Plant and Soil Science

Том 12, № 1. 2021

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 № 5 від 22 грудня 2020 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:
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https://agriculturalscience.com.ua/uk

Plant and Soil Science

Volume 12, No. 1. 2021

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. 5 of December 22, 2020)

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

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Редакційна колегія

Plant and Soil Science

Editorial Board

Зміст

Contents

Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en *Plant and Soil Science, 12(1), 7-17*

Received xx.xx.2020 Revised xx.xx.2021 Accepted xx.xx.2021

UDC 633.34: 631.526.3 (477.43/.44)

DOI: 10.31548/agr2021.01.0007

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Productivity of Soybean varieties in Podillia

Abstract. The features of soybean varieties for cultivation in Podillia were studied based on the analysis of scientific sources. The study considers the key lines of increasing the productivity of soybean varieties. The advantages, main disadvantages, and challenges of growing soybean varieties in Podilia are presented and substantiated. The characteristics of soybean varieties, the impact of the inoculation process and the effectiveness of microfertilisers were studied, which made it possible to develop measures of cultivation technology accounting for plant biology and changes in climatic conditions. The processes of cultivation and development of soybean varieties: *Maxus*, *Cordoba*, *Saska*, depending on seed processing with insecticidal-fungicidal seed treatment Standak Top, inoculants *Hi Stack*, *High Cat Super*, *High Cat Super Extender* and seed treatment with microfertiliser *KoMo 15*, in addition to foliar fertilisation with microfertilisers *Vuksal Boron* and *Bosfoliar* during the growing season. The research on different maturity groups of soybean varieties such as *Maxus*, *Cordoba*, *Saska*, revealed positive performance results from the application of microfertilisers, inoculants, treatment of soybean seed with inoculants and microelement *Vuxal CoMo 15*. Moreover, seed treatment *Standak Top 1 l/t* also prevents the development of diseases such as Fusarium, anthracnose, seed mold, promotes rooting of plants in the soil due to accelerated development of the root system, increases of the assimilation surface of the leaf apparatus, promotes the activation of nitroreductase, which also activates photosynthesis, manifested in the so-called AgCelence effect. Plants have an intensely saturated dark green color, soil pests are effectively eliminated. Experiments on the impact of seed inoculation on soybean yields were conducted by combining the inoculant, *Vuxal CoMo*, and the insecticidal fungicidal preparation *Sandak Top* in a tank mixture with a sowing

Suggested Citation:
Fedoruk, I., & Bakhmat, O. (2021). Productivity of Soybean varieties in Podillia. *Plant and Soil Science*, 12(1), 7-17. doi: 10.31548/agr2021.01.007.

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period of up to 5-7 days. One of the main requirements is the use of high-quality inoculants with a high content of viable nitrogen-fixing bacteria for soybean seed treatment, which is a necessity today, as it allows to fully reveal and realise the genetic and varietal potential of modern varieties. Moreover, this will contribute to high soybean yields with optimal costs and the fastest possible return on investment, especially in the current conditions. The study resulted in the development of new technological aspects of combining the inoculation process and the use of microfertilisers and insecticide-fungicide preparations in the cultivation technology, which gave significant results in increasing yields. The relative humidity of the air and the reserves of productive soil moisture should also be factored in. The findings of the research are aimed at solving urgent tasks in the technology of growing legumes, namely: developing a variant of soybean cultivation technology for the selection of varieties adapted to this climate zone, the use of inoculants and microfertilisers in the context of climate change in Podillia

Keywords: soy, variety, inoculation, microfertilisers, pre-sowing seed treatment, yield

RELEVANCE

Soybean is one of the most valuable oilseeds. The nutritional value of food is determined by its protein content and quality. The problem of vegetable protein can be solved by growing leguminous crops (Petrichenko & Likhochvor, 2014).

Growing soybeans in the face of climate change in Podillia is a very complex topic. Cultivation technology must combine all aspects: choosing the proper zoned variety, soil preparation, moisture conservation, providing plants with moisture, and selecting appropriate protection systems with products recommended for the variety and the climate zone. These are the elements that will affect soybean yields and grain quality.

Lack of micronutrients reduces yields, causes disease, and impairs grain quality. Trace elements are extremely important for the growth and development of soybeans, as their availability in sufficient quantities is a prerequisite for the intensive assimilation of nitrogen from the air (Shevnikov & Koblay, 2015; Melnyk *et al.*, 2007). However, an important point that occupies one of the main places in the technology is the treatment of high-performance seeds with inoculants. Inoculation of legume seeds with bacterial preparations (inoculants) has the ability to restore the biological potential of soils, in particular due to legumes that form symbiotic relationships with microorganisms in the soil.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Soybeans play a significant role in biological farming. It fixes nitrogen from the air, covering 60-70% of its needs, and leaves it in the soil along with plant residues after harvest. The introduction of scientifically based soybean cultivation technology allows for obtaining 2.5-3.0 t/ha of seeds (Petrichenko *et al.*, 2016; Singh, 2014).

The most important condition for high soybean yields is the availability of nutrients, nitrogen-fixing nodule bacteria, moisture and temperature levels in the soil. Therefore, it is important to determine and create optimal environmental conditions for the realisation of the potential nitrogen-fixing activity of soybeans of each variety in specific soil and climatic conditions (Babich & Babich-Berezhnaya, 2011;

Fedoruk, 2019). The analysis of the major studies and publications that addressed the problem demonstrates that trace elements also play a special role in improving the efficiency of mineral nutrition of plants (Likhochvor, 2008; Marchuk, 2009).

According to V.V. Moskalets & V.K. Shynkarenko (2004), mainly such trace elements as boron, molybdenum, copper, zinc, iron, manganese, cobalt, and magnesium. No plant can develop properly in their absence or deficiency, as they are part of the most important enzymes, vitamins, hormones and other physiologically active substances. Trace elements are involved in the synthesis of proteins, carbohydrates, fats, and vitamins. They increase the chlorophyll content in the leaves, enhance the assimilation activity of the plant, and boost the efficiency of the photosynthesis process. The purpose of the study was to examine the effect of seed inoculation and microfertiliser application on the formation of varietal productivity of soybean grain.

RESEARCH RESULTS

Legumes are gradually gaining popularity in Ukraine and are changing and optimising the structure of sown areas. They also have a positive effect on the structure of the soil complex, replenishing it with plant residues, which, in the process of mineralisation, contribute to the enrichment of the soil with nutrients.

Increasing the production of soybean grain is possible only through the improvement of existing and development of new agrotechnical elements of soybean cultivation technology, considering the significant climate change (Bakhmat & Bakhmat, 2001; Bakhmat & Fedoruk, 2017).

The selection of soybean varieties for cultivation in Podillia has its own unique features, as the natural conditions of Ukraine have limited light and heat resources for growing medium- and late-ripening varieties (the growing season is 145 days), and varieties must also be adapted to climate change, be flexible to soil fertility, both in the main and pre-sowing soil preparation, and form yields, considering the nutrition system and inoculation processes.

In the process of climate change, when the accumulated temperature rises, precipitation decreases, and drought is spreading not only in the soil but also in the air, selection should be carried out in specific conditions of growing areas or by taking these conditions into account.

It is crucial to properly select the variety, not only based on the natural and climatic conditions of cultivation, but also on the chemical composition. It is also important to consider the optimal height of the beans so that the harvester does not damage the beans and seeds during harvesting, thus reducing yield losses. Having 2-3 seeds in a bean is essential, and 4 is already an indication of high productivity, as is the presence of 10-11 productive nodes. The plant must be compact, with a complete type of growth. A ripe and ready-to-harvest variety does not crack or drop off leaves.

The variety realises its yield potential only when the cultivation technique fully meets its biological requirements. Given that varieties react differently to agrotechnical measures, it is necessary to determine the optimal timing and methods of sowing, seeding rates, fertiliser doses, and so on for each variety. Without this, it is impossible to realise the genetic potential of the variety (Babich *et al.*, 2000; Babich, 1974). As a result of the greater realisation of the potential of new varieties, crop yields can be significantly increased.

The following soybean varieties were studied in the experiment: *Maxus*, *Cordoba*, and *Saska.*

Soybean variety *Maxus* by Prograin. The growing season is 100-110 days. The type of plant growth is intensive. The oil content is 20.7%.

The height of the plants is 85-115 cm, the height of the lower beans is 15-17 cm, and the protein content is 41%. The weight of a thousand seeds is about 197 g, which affects the yield potential – up to 50 c/ha. Resistant to diseases and pests. It does not lodge or drop of leaves. Resistant to stem damage. Beans do not crack during ripening.

Soybean variety Saska by Prograin. The growing season is 115-120 days. The height of the lower pod is 15-20 cm. Adapts to a variety of soil and climatic conditions. The height of plants is 135 cm. The protein content is 41 %. The weight of a thousand seeds is about 156 g. Resistant to diseases and pests. It does not lodge or drop of leaves. Resistant to stem damage. Beans do not crack during ripening.

The genetically determined varietal adaptability of these varieties to different soil and climatic regions of Ukraine provides the effectiveness of scientifically based varietal technologies and high yields in all soil and climatic regions of the Forest-Steppe of Ukraine.

Cordoba is a high-yielding soybean variety developed by *SAATBAU*. Mid-early ripening period. The growing season is 105-110 days. The potential yield declared by the manufacturer is 50 c/ha, but during the research, the best yield was 33.3 c/ha. It is cultivated for grain. The *Cordoba* soybean variety is recommended for growing in all areas of the country. It is resistant to adverse weather conditions. Resistant to diseases and pests. It does not lodge or drop of leaves. Resistant to stem damage. Beans do not crack during ripening. Crop height – 90 cm. The weight of 1000 seeds is 170-185 g. The grain is large and of high quality. The protein content is 40-44% and the oil content is 22%.

SAATBAU soybean varieties are characterised by intensive development in the early stages, which greatly facilitates weed control, genetic resistance to viral diseases and excellent branching ability.

SAATBAU soybean varieties are characterised by intensive development in the early stages, which greatly facilitates weed control, genetic resistance to viral diseases and excellent branching ability.

The field experiment was conducted in the field crop rotation of field No. 2 of the agricultural enterprise LLC "Garant" of Kamianets-Podilskyi district, Khmelnytskyi Oblast, as a branch of the Department of Ecology, Quarantine and Plant Protection of Podilskyi State Agrarian and Technical University.

The experimental field was located in the southwestern forest-steppe part of the Khmelnytsky Oblast, which, according to the conditions of heat supply and moisture, belongs to the southern humid agroclimatic region of the Western Forest-Steppe.

The results obtained showed that the productivity of soybean grain depends on the cultivar, research factors (factor A – cultivar, factor B – microfertiliser, factor C – inoculation) and variants in the experiment, and climatic conditions of cultivation.

Analysis of the yield level of soybean varieties *Maxus*, *Cordoba*, *Saska* in the experiment revealed a composite index that included such components as genetic potential of the variety, soil fertility and availability of nutrients by periods of soybean growth and development, the formed nutrition regime based on mineral fertiliser rates, weather conditions during the vegetation period of the varieties, plant density, and quality of mechanised operations.

In view of the above, plants were selected and the structural analysis of the sheaf material was carried out. The structure of the crop was studied in sheaf samples, which were taken at full maturity, on 0.25 m^2 plots in four replications. The weight of the sheaf, the number of plants, branches, beans on the main and side branches, seeds per bean, the number and weight of seeds per plant, and the weight of 1000 seeds were determined. The harvest was calculated from the entire accounting area of each plot. The grain harvest was processed to 100% purity and 14% moisture content.

In the course of mathematical and statistical studies of the experimental data, the following were analysed: yield data (by the method of variance analysis of multifactorial complexes; correlation and regression analyses); quantitative plant traits (by the method of variation series, difference, correlation, regression, etc.).

The correlation and regression analysis showed a direct and close relationship between biometric parameters and soybean plant yield. It ranged from 0.81 to 0.99, depending on the variety. Out of these, the three most strongly correlated indicators were selected and a regression model of the linear dependence of these parameters was created. According to the regression equation, an increase in the number of beans per plant per unit resulted in an increase in soybean yield by 0.0428 t/ha in the *Maxus* variety, 0.1521 t/ha in the *Cordoba* variety, and 0.1034 t/ha in the *Saska* variety. An increase in the number of seeds per bean per unit resulted in an increase in soybean yield by 0.0205 t/ha in the *Maxus* variety, by 0.0732 and 0.0458 t/ha in the *Cordoba* and *Saska* varieties, respectively (Table 1).

Table 1. Mathematical models of correlation between actual yields and elements of soybean yield structure for 2015-2018

Indicators	Regression equation	Correlation coefficient, R	Determination coefficient, D, %
Maxus			
Number of beans, pcs.	$y = 0.0428x + 1.619$	0.960	92
Number of seeds, pcs.	$y = 0.0205x + 1.6689$	0.967	93
Seed weight per plant, g	$y = 0.11x + 1.6569$	0.965	93
Cordoba			
Number of beans, pcs.	$y = 0.1521x + 0.219$	0.953	91
Number of seeds, pcs.	$y = 0.0732x + 0.4116$	0.955	91
Seed weight per plant, g	$y = 0.3814x + 0.4035$	0.944	89
Saska			
Number of beans, pcs.	$y = 0.1034x + 0.669$	0.950	90
Number of seeds, pcs.	$y = 0.0458x + 0.9283$	0.905	82
Seed weight per plant, g	$y = 0.1638x + 1.3667$	0.906	82

The increase in seed weight per plant per unit led to an increase in soybean yield by 0.11 t/ha in the *Maxus* variety, by 0.1638 in the *Saska* variety, and the largest increase of 0.3814 t/ha in *Cordoba*.

Analysis of the yield indicators of soybean variety *Maxus* (Table 2), shows in particular that the lowest values of the indicators were inherent in the control variant (water irrigation).

Table 2. The yield of soybean varieties *Maxus, Cordoba, Saska* in the years of research depending on microfertilisers and inoculation (average for 2015-2018), t/ha

Study variant designations	Soybean grain yield by year			
	2015	2016	2017	2018
$A_0B_0C_0$	1.50	1.32	1.75	3.78
$A_0B_0C_1$	1.78	0.96	2.4	4.14
$A_0B_0C_2$	1.71	0.83	2.27	3.28
$A_0B_0C_3$	1.65	1.35	1.97	4.03
$A_0B_1C_0$	1.97	1.01	2.45	4.33
$A_0B_1C_1$	1.93	0.85	2.36	3.44
$A_0B_1C_2$	1.87	1.36	2.18	4.31
$A_0B_1C_3$	2.03	1.03	2.63	4.52
$A_0B_2C_0$	2.01	0.86	2.48	3.51
$A_0B_2C_1$	2.07	1.44	2.27	4.08
$A_0B_2C_2$	2.24	1.22	2.53	4.48
$A_0B_2C_3$	2.25	0.89	2.59	3.46
$A_1B_0C_0$	2.23	1.68	2.30	4.22
$A_1B_0C_1$	2.70	1.41	2.67	4.61
$A_1B_0C_2$	3.06	0.93	2.64	3.59
$A_1B_0C_3$	2.12	1.80	2.63	4.72
$A_1B_1C_0$	3.03	1.48	2.91	4.93
$A_1B_1C_1$	3.16	1.05	2.73	3.85
$A_1B_1C_2$	2.21	1.48	2.39	4.59
$A_1B_1C_3$	2.39	1.26	2.47	4.79
$A_1B_2C_0$	2.45	0.93	2.88	4.25
$A_1B_2C_1$	2.32	1.79	2.48	4.69
$A_1B_2C_2$	2.83	1.47	2.86	4.91
$A_1B_2C_3$	3.15	0.98	2.95	4.13
$A_2B_0C_0$	2.29	1.97	2.77	5.05
$A_2B_0C_1$	3.14	1.59	3.15	5.19
$A_2B_0C_2$	3.20	1.14	2.92	4.37
$A_2B_0C_3$	2.33	1.55	2.58	4.41

Table 2, Continued

Study variant designations		Soybean grain yield by year			
		2015	2016	2017	2018
$A_2B_1C_0$		2.45	1.30	2.69	4.71
$A_2B_1C_1$		2.59	0.94	2.64	3.62
$A_2B_1C_2$		2.42	1.83	2.67	4.58
$A_2B_1C_3$		2.94	1.52	3.15	4.84
$A_2B_2C_0$		3.28	1.00	2.39	3.85
$A_2B_2C_1$		2.38	2.04	2.96	4.53
$A_2B_2C_2$		3.20	1.67	3.49	4.96
$A_2B_2C_3$		3.35	1.17	2.67	3.71
LSD_{05}	**A**	0.06	0.08	0.07	0.07
	B	0.06	0.08	0.07	0.07
	C	0.07	0.10	0.08	0.09
	AB	0.10	0.15	0.12	0.13
	AC	0.12	0.17	0.14	0.15
	BC	0.12	0.17	0.14	0.15
	ABC	0.03	0.05	0.04	0.04

The results of the analysis on variance revealed that the difference between the experimental and control variants was significant, as they exceeded the index of the least significant difference.

According to Table 2, the yield in 2015 is quite high, especially high in the variant of the experiment with seed inoculation with *High Kot* on *Saska* variety – 3.06 t/ha, also in the variant with seed inoculation with *Hi Stick + High Kot Super + High Kot Super Extender + Vuksal Boron* on *Cordoba* variety – 3.14 t/ha, *Saska* – 3.20 t/ha. High yields are achieved by the variant with seed treatment with the inoculant *High Kot Super + High Kot Super Extender + Vuksal Boron + Bosfoliar* on the varieties *Cordoba* – 2.94 t/ha, *Saska* – 3.28 t/ha, as well as the variant with the inoculant *Hi Stick + High Kot Super + High Kot Super Extender + Vuksal Boron + Bosfoliar* on the varieties *Cordoba* – 3.20 t/ha, *Saska* – 3.35 t/ha.

In the 2016 season, inoculants had a different effect on yields depending on the maturity group of the varieties. The *Maxus* variety compared to the control showed an increase of 0.72 t/ha in the variant *Hi Stick + High Kot Super + High Kot Super Extender + Vuksal Boron + Bosfoliar, Cordoba* showed a result of 0.71 t/ha in this variant, and the late-ripening variety Saska showed a yield increase of 0.34 t/ha in the variant *Hi Stick + High Kot Super + High Kot Super Extender + Vuksal Boron + Bosfoliar*.

The weather and climatic conditions in 2017 were more favourable for crop cultivation compared to the previous vegetation year (2016). Soybean yield formation in the *Maxus* and *Cordoba* varieties (bean setting, filling) proceeded with moderate moisture in the soil and air. In the late-ripening variety *Saska*, the processes of flowering, bean setting, and filling for the first to fourth tiers occurred under relatively favourable conditions.

The analysis of the table data shows that in the variant without inoculants, but with the use of *Vuksal Boron* microfertiliser, regardless of the maturity group of soybean varieties, a yield increase ranged from 0.05 t/ha to 0.22 t/ha, which was 2.0-12.5%, respectively. Repeated use of microfertilisers, viz: *Bosfoliar*, allowed to obtain an additional 0.11 t/ha to 0.21 t/ha, the maximum effect was achieved with the *Maxus* variety – 0.21 t/ha, while the *Saska* variety only provided an additional 0.11 t/ha.

The weather and climatic conditions in 2018 are more favourable for crop production compared to the previous vegetation period (2017).

In 2018, inoculants and *Vuksal Boron* proved to be effective solutions for soybeans. Thus, in the budding phase, the start of flowering, the introduction of *Vuksal Boron* gave the following positive results. The early-ripening variety *Maxus* reached 0.81 t/ha of control with the use of *Hi Stick*, and 0.91 t/ha with the use of *High Kot Super + High Kot Super Extender* inoculant. The mid-season variety *Cordoba* produced 0.65 t/ha and 0.77 t/ha respectively. Similarly, high yield results were obtained on the late-ripening variety *Saska*, whereby the use of *Hi Stick* resulted in 0.97 t/ha compared to the control, and 0.85 t/ha with the use of *High Kot Super + High Kot Super Extender* inoculant.

Spring tillage started with harrowing (“moisture infiltration”). Soybean seeds were fertilised in advance using insecticidal and fungicidal seed treatment with physiological impact *Standak Top* at a rate of 1 l/t and inoculants according to the experimental scheme (*Hi Stick, Hi Kot*), as well as microfertilisers *Vuksal CoMo*. Inoculation of soybean seeds with *Hi Stick* was carried out on the day of sowing.

The advantages of *Standak Top* insecticidal-fungicidal seed treatment are its excellent protection against soil pests and sprout flies. The use of this agent prevents the spread of pathogens such as fusarium, anthracnose, and seed mold. It stimulates the rooting of plants in the soil through accelerated development of the root system, an increase of the assimilation surface of the leaf apparatus, and also promotes activation of nitroreductase, which also intensifies photosynthesis, resulting in intensely saturated dark green colour of the plants.

Due to the moisture deficit, cultivation was carried out on the day of sowing to a depth of 3-5 cm, with row spacing of 35 cm.

For sowing, the *Maxus* variety was used at a rate of 750 thousand/ha, the *Saska* variety at a rate of 550 thousand/ha, and the Cordoba variety at a rate of 450 thousand/ha. After sowing, the soil was rolled with spur rollers. After rolling, the next day soil herbicides were applied (*Stomp 330 + Frontier Optima* – 2 + 0.7 l/ha, the so-called European experience, this operation involves factoring in the mechanical composition of the soil). In the phase of 2-3 leaves, the herbicide *Pulsar 40* (1 l/ha) was applied with a working solution consumption rate of 250 l/ha.

In the budding phase, the beginning of flowering, microfertilisers from *Unifer Vuksal Boron* were applied at a rate of 1 l/ha, following the study scheme the fungicide *Abacus* was applied for all varieties at a rate of 0.8 l/ha. In the bean filling phase, *Abacus* was re-applied (background) at a rate of 0.7 l/ha and an insecticidal-acaricidal mixture against leaf-eating pests and ticks *Fastak 10% + Masai 20%* was preventively applied at a rate of 0.15 l/ha + 0.5 kg/ha. *Basfoliar* 12-4 -6 + S at a rate of 2 l/ha was applied according to the study scheme.

CONCLUSIONS

A large number of soybean varieties of different genetic character makes it impossible to distribute all the cultivation zones specified in the Register, and therefore soybean producers face a difficult choice of which variety to use in production, because the productivity traits that develop according to genetic potential are determined by the interaction of a set of traits with environmental conditions.

Analysis of the best variants in the study of cultivars, microfertilisers and inoculants of various formulae, along with optimisation of soybean cultivation technology elements is a topical issue for study in the Western Forest-Steppe. Especially relevant is the use of new foreign varieties and modern elements of soybean cultivation technology in specific soil and climatic conditions.

Having conducted research on different maturity groups of soybean varieties such as: *Maxus*, *Cordoba*, *Saska*, the results of using inoculants and microfertilisers proved to be positive. The optimal yield value on average for the years of research at 3.33 t/ha was provided by the variety Cordoba using the experimental variant *Hi Stick + High Kot Super + High Kot Super Extender + Vuxal Boron + Basfoliar*, exceeding the control by 43.5%, a similar variant of the experiment in the Maxus variety had an average of 2.97 t/ha, which exceeds the control by 42.8%, the *Saska* variety yielded 2.72 t/ha on the *Hi Stick + High Kot Super + High Kot Super Extender + Vuxal Boron + Bosfoliar* variant, which exceeds the control by 34.6%.

All of the soybean varieties studied had high productivity both in individual years and on average over three years of cultivation, with *Cordoba* being the most prominent, showing the best yield compared to *Maxus* and *Saska*. Soybean grain yields varied over the years depending largely on weather conditions and, above all, on the availability of moisture throughout the vegetation season.

The selection of varieties with good genetic potential recommended for the climatic conditions of Podillia, combined with the inoculation and applying microfertilisers in the cultivation technology, as shown by the results of the study, give significant results in increasing yields.

