% of inflorescences	cm	0.0	288.6	769.8	3,075.6	4,134.0	119.5
	% of total growth	-	7.0	18.6	74.4		
80% MWRC 100% inflorescences	cm	18.4	554.2	1,014.8	1,700.8	3,288.2	139.4
	% of total growth	0.6	16.9	30.9	51.7		
80% MWRC 75% of inflorescences	cm	30.0	447.8	1,058.8	2,094.4	3,631.0	107.9
	% of total growth	0.8	12.3	29.2	57.7		
80% MWRC 50% of inflorescences	cm	27.8	311.8	942.8	3,231.6	4,514.0	130.5
	% of total growth	0.6	6.9	20.9	71.6		
70% MWRC 100% inflorescences	cm	64.2	425.2	745.2	1,806.4	3,041.0	128.9
	% of total growth	2.1	14.0	24.5	59.4		

Table 2. Continued

Variant 0-50		Shoot length, cm				Total growth of shoots	
		51-100	101-150	>150	cm	% to control	
70% MWRC 75% of inflorescences	cm	28.0	399.8	847.2	3,384.4	4,659.4	138.5
	% of total growth	0.6	8.6	18.2	72.6		
70% MWRC 50% of inflorescences	cm	18.0	290.0	1,205.4	2,617.0	4,130.4	119.4
	% of total growth	0.4	7.0	29.2	63.4		
Control 100% inflorescences	cm	8.4	790.0	598.2	962.8	2,359.4	100
	% of total growth	0.4	33.5	25.4	40.8		
Control 75% of inflorescences	cm	64.0	507.2	1,136.0	1,657.0	3,364.2	100
	% of total growth	1.9	15.1	33.8	49.3		
Control 50% of inflorescences	cm	55.2	299.0	646.4	2,457.8	3,458.4	100
	% of total growth	1.6	8.6	18.7	71.1		

Note: * for each of the experimental variants, there is a control variant with the same load of inflorescences.

CONCLUSIONS

Irrigation of the vines and reduction of the load with inflorescences had a positive effect on the physiological and biochemical indicators of the grapes, stimulated the accumulation of chlorophyll in the leaves of the parent plants, improved the watering of the leaf tissues, and contributed to the increase in the intensity of respiration during the period of active growth and development of the grapes. A positive effect of irrigation and a reduction in the load of vines with inflorescences up to 50% and 75% on the agrobiological indicators of parent vines was noted. The highest values of the total length of the shoots and the degree of their maturation were found in the vines of the variants with PSWL 90% MWRC 50% inflorescences, 80%

MWRC 50% inflorescences, 70% MWRC 50% and 75% inflorescences. The analysis of different length groups of grape shoots showed that when the load of vines with inflorescences decreased, the proportion of long shoots (over 150 cm) increased the most in experiment 1 with PSWL 90% MWRC irrigation (up to 73.9-74.4%). The total growth (total length of all shoots) of irrigated vines exceeded the control. Thus, effective irrigation regimes and reducing the load of vines with inflorescences contributed to the growth of medium and strong full-fledged shoots, which are more productive. Further studies will analyse the qualitative and quantitative indicators of the yield of berries and the resulting grafting vine of grapes.

REFERENCES

- [1] Almanza-Merchán, P.J., Serrano-Cely, P.A., Forero-Ulloa, F.E. *et al.* (2014) Pruning affects the vegetative balance of the wine grape (*Vitis vinifera* L.). *Agronomía Colombiana*, 32, 180-187. <http://dx.doi.org/10.15446/agron.colomb.v32n2.43359>