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Продуктивність сортів сої на Поділлі

Анотація. На основі аналізу наукових джерел досліджено особливості сортів сої для вирощування в умовах Поділля. Розглянуто основні напрями підвищення продуктивності сортів сої. Представлено та обґрунтовано переваги, основні недоліки та проблеми вирощування сортів сої в умовах Поділля. Вивчено особливості сортів сої, вплив процесу інокуляції та ефективність мікродобрив, що дозволило розробити заходи технології вирощування з урахуванням біології рослин та змін кліматичних умов. Досліджено процеси вирощування та розвитку сортів сої: Максус, Кордоба, Саска залежно від обробки насіння інсектицидно-фунгіцидним протруйником Стандак Топ, інокулянтами Хай Стак, Хай Кет Супер, Хай Кет Супер Екстендер та обробки насіння мікродобривом КоМо 15, а також позакореневого підживлення мікродобривами Вуксал Бор і Босфоліар протягом вегетації. Дослідження на різних групах стиглості сортів сої, таких як Максус, Кордоба, Саска, показали позитивні результати від застосування мікродобрив, інокулянтів, обробки насіння сої інокулянтами та мікроелементом Вуксал КоМо 15. Крім того, протруювання насіння Стандак Топ 1 л/т також запобігає розвитку таких хвороб, як фузаріоз, антракноз, пліснявіння насіння, сприяє укоріненню рослин у ґрунті завдяки прискореному розвитку кореневої системи, збільшенню асиміляційної поверхні листкового апарату, сприяє активації нітроредуктази, яка також активізує фотосинтез, що проявляється у так званому AgCelence-ефекті. Рослини мають інтенсивно насичений темно-зелений колір, ефективно знищуються ґрунтові шкідники. Досліди з вивчення впливу інокуляції насіння на врожайність сої проводили шляхом поєднання інокулянту Вуксал КоМо та інсектицидно-фунгіцидного препарату Сандак Топ в баковій суміші з терміном посіву до 5-7 днів. Однією з основних вимог є використання високоякісних інокулянтів з високим вмістом життєздатних азотфіксуючих бактерій для обробки насіння сої, що є необхідністю на сьогоднішній день, оскільки дозволяє повністю розкрити та реалізувати генетичний та сортовий потенціал сучасних сортів. Крім того, це сприятиме отриманню високих врожаїв сої з оптимальними витратами та максимально швидкою окупністю інвестицій, особливо в нинішніх умовах. Результатом дослідження стала розробка нових технологічних аспектів поєднання процесу інокуляції з використанням мікродобрив та інсектицидно-фунгіцидних препаратів у технології вирощування, що дало значні результати у підвищенні врожайності. Слід також враховувати відносну вологість повітря та запаси продуктивної вологи в ґрунті. Результати досліджень спрямовані на вирішення актуальних завдань у технології вирощування зернобобових культур, а саме: розроблення варіанту технології вирощування сої з урахуванням підбору сортів, адаптованих до даної кліматичної зони, застосування інокулянтів та мікродобрив в умовах зміни клімату на Поділлі

Ключові слова: соя, сорт, інокуляція, мікродобрива, передпосівна обробка насіння, урожайність

Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en
Plant and Soil Science, 12(1), 18-27
Received xx.xx.2020 Revised xx.xx.2021 Accepted xx.xx.2021

UDC 633.321

DOI: 10.31548/agr2021.01.0018

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Economic and Energy Efficiency of Growing Different Varieties of Red Clover (*Trifolium pratense* L.) for Fodder

Abstract. The cultivation of red clover for fodder purposes on typical low-humus chernozems of the northern part of the Right-Bank Forest-Steppe of Ukraine is profitable. Regardless of the technology components, it provides a net profit of UAH 14,962-23,743 per hectare with a profitability of 88-259% and a cost of 1 ton of feed units of UAH 1,415-2,662 and raw protein of UAH 5,363-10,265, a payback of energy costs in terms of gross energy (EER) yield per hectare of 6.2-9.0 and metabolisable energy (BER) yield per hectare of 3.2-4.6, with energy costs per 1 ton of feed units of 2.86-4.20 GJ. The purpose of the study was to determine changes in the economic and energy efficiency of growing different varieties of red clover for fodder purposes depending on the methods of sowing, seed inoculation with nodule bacteria and fertilisation. During the research, the following methods were used: field and laboratory – for conducting research in the field and laboratory conditions, analytical – to determine the chemical composition of dry biomass of red clover, calculation – to determine the indicators of economic and energy efficiency. The best rates of economic and energy efficiency of red clover cultivation are provided by the variety Typhoon when seeds are inoculated with nodule bacteria on fertiliser-free soil. The additional application of P60K90 or N60R60K90 against the background of inoculation, which is necessary to preserve soil fertility, worsens them, reducing net profit by 3,486-5,943 UAH/ha

Keywords: bioenergy factor, cost and energy inputs, economic and energy efficiency, cost recovery, profitability, cost price, net profit

Suggested Citation:
Demidas, H., & Galushko, I. (2021). Economic and Energy Efficiency of Growing Different Varieties of Red Clover (*Trifolium pratense* L.) for Fodder. *Plant and Soil Science*, 12(1), 18-27. doi: 10.31548/agr2021.01.018.

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RELEVANCE

The successful development of Ukraine's livestock industry requires the development of energy- and resource-saving technologies in fodder production and grassland farming, based on the use of the enormous potential of perennial grasses, and legumes in particular, as a source of natural cheap symbiotic nitrogen. Only calculations of economic and energy efficiency make it possible to evaluate the relevant technological elements, identify the best ones, and provide the basis for a reasonable recommendation of certain feed production technologies to be implemented in agricultural production. Therefore, the final stage of research, including the identification of the best elements of technology for the formation of forage phytocoenoses, their fertilization systems and modes of use, etc. is their economic and energy assessment (Babich & Motornyi, 1986).

Technologies for the improvement and rational use of perennial grasses, including legumes, should be resource- and energy-saving, based on a combination of the latest scientific achievements and best practices, at the same time, providing a high return on the material and technical means used. Failure to comply with at least one requirement in the overall technological process leads to a decrease in yield and a sharper decline in the level of cost recovery. The cost of grass feed produced on forage lands, in particular on pastures, is several times lower than that obtained in the field (Kurhak, 2010).

The summarisation of published data, research results, and the experience of advanced farms in terms of the economic efficiency of feed production suggests that grass feed is the most economically efficient. However, the cost of 1 ton of feed units of fodder obtained from cultivated pastures is 1.9 times lower than the mowed green mass of perennial grasses, 2.5 times lower than hay from natural hayfields, 10.5 times lower than fodder root crops, and 3.9 times lower than concentrated fodder (Babich & Motornyi, 1986; Kurhak, 2010; Blagoveshchenskiy, 1995).

The low cost of fodder from perennial grasses is primarily attributable to the fact that the funds for grassland management and landscaping are distributed over a number of years, during which it is planned to use them with relatively low maintenance and operation costs (Andreev & Zotov, 1985; Kutuzova & Kozminykh, 1998; Yarmolyuk *et al*., 2013).

It should be noted that in recent years, due to rising energy costs and rising prices for mineral fertilisers and fuel, the cost of fertilising and cuttings and, in general, grass feed production has increased. Therefore, in the context of rising prices of mineral fertilisers, in particular nitrogen, an important factor in reducing the cost of feed is the use of legumes as a source of symbiotic nitrogen (Voloshyn, 2018; Prorochenko, 2020).

The energy analysis of technologies in feed production is particularly important because the energy contained in the feed is essential not only for the functioning of animals but also for the production of animal products. On the one hand, the energy output from 1 ha of forage land is used to determine the payback of costs for growing forage crops or producing certain types of grass feed, and on the other hand, to determine the energy-intensive units of feed. Ukraine has a tendency to accelerate the development of knowledge-intensive industries in line with changes in the structure and investment policy of the state in the agricultural sector (Medvedovsky & Ivanenko, 1988).

Given the rising cost of non-renewable energy sources used for feed production, an increase in feed and livestock production is possible with the widespread introduction of energy and resource-saving technologies, unconventional and continuously renewable energy sources, which reduce energy consumption for the production of certain types of feed.

Depending on the type of livestock product, feed accounts for 50 to 80% of the cost of production, so reducing energy consumption for its production is extremely important for reducing the cost of livestock products.

It is known that feed is a source of energy obtained both through photosynthesis and the total energy consumption for its production. The effect of converting the latter type of energy into livestock products is a criterion for assessing the energy saving balance. Therefore, the criterion of economic assessment of any technological process in agricultural production should include the criterion of energy balance assessment (Kulyk, 1997).

The life of any living organism is inextricably linked with the exchange and transformation of energy. Nutrients, in particular in the form of hydrocarbons, proteins, fats, etc., play a crucial role in the metabolism and energy in the animal body. Therefore, energy analysis of feed production is extremely important. The main task of the energy analysis of agricultural production is to comply with the basic principles that provide for the rational use of non-renewable (fuels and lubricants) and renewable (solar radiation) energy, operating assets and natural resources, and the protection and improvement of the agroecological condition of soils and agrophytocenoses (Kulyk, 1997).

According to V. Kurhak (2010), the energy efficiency coefficient as a ratio of output per 1 ha of gross energy to total costs for growing perennial legumes ranged from 6-8, and the bioenergy coefficient as a ratio of output per 1 ha of metabolisable energy to total costs – 3-4. An increase in these coefficients means an increase in energy efficiency. The task is reduced to obtaining the largest yield from 1 ha of gross or exchange energy at the lowest total cost.

The purpose of the study is to determine changes in the economic and energy efficiency of growing different varieties of red clover for fodder purposes depending on the methods of sowing, seed inoculation with nodule bacteria and fertilisation.

MATERIALS AND METHODS

The research plan included laboratory, field, and production experiments that were carried out in the scientific laboratories of the Department of Feed Production, Land Reclamation, and Meteorology in Field Crop Rotation of the Agronomic Research Station, a separate subdivision of the National University of Life and Environmental Sciences of Ukraine.

The soil structure is dominated by ordinary chernozems (about 70%) and meadow chernozems (20%), with a mix of meadow chernozem and podzolised chernozems. Meadow chernozems are characterised by the content of carbonates, the line of which varies from the surface to 1.2-1.5 m depending on moisture conditions, which significantly affects the phosphate regime of the soil. Common chernozems and meadow chernozems have a high supply of nitrogen and phosphorus, and a medium to low supply of potassium (according to *Machygin*). The humus content in the arable layer is 4.4-4.6%. The research was conducted in the period 2018-2020, according to the following scheme (Table 1).

Table 1. Experiment scheme

Factor A (fertiliser)	Factor B (varieties)	Factor C (sowing method)
1. No fertilisers (control)	1. Lybid	1. Bezpokryvnyy
2. seed inoculation with nodule bacteria (background)	2. Tayfun	2. undersown spring barley

Table 1, Continued

Factor A (fertiliser)	Factor B (varieties)	Factor C (sowing method)
3. Background + $P_{60}K_{90}$	3. Tina	
4. Background + $N_{60}P_{60}K_{90}$		

The economic assessment of the studied elements of the technology for growing red clover was carried out according to the methodology for assessing the effectiveness of scientific research using technological maps at prices prevailing in 2020 (Babich & Motornyi, 1986).

The energy efficiency of the studied elements of the technology for growing red clover was estimated according to the methods of O.K. Medvedovsky and P.I. Ivanenko (1988).

The initial indicators for calculating economic efficiency are the cost of gross output received and the total cost of funds for its production. Energy analysis is based on combining all types of labour and production costs in feed production through the production equivalent, which is reflected as the amount of non-renewable energy consumed by a particular process or technology in general. The energy efficiency of the technologies was assessed by the payback of total energy inputs in terms of gross or exchangeable energy output per hectare in GJ, which are called the energy efficiency ratio (EER) and the bioenergy ratio (BER), respectively.

RESULTS AND DISCUSSION

Analysis of the data on the economic efficiency of the cultivation of different varieties of red clover under different cultivation technologies showed that the cost of gross production ranged from 27,700-38,200 UAH/ha (Table 2). Similarly, to the fodder productivity, the highest yield per 1 ha of gross production among the varieties of red clover was achieved by the Tayfun variety, which outperformed the Lybid and Tina varieties by 2,550-6,000 UAH on different fertilisation backgrounds and with different sowing methods.

Table 2. Economic efficiency of growing red clover varieties under different cultivation technologies (average for 2018-2020)

Fertilisation	Cultivar	Gross production. UAH/ha	Costs. UAH / ha	Net profit. UAH/ha	Rentability. %	Cost price per ton. UAH	
						fodder unit	crude protein
Pure sowing							
No fertilisers	Lybid	28.350	8.325	20.025	241	1.468	6.033
	Tayfun	31.900	9.025	22.875	253	1.415	5.785
	Tina	27.700	8.205	19.495	238	1.481	5.659
Inoculation (background)	Lybid	30.400	8.755	21.645	247	1.440	5.956
	Tayfun	34.100	9.495	24.605	259	1.392	5.790
	Tina	30.100	8.675	21.425	247	1.441	5.597
Background + $P_{60}K_{90}$	Lybid	31.350	14.868	16.482	111	2.371	9.470
	Tayfun	35.700	15.748	19.952	127	2.206	8.999
	Tina	31.050	14.808	16.242	110	2.385	8.975

Table 2, Continued

Fertilisation	Cultivar	Gross production. UAH/ha	Costs. UAH / ha	Net profit. UAH/ha	Rentability. %	Cost price per ton. UAH	
						fodder unit	crude protein
Background + $N_{60}P_{60}K_{90}$	Lybid	32.000	17.038	14.962	88	2.662	10.264
	Tayfun	36.050	17.838	18.662	105	2.474	9.642
	Tina	32.200	17.078	15.122	89	2.652	9.703
Undersown spring barley							
No fertilisers	Lybid	28.900	8.455	20.445	242	1.463	5.831
	Tayfun	31.450	8.956	22.494	251	1.424	5.363
	Tina	28.600	8.395	20.205	241	1.468	5.750
Inoculation (background)	Lybid	29.950	9.052	20.898	231	1.511	5.955
	Tayfun	33.500	9.757	23.743	243	1.456	5.607
	Tina	28.650	8.793	19.857	226	1.535	5.710
Background + $P_{60}K_{90}$	Lybid	31.300	14.994	16.306	109	2.395	9.458
	Tayfun	34.100	15.554	18.546	119	2.281	8.546
	Tina	31.900	15.674	16.226	104	2.457	9.616
Background + $N_{60}P_{60}K_{90}$	Lybid	32.200	17.143	15.057	88	2.662	10.265
	Tayfun	38.200	17.943	20.257	113	2.349	9.544
	Tina	33.050	17.303	15.747	91	2.618	9.944

Regardless of the variety of red clover, the highest value of gross output (32,200-38,200 UAH/ha) was obtained by inoculating seeds with nodule bacteria in combination with the introduction of $N_{60}P_{60}K_{90}$, which is 8-11% more compared to the variant without fertilisers. When seeds were inoculated with nodule bacteria in the background without fertilizers and when $P_{60}K_{90}$ was applied in the background of inoculation, the cost of gross production increased less, namely by 3-8% compared to the variant without fertilisers.

On average, over the three years of research, there was no significant difference in the cost of gross production between sowing methods.

The lowest total costs for the cultivation of different varieties of meadow clover were in the variant without fertilisation and with different sowing methods, ranging from 8,325-9,025 UAH/ha. When seeds were inoculated with nodule bacteria, compared to the variant without fertilisers, they increased by only 403-470 UAH/ha. When applied in combination with inoculation of seeds with nodule bacteria $P_{60}K_{90}$, they increased to 14,868-15,748 UAH/ha, which is 1.7-1.8 times more compared to the variant without fertilisers. The highest total costs were for inoculation of seeds with nodule bacteria in combination with $N_{60}P_{60}K_{90}$, which ranged from 17,038-17,943 UAH/ha, 1.1-1.2 times more compared to the variant of inoculation of seeds with nodule bacteria in combination with $P_{60}K_{90}$ and 2.0 times more compared to the variant without fertilisation.

The sowing method and use of grass stands did not naturally affect the total costs of growing red clover over an average of three years of research. Among the varieties, regardless of fertilizers and sowing methods, energy costs were somewhat higher for the cultivation of the Tayfun variety.

The main indicator of economic efficiency is the net profit, which in this study on cultivation under different technologies and varieties of red clover ranged from 14,962 to 23,743 UAH/ha. Among the varieties of red clover, the highest net profit was provided by Tayfun, which on different fertiliser backgrounds and with different sowing methods prevailed over Lybid and Tina varieties – by 2,049-5,200 UAH/ha.

In the cultivation of different varieties of red clover among the fertilizer variants, the highest (except for the variety Tina with undersown spring barley) net profit (19,857-24,605 UAH/ha) was obtained for inoculation of seeds with nodule bacteria, which is 1,620-1,930 UAH/ha more compared to the variant without fertilisation, 3631-5,197 UAH/ha more compared to the fertilisation of seeds with nodule bacteria $_{60}K_{90}$ and 3,486-5,841 UAH/ha more compared to inoculation of seeds with nodule bacteria in combination with the introduction of $N_{60}P_{60}K_{90.}$ With the additional application of N_{60} on the background of $P_{60}K_{90}$ for the cultivation of red clover, the net profit varied differently. In most cases, it decreased by 479-1,249 UAH/ha, and for the Tayfun variety with undersown spring barley, it increased by 1,711 UAH/ha.

The analysis of economic efficiency indicators showed that the profitability of cultivating varieties of red clover under different technologies ranged from 88-251%. Regardless of the method of sowing and variety, it was the highest in the variant without fertilisers and under inoculation of seeds with nodule bacteria with fluctuations of 226-253%, which is 2.0-2.2 times more compared to the introduction of seeds with nodule bacteria $P_{60}K_{90}$ and 2.2-2.8 times more compared to the introduction of seeds with nodule bacteria $N_{60}P_{60}K_{90}$.

Among the varieties of red clover, the highest profitability was provided by Tayfun, which on different fertiliser backgrounds and with different sowing methods prevailed over Lybid and Tina varieties – by 12-25%. According to the calculations for an average of three years of research and use of grass stands, the method of sowing did not influence the profitability of growing red clover.

Unlike profit and profitability, the cost of 1 t of feed units and crude protein had an opposite dependence on varieties and technologies of growing red clover and ranged from 1,392-2,662 UAH and 5,363-10,265 UAH, respectively. Regardless of the method of sowing and variety, it was the lowest in the variant without fertilisers and under inoculation of seeds with nodule bacteria with fluctuations of 1,392-1,535 and 5,363-10,265 UAH, respectively, which is 1.6-1.7 times less compared to the introduction of seeds with nodule bacteria $P_{60}K_{90}$ and 1.7-1.8 times more compared to the introduction of seeds with nodule bacteria $N_{60}P_{60}K_{90}$.

Among the varieties of red clover, the most cost effective was Tayfun, which was 3-12% less expensive than Lybid and Tina with different fertilisers and different sowing methods. According to the calculations for an average of three years of research and use of grass stands, the method of sowing did not influence the cost of growing red clover.

The analysis of data on the energy efficiency of cultivating different varieties of red clover for fodder purposes showed that the total energy consumption ranged from 17.6-27.7 GJ/ha (Table 3).

Table 3. The energy efficiency of growing red clover varieties under different cultivation technologies (average for 2018-2020)

Fertiliser	Cultivar	Energy costs, GJ/ha	EER	BER	Energy consumption per 1 ton of feed, GJ
Pure sowing					
No fertilisers	Lybid	17.8	8.4	4.2	3.14
	Tayfun	18.3	8.9	4.6	2.87
	Tina	17.8	8.3	4.3	3.21
Inoculation (background)	Lybid	18.5	8.5	4.4	3.04
	Tayfun	19.3	8.7	4.6	2.83
	Tina	18.5	8.5	4.3	3.07
Background + $P_{60}K_{90}$	Lybid	22.6	7.2	3.7	3.76
	Tayfun	23.4	7.4	3.9	3.28
	Tina	22.5	7.2	3.8	3.62
Background + $N_{60}P_{60}K_{90}$	Lybid	26.9	6.3	3.2	4.20
	Tayfun	27.5	6.6	3.4	3.81
	Tina	27.0	6.3	3.3	4.19
Undersown spring barley					
No fertilisers	Lybid	17.6	8.6	4.4	3.04
	Tayfun	18.0	9.0	4.6	2.86
	Tina	17.6	8.6	4.4	3.08
Inoculation (background)	Lybid	18.4	8.5	4.4	3.07
	Tayfun	19.0	8.8	4.6	2.84
	Tina	18.3	8.4	4.4	3.19
Background + $P_{60}K_{90}$	Lybid	22.6	7.1	3.7	3.61
	Tayfun	23.1	7.5	3.9	3.39
	Tina	22.7	7.4	3.7	3.52
Background + $N_{60}P_{60}K_{90}$	Lybid	27.0	6.2	3.3	4.19
	Tayfun	27.7	6.5	3.5	3.62
	Tina	27.1	6.5	3.3	4.10

Note: EER is the ratio per 1 ha of gross energy to total energy consumption. BER is the ratio per 1 ha of exchangeable energy to total energy consumption

The lowest total energy costs for the cultivation of different varieties of red clover and sowing methods were in the variant without fertilisation, which ranged from 17.6-18.3 GJ/ha. When seeds were inoculated with nodule bacteria, they increased by 0.7-1.0 GJ/ha compared to the variant without fertilisers. When applied in combination with inoculation of seeds with nodule bacteria $P_{60}K_{90}$, they increased to 22.5-23. GJ/ha, which is 1.2-1.3 times more compared to the variant without fertilisers. The highest total energy costs were for inoculation of seeds with nodule bacteria in combination with $N_{60}P_{60}K_{90}$, which ranged from 26.9-27.7 GJ/ha, being 1.1-1.2 times more compared to the variant of inoculation of seeds with nodule bacteria in combination with $P_{60}K_{90}$ and 1.5 times more compared to the variant without fertilisation.

The method of sowing did not affect the total energy consumption for the cultivation of meadow clover on average over three years of cultivation and use of grass stands.

The main indicator of energy efficiency in fodder production is the return on energy costs per hectare of gross (energy efficiency ratio) and metabolic (bioenergy ratio) energy, which in this study on cultivation under different technologies and different varieties of red clover ranged from 6.2-9.0 and 3.3-4.6, respectively. Among the varieties of red clover, the Tayfun variety provided a slightly higher return on energy inputs in terms of gross and metabolisable energy per 1 ha than the Lybid and Tina varieties.

When growing different varieties of red clover among the fertilizer variants, the highest EER and BER were obtained in the variants without fertilisation and under seed inoculation with nodule bacteria with indicators of 8.3-9.0 and 3.2-4.6, respectively, which is 1.2-1, 5 and 0.5-0.8 units more compared to the application against the background of seed inoculation with nodule bacteria $P_{60}K_{90}$ and 2.1-2.3 and 1.0-1.2 units more compared to the inoculation of seeds with nodule bacteria in combination with the application of $N_{60}P_{60}K_{90.}$ With the additional application of N_{60} on the background of $P_{60}K_{90}$ for the cultivation of red clover, the payback of energy costs per 1 ha of gross and metabolisable energy decreased by 0.8-1.0 and 0.4-0.5, respectively.

Energy consumption per 1 t of feed units under different technologies of cultivation of red clover varieties ranged from 2.84-4.20 GJ. Regardless of the method of sowing and variety, it was the lowest in the variant without fertilisers and under inoculation of seeds with nodule bacteria with fluctuations of 2.84-3.21 GJ, which is 1.2 times compared to the background of inoculation of seeds with nodule bacteria $P_{60}K_{90}$ and 1.3-1.4 times less compared to the background of inoculation of seeds with nodule bacteria $N_{60}P_{60}K_{90}$.

The lowest energy consumption per 1 ton of feed units among the varieties of meadow clover was provided by Tayfun, and on different fertilisation backgrounds and with different sowing methods it was inferior to Lybid and Tina varieties – by 0.27-0.57 GJ. According to the calculations for an average of three years of cultivation and use of grass stands, the method of sowing did not affect the energy consumption per 1 t of feed units for growing red clover.

CONCLUSIONS

The cultivation of red clover for fodder purposes on typical low-humus chernozems of the northern part of the Right-Bank Forest-Steppe of Ukraine is profitable. Regardless of the technology components, it provides a net profit of UAH 14,962-23,743 per hectare with a profitability of 88-259% and a cost of 1 ton of feed units of UAH 1,415-2,662 and raw protein of UAH 5,363-10,265, a payback of energy costs in terms of gross energy (EER) yield per hectare of 6.2-9.0 and metabolisable energy (BER) yield per hectare of 3.2-4.6, with energy costs per 1 ton of feed units of 2.86-4.20 GJ.

The best rates of economic and energy efficiency of red clover cultivation are provided by the variety Typhoon when seeds are inoculated with nodule bacteria on fertiliser-free soil. The additional application of $P_{60}K_{90}$ or $N_{60}R_{60}K_{90}$ against the background of inoculation, which is necessary to preserve soil fertility, worsens them, reducing net profit by 3,486-5,943 UAH/ha.

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Економічна та енергетична ефективність вирощування різних сортів конюшини лучної (*Trifolium pratense* L.) на корм

Анотація. Вирощування конюшини лучної на кормові цілі на чорноземах типових малогумусних північної частини Правобережного Лісостепу України є рентабельним. Незалежно від складових технології воно забезпечує отримання чистого прибутку 14 962-23 743 грн з гектара за рівня рентабельності 88-259% та собівартості 1 т кормових одиниць 1 415-2 662 грн і сирого протеїну 5 363-10 265 грн, окупність енергетичних витрат за виходом валової енергії (ВЕР) з гектара 6. 2-9,0 та виходу обмінної енергії (ОЕ) з гектара 3,2-4,6, при витратах енергії на 1 т кормових одиниць 2,86-4,20 ГДж. Метою дослідження було визначити зміни економічної та енергетичної ефективності вирощування різних сортів конюшини лучної на кормові цілі залежно від способів сівби, інокуляції насіння бульбочковими бактеріями та внесення добрив. Під час досліджень використовували такі методи: польовий і лабораторний – для проведення досліджень у польових і лабораторних умовах, аналітичний – для визначення хімічного складу сухої біомаси конюшини лучної, розрахунковий - для визначення показників економічної та енергетичної ефективності. Найкращі показники економічної та енергетичної ефективності вирощування конюшини лучної забезпечує сорт Тайфун за інокуляції насіння бульбочковими бактеріями на бездобривному ґрунті. Додаткове внесення Р60К90 або N60R60K90 на фоні інокуляції, необхідне для збереження родючості ґрунту, погіршує їх, зменшуючи чистий прибуток на 3486-5943 грн/га

Ключові слова: біоенергетичний фактор, затрати коштів та енергії, економічна та енергетична ефективність, окупність витрат, рентабельність, собівартість, чистий прибуток

Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en *Plant and Soil Science, 12(1), 28-38*

Received xx.xx.2020 Revised xx.xx.2021 Accepted xx.xx.2021

UDC 631.8:633.85

DOI: 10.31548/agr2021.01.0028

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Fertiliser Efficiency in the Formation of Sunflower Productivity

Abstract. Plant nutrition throughout the vegetation period is one of the main factors aimed at realising the genetic potential of sunflower hybrids when cultivated in all soil and climatic conditions. Currently, it is important to study the genetic potential of domestic hybrids under different growing conditions to identify their competitiveness, thus improving crop quality and yields. The use of a wide range of complex microfertilisers in production along with the main fertiliser helps to increase the efficiency of plant nutrient utilisation of mineral fertilisers and soil and is one of the ways to improve crop yields and agricultural product quality. While sunflower is considered to be a key oilseed crop, its cultivation technology is not fully researched, and previous studies often contain contradictory data. An important part of the agrotechnical measures aimed at increasing crop productivity is to ensure

Suggested Citation:
Garbar, L., Lishchuk, U., Dovbash, N., & Knap, N. (2021). Fertiliser Efficiency in the Formation of Sunflower Productivity. *Plant and Soil Science*, 12(1), 28-38. doi: 10.31548/agr2021.01.028.

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optimal plant nutrition during the vegetation period. The purpose of the study was to determine the influence of crop nutrition conditions and to select high-yielding hybrids (*NK Diamantis*, *SI Kupava*, *NK Neoma*) for specific soil and climatic conditions through the formation of their productivity. The study was conducted in 2018-2019 on typical low-humus chernozems. The research program included a three-factor field experiment in which hybrids (*factor A*), fertiliser options (*factor B*), and foliar feeding of crops (*factor C*) were studied in the phase of 4 and 8 leaves of sunflower with *Ecoline Boron*, *Nertus Boron*, and *Bast Boron*. The sunflower hybrids studied were *NK Diamantis*, *SI Kupava*, and *NK Neoma*. The research results revealed significant changes in the diameter of the sunflower inflorescence under the influence of different nutritional conditions created by fertiliser variants. The influence of hybrid features also determined this indicator. Plants of the hybrid *NK Diamantis* formed heads with diameters ranging from 17.6 to 21.2 cm, *SI Kupava* - from 18.8 to 22.1 cm, *NK Neoma* – from 17.2 to 21.6 cm. The maximum index was achieved in the variant with the introduction of $N_{36}R_{56}K_{108}S_{28}$ + N_{23} + *Ecoline Boron* (phase 4 and 8 leaves) in plants of hybrid *SI Kupava*, and it amounted to 22.1 cm. The weight of 1,000 achenes, which is one of the genetically determined traits of the crop, in plants of the hybrid *NK Diamantis*, depending on the fertiliser variant, varied from 59.3 to 62.3 g, *SI Kupava* from 69.8 to 74.0 g, *NK Neoma* from 68.8 to 72.6 g. The maximum result was provided by the variant with the use of $N_{36}R_{56}K_{108}S_{28}$ +N_{23} + *Ecoline Boron* (phase 4 and 8 leaves). Studies have shown that the most productive hybrid was *Si Kupava* with the maximum yield in the variant with the use of $N_{36}R_{56}K_{108}S_{28}$ +N_{23} + *Ecoline Boron* (in the phase of 4 and 8 leaves of 1 l/ha) – 3.46 t / ha

Keywords: sunflower, fertilisers, microelements, boron, hybrids, *Ecoline Boron*, *Nertus Boron*, *Bast Boron*, head diameter, the weight of 1,000 achenes, yield

RELEVANCE

The appeal of sunflower lies in the strategic and significant economic efficiency of its cultivation. Compared to other oilseeds, sunflower has the highest oil yield per unit area (750 kg/ha on average in Ukraine). The share of sunflower oil reaches 90% of the total oil production in Ukraine. Sunflower seed oil is characterised by the high nutritional value. It is second only to olive oil. Sunflower oil contains polyunsaturated fatty linolenic acid, phosphates, stearins, and vitamins.

Along with the increase in the area under the crop, there is a decrease in its yield. The reasons for the decline in yields are a variety of factors, the most important of which are violations of crop rotation and cultivation technologies. At the same time, the excessive use of foreign hybrids characterised by low adaptability to the conditions of Ukraine has been recognised.

Among the factors that ensure high sunflower yields are plant nutrition conditions throughout the growing season and technological measures aimed at realising the genetic potential of the crop in certain regions of Ukraine. Today, it is necessary to study in-depth the potential of hybrids and varieties for growing them in different conditions to determine their competitiveness and popularisation, which will increase the quality and yield of the crop. (Eremenko *et al.*, 2019; Eremenko *et al.*, 2018, Ieremenko & Kalitka, 2016). That is why today much attention is paid to the study of the influence of nutritional conditions on the formation of productivity of hybrids of both foreign and domestic breeding, in specific soil and climatic conditions of Ukraine (Kalenska *et al.*, 2020; Domaratskiy *et al.*, 2018).

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The registered new sunflower hybrids have a high productivity potential, however, it is only partially realised in production, as evidenced by a number of literature sources (Ieremenko *et al.* 2017; Pysarenko *et al.*, 2006; Bondarenko *et al.*, 2002;)

Elements of any crop cultivation technology are determined by the characteristics of the variety or hybrid cultivated, its agrobiological profile, which includes requirements for growing conditions, as well as data on the crop's impact on soil properties depending on the specifics of biology and agricultural technology.

In recent years, the number of sunflower hybrids listed in the State Register of Plant Varieties Suitable for Distribution in Ukraine has increased significantly. The advantage of foreign-bred seed is its ability to produce high seed productivity, but these hybrids are inferior to domestic hybrids that are resistant to a number of pathogens inherent in the climatic conditions of the sunflower growing regions of Ukraine. The productivity of sunflower hybrids and varieties is a determining factor in yield formation and depends on both their biological characteristics and meteorological conditions and the cultivation technologies used (Alves *et al.*, 2017).

The formation of reproductive organs of sunflower hybrids and varieties, in particular, the diameter of the head, the weight of 1,000 seeds, and husk level are the determining factors in the formation of seed yield and quality (Markova, 2011).

Today, auxiliary elements of cultivation technology, such as inoculation of seeds with microorganism-based preparations, foliar feeding with biological products and microfertilisers, are widely used to increase sunflower productivity. For this purpose, complex fertilisers are often used, containing a full set of nutrients necessary to create optimal plant nutrition conditions during the so-called critical periods of their growth and development (Miao *et al.*, 2015; Carvalho *et al.*, 2016; Calvo *et al.*, 2014; Domaratskyi *et al.*, 2017; Domaratsky & Dobrovolsky, 2018).

Optimisation of sunflower plant nutrition during the vegetation period contributes to the creation of optimal nutritional conditions for the crop and ensures the formation of optimal leaf surface area and maximum realisation of the genetic potential of sunflower hybrids and varieties (Kalenska *et al.*, 2020; Helmy & Ramadan, 2009; Nizamov, 2018).

The fertilisation system for growing sunflower hybrids is determined based on the specific soil and climatic conditions, the level of intended yield, agronomic and organisational factors. At the same time, sunflower plants produce significantly higher amounts of nitrogen and phosphorus than other crops.

Sunflower has a prolonged period of nutrient absorption, so it requires significantly more nutrients (especially potassium) compared to cereals.

During the vegetation period, sunflower absorbs nutrients rather unevenly. The majority of nitrogen and phosphorus is consumed before the flowering phase, and during the formation of the leaf apparatus, stems and root system. After the heads form, phosphorus uptake decreases dramatically. Potassium is absorbed by sunflower almost throughout the entire vegetation period, but most intensively before flowering.

From the stage of 3-4 pairs of leaves to the flowering stage, plants use 70-80% of nitrogen. The lack of nitrogen during head formation has a negative effect. Excess nitrogen leads to excessive vegetative growth but reduces the fat content of the seeds.

Different nutrients affect growth, development, crop formation, and product quality differently. Thus, nitrogen enhances growth processes and promotes the formation of larger plants and heads. However, excessive nitrogen nutrition prolongs the vegetation, negatively affects the processes of oil accumulation in seeds, as the protein content in the seeds increases, and the oil content decreases sharply. Excessive nitrogen levels increase the risk of plant lodging and pathogen damage (phomopsis, white rot, etc.) (Vozhehova *et al.*, 2013; Tkalich, 2016, Shakaliy, 2017).

Phosphorus is absorbed by the plant from germination to flowering. It accumulates before flowering in the stem and leaves, then moves to the heads and eventually to the achenes. Plants absorb 60-70% of the total phosphorus required during the period of head formation – the end of flowering. Lack of phosphorus negatively affects the formation and filling of achenes and limits sunflower productivity. A sufficient amount of phosphorus increases the drought resistance of plants and the oil content of seeds. Phosphorus contributes to the formation of a powerful root system, the laying of reproductive organs with a large number of rudimentary flowers in the head. It is important to provide plants with phosphorus in the initial stages of organogenesis from seed germination to 3-4 pairs of true leaves. With sufficient phosphorus nutrition, the development of plants is accelerated, and there is a more rational consumption of moisture, as a result of which they can withstand dry winds and soil moisture deficit. With increased phosphorus nutrition, the coefficient of water consumption by sunflower plants sharply decreases (Buldykova *et al.*, 2015; Yeremenko *et al.*, 2017).

The purpose of the study was to identify the influence of the factors studied on the formation of productivity elements of sunflower hybrids.

MATERIALS AND METHODS

The study was conducted in 2018-2019 in the Chernihiv Oblast on typical low-humus chernozems. According to the set objective, a study plan and a field experiment programme were developed (Table 1). The design of the experiment involved the study of hybrids (*factor A*), fertiliser options (*factor B*) and the use of foliar fertilisation of crops (*factor C*) in the phase of 4 and 8 leaves of sunflower.

Table 1. Formation of sunflower productivity elements under the influence of nutritional parameters (experimental scheme)

Hybrids (*factor A*)/variant designation	Fertilisation variants (*factor B*)/variant designation	Foliar fertilisation (*factor C*)/variant 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*

Ecoline Boron Organic micronutrient fertiliser (nitrogen (N-NH_2) – 6.5%; boron (*B*) – 15.5%) is a concentrated liquid boron fertiliser intended for foliar feeding of crops requiring boron supply, containing boron in the form of an organic compound. The application of the fertiliser during critical periods of plant development contributes to stress resistance, cold resistance of plants, provides regulation of the flowering process and improves the quality of the crop. The rate of foliar fertilisation is 1-2 l/ha.

Hertus Boron microfertiliser (150 g/l (boron-ethanolamine) helps to increase yields and resistance to stresses, bacterial damage, reduces the risk of fruit and root rot, is compatible with most pesticides without reducing their effectiveness in mixtures. The rate of foliar fertilisation is 1-5 l/ha.

BAST Boron (B (200 g/l); N (70 g/l)) quickly eliminates boron deficiency, stimulates the formation and development of growth points, leaves, flowers, fertilisation, and fruit formation, provides drought resistance of crops, prevents diseases resulting from boron deficiency, increases yields and improves product quality. The rate of foliar fertilisation is 1-2 l/ha.

The accounting area is 50 m^2 with four repetitions. The location of the plots is systematic (Ermantraut *et al.*, 2014; Rozhkov *et al.*, 2016).

The seeding rate is 50,000 germinating seeds/ha. Fertilisers $N_{27}R_{42}K_{81}S_{21}$ and $N_{36}R_{56}K_{108}S_{28}$ were introduced into pre-sowing cultivation, N_{23} in the form of urea was applied during sowing. Fertilisation was performed twice foliarly with *Ecoline Boron*, *Nertus Boron*, *Bast Boron* in the phase of 4 and 8 leaves at 1 litre/ha. The weight of 1,000 seeds was determined in accordance with DSTU 4138-2002, the yield was determined by the accounting method, and the statistical processing of the data was performed using SAS 9.4.

RESULTS AND DISCUSSION

The research program included investigating the influence of the factors under study on the formation of productivity elements of sunflower hybrids. The results obtained show that structural analysis of sunflower generative organs allows for a better understanding of the structure of yield formation and the identification of indicators that are crucial for achieving a particular level of yield. To complete these analyses, the following parameters were determined: head diameter, number of heads per unit area, weight of 1,000 seeds.

The diameter of the sunflower head is an important indicator for sunflower, which varies widely depending on the growing conditions. According to previous studies, on 5 linear meters of a row on with 18-20 plants, the diameter of the plant head can vary from 10-12 to 20-24 cm.

When determining the number of achenes in the head, the scientists consider the total number of seeds and the number of performed seeds among them.

There were significant changes in the diameter of sunflower inflorescence under the influence of different nutritional conditions created by fertiliser variants. Notably, there was a significant difference between the hybrids. Thus, plants of the hybrid *NK Diamantis* formed heads whose diameter, depending on the fertiliser varied from 17.6 to 21.2 cm, *SI Kupava* – from 18.8 to 22.1 cm, *NK Neoma* – from 17.2 to 21.6 cm (Table 2).

Table 2. Sunflower hybrid head diameter, cm (average for 2018-2019)

Fertiliser variant	Hybrid		
	NK Diamantis	SI Kupava	NK Neoma
$N_{27}R_{42}K_{81}S_{21}$+N_{23} (background 1)	17.6	18.8	17.2
$N_{36}R_{56}K_{108}S_{28}$ +N_{23}(background 2)	19.9	21.3	20.7
Background 1 + Ecoline Boron (5-6 leaves)	19.9	20.7	20.1
Background 1 + Nertus Boron (5-6 leaves)	18.4	19.3	18.5
Background 1+ Bast Boron (5-6 leaves)	20.3	20.5	21.0
Background 2 + Ecoline Boron (5-6 leaves)	21.2	22.1	21.6
Background 2 + Nertus Boron (5-6 leaves)	19.6	21.6	20.9
Background 2 + Bast Boron (5-6 leaves)	20.7	21.7	21.3

The maximum index was achieved in the variant with the introduction of $N_{36}P_{56}K_{108}S_{28}$ +N_{23} +N23 + *Ecoline Boron* (phase 4 and 8 leaves) in plants of hybrid *SI Kupava*, and it amounted to 22.1 cm. The weight of 1,000 seeds is a genetically determined trait, but the response rate of this indicator is significant. Analysis of the results showed that in plants of the hybrid *NK Diamantis*, the weight of 1,000 seeds, depending on the fertilisation, varied from 59.3 to 62.3 g, *SI Kupava* – from 69.8 to 74.0 g, *NK Neoma* – from 68.8 to 72.6 g (Table 3).

Table 3. Weight of 1,000 seeds of sunflower hybrids, g (average for 2018-2019)

Fertiliser variant	Hybrid		
	NC Diamantis	SI Kupava	NK Neoma
$N_{27}R_{42}K_{81}S_{21}$+N_{23} (background 1)	59.3	69.8	68.8
$N_{36}P_{56}K_{108}S_{28}$+$N_{23}$(background 2)	61.0	72.8	71.4
Background 1 + Ecoline Boron (5-6 leaves)	61.8	72.2	71.9
Background 1 + Nertus Boron (5-6 leaves)	59.6	70.2	69.1
Background 1+ Bast Boron (5-6 leaves)	61.2	71.0	71.3
Background 2 + Ecoline Boron (5-6 leaves)	62.3	74.0	72.6
Background 2 + Nertus Boron (5-6 leaves)	61.4	73.1	71.6
Background 2 + Bast Boron (5-6 leaves)	61.7	73.4	72.1

The maximum index was achieved in the variant with the introduction of $N_{36}P_{56}K_{108}S_{28}$ +N_{23} +N23 +N23 + *Ecoline Boron* (phase 4 and 8 leaves) in plants of hybrid *SI Kupava*, and it amounted to 22.1 cm.

The yield of seeds from sunflower heads differed only slightly under the influence of the factors studied. According to the study results, the average seed yield for the variants of the hybrid *NK Diamantis* was 72.0%, the hybrid *SI Kupava* – 74.3%, *NK Neoma* – 73.2%. At the same time, the indicators varied within the limits: *NK Diamantis* – from 69.7 to 73.4%, *SI Kupava* – 72.6-75.7%, *NK Neoma* – 71.0-75.0% (Table 4).

Table 4. Seed yield per head, % (average for 2018-2019)

Fertiliser variant	Hybrid		
	NC Diamantis	SI Kupava	NK Neoma
$N_{27}R_{42}K_{81}S_{21}$+N_{23} (background 1)	69.7	72.6	71.0
$N_{36}P_{56}K_{108}S_{28}$+$N_{23}$(background 2)	72.3	74.4	74.0
Background 1 + Ecoline Boron (5-6 leaves)	72.8	74.8	73.2
Background 1 + Nertus Boron (5-6 leaves)	70.1	72.8	71.4
Background 1+ Bast Boron (5-6 leaves)	72.1	74.0	72.3
Background 2 + Ecoline Boron (5-6 leaves)	73.7	75.7	75.0
Background 2 + Nertus Boron (5-6 leaves)	72.4	74.7	74.3
Background 2 + Bast Boron (5-6 leaves)	73.1	75.1	74.6

Analysis of the huskiness of sunflower achenes showed that the lowest values were in hybrid *SI Kupava*, which varied from 20.2 to 21.9% under different nutritional conditions. There was no clear correlation between the fertiliser variants.

The main task of cultivation technology is to provide the most favourable regulated factors during the growth and development of plants while ensuring the rational use of materials and funds.

It is worth noting that providing sunflower plants with the necessary nutrients (macro- and micro-nutrients) throughout the growing season allows for an increase in crop productivity, but at the same time, production costs increase significantly.

The level of the yield of hybrids in the experiment was affected by the weather conditions of the year of research, morphobiological characteristics of the hybrids that were subject to the study and nutritional conditions formed by fertiliser variants (Fig. 1).

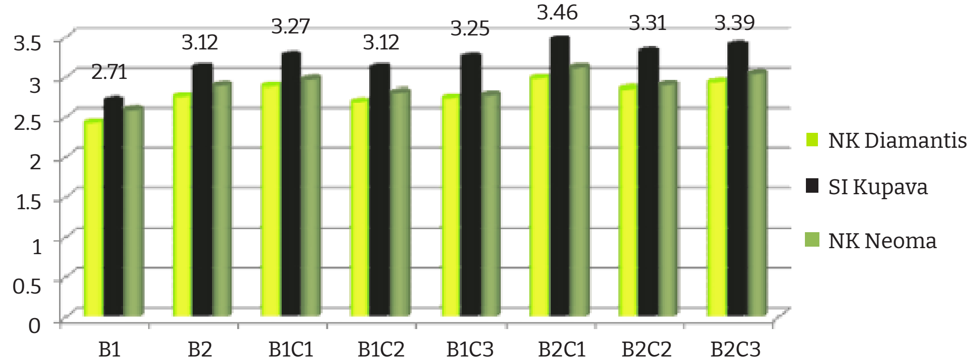

Figure 1. Yield of sunflower hybrids, t/ha

Note: LSD^{05} A = 0.27; B = 0.14; C = 0.11; ABC = NN0.39

The study results showed that in the variants without fertilisation, the yield of the hybrid *NK Diamantis* varied 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.

Foliar fertilisation in combination with the basic microelement fertilisation contributed to yield increase compared to the basic fertiliser variants in the range from 0.46 to 0.56 t/ha in 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* (Fig. 1).

The most productive hybrid was *SI Kupava* with the maximum yield in the variant with the application of $N_{36}P_{56}K_{108}S_{28}$ +N_{23} + N23 + *Ecoline Boron* – 3.46 t/ha.

The correlation analysis allowed to establish a close correlation between the weight of 1,000 achenes of sunflower hybrids and the yield of sunflower hybrids. The correlation coefficient varied depending on the fertiliser variant from 0.845 to 0.943.

The weather conditions during the vegetation period in 2018 proved to be more favourable for the cultivation of the sunflower hybrids studied.

CONCLUSIONS

The findings of the research showed that the use of *Ecoline Boron*, *Nertus Boron*, and *Bast Boron* twice in fertilisation at the initial stages of plant growth and development (phase 4 and 8 leaves) of sunflower hybrids in combination with the basic fertiliser provided favourable conditions for the formation of hybrid productivity elements and contributed to an increase in yield. The maximum effect from the application of fertilisers was obtained by applying $N_{36}P_{56}K_{108}S_{28}$ +N_{23} + N23 and foliar fertilisation with *Ecoline Boron* in plants of the *SI Kupava* hybrid, resulting in the formation of heads with a diameter of 22.1 cm and a weight of 1,000 achenes of 74 g.

The influence of unregulated environmental factors and factors studied contributed to the formation of the yield of the hybrid *SI Kupava* in the variant with the use of $N_{36}P_{56}K_{108}S_{28}$ + N_{23} + N23 and foliar feeding with *Ecoline Boron* (phase 4 and 8 leaves (0.1 l / ha)) with an output of 3.46 t/ha.

The study revealed a close correlation between the weight of 1,000 cotyledons and crop yield, which varied from 0.845 to 0.943 depending on the factors of the experiment.

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Ефективність добрив у формуванні продуктивності соняшнику

Анотація. Живлення рослин протягом усього періоду вегетації є одним з основних факторів, спрямованих на реалізацію генетичного потенціалу гібридів соняшнику при вирощуванні в будь-яких ґрунтово-кліматичних умовах. Наразі актуальним є вивчення генетичного потенціалу вітчизняних гібридів за різних умов вирощування з метою виявлення їх конкурентоспроможності, що дасть змогу підвищити якість продукції та врожайність. Використання широкого спектру комплексних мікродобрив у виробництві разом з основним добривом сприяє підвищенню ефективності використання рослинами поживних речовин мінеральних добрив та ґрунту і є одним із шляхів підвищення врожайності та якості сільськогосподарської продукції. Хоча соняшник вважається однією з ключових олійних культур, технологія його вирощування не є повністю вивченою, а попередні дослідження часто містять суперечливі дані. Важливою частиною агротехнічних заходів, спрямованих на підвищення продуктивності культури, є забезпечення оптимального живлення рослин протягом вегетації. Метою дослідження було визначення впливу умов живлення рослин та добір високоврожайних гібридів (НК Діамантіс, СІ Купава, НК Неома) для конкретних ґрунтово-кліматичних умов через формування їх продуктивності. Дослідження проводили у 2018-2019 роках на чорноземах типових малогумусних. Програма досліджень включала трифакторний польовий дослід, в якому вивчали гібриди (фактор А), варіанти удобрення (фактор В) та позакореневе підживлення посівів (фактор С) у фазі 4 та 8 листків соняшнику препаратами Еколайн Бор, Нертус Бор та Баст Бор. Досліджували гібриди соняшнику НК Діамантіс, СІ Купава та НК Неома. Результати досліджень виявили суттєві зміни діаметра суцвіття соняшнику під впливом різних умов живлення, створених варіантами удобрення. Вплив гібридних особливостей також визначав цей показник. Рослини гібриду НК Діамант формували головки діаметром від 17,6 до 21,2 см, СІ Купава – від 18,8 до 22,1 см, НК Неома – від 17,2 до 21,6 см. Максимального показника було досягнуто у варіанті з внесенням N36R56K108S28 + N23 + Еколайн Бор (фаза 4 і 8 листків) у рослин гібрида СІ Купава, і він становив 22,1 см. Маса 1000 сім'янок, яка є однією з генетично детермінованих ознак врожаю, у рослин гібрида НК Діамантіс залежно від варіанту удобрення варіювала від 59,3 до 62,3 г, СІ Купава - від 69,8 до 74,0 г, НК Неома - від 68,8 до 72,6 г. Максимальний результат забезпечив варіант із застосуванням N36R56K108S28 + N23 + Еколайн Бор (фаза 4 і 8 листків). Дослідження показали, що найбільш продуктивним виявився гібрид Сі Купава з максимальною врожайністю у варіанті із застосуванням N36R56K108S28 + N23 + Еколайн Бор (у фазу 4 та 8 листків по 1 л/га) – 3,46 т/га

Ключові слова: соняшник, добрива, мікроелементи, бор, гібриди, Еколайн Бор, Нертус Бор, Баст Бор, діаметр кошика, маса 1000 сім'янок, урожайність

Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en
Plant and Soil Science, 12(1), 39-49
Received xx.xx.2020 Revised xx.xx.2021Accepted xx.xx.2021

UDC 633.85.00313:631.8 (477.44)

DOI: 10.31548/agr2021.01.0039

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The Efficiency of Fertilisation in the Cultivation of High Oleic Sunflower on Typical Low Humus Chernozems

Abstract. The cultivation of high oleic sunflower hybrids is very promising as sunflower is highly competitive on the international market and has a growing demand for oil as the main product of its processing. Despite the significance of sunflower as one of Ukraine's traditional crops, its cultivation technology still has many unresolved issues. Among the elements of cultivation technology aimed at increasing crop yields, research with high-oleic hybrids is of particular importance, as it requires studying the level of mineral nutrition and the need for sulfur application, considering their impact on the oleic acid content. The purpose of the study is to determine the effect of sulfur at different rates of mineral fertilisers on the formation of productivity of high-oleic sunflower plants on typical low-humus chernozems of the Right-Bank Forest-Steppe of Ukraine. The research programme envisaged the establishment of a field trial in 2015-2017. The research was conducted in the form of a two-factor field experiment. The experimental program provides for the study of the following factors: factor A – mineral fertiliser application rates, factor B – sulfur application. The study was conducted using generally accepted methods for scientific research in crop production. The study revealed that the maximum amount of dry matter was accumulated in the variants with the introduction of $N_{90}R_{75}K_{135}+S_{30}$ and $N_{120}R_{100}K_{180}+S_{30}$. The addition of sulfur increases the dry matter yield from 5.69% to 9.27%. The highest yield of sunflower seeds is formed by applying $N_{90}R_{75}K_{135}+S_{30}$ -4.12 t/ha. A further increase in the rate of application of mineral fertilisers does not lead to a significant increase in yield. The introduction of S_{30} in combination with $N_{90}R_{75}K_{135}$ allows increasing the yield of sunflower seeds by 0.35 t/ha or 9.28%. The correlation and regression analysis of the obtained research results shows a close correlation between the accumulation of dry matter mass in BBCH55-57 and BBCH 65-67 and the level of yield (respectively $r = 0.917$ and $r = 0.972$). The highest fat content in seeds (49.7%) with the

Suggested Citation:
Yunyk, A. (2021). The efficiency of fertilisation in the cultivation of high oleic sunflower on typical low humus chernozems. *Plant and Soil Science*, 12(1), 39-49. doi: 10.31548/agr2021.01.039.