- [2] Avidzba, A.M. (ed.) (2004). Methodical recommendations on agrotechnical researches in viticulture of Ukraine. Yalta : Institut vinograda i vina "Magarach".
- [3] Chulkov, V.V., Mukhortova, V.K. (2018). Pruning and loading of mother bushes of grapes: scientific and practical recommendations. *Persianovskiy: Donskoy GAU*.
- [4] DSTU 7595:2014. (2015). Microirrigation. Drip irrigation of vineyards. General requirements and control methods. Kyiv: Ministry of Economic Development of Ukraine. (National standard of Ukraine).
- [5] Dykan, A.P. (2001). Crimean viticulture. Simferopol': Biznes Inform.
- [6] Feitosa, C. *et al.* (2018). Bud load management on table grape yield and quality – cv. Sugrathirteen (midnight beauty®) *Bragantia*, 77(4), 577-589. DOI: 10.1590/1678-4499.2017332
- [7] Keller, M. (2020). *The Science of Grapevines (Third Edition)*. Cambridge: Academic Press. <https://doi.org/10.1016/C2017-0-04744-4>
- [8] Kirichenko, A.V. (2003). Biological substantiation of irrigation of industrial vineyards in the South of the Russian Federation. Russia, Novochoerkassk: All-Russian Research Institute named after Ya.I. Potapenko for Viticulture and Winemaking.
- [9] Kozhukharenko, V.A. (2013). Influence of shoot load and chasing on the background of intrasoil drip irrigation on the productivity of table grapes. *Vinogradarstvo i vinorobstvo. Odesa : NNTs "IViV im. V. Tairova"*, 50, 123-126.
- [10] Kudryashova, V.V. (2006). Influence of drip irrigation and biologically active substances on the productivity and quality of grapes in the conditions of the Western Ciscaucasia. Russia, Krasnodar: Federal State Budget Scientific Institution "North Caucasian Federal Scientific Center of Horticulture, Viticulture, Wine-making".
- [11] Kumar, A.R., Parthiban, S., Subbiah, A., Sangeetha, V. (2017). Effect of pruning severity and season for yield in grapes (*Vitis vinifera* L.) Variety Muscat Hamburg. *Int. J. Curr. Microbiol. Appl. Sci.*, 6, 1814-1826. <https://dx.doi.org/10.20546/ijcmas.2017.603.207>.
- [12] Mikitenko, S.V., Polyakov, V.I., Yakimenko, V.I. (1990). The influence of agricultural techniques on the productivity of irrigated mother plants of graft vines. *Vinogradarstvo i vinodeliye: respublikanskiy mezhvedomstvennyy tematcheskiy nauchnyy sbornik*. Kyiv: Urozhay, 33, 11-13.
- [13] Pavelkivs'ka, O.Ye. (2013). Substantiation of drip irrigation regimes of young vineyards of table varieties in the conditions of the Southern Steppe of Ukraine. Ukraine, Kyiv. Institute of Water Problems and Land Reclamation.
- [14] Perstnev, N.D. (2001). *Viticulture*. Kishinev. ISBN 9975-78-091-1.
- [15] Shevchenko, I.V. (ed.) (2019). *Modern vineyard irrigation systems*. Kherson: Aylant.
- [16] Stoyev, K.D. (1984). *Physiology of grapes and the basics of its cultivation*. Sofiya: Izd-vo Bolgarskoy akademii nauk, 3.
- [17] Tret'yakov, N.N. *et al.* (1990). *Plant Physiology Workshop (3rd ed.)*. Moskva: Agropromizdat.
- [18] Ursu, V.A. (1989). The mother graft grape plantings of intensive type and accelerated reproduction of grapes. Kishinev: Shtiintsa.
- [19] Vlasov, V.V. (ed.) (2015). *System of certified grape nursery of Ukraine*. Kyiv: Agrarna nauka.

Н.М. Зеленянська

Доктор сільськогосподарських наук, заступник директора
Національний науковий центр
«Інститут виноградарства і виноробства імені В.Є. Таїрова»
65496, вул. 40-річчя Перемоги, 27, м. Таїрове, Україна

О.І. Гогулінська

Кандидат сільськогосподарських наук, старший науковий співробітник
Національний науковий центр
«Інститут виноградарства і виноробства імені В.Є. Таїрова»
65496, вул. 40-річчя Перемоги, 27, м. Таїрове, Україна