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highest oleic acid content (88.5%) and the maximum oil yield (2.05 t/ha) is provided by the cultivation of the ES Romantic hybrid with the introduction of $N_{90}R_{75}K_{135}+S_{30}$

Keywords: oilseeds, hybrids, mineral nutrition, mineral fertiliser application rates, dry matter, yield

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The share of foreign-bred hybrids in Ukraine is 60-70%. In addition to high productivity, foreign hybrids also have high quality indices, which are best manifested in the environments where they were produced. In the harsh soil and climatic, agronomic, and extreme weather conditions of Ukraine, they may not have advantages over domestic varieties. Therefore, it is important to consider their bioadaptability and disease resistance. Adaptation of sunflower hybrids to different soil and climatic conditions in view of constant climate change should be based on a detailed analysis of the response to changing conditions and crop cultivation technology. Sunflower is a culture of moderate climate zone and is quite flexible to weather and soil changes (Yeremenko *et al.*, 2018; Chutamard *et al.*, 2011). The introduction of hybrids with high yield potential into production is complicated by the issue of ecological adaptation: the potential of the cultivation zone cannot rise in proportion to the growth of the genetic potential of hybrids (Calamai *et al*, 2018; Canavar *et al.*, 2010). The adaptability of hybrids is an extremely important feature due to variable abiotic and biotic environmental factors (Gonzáles *et al.*, 2013). Sunflower is characterised by high adaptability (Debaeke *et al.*, 2017).

Sunflower reacts intensively to changes in mineral nutrition, and therefore it is important to regulate it by applying mineral fertilisers. This agricultural measure maximises the impact on plant growth and development, which subsequently affects the yield (Kokovikhin *et al.*, 2015). An optimally formed sunflower agrocenosis contributes to the formation of high-quality seeds (Nel *et al.*, 2000) It is the formation of an agrocenosis with optimal plant density and optimal supply of nutrients that ensures the growth of its productivity (Gholinezhad *et al.*, 2009).

Morphological features of a plant are varietal characteristics, but they can change under the influence of environmental factors and growing technologies (Ion *et al.*, 2015). The application of nitrogen fertilisers increased the yield of sunflower hybrids and the diameter of the baskets (Ahmad *et al.*, 2017). The growth of leaf surface area and photosynthesis processes in them largely depend on the influence of different rates of mineral fertilisers (Yeremenko, 2017; Nizamov, 2018).

Sunflower responds positively to nutrients and soil cultivation. Thus, the efficiency of different tillage and fertilisation systems was studied in field experiments at the Institute of Oilseeds of the National Academy of Agrarian Sciences of Ukraine in Zaporizhzhia Oblast. The largest weight of 1000 seeds were formed under the classical tillage system and depended on fertiliser: control – 50.0-50.6, with N_{40} – 51.5-51.8, $N_{40}P_{60}$ – 51.9-52.3, $N_{60}P_{60}K_{60}$ – 52.4-52.7 g. The highest yield in the hybrid Ratnyk (3.34 t/ha) was observed when cultivated with the introduction of $N_{60}P_{60}K_{60}$ for pre-sowing cultivation and treatment of crops in the phase of 6-8 pairs of true leaves with a mixture of 'Rost-kontsentrat' and 'Khelatyn oliyni' (Polyakov *et al.*, 2017).

Sunflower is a highly sulfur-sensitive crop. A feature of the crop's mineral nutrition is its higher sulfur intake: three times higher than that of cereals, which make up almost 50% of rapeseed's needs. Sulphur plays an important role in plant nutrition and is one of the nine elements necessary for plant nutrition (Hayfa *et al.*, 2003). In cells, it performs the following biological functions: energetic, structural (as part of proteins, carbohydrates, lipids, etc.), catalytic (in the active centre of enzymes, a component of cofactors), redox (balance in the cell), initiating (during cell division), and growth (in the polypeptide chain during protein synthesis). Sulphur is actively consumed by cultivated plants in the biological cycle and is alienated from the harvest. Sufficient sulfur nutrition increases the resistance of plants to low temperatures, drought, diseases, and soil salinity. In old leaves, it is highly labile and is a source of a certain amount of mobile sulfur for the meristems of young leaves and roots, which are in greater need of it and actively dividing (Shevyakova, 1979). With sulfur starvation, the leaves do not die off, although their colour becomes paler.

Studies have also shown that sulfur-containing fertilisers contributed to a more intensive supply of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur and a number of trace elements to corn, sugar beet, potato and rapeseed plants (Bloem *et al.*, 2002).

The purpose of the study is to determine the sulfur influence on the formation of high-oleic sunflower plant productivity on typical low-humus black soils of the Right-Bank Forest-Steppe of Ukraine at different rates of mineral fertiliser application.

MATERIALS AND METHODS

The study was conducted in an 8-seed stationary grain-tilled crop rotation of the Department of Plant Production at the Agronomic Research Station of the National University of Life and Environmental Sciences of Ukraine and in the analytical research laboratory of the Department of Plant Production in 2015-2017. The soils of the experimental field are typical low-humus medium loamy chernozems with a humus content of 4.38-4.53% in the topsoil and a pH of 6.9-7.3 in the salt extract.

The research station is located in the Kyiv Oblast. The annual precipitation is 543 mm. Their distribution by vegetation period and intensity is uneven. In 2015 and 2017, there were some deviations of the main weather indicators from the long-term average, while in 2016 they were close to the long-term average and the most favourable for crop growth and development. The weather conditions in 2015 showed certain unique characteristics: the amount of precipitation at the beginning of the growing season was below the long-term average. While the deficit was compensated for at the beginning of the growing season through soil moisture use, the June drought was complicated by high temperatures. The moisture deficit in the first half of the 2017 growing season was accompanied by severe frosts in the third decade of April.

The study programme envisaged a two-factor field experiment in 2015-2017. The following factors were to be studied: factor A – mineral fertiliser application rates, factor B – sulfur application (Table 1). Fertiliser application rates were calculated using the balance method for the planned yield, considering the content of the main mineral nutrients in the soil.

The subject of the study was a hybrid of high leucine sunflower ES Romantic (applicant

Euralis Semences Ukraine LLC), which is resistant to broomrape races A-G. Ripening group: mid-early. Development type: moderately intensive. Plant height: 165-175 cm, head diameter: 22-24 cm, head inclination: semi-raised. Fat content: 49-50%, oleic acid content: 88-89%.

Table 1. Efficiency of fertiliser application for sunflower cultivation (experimental scheme)

Fertiliser application rates (factor A) / variant designation	Fertiliser application rates (factor A) / variant indication
1. $N_{60}R_{50}K_{90}$ (control)	1. $N_{60}R_{50}K_{90}$ + S_{30}
2. $N_{90}R_{75}K_{135}$	2. $N_{90}R_{75}K_{135}$ + S_{30}
3. $N_{120}R_{100}K_{180}$	3. $N_{120}R_{100}K_{180}$ + S_{30}

The cultivation technology is standard for the Forest-Steppe zone, except for the elements under study. Phosphorus and potassium fertilisers were applied for basic tillage, nitrogen fertilisers were applied in fractions: part for basic tillage, the rest for pre-sowing cultivation; sulfur was applied in the form of ammonium sulfate ($(NH_4)_2SO_4$) for pre-sowing cultivation.

The area of the sample plot is 50 m^2, the repetition rate is four times, and the placement of variants is sequential. The research was conducted using generally accepted methods of scientific research in agronomy (Rozhkov, 2016).

RESULTS AND DISCUSSION

The study of the dynamics of dry matter accumulation depending on the mineral nutrition system of sunflowers is of considerable scientific and practical interest. Dry matter is closely related to varietal characteristics and mineral fertiliser application rates (Fig. 1). The dry matter content of plants was determined by the main stages of growth and development of sunflower plants.

The level of fulfilment of the biological potential of varieties and hybrids depends on the climatic conditions of a particular year, cultivation technology and their interaction (Kalenska *et al.*, 2010, Ion *et al.*, 2013; Mijic *et al.*, 2020), which is confirmed by the results of this research: the accumulation of dry matter is uneven and depends on the factors studied.

The dry matter content of microstages of BBCH 15-17 (rosette phase) ranged from 54.4 g/m^2 in the control variant to 62.9 g/m^2 when $N_{120}R_{100}K_{180}$+S_{30} was applied. At the beginning of the growing season, this indicator was significantly influenced by the rates of mineral fertilisers, while sulfur input had no significant effect. During the period BBCH 15-17-BBCH 55-57, due to the active growth and development of plants, the dry matter content increased by more than 4 times and was the highest in the variant with the introduction of $N_{120}R_{100}K_{180}$+S_{30}. In the microstages of BBCH 55-57 (budding phase), it is noted that sulfur affects the accumulation of dry matter in variants with increased rates of mineral fertilisers.

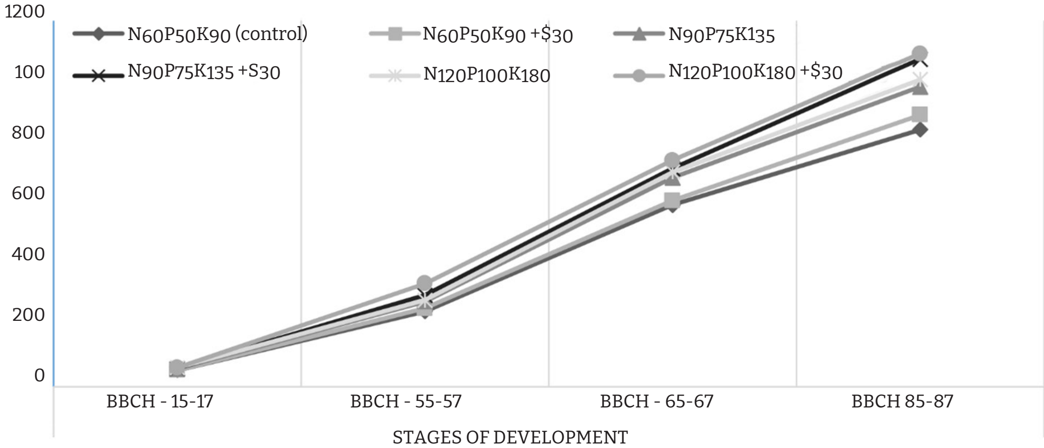

Figure 1. Dynamics of dry matter accumulation by sunflower plants, g/m2 (average for 2015-2017)
Note: LSD_{05} BBCH – 15–17=0,28; BBCH – 55–57=18.7; BBCH – 65–67=25.4; BBCH – 85–87=37.4

In the later phases (period of BBCH 65-67 – BBCH 85-88), more intensive accumulation of dry matter occurs in variants with the introduction of $N_{90}R_{75}K_{135}+S_{30}$ and $N_{120}R_{100}K_{180}+S_{30}$. In the microstages of BBCH 85-88 (ripening phase, seed moisture content of 15%), the difference between the variants with the maximum mineral fertilisation is not significant, which is explained by the extended performance of leaves when $N_{90}R_{75}K_{135}+S_{30}$ was applied, less affected by diseases.

Thus, the introduction of sulfur increases the accumulation of dry matter by sunflower crops from 5.69% in the control variant to 9.27% – with the introduction of $N_{90}R_{75}K_{135}$.

The yield level is determined by a set of zonal agrotechnological measures and weather conditions. A number of scientific studies have shown that the interaction of hybrid-fertiliser factors has the greatest impact on yields as new hybrids are introduced and put into production. Moreover, intensive hybrids require more nutrients to generate high yields, and in some years, especially with a water consumption factor of more than 1, the share of fertiliser influence increases to 60%. However, these studies were conducted with linoleic hybrids with a linoleic acid content of 55-60%. Therefore, research on high-oleic hybrids requires studying the level of mineral nutrition, the need for sulfur application, based on their impact on the content of oleic acid. The results of this study demonstrate that weather conditions have a significant impact on sunflower yields (Table 2). Thus, for all variants of the experiment, the highest yield was obtained in 2016, which was the most common in terms of multi-year indicators, and the lowest in 2017.

Table 2. Sunflower yield, t/ha

Fertilisation variants	Years			The average for 2015-2017
	2015	2016	2017	
$N_{60}R_{50}K_{90}$ (control)	3.15	3.45	3.11	3.24
$N_{60}R_{50}K_{90}$+S_{30}	3.38	3.73	3.31	3.47
$N_{90}R_{75}K_{135}$	3.69	4.11	3.52	3.77
$N_{90}R_{75}K_{135}$+S_{30}	4.03	4.55	3.79	4.12
$N_{120}R_{100}K_{180}$	3.81	4.38	3.64	3.94
$N_{120}R_{100}K_{180}$+S_{30}	4.04	4.7	3.83	4.19
$LSD_{0.05}$	0.16	0.18	0.15	

It was revealed that sunflower yield is determined by the level of mineral nutrition. On average, over 3 years of research, when $N_{60}P_{50}K_{90}$ (control) was applied, the seed yield was the lowest and amounted to 3.24 t/ha. The application of mineral fertilisers at the rate of $N_{90}P_{75}K_{135}$ increased the yield of sunflower compared to the control variant by 0.53 t/ha or 16.4%. With an increase in the application rate to $N_{120}P_{100}K_{180}$, the seed yield increases to 3.94 t/ha (+0.7 t/ha (+21.6%) compared to the control).

The highest seed yield was obtained by applying $N_{90}R_{75}K_{135}$+S_{30} and amounted to 4.12 t/ha. A further increase in the rate of application of mineral fertilisers does not lead to a significant increase in yield. The introduction of S_{30} in combination with $N_{90}R_{75}K_{135}$ allows increasing the yield of sunflower seeds by 0.35 t/ha or 9.28%.

Thus, based on the findings, it can be argued that the introduction of S_{30} on the background of $N_{90}P_{75}K_{135}$ provides optimal conditions for the formation of the crop when growing a high-oleic sunflower hybrid ES Romantic. The correlation and regression analysis of the obtained research results shows a close correlation between the accumulation of dry matter in 55-57 BBCH and the level of yield (r = 0.917) (Fig. 2). A closer direct correlation between the mass of dry matter and yield was noted in BBCH 65-67 (r = 0,972).

The dependencies obtained can be described by regression equations: Yield, t/ha = .80370 + 0.01051 X dry matter weight, g/m^2 (BBCH – 55-57); yield, t/ha = -0.7319 + 0.00674 X dry matter weight, g/m^2 (BBCH – 65-67).

Various factors determine the fat content of seeds. The main ones are the genetic characteristics of hybrids and mineral application rates, which are confirmed by the findings of this study (Table 3). Analysis of the fertilisation rates' influence on the fat content of seeds, revealed that the highest values (49.7%) were in the variant with $N_{90}R_{75}K_{135}$+S_{30}. The minimum amount of fat (46.2%) was observed in the $N_{120}R_{100}K_{180}$ variant, which is associated with excess nitrogen, which leads to an increase in the protein content in the nucleus as there is an inverse correlation between the protein and fat content in the kernel.

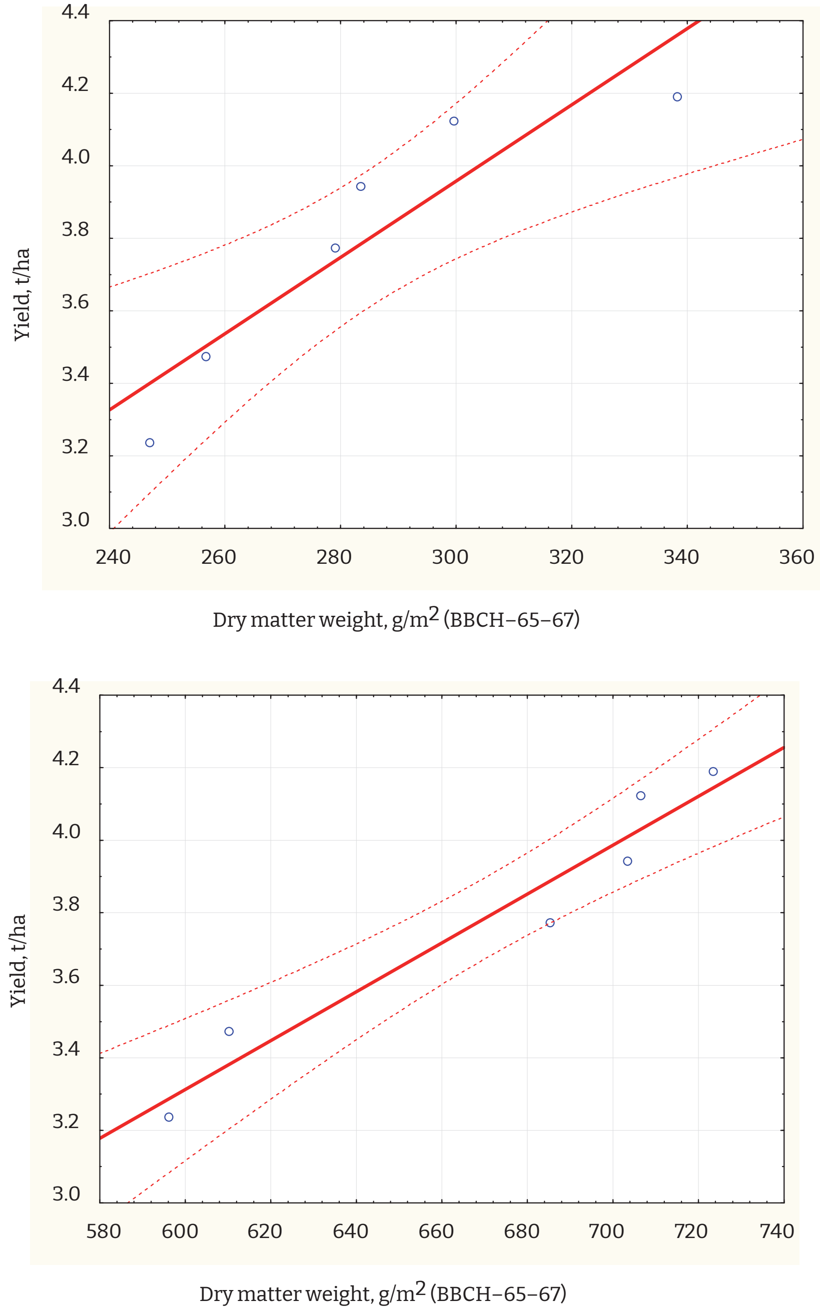

Figure 2. Correlation between yield (y) and dry matter weight (X) of sunflower seeds in microstages BBCH 55-57 and BBCH 65-67 (Average for 2015-2017)

Table 3. Oil quality indicators and yield (average for 2015-2017)

Fertiliser variant	Quality indicators		
	fat content, %	oleic acid content, %	oil yield, t/ha
$N_{60}R_{50}K_{90}$ (control)	47.3	85.6	1.53
$N_{60}R_{50}K_{90}+S_{30}$	48.8	86.7	1.69
$N_{90}R_{75}K_{135}$	48.1	87.3	1.81
$N_{90}R_{75}K_{135}+S_{30}$	49.7	88.5	2.05
$N_{120}R_{100}K_{180}$	46.2	83.4	1.82
$N_{120}R_{100}K_{180}+S_{30}$	47.2	85.1	1.98
$LSD_{0.05}$	1.4	3.3	

Excess nitrogen affects the content of oleic acid, leading to its reduction, which is undesirable for high-oleic hybrids. The lowest content of oleic acid was observed in the variant $N_{120}R_{100}K_{180}$ – 83.4% against 87.3% when $N_{90}R_{75}K_{135}$ was applied. All fertiliser variants with sulfur application showed a tendency to increase the content of oleic acid. However, on average over 3 years, this difference was within the margin of error.

The studies conducted show that, in general, the fertiliser variants under study provide a high yield of oil per unit area. However, the highest oil yield is provided by the cultivation of the ES Romantic hybrid with the introduction of $N_{90}R_{75}K_{135}+S_{30}$ and is 2.05 t/ha, which is more than 0.52 t/ha compared to the control variant.

CONCLUSIONS AND PROSPECTS

The study revealed that the maximum amount of dry matter was accumulated in the variants with the introduction of $N_{90}P_{75}K_{135}+S_{30}$ and $N_{120}P_{100}K_{180}+S_{30}$. The addition of sulfur contributes to an increase in dry matter weight from 5.69% to 9.27%.

The highest yield of sunflower seeds is formed by applying $N_{90}R_{75}K_{135}+S_{30}$ – 4.12 t/ha. A further increase in the rate of application of mineral fertilisers does not lead to a significant increase in yield. The introduction of S_{30} in combination with $N_{90}R_{75}K_{135}$ allows increasing the yield of sunflower seeds by 0.35 t/ha or 9.28%.

The correlation and regression analysis of the obtained research results shows a close correlation between the accumulation of dry matter mass in BBCH55-57 and BBCH 65-67 and the level of yield (respectively $r = 0.917$ and $r = 0.972$).

The highest fat content in seeds (49.7%) with the highest oleic acid content (88.5%) and the maximum oil yield (2.05 t/ha) is provided by the cultivation of the ES Romantic hybrid with the introduction of $N_{90}P_{75}K_{135}+S_{30}$.

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Ефективність добрив при вирощуванні високоолеїнового соняшнику на чорноземах типових малогумусних

Анотація. Вирощування високоолеїнових гібридів соняшнику є дуже перспективним, оскільки соняшник є висококонкурентним на міжнародному ринку та має зростаючий попит на олію як основний продукт його переробки. Незважаючи на важливість соняшнику як однієї з традиційних культур в Україні, технологія його вирощування все ще має багато невирішених питань. Серед елементів технології вирощування, спрямованих на підвищення врожайності культури, особливого значення набувають дослідження з високоолеїновими гібридами, оскільки вони потребують вивчення рівня мінерального живлення та потреби у внесенні сірки з урахуванням їх впливу на вміст олеїнової кислоти. Мета дослідження – визначити вплив сірки в різних нормах мінеральних добрив на формування продуктивності рослин високоолеїнового соняшнику на чорноземах типових малогумусних Правобережного Лісостепу України. Програма досліджень передбачала закладання польового досліду впродовж 2015-2017 років. Дослідження проводили у формі двофакторного польового досліду. Програмою досліду передбачено вивчення наступних факторів: фактор А – норми внесення мінеральних добрив, фактор В – внесення сірки. Дослідження проводили з використанням загальноприйнятих методів наукових досліджень у рослинництві. Дослідженнями встановлено, що максимальна кількість сухої речовини накопичувалася у варіантах із внесенням $N_{90}R_{75}K_{135}+S_{3}0$ та $N_{120}R_{100}K_{180}+S_{30}$. Внесення сірки збільшує вихід сухої речовини з 5,69% до 9,27%. Найвища врожайність насіння соняшнику формується при внесенні $N_{90}R_{75}K_{135}+S_{30}$ –4,12 т/га. Подальше збільшення норми внесення мінеральних добрив не призводить до суттєвого підвищення врожайності. Внесення S_{30} у поєднанні з $N_{90}R_{75}K_{135}$ дозволяє підвищити врожайність насіння соняшнику на 0,35 т/га або 9,28%. Кореляційно-регресійний аналіз отриманих результатів досліджень свідчить про тісний кореляційний зв'язок між накопиченням маси сухої речовини у ЧС 55-57 і ЧС 65-67 та рівнем урожайності (відповідно $r = 0{,}917$ і $r = 0{,}972$). Найвищий вміст жиру в насінні (49,7%) з найбільшим вмістом олеїнової кислоти (88,5%) та максимальним виходом олії (2,05 т/га) забезпечується за вирощування гібрида ЕС Романтик з внесенням $N_{90}R_{75}K_{135}+S_{30}$

Ключові слова: олійні культури, гібриди, мінеральне живлення, норми внесення мінеральних добрив, суха речовина, урожайність

Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en
Plant and Soil Science, 12(1), 50-58
Received xx.xx.2020 Revised xx.xx.2021 Accepted xx.xx.2021

UDC 635.21/631.815

DOI: 10.31548/agr2021.01.0050

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Economic efficiency of balanced fertilisation systems for table potatoes with macro- and meso-elements on dark grey podzolic soil using liquid phosphorus fertilisers

Abstract. Today's market conditions require producers to minimise the cost of technological processes for growing crops to maximise profits. One of the important conditions for the selection and application of certain agrotechnical measures in potato growing technology is to obtain high yields, maximum net profit and a high level of profitability. Among the technological methods for growing table potatoes, the use of fertilisers is one of the most expensive items. Therefore, the use of liquid phosphate fertilisers and balancing fertilisation systems with meso-elements is one of the most promising measures in this regard. The purpose of the research was to determine the

Suggested Citation:
Bykin , A., Bordyuzha, L., Bordyuzha, N., & Bykina, N. (2021). Economic efficiency of balanced fertilisation systems for table potatoes with macro- and meso-elements on dark grey podzolic soil using liquid phosphorus fertilisers. *Plant and Soil Science*, 12(1), 50-58. doi: 10.31548/agr2021.01.050.

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economic efficiency of systems of balanced nutrient supply of table potatoes with macro- and meso-elements on dark grey podzolic soil in the conditions of the Left-Bank Forest-Steppe of Ukraine using liquid phosphorus fertilisers. The research was conducted in the field experiment of the O.I. Dushechkin Department of Agrochemistry and Quality of Crop Production of the National University of Life Sciences of Ukraine at Biotech LTD (Boryspil district, Kyiv oblast) during 2015-2017. The area of the registered plot was 40 m^2, and the repetition rate of the experiment is 3 times. The placement of variants is systematic. The research showed that the use of liquid phosphorous fertilizers in the rate of P_{105} on the background of $N_{120}K_{180}$ showed high economic efficiency in the cultivation of table potatoes and allowed to obtain a conditional net profit of 54.4 thousand UAH/ha and a profitability level of 59%. The introduction of the starter fertiliser $Ca_{21}Mg_{15}B_{1.5}$ into the scheme provoked a rise in economic indicators relative to the control, but a decrease compared to similar variants without these elements. The reason for this is the introduction of phosphorus and calcium into one layer of dark grey podzolic soil, which provoked their interaction and the formation of tri-substituted phosphates, which, in turn, led to a decrease in yield. The multi-depth application of nutrients in the technologies of growing table potatoes is a promising area for further study

Keywords: fertilisers, LCF 11-37, calcium, magnesium, boron, operating profit, profitability, fertiliser costs, yield, start fertiliser, profit

RELEVANCE

Current market conditions require producers to reduce the costs of growing crops in order to maximise profits (Lavrov, 2007). However, modern potato production must still be based on the latest scientific and technical achievements: varieties of intensive type, the use of high-quality seeds (Ostapenko *et al.*, 2020; Bordyuzha, 2019), advanced cultivation techniques, an effective system of fertilisers and plant protection products, and a high level of logistics. These techniques and elements of technology should be adapted to individual soil and climatic zones (Bordyuzha, 2019).

One of the important conditions for the selection and application of certain agrotechnical measures in potato cultivation technology is to obtain high yields, maximum net profit and a high level of profitability. The main task that remains to be solved is achieving the highest quantity of products of appropriate quality per unit area at the lowest labour and money costs (Khodakovsky *et al.*, 2006; Shchitkin, 2004). Among the agrotechnical methods for growing table potatoes, the use of fertilisers is one of the most expensive items (Holubev, 1991). That is why the use of liquid phosphate fertilisers is one of the most practical measures in this regard. They are characterized by better mobilisation properties and availability of nutrients for plants, which allow for obtaining better results than other forms of fertilisers (Zinchenko *et al.*, 2001).

However, apart from the form of fertiliser, achieving balanced nutrition of potatoes not only with macronutrients but also with meso-nutrients is also essential in today's climate instability, which is the reason for the low yields of this crop in Ukraine in recent decades. Therefore, technological solutions that include the possibility of its initial provision with macro- and meso-elements are relevant (Bordyuzha, 2019), therefore becoming the basis of this research.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The key to growing profits from potato farming is high yields of high quality at reduced costs. At the same time, according to R.O. Myalkovsky (2017), A.I. Fateev and M.A. Zakharova (2005). At the same time, according to R. Rozhnyatovsky (2019), the main criterion for managing yield and product quality is an optimisation of plant nutrition, which is based on the principle of nutritional comfort, i.e., the creation of conditions that eliminate stress caused by lack of nutrients, ensure positional availability of their root system, etc. Therefore, according to scientists (Koval & Ilchuk, 2019; Hamayunova *et al.*, 2018), the high share of mineral fertilisers in the structure of potato production costs (19-21%) requires a constant search for new ways to reduce the cost of production. This question was studied by the following scientists: A.V. Bykin & I.P. Bordyuzha (2018), V.M. Hamayunova *et al.* (2018), Fr.V. Ostapenko *et al.* (2020), R.O. Myalkovsky (2017) and others. Among the possible solutions to this issue, they consider local fertilisation, foliar fertilisation with microelements, irrigation, etc. However, the issue of selecting the optimal physical form of fertiliser, as well as the possibility of balancing fertilisation systems with meso-elements, remains unaddressed, which is what this study aimed to investigate.

The purpose of the study is to establish the economic efficiency of balanced nutrition plans for table potatoes with macro- and meso-elements on dark grey podzolic soil in the conditions of the Left-Bank Forest-Steppe of Ukraine using liquid phosphorus fertilisers.

MATERIALS AND METHODS

The research was conducted in the field experiment of the O.I. Dushechkin Department of Agrochemistry and Quality of Crop Production of the National University of Life Sciences of Ukraine at Biotech LTD (Boryspil district, Kyiv oblast) during 2015-2017.

The area of the registered plot was 40 m^2, the repetition rate of the experiment is 3 times. The placement of variants is systematic. The medium-late variety Mozart (originator HZPC Holland, the Netherlands) was chosen for the research.

The soil of the experimental plot is dark grey podzolic coarse-dusted light loamy on loess. It was characterised by a slightly acidic reaction of the soil solution (5.20), low mineral nitrogen content (13.4 mg/kg), a high degree of provision of mobile phosphorus (168 mg/kg) and potassium (174 mg/kg) and an average – exchangeable calcium (7.42 mg equivalent/100 g of soil) and magnesium (1.64 mg equivalent/100 g of soil).

The experimental design included the following fertilisation schemes:

1. No fertilisers (control);
2. $N_{120}P_{35}K_{180}$ (Rlcf;
3. $N_{120}P_{70}K_{180}$ (Rlcf);
4. $N_{120}P_{105}K_{180}$ (Rlcf);
5. $N_{120}Rlcf_{35}K_{180}Ca_{21}Mg_{15}B_{1.5}$ (p.Ca, Mg);
6. $N_{120}Rlcf_{70}K_{180}Ca_{21}$ $Mg_{15}B_{1.5}$ (p.Ca, Mg);
7. $N_{120}Rlcf_{105}K_{180}Ca_{21}Mg_{15}B_{1.5}$ (p.Ca, Mg);

The following fertilisers were used in the experiment: ammonium nitrate (DSTU 7370:2013), LCF 11-37 (TU – 2186-627-00209438-01), potassium sulfate (GOST 4145-74), magnesium sulphate, Bospholyar Boron (B-21%). The cost-effectiveness was determined at the prices of 2015-2017.

RESULTS AND DISCUSSION

Applying liquid forms of phosphorous fertilisers is a cost-effective measure. This study revealed that the use of liquid phosphate fertilisers at the rate of P_{35} had a positive impact on economic efficiency (Figures 1 and 2). Operating profit at this rate of phosphorus reached 18.2 thousand UAH/ha with a profitability level of 20.2%. As the rate of phosphorus fertilisers increased, production costs also increased (Fig. 3), but the effectiveness of these fertilisers resulted in higher yields of table potatoes, which in turn contributed to high profits. With the use of LCF 11-37 in the rate of P_{75}, the conditional net income amounted to 30.1 thousand UAH/ha (33.0% profitability). The highest performance indicators were shown by the variant with the application of LCF 11-37 in the rate of P_{105} in combination with $N_{120}K_{180}$, where the operating profit was 54.4 thousand UAH/ha and the profitability level is 59%. In the control, the cost of cultivating potatoes exceeded the value of the harvest by 19.7 thousand UAH (Fig. 3), so there was no profit in this variant.

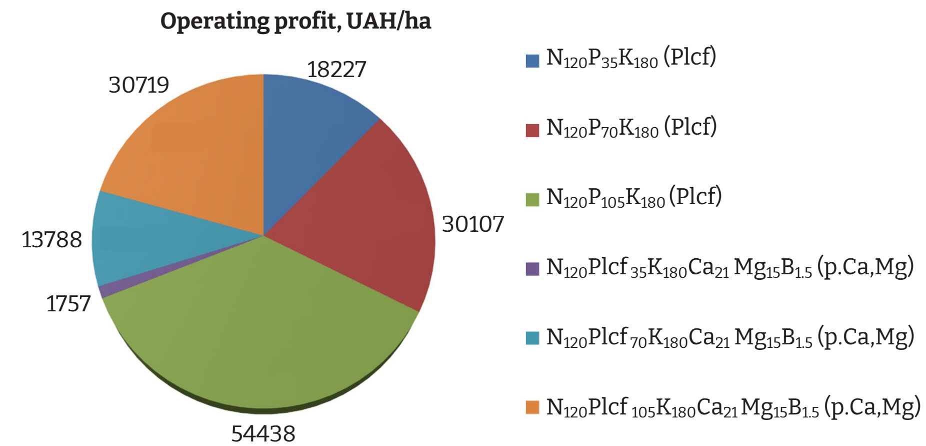

Figure 1. Operating profit generated by cultivating table potatoes of the Mozart variety using macro- and meso-elements in fertilisation systems, 2015-2017

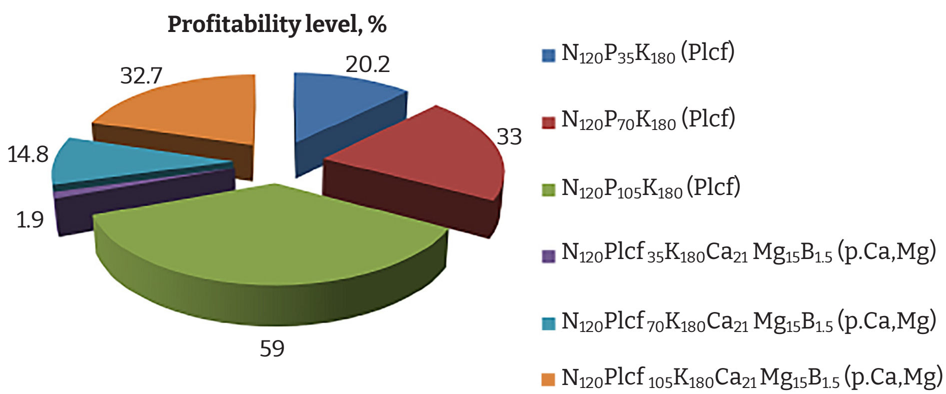

Figure 2. The level of profitability of the cultivation of the Mozart variety table potato using macro- and meso-elements in its fertilisation systems, 2015-2017

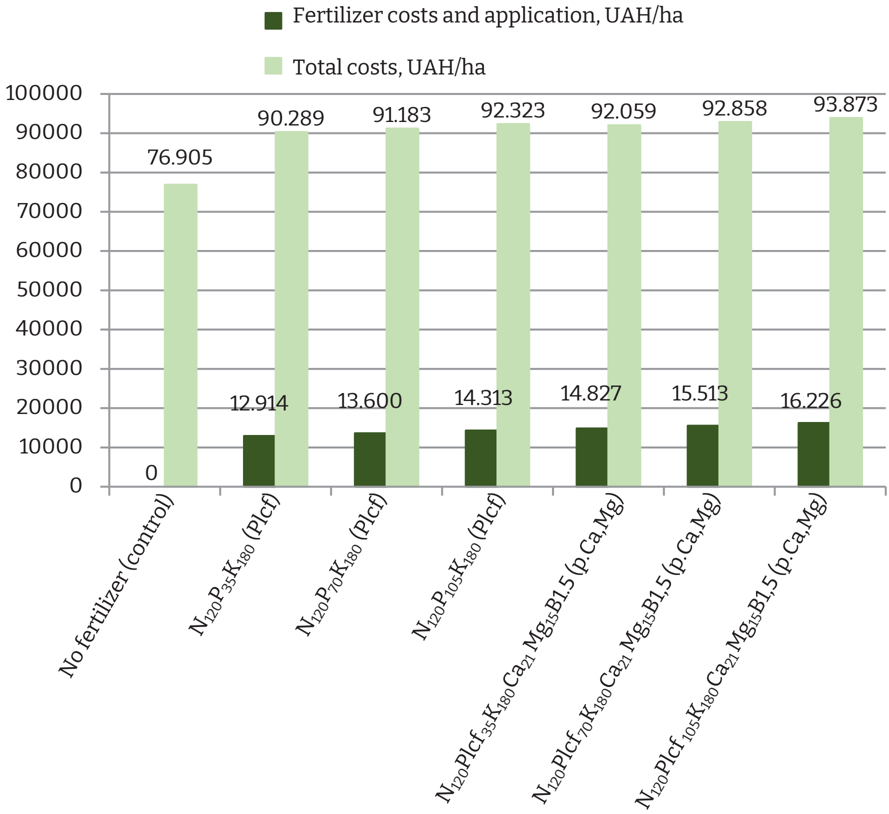

Figure 3. Production costs related to the cultivation of table potatoes of the Mozart variety using macro- and meso-elements in its fertilisation systems, 2015-2017

The introduction of fertilisers with calcium, magnesium and boron into the fertiliser system resulted in an increase in production costs by an average of 16,025 UAH/ha (Fig. 3) and an increase in profitability as compared to the control. At the rate of P_{35} with $Ca_{21}Mg_{15}B_{1.5}$, this economic indicator was 1.9%, at the rate of P_{70} and P_{105} – 14.8% and 32.7%, respectively. However, due to lower yields (Fig. 4), which were caused by a decrease in the amount of available phosphorus in the soil, as phosphorus and calcium were applied in one layer, along with higher production costs, these options were less profitable than those using only NPK. Thus, when using $N_{120}Rlcf_{35}K_{180}Ca_{21}Mg_{15}B_{1.5}$ (p.Ca, Mg) yield decreased by 2.9 t/ha (fig. 4) compared to the same variant without meso-elements with an increase in production costs by 1,770 UAH/ha (fig. 3), when $N_{120}Rlcf_{70}K_{180}Ca_{21}Mg_{15}B_{1.5}$ (p.Ca, Mg) was applied: -4.8 t/ha of potato tubers and +1675 UAH/ha of costs, $N_{120}Rlcf_{105}K_{180}Ca_{21}Mg_{15}B_{1.5}$ (p.Ca, Mg): -7.3 t/ha of tubers and +1550 UAH/ha of expenses.

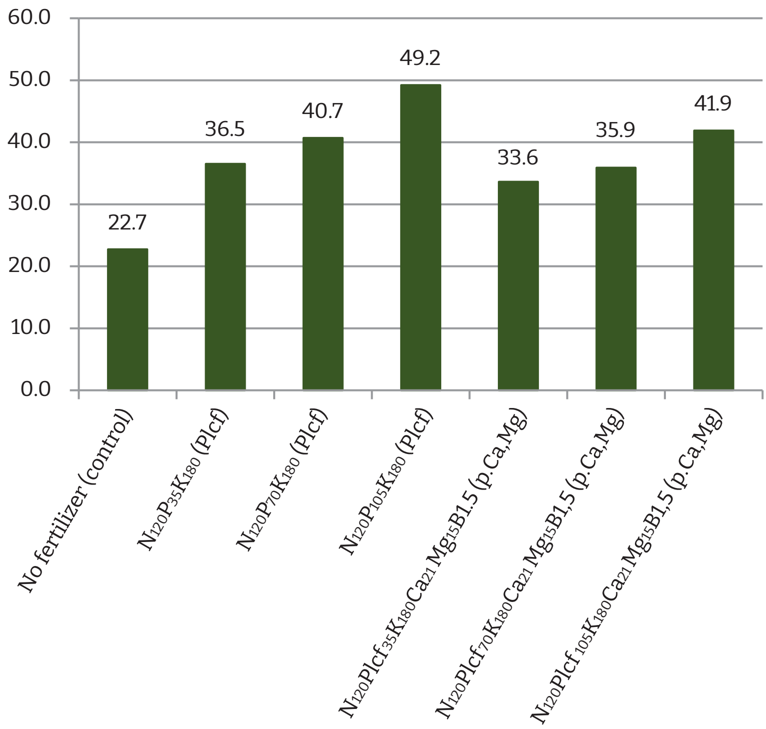

Figure 4. The yield of table potatoes of the Mozart variety when cultivated on dark grey podzolic soil, 2015-20107

CONCLUSIONS

The application of liquid phosphorus fertilisers in the rate of P_{105} in combination with $N_{120}K_{180}$ showed high economic efficiency in the cultivation of table potatoes and allowed to obtain an operating profit of 54.4 thousand UAH/ha and a profitability level of 59%. The introduction of the starter fertiliser $Ca_{21}Mg_{15}B_{1.5}$ into the scheme provoked a rise in economic indicators relative to the control, but a decrease compared to similar variants without these elements. The reason for this is the introduction of phosphorus and calcium into one layer of dark grey podzolic soil, which triggered their interaction and the formation of tri-substituted phosphates, which, in turn, led to a decrease in the yield of potato tubers. The multi-depth application of nutrients in the technologies of growing table potatoes is a promising area for further study.

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Економічна ефективність збалансованих систем удобрення картоплі столової макро- і мезоелементами на темно-сірому опідзоленому ґрунті з використанням рідких фосфорних добрив

Анотація. Сучасні ринкові умови вимагають від виробників мінімізації витрат на технологічні процеси вирощування сільськогосподарських культур для отримання максимального прибутку. Однією з важливих умов вибору та застосування тих чи інших агротехнічних заходів у технології вирощування картоплі є отримання високих врожаїв, максимального чистого прибутку та високого рівня рентабельності. Серед технологічних прийомів вирощування столової картоплі застосування добрив є однією з найдорожчих статей. Тому застосування рідких фосфорних добрив та балансування систем удобрення мезоелементами є одним із найперспективніших заходів у цьому плані. Метою досліджень було визначення економічної ефективності систем збалансованого живлення картоплі столової макро- та мезоелементами на темно-сірому опідзоленому ґрунті в умовах Лівобережного Лісостепу України з використанням рідких фосфорних добрив. Дослідження проводили в польовому досліді кафедри агрохімії та якості продукції рослинництва ім. О.І. Душечкіна Національного університету біоресурсів і природокористування України на базі ТОВ «Біотех» (Бориспільський район, Київська область) протягом 2015-2017 років. Площа облікової ділянки становила 40 м2, повторність досліду – 3-кратна. Розміщення варіантів – систематичне. Дослідження показали, що застосування рідких фосфорних добрив у нормі P_{105} на фоні $N_{120}K_{180}$ показало високу економічну ефективність при вирощуванні картоплі столової та дозволило отримати умовний чистий прибуток 54,4 тис. грн/га та рівень рентабельності 59%. Внесення в схему стартового добрива $Ca_{21}Mg_{15}B_{1,5}$ спричинило зростання економічних показників відносно контролю, але зниження порівняно з аналогічними варіантами без цих елементів. Причиною цього є внесення фосфору та кальцію в один шар темно-сірого опідзоленого ґрунту, що спровокувало їх взаємодію та утворення тризаміщених фосфатів, які, в свою чергу, призвели до зниження врожайності. Перспективним напрямом подальших досліджень є різноглибинне внесення поживних речовин у технологіях вирощування картоплі столової

Ключові слова: добрива, LCF 11-37, кальцій, магній, бор, операційний прибуток, рентабельність, витрати на добрива, урожайність, стартове добриво, прибуток

Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en *Plant and Soil Science, 12(1), 59-67*

Received xx.xx.2020 Revised xx.xx.2021 Accepted xx.xx.2021

UDC 332.3:631.4

DOI: 10.31548/agr2021.01.0059

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Improvement of biological productivity of saline and erosion-prone lands of Donetsk oblast by meadowing

Abstract. This study examined the soil cover and the state of the natural grass stand of saline and erosion-prone lands in the valley and gully system of the Sukhi Yaly River. Low-productive saline lands are located on the slopes and bottoms of gullies, micro-depressions of lowland and floodplain meadows. Plant groups associated with such soils are characterised by low species diversity and a lack of species valuable for fodder. The article presents the results of research on the improvement of low-productive lands on saline soils by sowing a set of forage grasses that can grow under saline soil conditions and have high fodder value. It was found that during the observation period, the yield of green mass and hay on all variants was significantly higher than the yield of natural herbage. The biochemical composition of forage grasses is characterised by an increased content of crude protein, hydrocarbons, vitamin C and essential amino acids. Data on the introduction of be herbs to improve saline fodder lands in combination with wild bee plants are presented, and their nectar content is determined. This paper presents a bio-agronomic assessment of fodder plants cultivation on black alkali soil. The authors provide recommendations for improving fodder lands on saline and alkaline soils

Keywords: low-productive and erosion-prone lands, hydromorphic meadow salt marsh, black alkali soil, fodder grasses, meadowing

Suggested Citation:
Bulygin, S., Vitvitskyy, S., & Chayka, M. (2021). Improvement of biological productivity of saline and erosion-prone lands of Donetsk oblast by meadowing. *Plant and Soil Science*, 12(1), 59-67. doi: 10.31548/agr2021.01.059.

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RELEVANCE

An important factor limiting the highly efficient use of soils in southern Ukraine is the significant prevalence of saline and alkaline soil types. In total, 4.7 million hectares of alkali soils were found in the steppe regions, which is 48% of arable land. Almost half of them is comprised of strong and medium alkaline soils – 2.3 million hectares (National Report on Soil Fertility, 2010).

According to the State Land Cadastre of Ukraine, saline and alkaline soils cover a total area of 2.8 million hectares (including 2.0 million hectares of arable land): saline soils are spread over 2.2 million hectares and alkaline complexes over 0.6 million hectares. The main requirement for the rational use of Ukraine's alkaline soils in modern conditions is the need for a landscape-geochemical assessment of their formation and distribution and the adaptive use of conventional and new energy-saving types of reclamation. This allows for the protection and improvement of the effective fertility of alkaline soils and the optimisation of the conditions for crops.

In the context of land reform, the system of measures for the renaturalisation of agricultural landscapes in areas of alkaline soils should in the short term provide for the withdrawal of highly saline soils and alkaline complexes with saline patches of 50% or more from arable land for the introduction of cultivated hayfields and pastures. It is recommended to use salt- and alkaline-tolerant grasses adapted to soil conditions for meadowing.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Methodological aspects of environmental sustainability of agro-landscapes in the current conditions of land relations transformation have been the subject of numerous works (Medvedev & Laktionova, 1998; Bulyghin, 2005; Bulyghin & Vitvitsky, 2018).

However, given the diversity of natural and economic conditions, it is necessary to find optimal solutions to improve erosion resistance and increase the productivity of marginal lands, considering the specifics of a given area.

Given the current shortage of resources, lack of funds, and limited state soil protection policy, the priority and mandatory measure to prevent further degradation of agricultural landscapes and soil cover is to withdraw low-productive and erosion-prone lands from cultivation and transform them into natural fodder lands (Sayka, 2000; Bulyghin & Dumin, 2001; Antypova, 2015; Antypova *et al.*, 2018; Cosgrove & Barrett, 1987; Sapck, 1998)

To improve low-productive lands on saline soils in the region, it is necessary to test a set of forage grasses that can grow in conditions of soil salinity and exhibit traits of high fodder value (Khromtsov, 2001; Patyka *et al.*, 2003; Petrychenko *et al.*, 2018; Kurhak & Tkachenko, 2016).

The purpose of the study is to examine the soil cover and the status of the natural grass stand of saline and erosion-prone lands in the valley and gully system of the Sukhi Yaly River; to conduct research on sowing a set of fodder and bee grasses to improve low-productive fodder lands; and to provide recommendations for increasing the productivity and value of fodder lands on saline and alkaline soils.

MATERIALS AND METHODS

A field experiment on the introduction of meadow-field crop rotation on saline fodder lands was established in a floodplain on the right bank of the Sukhi Yaly River. The soil type is hydromorphic meadow salt marsh. Experiments on testing bee plants were also conducted at the same site.

The plot was divided into two parts. The coastal part (water protection zone) of 25-50 m was left for control as a plot with a natural grass stand, the yield of green mass and hay from which was compared with the yield of grasses and grass mixtures sown in five variants. The second part was used for experimental purposes. The surface was levelled and disked with disk harrows, mineral fertilisers were applied at a dose of $N_{60}P_{60}K_{60}$ per hectare, and gypsum at a dose of 2 t/ha. After applying fertiliser and gypsum, the area was ploughed to a depth of 28-30 cm.

Grasses were sown manually – *Medicago sativa* (Zaykevych variety), *Trifolium* (Skif variety) and grass mixtures: (#1) – *Medicago sativa* (Zaykevych variety) + *Medicago romanica* + *Trifolium* (Skif variety) + *Festuca gigantea* + *Festuca arundinacea* + *Elytrigia elongata* (Host) Nevski + *Phalaris arundinacea*; (No. 2) *Medicago sativa* (Zaykevych variety) + *Medicago romanica* + *Trifolium* (Skif variety) + *Festuca gigantea* + *Festuca arundinacea* + *Elytrigia elongata* (Host) Nevski + *Phalaris arundinacea* + *Isatis tinctoria* + *Bunias orientalis*. The research was conducted according to the methodology of experiments on hayfields and pastures (1969) and the methodology of perennial grasses selection (Konstantinov *et al.*, 1971).

The sowing of honey species was carried out in a wide-row method, manually. The seeding rate was calculated at 30 kg/ha of *Borago officinalis*, 4 kg/ha of *Nepeta cataria* spp. *citriodora*, 4 kg/ha of *Trifolium* and 4 kg/ha of *Melilotus officinalis* L. The nectar content of plants was determined by the method of B.I. Fesko and Ye.I. Karklyn (1967).

The experiments on the introduction of fodder plants on the black alkali soil marsh were initiated to increase the species composition of valuable fodder species and to increase the yield of low-productive fodder land.

RESULTS AND DISCUSSION

The soil profile of the salt marsh has clear signs of hydromorphism under poor drainage conditions on the floodplain terrace of the river with the close occurrence of mineralised groundwater (humus content in the Hs horizon is 3.83-5.69%). The reaction of the soil solution of the upper horizons is alkaline (pH 7.5-8.1), the lower ones are low-alkaline (pH 7.4-7.5). The content of mobile forms of phosphorus and potassium in the upper horizons is very high. However, the high concentration of salts in the soil solution significantly increases its osmotic pressure, disrupts the supply of water and plant nutrients; there is a direct toxic effect of salts on plants, which leads to their severe depression.