Н.В. Подуст

Кандидат сільськогосподарських наук, старший науковий співробітник
Національний науковий центр
«Інститут виноградарства і виноробства імені В.Є. Таїрова»
65496, вул. 40-річчя Перемоги, 27, м. Таїрове, Україна

Вплив краплинного зрошення та навантаження суцвіттями на ріст і розвиток маточних кущів винограду

Анотація. Високий вихід щеплених саджанців винограду та їхня якість залежать від багатьох факторів, у тому числі від якості прищепно-підщепних компонентів, що так само визначається належним доглядом за маточними насадженнями прищепних та підщепних лоз. Їхня агротехніка має бути направлена на кращий ріст та визрівання пагонів. На маточних кущах є обов'язковим технологічний прийом обломовання пагонів, часткове видалення суцвіть не є таким поширеним у агротехніці маточників, однак позитивно впливає на загальний розвиток рослин. Маточні насадження за можливості слід зрошувати, оскільки недостатнє забезпечення вологою негативно впливає на стан кущів упродовж усього вегетаційного періоду та зимівлі. У даній роботі досліджено вплив прийому часткового видалення суцвіть (навантаження суцвіттями 100, 75 та 50 % від їхньої загальної кількості) на маточних кущах та вплив різних режимів зрошення (рівні передполивної вологості ґрунту 90, 80 та 70 % від найменшої вологоємності) на станматочних насаджень, зокрема на фізіологічні, біохімічні та біометричні показники рослин. Показано, що зрошення кущів та зменшення навантаження суцвіттями до 50 та 75 % від їхнього загальної кількості стимулювали накопичення хлорофілу в листках маточних рослин, покращували обводнення тканин листків, сприяли підвищенню інтенсивності дихання в період активного росту та розвитку винограду. Відмічено позитивний вплив зрошення та зменшення навантаження кущів суцвіттями до 50 та 75 % на агробіологічні показники маточних кущів винограду. Найбільші значення загальної довжини пагонів та ступеня їхнього визрівання були в кущів варіантів із РПВГ 90 % НВ 50 % суцвіть, 80 % НВ 50 % суцвіть, 70 % НВ 50 та 75 % суцвіть. Отже, ефективні режими зрошення та зменшення навантаження кущів суцвіттями сприяли росту середніх та сильних повноцінних пагонів, які є більш продуктивними

Ключові слова: прищепні маточники винограду; рівень передполивної вологості ґрунту; кількість суцвіть; обводнення тканин листків; інтенсивність дихання; вміст пігментів; агробіологічні показники кущів

PLANT AND SOIL SCIENCE

Scientific Journal

Volume 12, No. 4. 2021

Founded in 2010. Published four times per year

The original layout of the publication is made in the Department of Scientific and Technical Information of National University of Life and Environmental Sciences of Ukraine

Managing Editor:

H. Ivchenko

Editing English-Language Texts:

S. Vorovsky, K. Kasianov

Desktop Publishing:

M. Kryshstal

Signed for print of November 24, 2021

Format 70*100/16

Conventional printed pages 11.21

Circulation 50 copies

Editors Office Address:

National University of Life and Environmental Sciences of Ukraine

03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

E-mail: info@agriculturalscience.com.ua

<https://agriculturalscience.com.ua/en>

РОСЛИННИЦТВО ТА ҐРУНТОЗНАВСТВО

Науковий журнал

Том 12, №4. 2021

Заснований у 2010 р. Виходить чотири рази на рік

Оригінал-макет видання виготовлено у відділі науково-технічної інформації
Національного університету біоресурсів і природокористування України

Відповідальний редактор:

Г. Івченко

Редагування англomовних текстів:

С. Воровський, К. Касьянов

Комп'ютерна верстка:

М. Кришталь

Підписано до друку 24 листопада 2021 р.

Формат 70*100/16

Умов. друк. арк. 11,21

Наклад 50 прим.

Адреса видавництва:

Національний університет біоресурсів і природокористування України

03041, вул. Героїв Оборони, 15, м. Київ, Україна

E-mail: info@agriculturalscience.com.ua

<https://agriculturalscience.com.ua/uk>