Structure of the profile of a hydromorphic meadow salt marsh:

Hs 0-45 cm – humus, saline, dark grey, moist, medium loamy, lumpy-grained, loose, fine-porous, salts in the form of dots and thin veins, gradual transition;

Hpsk 46-65 cm – upper transitional, saline, carbonate, dark grey, moist, medium clay, lumpy-grained, loose, porous, salts in the form of veins, gradual transition;

Phskgl 66-87 cm – lower transitional, saline, carbonate, grey, darkish dirty olive with rusty spots, moist, medium clayey, lumpy-nutty, slightly compacted, porous, gradual transition;

PksGl 88 and deeper – loess loam, carbonate, saline, heavily silty, brownish-grey with bluish tint and abundant rusty spots, damp, medium clayey, lumpy, compacted, viscous.

During the observation period, the yield of green mass and hay in all variants is significantly higher than the yield of natural grass (Table 1). On average, over three years, the yield of green mass of *Medicago sativa* was 37.3 t/ha, *Trifolium* – 37.3 t/ha, grass mixture No. 1 – 40.7 t/ha, grass mixture No. 2 – 41.7 t/ha. The yield of dry mass (hay) in the experimental variants was as follows: *Medicago sativa* – 7.73 t/ha, *Trifolium* – 7.64 t/ha, grass mixture No. 1 – 9.32 t/ha, grass mixture No. 2 – 9.70 t/ha, *Medicago sativa* + *Trifolium* – 10.74 t/ha.

Table 1. Harvest of green and dry masses of grasses and grass mixtures

Variant	Green mass over the years of vegetation, t/ha			Dry mass (hay) over the years of vegetation, t/ha		
	first	second	third	first	second	third
Control	10.1	24.5	24.6	1.14	2.73	2.75
Medicago sativa	14.2	45.2	47.1	3.28	9.69	10.22
Trifolium	19.3	47.4	45.2	3.42	10.26	9.24
Medicago sativa +Trifolium	22.2	52.4	32.1	4.16	14.09	13.99
Grass mixture No. 1	20.6	51.2	50.2	3.76	12.16	12.04
Grass mixture No. 2	26.4	50.3	48.3	6.76	11.54	10.82

Depending on the farming use of meadow-field crop rotations, it is necessary to consider the full development (in *Trifolium*, *Isatis tinctoria*, and *Bunias orientalis* – in the second year of vegetation, in *Medicago sativa* – in the second, third, and in cereals – in the third, fourth).

At the same time, the biochemical composition of plants under study was determined (Tables 2, 3), in phases corresponding to the pasture and haymaking stages of grasses according to the methods used in feed biochemistry.

Table 2. Biochemical composition of fodder grasses

Plant names	Nutrient content, %				Amount, % per absolutely dry matter		Content of vitamin	
	Crude protein	Crude fat	Crude fibre	Ash	Carbohydrates	Total essential amino acids g/kg	C, mg/kg	Carotene, %
Isatis tinctoria	12.03	3.47	15.53	13.65	22.21	22.19	195	2.61
Bunias orientalis	20.93	3.97	15.68	14.03	18.26	29.39	245	1.10
Trifolium pratense	10.58	4.26	33.07	10.81	18.74	21.67	100	2.12
Medicago romanica	19.96	4.42	34.5	9.62	8.18	78.73	146	2.84
Alfalfa	13.02	3.51	35.94	6.77	7.10	75.76	98	2.01
Festuca arundinacea	8.79	3.51	31.68	8.27	12.32	20.94	135	3.05
Festuca gigantea	8.53	2.68	34.01	8.11	12.04	24.11	210	2.84
Phalaris arundinacea	8.71	4.34	25.0	10.6	10.88	10.15	35	4.64
Elytrigia elongata (Host) Nevski	7.69	3.75	33.82	7.27	10.56	20.94	120	1.59
Control	13.19	3.89	27.74	8.02	9.93	50.71	128	1.24

Table 3. Nectar content and number of flowers per plant

Plant names	Nectar-forming capacity, kg/ha of sugar	Number of flowers, pcs.
Borage	776.2	3881
Nepeta cataria spp. *citriodora*	350.9	1493
Trifolium pratense	89.3	495
Melilotus albus	3280.6	18226

Bee plants form a large number of flowers (on one plant of Melilotus albus – 18226 pcs., *Borago officinalis* – 3881 pcs., *Nepeta cataria* spp. *citriodora* – 1493 pcs., *Trifolium* pratense – 495 pcs.) By improving saline fodder lands with wild honey bee plants, it is possible not only to increase the honey supply of the area, but also to preserve wild species.

Black alkali soils are found in large patches among other soil types. Profile structure of black alkali soil:

NEd 0-10 cm – humus-eluvial, dark grey, fresh, heavy loam, dusty-lumpy with a well-defined horizontal division, loose, coarsely porous, many roots, clear transition;

Eh 11-22 cm – eluvial, light grey, slightly humified, fresh, heavily loamy, lamellar, coarsely porous, many roots, sharp transition;

Ih 23-40 cm – illuvial, brownish-dark grey, fresh, medium clay, columnar-prismatic, dense, finely fissured, separate roots, gradual transition;

PIhk 41-65 cm – transitional, illuviated, light grey with a brown tint, dark brown in the lower part, light clay, nutty-prismatic, compacted, slobose, carbonates from a depth of 42 cm, some thin roots, gradual transition;

Pk(h) 66-86 cm – green-grey slightly humic clay, lumpy, compacted, slightly porous, gradual transition;

Pks 86 and deeper – greenish-grey clay, oily, from a depth of 87 cm – salts in the form of fades, from a depth of 130 cm – small gypsum druses and salt veins.

The description of the alkaline soil profile shows that it is strictly divided into eluvial (supra-salt) and illuvial (alkaline) horizons. In terms of the depth of occurrence of illuvial (alkaline) soil, it should be classified as deep.

The upper horizon is characterised by a reduced content of mobile forms of nitrogen, phosphorus, and potassium due to their leaching. The physical properties of alkali soils are unfavourable for plants. The alkaline horizon is very dense in the dry state, while in the wet state it is viscous, swells and becomes impermeable to water.

The results of phenological observations and determination of green mass productivity showed that its yield is directly dependent on the length of shoots, volume and length of root mass. Thus, in white Melilotus albus, the volume of the root system was 82 ml, the length of the root system reached 28 cm and the plant reached 100-110 cm in height (Table 4). In the year of sowing, the plants of the Psathyrostachys juncea had a root system volume of 16 ml with a length of 25 cm reaching 86 cm in height. Accordingly, the yield of the green mass of Melilotus albus was 20.5 t/ha, and of Psathyrostachys juncea – 12.8 t/ha.

Table 4. Bio-agronomic characteristics of fodder plants on black alkali soils

Plant names	Shoot length, cm		Inflorescence length, number of spikelets and whorls			Root mass*			Yield, t/ha		
	Generative	Vegetative	Inflorescence, cm	Spikelets, pcs.	Whorls, pcs	*V*, ml	*H*, cm	*L*, cm	Green mass	Dry mass	Seeds
Psathyrostachys juncea	85.75	36.73	12.6	33	-	16.2	0-25	25	12.8	3.1	0.47
Elytrigia elongata (Host) Nevski	82.65	25.6	22	14	-	5	0-18	18	10.8	3.8	1.36
Leymus racemosus	87.13	49.9	25.7	30	-	35	0-25	25	9.8	3.9	1.85
Festuca arundinacea	70.48	31.32	28.6	-	15	-	-	-	10.1	2.6	1.25
Elymus repens	56.4	19.1	10.5	13	-	3.6	3-10	14	6.1	2.7	1.09
Melilotus albus	101.6	-	-	-	-	82	3-16	28	20.5	8.6	-
Melilotus wolgicus	72.9	-	-	-	-	-	-	-	7.4	3.3	-

Notes: *V* – volume of root mass; *H* – depth of accumulation of the main body; *L* – length in the second year of vegetation

The analysis of the data on dry mass yield showed that despite the lower levels of green mass compared to the Psathyrostachys juncea, more dry mass was obtained by *Elytrigia elongata* (Host) Nevski and Leymus racemosus – 3.1 and 3.8-3.9 t/ha, respectively, and the maximum value was obtained in the variant with Melilotus albus – 8.6 t/ha.

Similar patterns are also observed for seed yields: Psathyrostachys juncea – 0.47 t/ha, *Elytrigia elongata* (Host) Nevski – 1.36 t/ha, Leymus racemosus – 1.85 t/ha.

The seed productivity of the Psathyrostachys juncea, *Elytrigia elongata* (Host) Nevski and Leymus racemosus was the highest in the third year of life, and that of the *Festuca arundinacea* in the fourth year. Optimal yields of grasses on the black alkali soil were observed in Elytrigia repens in the second and third years, Psathyrostachys juncea and *Elytrigia elongata* (Host) Nevski in the third and fourth years, in *Festuca arundinacea* in the third and fourth years, and in Leymus racemosus in the fourth and fifth years. In the following years of vegetation, the productivity of these grasses decreases gradually and more significantly in *Festuca arundinacea*.

CONCLUSIONS

During the observation period, the yield of green mass and hay on all variants was significantly higher than the yield of natural herbage. On average, over three years, the yield of the green mass of *Medicago sativa* was 37.3 t/ha, *Trifolium* – 37.3 t/ha, grass mixture No. 1 – 40.7 t/ha, grass mixture No. 2 – 41.7 t/ha. The yield of dry mass (hay) was as follows: *Medicago sativa* – 7.73 t/ha, *Trifolium* – 7.64 t/ha, grass mixture No. 1 – 9.32 t/ha, grass mixture No. 2 – 9.70 t/ha, *Medicago sativa* + *Trifolium* – 10.74 t/ha.

In terms of crude protein content, the highest protein crops are *Bunias orientalis* and *Medicago romanica* (17-28%); medium protein crops (12-16%) are *Isatis tinctoria* and *Medicago sativa* (12-16%); all others are low protein crops (8-11%). Brassicaceae and *Trifolium* pratense have the highest content of carbohydrates and vitamin C, while *Medicago sativa* and *Medicago romanica* have the highest content of essential amino acids.

Studies of sowing bee grasses on the hygromorphic meadow salt marsh revealed that the highest nectar content was found in *Melilotus officinalis* – 3280.6 kg/ha, *Borago officinalis* – 776.2 kg/ha and *Nepeta cataria* spp. *citriodora* – 350.9 kg/ha. The yield of green mass of fodder grasses is directly related to the length of shoots, volume and length of the root mass. The yield of green mass was 12.8 t/ha for Psathyrostachys juncea, and 20.5 t/ha for Melilotus albus. For the cultivation of *Elytrigia elongata* (Host) *Nevski* and *Leymus* racemosus, a dry weight of 3.8-3.9 t/ha was obtained, and the maximum value was found in the variant with *Melilotus albus* – 8.6 t/ha. Seed yield: *Psathyrostachys juncea* – 0.47 t/ha, *Elytrigia elongata* (Host) *Nevski* – 1.36 t/ha, Leymus racemosus – 1.85 t/ha.

Given the low fertility of saline soils and their poor aeration, the arrangement of permanent hayfields and pastures on them is not rational. It is recommended to introduce meadow-field (2-3 field crops, 5-7 grass crops) crop rotations. To improve the productivity and value of fodder lands on saline soils, honey plant species should be introduced – *Borage officinalis*, *Nepeta cataria* spp. *citriodora*, *Trifolium* pratense, *Melilotus albus*.

The following should also be applied to alkali soils: *Melilotus albus*, *Melilotus wolgicus*, *Psathyrostachys juncea*, *Leymus racemosus*, *Festuca arundinacea*, *Elytrigia repens*, *Elytrigia elongata* (Host) *Nevski*, which go through a full development cycle on alkali soil algae.

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Підвищення біологічної продуктивності засолених та ерозійно небезпечних земель донецької області шляхом залуження

Анотація. Досліджено ґрунтовий покрив та стан природного травостою засолених та ерозійно небезпечних земель долинно-балкової системи р. Сухі Яли. Малопродуктивні засолені землі розташовані на схилах і днищах балок, мікрозападин низинних і заплавних лук. Рослинні угруповання, пов'язані з такими ґрунтами, характеризуються низьким видовим різноманіттям і відсутністю цінних для кормів видів. У статті представлено результати досліджень щодо поліпшення малопродуктивних земель на засолених ґрунтах шляхом посіву комплексу кормових трав, які здатні рости в умовах засолених ґрунтів і мають високу кормову цінність. Встановлено, що за період спостережень урожайність зеленої маси та сіна на всіх варіантах була значно вищою, ніж на природному травостої. Біохімічний склад кормових трав характеризується підвищеним вмістом сирого протеїну, вуглеводнів, вітаміну С та незамінних амінокислот. Наведено дані щодо інтродукції бджолоносних трав для поліпшення засолених кормових угідь у поєднанні з дикорослими бджолоносіями та визначено їх нектароносність. Наведено біолого-агрономічну оцінку вирощування кормових рослин на чорноземі вилугуваному. Надано рекомендації щодо поліпшення кормових угідь на засолених і солонцюватих ґрунтах

Ключові слова: малопродуктивні та ерозійно небезпечні землі, гідроморфне лучне солончакове болото, чорнозем солонцюватий, кормові трави, луківництво

Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en
Plant and Soil Science, 12(1), 68-76
Received xx.xx.2020 Revised xx.xx.2021 Accepted xx.xx.2021

UDC 633.11: 504.53.052

DOI: 10.31548/agr2021.01.0068

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Microbiological Evaluation of Meadow Chernozem Carbonate Soil under Various Fertiliser Systems

Abstract. Microorganisms play an important role in shaping soil fertility, maintaining its performance as a bio-inert matter, and are an indicator of qualitative changes in the soil. As a result of anthropogenic impact on the soil, the number and species composition of the microbiota is decreasing. The purpose of the study was to assess the number of different physiological groups of microorganisms on meadow chernozem carbonate soil under different pea fertilisation systems. The number of different groups of soil microorganisms was estimated according to the method

Suggested Citation:
Motruk, H.V., Tonkha, O.L., Hryshchenko, O.V., Pikovska, O.V., & Likar, Ya.O. (2021). Microbiological evaluation of meadow chernozem carbonate soil under various fertiliser systems. *Plant and Soil Science*, 12(1), 68-76. doi: 10.31548/agr2021.01.068.

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of D.H. Zvyagintsev by sowing soil suspension on solid culture media. It was found that the most favourable indicators of micro biocenosis and the highest yield of peas of the Tsarevych variety were formed by the residual effect of organic fertilisers and $N_{45}P_{45}K_{45}$. The variant without fertilisers induces the development of organic matter mineralisation processes in meadow chernozem carbonate soil by the content of pedotrophic and humate-decomposing organisms and formed the lowest pea yield. The introduction of only mineral fertilizers for pea cultivation formed a high rate of humus accumulation at the level of $K_{ac.}$ =1,6-1,9

Keywords: microbiological activity of the soil, meadow chernozem carbonate soil, microorganisms, peas, fertiliser systems, organic matter

RELEVANCE

The biological activity of the soil is determined by soil microorganisms, which are an important component of the biological cycle of substances. The study of the soil microbiome makes it possible to understand and identify patterns of organic matter transformation processes, fertility, ecological and phytosanitary conditions (Tonkha *et al.*, 2017). Important factors influencing these processes and plant productivity are the use of various fertiliser systems, treatments, land reclamation agents, etc. (Tonkha *et al.*, 2019).

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The microbiological state is an indicator of changes in soils and an indicator of their ability to regenerate and rehabilitate themselves. Research by S.Yu. Bulyhin and O.L. Tonkha (2018) revealed that the basis for improving highly efficient farming systems and management of microbial processes in chernozems under different anthropogenic uses is a comprehensive assessment of the microbial microbiota, studying the biodiversity and spatial and functional structure of these organisms.

Long-term soil fertilisation significantly increased soil microbial biomass and dehydrogenase activity. Organic fertilisers had a greater effect on biomass and activity compared to mineral fertilisers (Nannipieri *et al.*, 2003). Soil microbiological activity is closely related to soil organic matter (Demianiuk, 2018). Wheat straw left on the soil increased nitrogen content and resulted in an upward trend in organic carbon content (Patyka *et al.*, 2014).

In the studies by Campbell *et al.* (1991), the use of green manure and by-products increased the number of azotobacter, reduced the specific content of melanin-synthesising micromycetes by 12.4, and reduced soil phytotoxicity by 16.8% compared to the variant without organic matter. They also point out that optimisation of plant mineral nutrition leads to a slowdown in the mineralisation of humus, total organic matter of the soil and nitrogen compounds.

The positive impact of organic fertilization systems has been documented in works by (Chu *et al.*, 2007; Malynovska *et al.*, 2014; Tonkha *et al.*, 2017; Demydenko *et al.*, 2017). At the same time, when by-products are removed from the field, the balance of organic matter becomes deficient and amounts to -0.19 t/ha, and the deficit of nutrients increases by 125% (Pylypenko *et al.*, 2016). Among the indicators that assess the biological activity of soil, the most complete should be considered the total number of microorganisms in the soil environment, although it can only assess the potential activity, which will be high under favourable environmental conditions and low under unfavourable conditions (Yeshchenko *et al.*, 2011).

Aside from tillage, crop rotation, predecessors, tillage, fertiliser application, etc. have a significant impact on the biological activity of the soil. As the intensity of biochemical processes increases, crop productivity rises, organic matter accumulates in the soil, and its physical and chemical properties and fertility improve (Tonha *et al.*, 2017; Malynovska *et al.*, 2014).

The study of soil biological activity is important in researching the processes of organic matter transformation and evaluating pea fertilisation systems. Each element of mineral nutrition has a specific value (Ushkarenko, 2008). Studies have shown that the yield of peas (*Pisum sativum* L.) does not depend on the levels of application of nitrogen, phosphorus, and potash fertilisers, but only on the on the amount of water in the soil. The minimum values of nutrients in soils – 73 mg/kg of mineral nitrogen, 10 phosphorus (by Olsen) and 60 mg/kg of exchangeable potassium – did not affect pea yields. The authors concluded that the current high fertiliser application rates for peas need to be reconsidered, as they may be unnecessary and unprofitable (Kakar *et al.*, 2002; Amjad *et al.*., 2004).

Peas have the ability to symbiosis with nodule bacteria and maintain a positive nitrogen balance in agriculture. Currently, the question of the impact of different fertiliser rates on the number of microorganisms involved in the transformation of nitrogen and carbon remains unresolved.

The purpose of this study was to assess the number of different physiological groups of microorganisms on meadow chernozem carbonate soil under different fertilization systems.

MATERIALS AND METHODS

The research was conducted within the stationary experiment of the Agronomic Research Station of the National University of Life Sciences of Ukraine in a six-crop rotation with the following crops: peas – winter wheat – corn – soybeans – spring barley – corn for grain. The soil of the experimental site is meadow chernozem carbonate low-humus coarse-pulverulent-medium loamy on loess-like loam. The total humus content in the soil of the experimental plots was 4.09-4.50%. The experiment studied fertilisation variants: 1) no fertilisers (control); 2) residual effect of manure +$N_{15}P_{15}K_{15}$; 3) residual effect of manure +$N_{30}P_{30}K_{30}$; 4) residual effect of manure +$N_{45}P_{45}K_{45}$; 5) $N_{30}P_{30}K_{30}$. The pea variety is Tsarevych. The soil cultivation system is surface tillage. Soil sampling was performed in the 0-20 and 20-40 cm soil layers in May.

The selection and preparation of soil samples for the study of aerobic microbiota in the laboratory was carried out in accordance with DSTU ISO 10381-6-2001. The number of different groups of soil microorganisms was estimated according to the method of D.H. Zvyagintsev by sowing soil suspension on solid culture media. The total number of microorganisms that decompose organic compounds containing nitrogen was studied on meat-peptone agar (MPA). Microorganisms that assimilate mineral forms of nitrogen were studied on a starch-ammonia medium (SAM). The number of microorganisms that synthesize melanins on Chapek's medium at pH = 5.0, decompose humates on sodium humate medium, pedotrophs on soil agar. Statistical data processing was performed using the Statistica software package.

RESULTS AND DISCUSSION

Different intensity of soil use has led to changes in the number of microorganisms engaged in the nitrogen cycle. In the meadow chernozem carbonate soil, the number of ammonifiers depended on the fertiliser system and soil layer (Table 1).

Table 1. Number of ammonifying and amylolytic microorganisms in meadow chernozem carbonate soil under different fertilisation methods, million. CFU/g of soil

Fertiliser variant	Soil layer, cm	Ammonifying	Amylolytic
No fertilisers (control)	0-20	5.75 ± 1.26	0.36 ± 0.06
	20-40	26.11 ± 2.48	0.50 ± 0.02
$N_{30}P_{30}K_{30}$	0-20	12.57 ± 0.10	0.41 ± 0.02
	20-40	3.01 ± 0.10	0.51 ± 0.02
Organic residual effect+ $N_{30}P_{30}K_{30}$	0-20	7.00 ± 0.79	0.43 ± 0.00
	20-40	20.52 ± 1.00	1.03 ± 1.41
Organic residual effect+ $N_{45}P_{45}K_{45}$	0-20	8.45 ± 0.45	0.45 ± 0.12
	20-40	29.58 ± 2.01	0.67 ± 0.01
Organic residual effect+ $N_{15}P_{15}K_{15}$	0-20	27.66 ± 1.03	0.91 ± 0.02
	20-40	30.65 ± 4.60	0.98 ± 0.09

A larger number of microorganisms that decompose organic and synthesize mineral forms of nitrogen was obtained in a layer of 20-40 cm, with the exception of variant $N_{30}P_{30}K_{30}$. The difference compared to the 0-20 cm layer was 10-80%. The highest number of ammonifying microorganisms in the layer of 20-40 cm was observed with the application of $N_{15}P_{15}K_{15}$ in combination with the residual effect of organic matter, and the lowest with the application of only mineral fertiliser system $N_{30}P_{30}K_{30}$. This leads us to the conclusion that mineral fertilisers alone have a negative impact on soil organic matter.

In terms of the number of amylolytic microorganisms, the difference between some variants of the systems did not exceed 5%. Evaluating the degree of enrichment by the number of ammonifiers according to the method of D.G. Zvyagintsev, it is necessary to note that all fertiliser variants were characterized as poor.

According to H.O. Iutynska, 2006, pedotrophic microorganisms are involved in the decomposition of peripheral chains of humus molecules, and deep destruction is carried out by humate-decomposing microorganisms (Table 2).

Table 2. The number of pedotrophic, humate-decomposing microorganisms and micromycetes in meadow chernozem carbonate soil under different fertilisation variants, million CFU*/g soil

Fertiliser variant	Soil layer, cm	Pedotrophic	Humate-decomposing	Micromycetes, thousand CFU/g of soil.
No fertilisers (control)	0-20	11.22 ± 0.83	4.45 ± 0.61	6.19 ± 0.01
	20-40	17.73 ± 2.93	18.33 ± 0.89	10.32 ± 1.49
$N_{30}P_{30}K_{30}$	0-20	10.35 ± 1.15	3.99 ± 0.10	22.96 ± 0.99
	20-40	4.77 ± 1.13	2.04 ± 0.59	13.23 ± 0.00
Organic residual effect+ $N_{30}P_{30}K_{30}$	0-20	8.56±0.07	1.63 ± 0.05	9.05 ± 0.49
	20-40	14.65 ± 0.51	6.59 ± 0.10	18.93 ± 2.49

Table 2, Continued

Fertiliser variant	Soil layer, cm	Pedotrophic	Humate-decomposing	Micromycetes, thousand CFU/g of soil.
Organic residual effect+ $N_{45}P_{45}K_{45}$	0-20	6.80±0.21	5.53±0.15	35.85±0.50
	20-40	23.79±0.01	14.43±2.16	47.46±5.54
Organic residual effect+ $N_{15}P_{15}K_{15}$	0-20	18.74±1.15	8.99±1.28	69.79±1.54
	20-40	16.93±0.55	13.20±0.87	38.15±2.55

Note: * – thousand. CFU/g of soil

The highest number of the above microorganisms was observed under the residual effect of organic matter with full mineral fertilization in the norms of $N_{45}P_{45}K_{45}$ and $N_{15}P_{15}K_{15}$, and also in the control. Thus, when organic fertilisers are applied, organic matter is restored, and without fertilisers, humus decomposes. The application of $N_{30}P_{30}K_{30}$ mineral fertiliser alone resulted in the lowest number of pedotrophic microorganisms in the 20-40 cm layer. The difference between the variant with the highest values was 4.6 times. The highest number of micromycetes was observed in the organic-mineral fertiliser system with $N_{15}P_{15}K_{15}$ in the layer 0-20 cm and amounted to 69.79±1.54 thousand. CFU/g, which is 10 times less compared to the control.

An in-depth analysis of the structure of the microbial community under different fertiliser variants made it possible to determine the direction of microbiological processes in the soil (Table 3).

Table 3. Indicators of the direction of microbiological processes in meadow chernozem carbonate soil under different fertilisation variants, million CFU*/g of soil

Fertiliser variant	Soil layer, cm	Pedotrophy coefficient	Organic matter accumulation coefficient
No fertilisers (control)	0-20	2.0	0.40
	20-40	0.7	0.32
$N_{30}P_{30}K_{30}$	0-20	0.8	1.60
	20-40	1.6	1.94
Organic residual effect+ $N_{30}P_{30}K_{30}$	0-20	1.2	0.89
	20-40	0.7	0.89
Organic residual effect+ $N_{45}P_{45}K_{45}$	0-20	0.8	2.91
	20-40	0.8	1.12
Organic residual effect+ $N_{15}P_{15}K_{15}$	0-20	0.7	2.52
	20-40	0.6	1.19

Note: * – thousand. CFU/g of soil

The pedotrophicity coefficient reflects the functionality of the soil microcenosis structure and points to the degree of organic matter assimilation. The highest rates were observed in the upper layer of the control, in the lower layer of the $N_{30}P_{30}K_{30}$ variant and in the upper layer of the variant with the residual effect of organic matter $+N_{30}P_{30}K_{30}$ (K_{ped} = 2.0, 1.6 and 1.2, respectively), all other rates are in the same range (limits from 0.6 to 0.8). Analysis of the data shows that in variants with higher values, the intensity of decomposition of soil organic matter, in particular humus compounds, increases, which promotes the development of autochthonous microbiota and increases mineralisation processes from the general fund.

The coefficient of organic matter accumulation characterises the intensity of the accumulation of organic compounds in the soil. The highest accumulation rates were observed in the upper layers of the "residual effect of organic matter+$N_{45}P_{45}K_{45}$ and „residual effect of organic matter $+N_{15}P_{15}K_{15}$" ($K_{ac.}$ = 2.91 and 2.52, respectively), slightly lower rates were observed in variant $N_{30}P_{30}K_{30}$ in both layers and in the lower layers of the variants "residual effect of organic matter+$N_{45}P_{45}K_{45}$" and "residual effect of organic matter+$N_{15}P_{15}K_{15}$"($K_{ac.}$ = 1.60, 1.94, 1.12, and 1.19, respectively). The lowest rates were observed in the tilth layer unfertilised ($K_{ac.}$ = 0.40 and 0.32). Thus, when growing peas on meadow chernozem carbonate soil, the best results in humus accumulation are observed with a combination of organic and mineral fertilizers.

The highest yield of peas of the Tsarevych variety was obtained on the variant "residual effect of organic matter $+N_{45}P_{45}K_{45}$" and amounted to 2.94 t/ha, which is 35% more than the control. Organo-mineral fertiliser variants with $N_{15}P_{15}K_{15}$and $N_{30}P_{30}K_{30}$ formed a higher yield than the variant without fertilisers and the indicators were 2.45 and 2.63 t/ha, respectively.

CONCLUSIONS AND PROSPECTS

The study demonstrated changes in the microbiological parameters of meadow chernozem carbonate soil under different fertilisation systems in the Right-Bank Forest-Steppe. Specific features affecting the processes of humus formation under different fertilisation systems used on pea crops were determined.

It was found that the low agrochemical profile of the variant without fertilisers adversely affects the humification processes in the soil and causes the rapid development of microorganisms engaged in the destruction of the peripheral and nuclear parts of humus substances. The study revealed a high number of pedotrophic and humate-decomposing microorganisms and the lowest coefficient of organic matter accumulation ($K_{ac.}$ = 0.40 and 0.32). Applying only mineral fertilisers during pea cultivation formed a high rate of humus accumulation at the level $K_{ac.}$ = 1.6-1.9. The most favourable conditions for the accumulation of organic matter in the meadow chernozem soil and the highest pea yields of the Tsarevych variety are obtained with the residual effect of organic fertilisers and $N_{45}P_{45}K_{45}$.

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Мікробіологічна оцінка лучно-чорноземного карбонатного ґрунту за різних систем удобрення

Анотація. Мікроорганізми відіграють важливу роль у формуванні родючості ґрунту, підтримці його продуктивності як біоінертної речовини та є індикатором якісних змін у ґрунті. Внаслідок антропогенного впливу на ґрунт чисельність та видовий склад мікробіоти зменшується. Метою дослідження була оцінка чисельності різних фізіологічних груп мікроорганізмів на лучно-чорноземному карбонатному ґрунті за різних систем удобрення гороху. Чисельність різних груп ґрунтових мікроорганізмів визначали за методом Д. Г. Звягінцева шляхом висіву ґрунтової суспензії на тверді живильні середовища. Встановлено, що найсприятливіші показники мікробіоценозу та найвищу врожайність гороху сорту Царевич формували варіанти із залишковою дією органічних добрив та $N_{45}P_{45}K_{45}$. Варіант без добрив індукує розвиток процесів мінералізації органічної речовини в лучно-чорноземному карбонатному ґрунті за рахунок вмісту педотрофних і гуматрозкладаючих організмів і формує найнижчу врожайність гороху. Внесення лише мінеральних добрив під горох формувало високі темпи гумусонакопичення на рівні $K_{ac.}$ =1,6-1,9

Ключові слова: мікробіологічна активність ґрунту, лучно-чорноземний карбонатний ґрунт, мікроорганізми, горох, системи удобрення, органічна речовина

Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en *Plant and Soil Science, 12(1), 77-85*
Received xx.xx.2020 Revised xx.xx.2021 Accepted xx.xx.2021

UDC 631.416.14

DOI: 10.31548/agr2021.01.0077

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Changes in the Nitrogen Status of Grey Forest Coarse Dusty Light Loam Soil under Different Systems of Fertilisation and Chemical Amelioration

Abstract. This paper presents the results of research in a stationary experiment, launched in 1992 on grey forest coarse-dusty light loamy soil, aimed at studying the influence of long-term chemical amelioration and various fertilisation systems (mineral, organic, organic-mineral) on the nitrogen regime. Nitrogen is extremely important in agriculture, as all growth processes, photosynthesis, metabolism, and yield volume and quality eventually depend on this element. In Ukraine, the share of soils of woodland composition in total soil cover exceeds 33%, while the share of agricultural land is 25%. Since the humus content and its total reserves are an integral measure of soil formation and a key characteristic that determines the overall habitat of the soil, the article analyses changes in humus content as a response to the above factors. It has been found that the gross nitrogen content reflects the humus content, fully depends on and varies with the humus content of the latter. There is a high

Suggested Citation:

Dmytrenko, O.V., Tkachenko, M.A., & Pavlichenko, A.I. (2021). Changes in the nitrogen status of grey forest coarse dusty light loam soil under different systems of fertilisation and chemical amelioration. *Plant and Soil Science*, 12(1), 77-85. doi: 10.31548/agr2021.01.077.

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correlation between these indicators for all variants of the experiment (r = 0.991). The data obtained indicate that only with the use of green manure and by-products of the predecessor and moderate doses of mineral fertilisers in combination with liming, there is a moderate increase in total nitrogen as compared to the initial level. The rise amounted to 0.36-0.45 t/ha and in this case, it is possible to observe its extended reproduction. Only after mineralisation does the nitrogen of organic compounds become available to plants. The easily hydrolysed form of nitrogen is a fairly reliable indicator of whether the plants are supplied with this element. According to the classification, the soil under study, with a mobile compound content of 81.2-103 mg/kg, falls into the group of soils with a very low degree of nutrient supply, but the degree of hydrolysis of organic matter in it is high (9.6-10.2%). With the combined use of green manure, non-commodity crop products, and one-dose mineral fertilisers along with lime, this form of nitrogen increased by 27.5% compared to the control. Under the above fertiliser complex, there was an increase of 16.5 mg/kg in the amount of $N\text{-}NO_3^-$+$N\text{-}NH_4^+$ compared to the control, plus 7.4 mg/kg of soil nitrification capacity.

Keywords: total nitrogen, ammonia and nitrate, nitrification capacity, humus, soil, yield increase

RELEVANCE

Nitrogen in the soil plays a special role. Its content and reserves depend on the type of soil (the nitrogen content in humus is about 5%). According to M. Melnychuk and other scientists (Melnychuk M. *et al.*, 2004), the greater part of nitrogen in the soil is contained in the form of complex organic substances, which account for 93-97% of its total content, while mineral nitrogen compounds make up only 3-7%. Only the latest forms of nitrogen are available for plant nutrition. The main issue with nitrogen is its high uptake by plants, significant leaching by infiltration water under flushing conditions, and denitrification processes. This element is at the lowest level among the nutrients in the grey forest soils of the Right-Bank Forest-Steppe. The content of gross nitrogen they contain is low (0.05-0.08%), which is due to their low humus content. The accumulation of mobile forms of nitrogen is slow. Nitrification processes are particularly critical (Bober L.V., 1991; Kauricheva I.S., 1989; Vernander N.B., Godlin M.M., Sambur G.N., 1951), which is to some extent related to the acid reaction of these soils. Notably, forest soils cover a large area in the country (25% of agricultural land), and the problem of their genesis remains open to debate. Nitrogen also plays a crucial physiological role in plant growth, as it is the basis for protein synthesis. All growth processes such as photosynthesis, metabolism and other important growth functions would be impossible without the presence of this element.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Long-term use of soils in agriculture changes their humus status, affecting not only the total humus content but also its quality composition. These changes depend on many factors, including the effect of fertilisers, ameliorants, soil cultivation, crop rotation, etc. (Dehodyuk S.E., Litvinova O.A., Smishna-Starynska L.V., 2014; Boyko P., *et al.*, 2019; Sufia Murtazina, *et al.*, 2020). The problem of nitrogen in agriculture is closely related to the content of organic matter in the soil. It contains 97-99% of all nitrogen reserves, the content of which is entirely determined by the processes of humus formation and biological activity of the soil (Saydak R.V. *et al.*, 2013; Litvinova O. *et al.*, 2019). Optimization of the soil nitrogen status under the influence of different fertilisation and tillage systems contributes to a more complete fulfilment of the genetic potential of plant productivity, obtaining consistently high yields of crops (Kolos M.O., 2017).

The study and optimisation of the nutrient nitrogen status of the soil as one of the leading factors in the formation of organic matter of plants will make it possible to increase the efficiency of growing key crops. Therefore, in this context, it is important to conduct research aimed at establishing the impact of fertilisation and tillage systems on the dynamics of mobile nitrogen compounds in the tilth layer of soil (Centilo L.V., Tsyuk A.A., 2019; China Yushu Zhang, *et al.*, 2018).

Purpose of the study. The main goal of the study was to evaluate different fertilisation systems and the long-term effects of chemical amelioration on the nitrogen regime of forest soils, which is the basis for crop formation and quality, and therefore to find the best combinations of integrated application of these fertilisers for enhanced nitrogen reproduction in the soil.

MATERIALS AND METHODS

The object of the study was grey forest coarse-dusty light loamy soil of the long-term field experiment "Study of technological methods of reproduction and regulation of grey forest soil fertility" of the Department of Agrosoil Science and Soil Microbiology of the National Research Centre "Institute of Agriculture of the National Academy of Sciences of Ukraine", which was launched in 1992 on 3 fields of seven-field grain crop rotation. The chemical reclamation was carried out in 2006, lime was applied with a full dose of 1.0 pH (defecate 4.5-6.0 t g ha $CaCO_3$), and in the reporting year, after-effects studies were conducted for the 12th to 14th year.

The fertilisation system for crop rotation and the calculation of doses of biogenic and alkaline earth elements were based on the utility model patent. No. 133924. According to the calculations, the application of biogenic and alkaline earth elements for crops according to their SSGR is as follows: winter wheat N-51.4%; P-16.7%; K-22.1%; Ca-5.7%; Mg-4.1%; soybean N-57.6%; P-12.2%; K-14.5% Ca-14.3%, Mg-2.5%; spring barley N-38.8%; P-19.7%; K-29.0%; Ca-8.2%; Mg-4.8%; white lupine N-47.0%; P-13.4%; K-23.2%; Ca-10.0%; Mg-6.4%. Accordingly, a one-dose active ingredient for winter wheat is $N_{60}R_{30}K_{60}$ and $N_{60}P_{20}K_{26}Ca_7Mg_5$, soy – $N_{30}R_{30}K_{45}$ and $N_{30}P_6K_8Ca_7Mg_1$, barley – $N_{60}R_{30}K_{45}$ and $N_{60}P_{25}K_{36}Ca_{10}Mg_6$ and lupin $N_{30}P_{30}K_{45}$ and $N_{30}P_{8,54}K_{14.8}Ca_{6.4}Mg_{4.1}$. Besides the efficiency of introducing different doses of biogenic and alkaline soil elements, their combination, the experiment studied the effectiveness of seed inoculation, which was carried out with a microbial preparation: winter wheat, spring barley – "Phosphoagrobacterin" which is a composite of several poly-strains *Agrobacterium radiobacter* + poly-strain *Bacillus subtilis*, for soy "Phosphonitragin" (*Bradyrhizobium japonicum* 634b + poly-strain *Bacillu subtilis*). In 2019, fertilisers Omya Calciprill (CaO 52% + MgO 0.5%) and Omya Magprill (CaO 36% + MgO – 15%) produced by Omya were applied.

For a more objective assessment of these effects on the soil nitrogen status, the variant results were compared not only with the absolute control but also with the initial status. A full-profile soil transect was dug on a fallow land (the age of fallow land is 28 years), which is located next to the experimental field, in which soil samples were taken across the entire surface profile. The thoroughly mixed samples were analysed simultaneously with the stationary samples according to the scheme. Agrochemical sampling and analysis of soils were carried out according to generally accepted methods: total humus content according to DSTU 4289:2004, total nitrogen according to DSTU ISO 11261: 2001, the content of highly hydrolysable nitrogen according to Kornfield; ammonium nitrogen content – by the photocolorimetric method with Nessler's reagent (DSTU 4729: 2007); nitrous nitrogen – by the inometric method (DSTU 4729:2007), nitrification capacity according to DSTU 4362:2004. The analytical work was carried out at the Laboratory of Ecological Safety of Land, Product Quality and Environment of the Soil Protection Institute of Ukraine. Abbreviations used in the article: SAC – soil-absorbing complex, SSGR species-specific genotype ratio.

RESULTS AND DISCUSSION

Humus content and its total reserves are an integral index of soil formation. The agronomic properties of arable land and the dynamics of soil fertility are closely related to the transformation of humus through agricultural use (Lykov A.M., Eskov A.I., Novykov M.N., 2004; Sypko A.O., Goruk G.S., 2014; Chebotarev N.T., Yudin A.A., Bubnova V.N., 2014). It is worth noting that grey forest soils are characterised by a distinct profile differentiation by eluvial-illuvial type and a specific accumulation of humus in it. According to the data, out of the generalised 124.0 t/ha of the soil under study in long-term fallow, 44.1 t/ha is contained in the 0-20 cm layer, which is 35.5%. Thus, the vast majority of humus reserves are concentrated mainly in the upper humus layer (Table 1). A variant comparison of the humus content without considering its initial content shows that all fertilisation systems contribute to its increase in one way or another. However, if the results are compared with the original data, the conclusions differ significantly. The data obtained show that the use of soils in agriculture without fertilisation leads to the predominance of humus decomposition over synthesis, which gradually reduces its content.

Table 1. Nitrogen status of grey forest soil depending on liming and fertilisation

Experimental variants	Humus content		Total nitrogen content (N)		highly hydrolysable nitrogen		$N\text{-}NO_3^-+N\text{-}NH_4^+$	Soil nitrification capacity
	%	t/ha	%	t/ha	mg/kg	kg / ha	mg/kg	
No fertilisers (control)	1.40	42.1	0.082	2.46	81.2	243.6	36.5	6.4
$CaCO_3$ (1.0Hr)	1.42	42.6	0.086	2.58	81.8	245.4	37.0	7.4
NPK	1.45	43.5	0.087	2.61	80.0	240.0	37.1	6.8
NPK + $CaCO_3$ (1.0Hr)	1.50	45.1	0.089	2.67	83.8	251.4	37.9	8.9
2NPK + $CaCO_3$ (1.0Hr)	1.30	39.1	0.078	2.34	75.0	225.0	35.9	5.5
NPK by SSGR	1.52	45.6	0.090	2.70	81.2	243.6	37.6	7.0
NPK by SSGR + $CaCO_3$ (1.0Hr)	1.60	48.1	0.095	2.85	81.4	244.2	38.8	7.5
Green Manure + $CaCO_3$ (1.0Hr)	1.62	48.6	0.098	2.94	84.0	252.0	42.4	9.5
Green manure + BP + NPK by SSGR	1.65	49.5	0.099	2.97	86.8	260.4	44.3	11.2
Green manure + BP + NPK + $CaCO_3$ (1.0Hr)	1.63	48.9	0.098	2.94	103.6	310.8	50.1	13.5
Green manure + BP + 1.5 NPK + $CaCO_3$ (1.0Hr)	1.68	50.4	0.101	3.03	102.8	308.4	53.0	13.8

Table 1, Continued

Experimental variants	Humus content		Total nitrogen content (N)		highly hydrolysable nitrogen		$N\text{-}NO_3^- + N\text{-}NH_4^+$	Soil nitrification capacity
	%	t/ha	%	t/ha	mg/kg	kg / ha	mg/kg	
Output sample	1.47	44.1	0.086	2.58	82.4	247.2	37.0	6.8
Average	1.5	45.6	0.1	2.7	85.3	256.0	40.6	8.7
Sx=	0.03	1.01	0.002	0.06	2.54	7.62	1.65	0.80
V%=	7.7	7.7	8.1	8.1	10.3	10	14.0	31.9
S=	0.12	3.50	0.01	0.22	8.80	26.39	5.70	2.78
LSD05=	0.11	3.14	0.01	0.20	7.90	23.70	5.12	2.49

Note: *Sx* – standard error; *X* – mean; *S* – standard deviation (an indicator characterising the variation of the sample). Main deviation of a statistical series from the arithmetic mean; V, % – coefficient of variation

In this experiment, by 4.5% to the initial level, or by 2.0 t/ha. Liming on an unfertilised base by hydrolytic acidity practically did not affect the total humus content compared to the control variant. Thus, in the control, its content was 42.1 t/ha, and in the limed variant at the full rate of hydrolytic acidity 42.6 t/ha.

Cultivation of crops with one mineral system, despite a significant increase in yield, and thus a larger vegetative mass of root and post-harvest residues entering the soil, resulted in humus reserves in this variant increasing by only 1.4 t/ha compared to the control, but were 0.6 t/ha less than in the original sample. This indicates that, although humus losses have decreased, a positive balance has not been achieved in this variant. Extended humus reproduction is possible if mineral fertilisers are used on limed soil.

Thus, when they were applied in moderate doses against the background of lime by hydrolytic acidity in this experiment, humus reserves increased by 3.0 t/ha relative to the control and by 1.0 t/ha to the baseline. The humus content of the soil decreases by 5.0 t/ha when double rates of mineral fertilisers are applied with lime compared to virgin soil. In this case, there is not enough lime to neutralise excessive acidity.

Organo-mineral fertilisation systems with moderate doses of mineral fertilisers, using green manure and plant by-products, contribute to a deficit-free humus balance with a clear positive trend, especially on limed soils. In this case, the expanded reproduction of humus to the original level in different variants ranged from 8.8 to 14.3%. It should be noted that in the variant with SSGR (species-specific genotype ratio), in which moderate and balanced rates of mineral fertilisers were applied, considering the needs of plants for nutrients and thus high yields of the main crops, and thus an increased mass of by-products and root residues, the positive humus balance increased by 3.4%, and on limed soil – by 8.8% to the initial level.

As for the content of total nitrogen in the HE horizon, it reflects the humus content in this horizon. Its absolute values for all variants presented in the table show that there is a high correlation between them ($r = 0.91$, $D = 982$). Thus, the gross nitrogen content depends almost entirely on the content and reserves of humus and varies depending on the humus content of the latter (Aleksandrova L.N., 1980; Vozbutskaya A.E., 1986; Gamzikov G.P., Emelyanova V.N., 1985; Kononova M.M., 1963; Mukha V.D., Kartamyshev N.I., Mukha D.V, 2003; Litvinov D.V., *et al.*, 2019). It is mainly represented by biologically stable organic compounds, as well as small amounts of labile compounds.

Changes in the humus status of grey forest soil that occur as a result of chemical amelioration and the use of organic and mineral fertilisers determine the dynamics of changes in total nitrogen. The results of research by Shklyar V.M. (Shklyar V. indicate that soil that has not been fertilised for a long time loses organic matter of light fractions, which is accompanied by losses of organic nitrogen and, most importantly, soluble compounds of the latter. A steady trend toward this is observable in the present study. During the operation of the experiment on the control variant, the content of total nitrogen decreased by 0.12 t/ha compared to the initial level. The study of the impact of liming at the full rate, as well as the use of a mineral fertiliser system alone, shows that they had almost no effect on the dynamics of increasing total nitrogen in the soil. When they are used together, the increase of this indicator is observed (an increase of 0.21 t/ha relative to the control). The application of double doses of mineral fertilisers even on limed soil at the full dose reduces the reserves of total nitrogen (by 0.12 t/ha compared to the control). The latter can be attributed to a certain extent to the high acidity of the soil in this variant (pH sol. 4.4, hydrolytic acidity 3.48 mg/eq per 100 g of soil). The results show that only the use of organic fertilisers in the form of green manure and plant by-products in the tilth layer of soil showed a significant increase in total nitrogen compared to the baseline. On these variants, the growth was 0.36-0.45 t/ha. This is caused by the presence of an additional quantity of this element applied with these fertilisers. Only after mineralisation does the nitrogen of organic compounds become available to plants. It is important to analyse the direction of changes under the influence of different fertilisation systems and chemical amelioration of nitrogen forms formed from nitrogenous organic compounds (amides, amino acids, etc.) that decompose rapidly and turn into mineral nitrogen, and they become the closest reserve of mineral nitrogen, and in agricultural use can be both accumulated and consumed. This form of nitrogen is a fairly reliable indicator of plant nutrition. In the original sample, this form of nitrogen according to Kornfield reaches 82.4 mg/kg. Based on this classification, soils with such a content of mobile nitrogen forms are considered to be very low in nitrogen supply. The results of this form of nitrogen also indicate the overall low humus content of virgin soil. However, the level of hydrolysis of organic matter in it is high, and for all variants is 9.6-0.2%. For example, in a typical medium loamy chernozem, it accounts for 2-4%.

The amount of alkaline-hydrolysed nitrogen in the soil varied depending on the fertilisation system and chemical reclamation, similar to the change in total nitrogen content. Thus, in the control variants with lime and only mineral fertiliser system, the content of alkaline-hydrogenated nitrogen was low and amounted to 240.0-243.6 kg/ha. There is a significant upward trend in its content compared to the control (by 3.2%) when applying single doses of mineral fertilisers on limed soil, and the application of double doses reduces its content by 7.7%. Nitrogen reserves remained virtually unchanged when using mineral fertilisers based on the SSGR principle. They increased significantly under the organic-mineral fertiliser system. The combined use of green manure, plant by-products, and single doses of mineral fertilisers on limed soil resulted in the highest growth of this form of nitrogen (27.5% over the control). A further increase in mineral fertiliser doses did not have a positive impact on the content and reserves of alkaline hydrolysed nitrogen.

Among the mineral nitrogen compounds, nitrate and ammonium nitrogen are important in plant nutrition, although the amount of mobile mineral nitrogen compounds is very small. These compounds are easily dissolvable, mobile, and dynamic in time. The content of these forms of nitrogen fluctuates significantly during the growing season, and soil moisture and temperature are of great importance, with which the activity of microorganisms is closely related. The experiment did not reveal a clear dependence of ammonium and nitrate nitrogen content on liming, the use of mineral fertilisers applied separately or in combination or by the SSGR principle. Their content increases significantly when using an organic-mineral fertiliser system. The maximum growth was achieved with the combined use of green manure, plant by-products and one and a half doses of mineral fertilisers on limed soil (an increase of 16.5 mg/kg or 45.2% compared to the control).

An important indicator of the soil's nitrogen regime is its nitrification capacity, which is the ability of the soil to accumulate nitrate-nitrogen under favourable conditions, allowing to draw conclusions about potential nitrogen reserves and its impact on crop formation. Nitrification can accumulate 100-300 kg/ha of nitrogen in the soil. The variant analysis shows that the soil under study has a low nitrification capacity according to Kravkov (5.1-8.0 mg/kg) in the vast majority of variants. The use of organic and organo-mineral fertilisation systems contributes to its transfer to the group of soils with an average nitrification capacity of 8.1-15 mg/kg.

CONCLUSIONS

The studied grey forest soils fall into the group of soils with a low humus content (1.47%) and total humus reserves (124.0 t/ha), which are inherited from the original pedogenesis and modern soil formation processes. The humus type (humate-fulvate) does not change over time under the influence of a set of agrotechnical practices, which indicates the unchanging direction of soil formation processes.

Gross nitrogen reserves (2.58 t/ha) depend almost entirely on the content and stock of humus and vary depending on the humus content of the latter. There is a high correlation between these indicators for all variants of the experiment (r = 0,991, D = 98,2). Grey forest soils are characterised by a high degree of hydrolysis of organic matter. The highly hydrolysable fraction of nitrogen in the 0-20 cm layer of the initial soil is 81.2 mg/kg of soil, which corresponds to 9.6% of the gross content. This form of nitrogen is a fairly reliable indicator of nitrogen supply to plants. The integrated use of fertilisers in combination with chemical amelioration will optimise the nitrogen status of grey forest soil, allowing for higher crop productivity.

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Зміни азотного режиму сірого лісового крупнопилуватого легкосуглинкового ґрунту за різних систем удобрення та хімічної меліорації

Анотація. У статті наведено результати досліджень у стаціонарному досліді, закладеному в 1992 р. на сірому лісовому крупнопилувато-легкосуглинковому ґрунті з метою вивчення впливу тривалої хімічної меліорації та різних систем удобрення (мінеральної, органічної, органо-мінеральної) на азотний режим ґрунту. Азот є надзвичайно важливим елементом у сільському господарстві, оскільки від нього залежать усі ростові процеси, фотосинтез, обмін речовин, а також об'єм та якість врожаю. В Україні частка ґрунтів лісового складу в загальному ґрунтовому покриві перевищує 33%, тоді як частка сільськогосподарських угідь становить 25 %. Оскільки вміст гумусу та його загальні запаси є інтегральним показником ґрунтоутворення та ключовою характеристикою, що визначає загальне середовище існування ґрунту, у статті проаналізовано зміни вмісту гумусу як реакцію на вищезазначені фактори. Встановлено, що валовий вміст азоту відображає вміст гумусу, повністю залежить від нього і змінюється разом із вмістом гумусу. Між цими показниками спостерігається високий кореляційний зв'язок на всіх варіантах досліду ($r = 0{,}991$). Отримані дані свідчать, що лише при використанні сидератів і побічної продукції попередника та помірних доз мінеральних добрив у поєднанні з вапнуванням спостерігається помірне зростання загального азоту порівняно з вихідним рівнем. Приріст становив 0,36-0,45 т/га і в цьому випадку можна спостерігати його розширене відтворення. Лише після мінералізації азот органічних сполук стає доступним для рослин. Легкогідролізована форма азоту є досить надійним показником забезпеченості рослин цим елементом. За класифікацією, досліджуваний ґрунт з вмістом рухомих сполук 81,2-103 мг/кг відноситься до групи ґрунтів з дуже низьким ступенем забезпеченості поживними речовинами, але ступінь гідролізу органічної речовини в ньому високий (9,6-10,2%). При сумісному застосуванні сидератів, нетоварної продукції рослинництва та одноразового внесення мінеральних добрив разом з вапном ця форма азоту зросла на 27,5% порівняно з контролем. За вказаного комплексу добрив відбулося збільшення на 16,5 мг/кг суми $N\text{-}N0_3^-$+$N\text{-}NH_4^+$ порівняно з контролем, а також на 7,4 мг/кг нітрифікаційної здатності ґрунту

Ключові слова: загальний азот, аміак і нітрати, нітрифікаційна здатність, гумус, ґрунт, прибавка врожаю

Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en
Plant and Soil Science, 12(1), 86-93
Received xx.xx.2020 Revised xx.xx.2021 Accepted xx.xx.2021

UDC 631.452: 631.445.41: 551.583

DOI: 10.31548/agr2021.01.0086

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Changes in Anti-deflation Resistance of Chernozem Typical under Different Tillage and Fertilizers

Abstract. The scale wind erosion is increasing in Ukraine in connection with the arid climate and intensive agricultural land use. Deflation causes significant damage not only to the soil cover, but also to the environment. Research showed that the resistance of soils to deflation depended on their structural state. The aim of the present study was to establish the influence of different tillage systems and fertilizers on agrophysical parameters of the soil. According to the method of dry sieving according to Savvinov, the content of particles larger than 1 mm and the number of agronomically valuable particles per 1% of humus according by V.V. Medvedev were determined in the soil. The research was conducted on a stationary experiment of the M.K. Shikula Department of Soil Science and Soil Conservation in Separated subdivision of NULeS of Ukraine "Oleksandr Muzychenko Velykosnytinske Educational and Research Farm" of Fastiv district of Kyiv region. The soil of the experimental site is chernozem typical. It was found that in the variant with the application of straw, green manure and mineral fertilizers for reduced tillage, the content of particles larger than 1 mm was the highest and amounted to 75.1-77.5%. Conservation tillage systems provided a deflation-resistant soil surface, as the content of particles over 1 mm was greater than 60%. Reduced tillage together with the fertilizer variant "Straw 1.2 t/ha + N_{12} + $N_{78}P_{68}K_{68}$" creates the best conditions for aggregation in a layer of 0-30 cm of chernozem typical. On non-plowing tillage, more favorable aggregation conditions were on the variant "Straw 1.2 t/ha + green manure N_{12} + $N_{78}P_{68}K_{68}$". On variant with plowing, the indicators of the structural state of chernozem typical deteriorated

Keywords: wind erosion, lumpiness, soil structure, reduced tillage, aggregation standards, typical chernozem

Suggested Citation:
Pikovska, O.V. (2021). Changes in anti-deflation resistance of chernozem typical under different tillage and fertilizers. *Plant and Soil Science*, 12(1), 86-93. doi: 10.31548/agr2021.01.086.

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INTRODUCTION

Wind erosion is second among all soil degradation processes and causes substantial damage to agriculture (Yang, Geng, Fu, Coulter, Chai, 2020).

In the spring of 2020, an extraordinary meteorological phenomenon occurred – a powerful dust storm that covered the territory of Kyiv, Zhytomyr, Chernihiv and other regions of Ukraine. The main reason for this phenomenon was the abnormal weather conditions of 2019 and the first half of 2020: insufficient rainfall in autumn and spring in combination with a snowless winter, as well as high wind speeds. is not only due to climate change. An essential factor in the occurrence of dust storms is the irrational use of soil resources. After all, the main factor in wind erosion or deflation is excessive plowing of agricultural and (Fig. 1).

Figure 1. Dust storm in Kyiv, April 18, 2020

According to the the State Service of Ukraine for Geodesy, Cartography and Cadastre, as of 01.01.2016, the total area of agricultural land in Ukraine was 41.5 million hectares, including arable land – 32.5 million hectares. Plowing of soils on average in Ukraine is 78.4%. This is one of the highest rates in the world, which has continued to grow in recent years. At the same time, the area of forest, protective forest belts, hayfields and pastures is declining. This causes a violation of the ecological balance in agricultural landscapes, which leads to a decrease in their resistance to degradation processes, including water and wind erosion. The cause of wind erosion is the destruction of the soil structure. That is why scientific studies of soil deflation stability are important.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Intensity of the effects of deflation processes depends on the physical and geographical conditions of the distribution of agricultural land, systematic soil protection activities and the availability of vegetation. It was established that the acceleration of the deflation processes occured in the territories with increased anthropogenic pressure. An understanding of soil resistance to wind erosion as affected by the integration of cropping system intensification and tillage method is imperative for reducing wind erosion, thereby improving global food security and reducing environmental degradation (Dudiak, Pichura, Potravka, Stroganov, 2020).

The intensity of deflation directly depends on the degree of wind resistance of the soil surface and wind speed. The degree of anti-deflation resistance of the upper layer is determined both directly by the stability of the soil and plant debris on its surface. (Voloshenyuk, A.V., 2015).

Significant changes in soil aggregate size distribution associated with wind erosion processes may occur in short periods of time. Thus, temporal variability of soil surface properties, including crust and clods stability, needs to be considered in wind erosion research in agricultural soils (López, Gracia, Arrúe,2000).

Conservation tillage is commonly used in regions affected by water and wind erosion. Research scientists found the positive impact of reducing the intensity of tillage on fertility rates (Tan, Cao, Yuan *et al.*, 2015; Berezhniak, M., & Berezhniak, E., 2019; Pikovska, 2011; Tykhenko O.V., 2016). Soil erosion estimates in the study area under conservation tillage with stubble retention was significantly lower than that under conventional tillage during the monitoring period. (Gao, Dang, Yu, Li, Liu, and Wang, 2016).

The size distribution and stability of soil aggregates have a major influence on the wind erodibility or soils (Tatarko, 2001). Geometric mean diameter, erodible fraction, and dry aggregate stability are soil parameters deduced by dry sieving that are used to identify soil susceptibility to wind erosion (Graciela Hevia, Mariano Mendez, Daniel Buschiazzo, 2007).

MATERIALS AND METHODS

The research was conducted on a stationary experiment of the M.K. Shikula Department of Soil Science and Soil Conservation in Separated subdivision of NULeS of Ukraine "Oleksandr Muzychenko Velykosnytinske Educational and Research Farm" of Fastiv district of Kyiv region. The soil of the experimental site is chernozem typical. The soil of the experimental site was characterized by the following indicators. The content of physical clay in the upper horizon was 34.5%, in the middle 22% of silt and 28% of sand, the content of coarse dust – 46.3, middle – 6.8, fine – 3.4%. The humus content in the subsoil is 3.6%, in the subsoil – 3.5%. The reaction of the soil medium is neutral, the number of absorbed cations is 35.4 mg-eq / 100 g of soil, and the degree of saturation of the bases is 93.4%.

The experiment includes three variants of tillage:

a) plowing at 25-27 cm;

b) deep plowless cultivation;

c) reduced tillage on deep 10-12 sm.

3 fertilization systems with the introduction of 1 ha of crop rotation area were researched:

1. Control (without fertilizers)
2. Straw 1.2 t/ha + N_{12} + $N_{78}P_{68}K_{68}$
3. Straw 1.2 t/ha + N_{12} + sideats + $N_{78}P_{68}K_{68}$.

Indicators of the structural state were determined by N. I. Savvinov, the humus content – by the method of I.V. Tyurin in the modification of V.N. Simakov. The norm of soil structure formation (aggregation) was the number of structural units (agronomically valuable structure ranging in size from 10 to 0.25 mm), which accounts for 1% of the total humus (Medvedev, V. V., 2010).

Indicators of soil macrostructure, in particular the content of aggregates more than 1 mm in dry sieving by the method of Savvinov, are used as an indirect but universal indicator of anti-deflation resistance of soil (Chornyy, S.H., Vydynivs'ka, O.V., Voloshenyuk, A.V., 2012; Chornyy, S.G, Pysmennyj, O.V., 2011).

The aim of the research was to establish the impact of various farming practices on structural indicators aggregate composition.

RESULTS

Tillage systems significantly affected the structural and aggregate composition of chernozem typical of Right-Bank Forest-Steppe of Ukraine. The highest content of dust particles in all variants was observed in the upper layer of 0-10 cm, while cloddy – in the layer of 20-30 cm for plowing 28.20-32.4%. The content of units with a size of 0.25-0.5 mm is higher under plowing on all fertilizer variants.

To assess the resistance of soils to blowing on the content of particles larger than 1 mm, the most informative is their number in the upper 0-10 cm layer. In the present studies, their content varied significantly according to the options in the above layer and was 52-77.5%. The lowest values were found in the control of plowing, while on deep non-plowing tillage – 56.8%. Minimization of tillage of chernozem typical helped to create conditions for the formation of a deflation-resistant soil surface even without fertilizer, where the percentage of particles over 1 mm was 67.7 (Fig. 2).

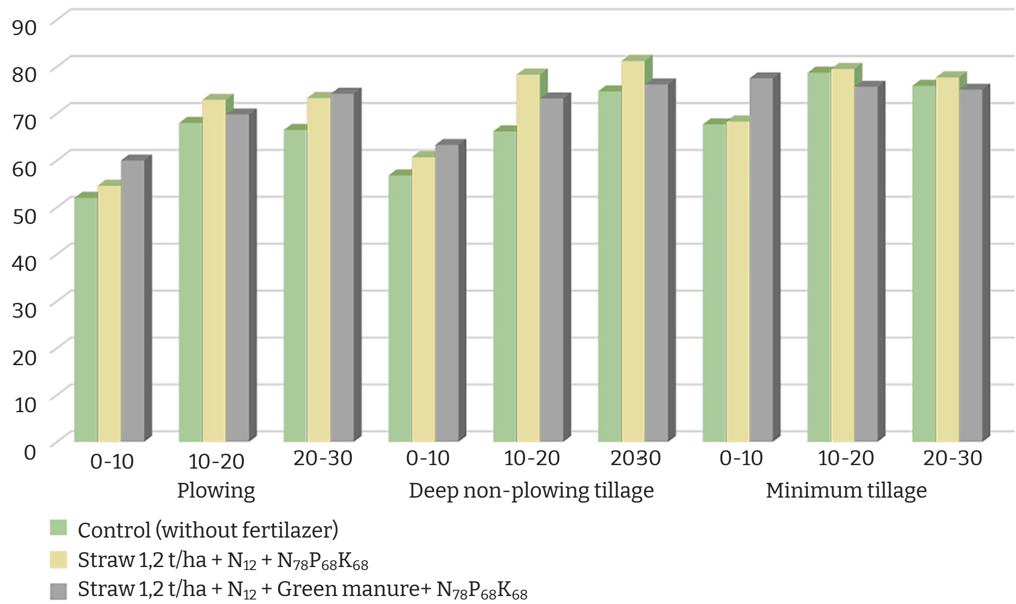

Figure 2. The content of aggregates sizes larger 1 mm in chernozem typical

In the layer of 10-20 cm, similarly to the upper 0-10 cm layer, higher values of particles larger than 1 mm were observed: for deep non-plowing tillage 66.2-78.3 and for the reduced tillage – 75.7-79.5%. However, in the deepest researched layer of 20-30 cm, the advantages were for deep non-plowing tillage (74.7-81.2%) against 75.1-77.7% for the reduced tillage and 66.5-74.2 on plowing.

The use of organo-mineral fertilizers increased the deflation stability of the surface of chernozem typical. In the variant with the combined use of straw and mineral fertilizers, the particle content of more than 1 mm was higher compared to the control without fertilizer for plowing by 2.6-6.8%, for deep non-plowing tillage – by 3.9-12.1%, while under the reduced tillage increase in the percentage of particles was only 0.6-1.8. Reduced tillage provided the best conditions for soil structuring under the influence of green manure. In the variant with the application of straw, green manure and mineral fertilizer, the content of particles larger than 1 mm was 75.1-77.5%.

Studies on chernozem ordinary Northern Steppe of Ukraine established that the use of reduced and zero tillage ensured the preservation of their fertility. The content of aggregates larger than 1 mm in the 0-10 cm layer of ordinary chernozem at reduced tillage was 60%, at No-till – 62%, while during plowing the particle content was only 49%. (Pikovska, 2020)

Medvedev V.V. (2010) on the basis of research established a relationship between the content of agronomically valuable structural aggregates (10-0.25 mm) and the content of humus in the soil. He recommends the use of aggregation standards for soils of Ukraine: the content of macroaggregates of 10-0.25 mm, which is 1% of humus, in the

Forest-Steppe for medium loamy soils should be 20%. This level of structuring of arable soils, which is provided by the relevant aggregation factors, should be maintained and their deterioration should not be allowed. The consequence will be the reduction of aggregation agrophysical degradation, leading to deterioration of soil resistance to the action of water and wind erosion.

These V.V. Medvedev's (2010) standards were used to identify potential realization of aggregation, comparing the ratio of the actual value of the index options aggregation experiment. If the actual value is less than the standards, then there are conditions in the soil that inhibit the process of aggregation. The results of calculations of indicators for different options are shown in Figure 3.

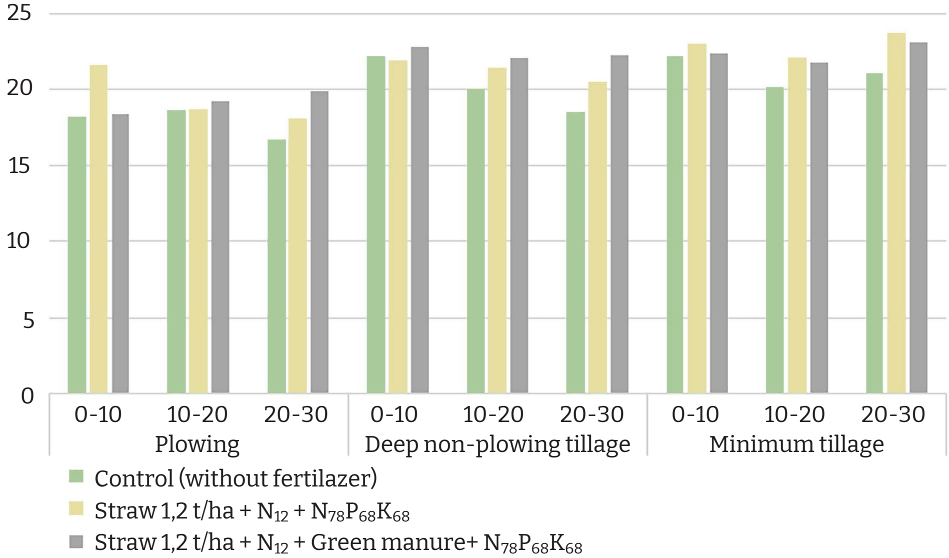

Figure 3. Content of agronomically valuable aggregates 10-0.25 mm per 1% of humus in chernozem typical

It was found that the aggregation rate for the content of agronomically valuable aggregates for all fertilizer variants compared to plowing increased. In the case of reduced tillage, this content was the highest – 20.1-23.7, while in deep non-plowing tillage it was in the range of 18.5-22.8; for plowing the values were the lowest – 16.7-21.6%.

The lowest values of indicators for different tillage systems were found in the layer of 0-10 sm. During plowing in almost all layers and variants of fertilizers the values were lower than the normative 20%, which indicates the presence of factors that slow down the process of aggregation in the arable layer.

Deep non-plowing tillage increased the aggregation capacity of the soil on all variants of fertilizer in a layer of 0-30 cm compared to plowing. It should be noted that fertilizer options helped to improve soil aggregation conditions. The best conditions for aggregation in all layers of the studied soil (22.1-22.8%) were created on the variant "Straw fertilizer 1.2 t/ha + N_{12} + green manure + $N_{78}P_{68}K_{68}$. And for this variant of cultivation there was the smallest differentiation of soil layer 0-30 cm. In the variant of minimal tillage, some changes were noted in the variants of fertilizer compared to deep non-plowing tillage.

The highest content of aggregates with a size of 10-0.25 mm, per 1% of humus, was observed in the variant of joint application of straw and mineral fertilizers (22.1-23.7%). Slightly lower values of this indicator were in the case of straw, green manure and mineral fertilizers (21.8-23.1%). We explain this phenomenon by the fact that with shallow cultivation there is a worse earning of green mass of green manure in the soil.

Thus, the application of reduced tillage in conjunction with the fertilizer option «Straw 1.2 t/ha + N12 + $N_{78}P_{68}K_{68}$ « creates the best conditions for aggregation in 0-30 cm layer of typical chernozem. However, with deep tillage to create favorable conditions for aggregation, we can recommend the option «Straw 1.2 t/ha + green manure N_{12} + $N_{78}P_{68}K_{68}$ «. Systematic application of plowing will worsen the structural condition of soils, especially without the use of fertilizers, which can reduce the resistance of soils to deflation.

CONCLUSIONS

Irrational agricultural use of soils leads to the development of degradation processes, including wind erosion. Based on the research, it is established that tillage systems have a significant impact on the development of deflationary processes. To assess the anti-deflation stability of chernozem typical use parameters of the structural and aggregate composition of the soil. It was found that the reducing of tillage together with the organo-mineral fertilizer system provides the formation of deflation-resistant surface of chernozem typical in the conditions of the Right Bank Forest-Steppe of Ukraine compared to plowing, where the content of particles larger than 1 mm was less than 60%. Further researches on establishment of moisture-preserving effect of various systems of tillage in the conditions of aridization of climate are perspective.

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Зміни антидефляційної стійкості чорнозему типового за різного обробітку ґрунту та удобрення

Анотація. Масштаби вітрової ерозії в Україні зростають у зв'язку з посушливим кліматом та інтенсивним сільськогосподарським використанням земель. Дефляція завдає значної шкоди не тільки ґрунтовому покриву, а й навколишньому середовищу. Дослідження показали, що стійкість ґрунтів до дефляції залежить від їхнього структурного стану. Метою даного дослідження було встановити вплив різних систем обробітку ґрунту та добрив на агрофізичні показники ґрунту. Методом сухого розсіву за Саввіновим у ґрунті визначали вміст часток розміром більше 1 мм та кількість агрономічно цінних часток на 1 % гумусу за В. В. Медведєвим. Дослідження проводили на стаціонарному досліді кафедри ґрунтознавства та охорони ґрунтів ім. М. К. Шикули у Відокремленому підрозділі НУБіП України "Великоснітинське навчально-дослідне господарство ім. О. В. Музиченка" Фастівського району Київської області. Ґрунт дослідної ділянки - чорнозем типовий. Встановлено, що у варіанті з внесенням соломи, сидератів та мінеральних добрив за мінімального обробітку ґрунту вміст часток розміром більше 1 мм був найвищим і становив 75,1-77,5 %. Ґрунтозахисні системи обробітку забезпечували дефляційно стійку поверхню ґрунту, оскільки вміст часток розміром понад 1 мм перевищував 60%. Поглиблений обробіток ґрунту разом з варіантом удобрення "Солома 1,2 т/га + N_{12} + $N_{78}P_{68}K_{68}$" створює найкращі умови для агрегації в шарі 0-30 см чорнозему типового. За безполицевого обробітку ґрунту більш сприятливі умови агрегації були на варіанті "Солома 1,2 т/га + сидерат N_{12} + $N_{78}P_{68}K_{68}$". На варіанті з оранкою показники структурного стану чорнозему типового погіршилися

Ключові слова: вітрова ерозія, грудкуватість, структура ґрунту, мінімальний обробіток, показники агрегатного стану, чорнозем типовий

Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en
Plant and Soil Science, 12(1), 94-101
Received xx.xx.2020 Revised xx.xx.2021 Accepted xx.xx.2021

UDC 582.288:581.2: 634.711.1

DOI: 10.31548/agr2021.01.0094

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Phytopathogenic Mycobioma in Organic Production of Raspberry (*Rubus idaeus* L.) Cultivars J Jay and Himbo-Top

Abstract. This study presents the findings on the influence of raspberry varieties on the species composition of micromycetes in rhizosphere soil and on the vegetative organs of plants in organic production. The mycobiota of raspberry varieties Joan J and Himbo-Top was analysed during plant ontogeny and the species composition of phytopathogenic microspecies in the rhizosphere and on plant leaves was determined. It was found that the population is dominated by fungi: Septoria rubi, West, Botrytis cinerea, Pers, Aspergillus niger, V. Tiegh, Alternaria alternata, (Fr.) Keissl., Fusarium graminearum, Schwabe, regardless of the phase of plant ontogeny, which are producers of mycotoxins. The results of the study suggest that during the phase of inflorescence in the rhizosphere soil mycobiota and on the vegetative organs of raspberry plants of the Joan J and Himbo-Top varieties, the isolates of Septoria rubi and Alternaria alternata fungi are characterised by the highest competitive ability. A study of raspberry cultivars has shown a significant differentiation in the effect on the mycobiota of rhizosphere soil and vegetative organs during intensive fruiting. It was found that isolates of Aspergillus flavus, Aspergillus niger,

Suggested Citation:
Mineralova, V., Parfeniuk, A., & Mineralov, O. (2021). Phytopathogenic Mycobioma in Organic Production of Raspberry (*Rubus idaeus* L.) Cultivars J Jay and Himbo-Top. *Plant and Soil Science*, 12(1), 94-101. doi: 10.31548/agr2021.01.094.

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Aspergillus oryzae and Alternaria alternate, which parasitise plants of the Himbo-Top variety, are characterised by a higher rate of radial mycelial growth and competitive ability compared to those parasitising the raspberry variety Joan J

Keywords: raspberries, rhizosphere, mycobiota, radial growth rate, vegetative organs of plants, isolates, phytopathogens, organic production

RELEVANCE

Raspberries are a valuable berry crop but obtaining high and sustainable yields depends on reducing losses caused by a range of pests and pathogens, including widespread fungal infections. The chronic nature of these diseases, the propagation of raspberries by vegetative means, and the lack of insufficient disease control during the growing season contribute to the accumulation and spread of phytopathogenic microbes. In the Forest-Steppe of Ukraine, raspberries are affected by diseases, among which the most common are anthracnose, septoria, fusarium, and alternaria (Hvozdiak, R.I., 2011). Their extensive spread can lead to the loss of fruiting stems and shoots, which significantly reduces yields. Plants lose resistance to low temperatures and react poorly to soil drought. The quality of planting material deteriorates. Yields can drop as much as 40% (Ostapenko, V.M., *et al.*, 2013). In addition, the pathogens of these diseases significantly reduce the nutritional and commercial quality of berries. Among them are toxin-forming fungi, which are considered to be factors of biological pollution of biocenoses. Nowadays, the organic nature of fruits is highly regarded, and the presence of toxin-forming micro-microbes in raspberry agrophytocenoses poses a potential danger of accumulation of harmful metabolites in plant products. Therefore, it is necessary to explore new technologies and varieties of raspberries that can inhibit the development of phytopathogenic microbes long-term. Therefore, the present study investigated the biological properties of isolates of phytopathogenic microbial agents present in the rhizosphere and ground vegetation organs of raspberry plants of foreign-bred raspberry varieties Joan J and Himbo-Top during plant ontogeny.

The purpose of the study was to determine the influence of remontant raspberry varieties on the number and competitive ability of isolates of phytopathogenic fungi parasitising the rhizosphere and vegetative organs of plants under organic production conditions.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The cultivation of berry crops, in particular remontant raspberries, using organic technologies on industrial plantations involves the introduction of resistant varieties (Archer, L., *et al.*, 2016, Prakash, B., *et al.*, 2011, Sekizuka, M., 2014, Ternovyi, Yu.M., *et al.*, 2010, Wang, Shiow, Y. & Lin, Hsin-Shan, 2000). Ukrainian scientists confirm the expediency of evaluating cultivars of cultivated plants as an ecological factor in the formation of a phytopathogenic background, which makes it possible to address the problem of controlling the number of populations of phytopathogenic microbes in agrocenoses (Parfeniuk *et al.*, 2015, Parfeniuk *et al.*, 2020). Varieties and hybrids are known to stimulate or restrain the intensity of spore formation of phytopathogenic fungi at different stages of ontogeny (Parfeniuk, A.I. & Beznosko, I.V., 2012). It is known that the species of *Fusarium spp.* cause pathological changes in experimental plants (stunted growth and wilting), although their aggressiveness is only moderate and they were classified as the second pathogenicity group (Furtat, I., 2020). However, there is no data on the effect of raspberry remontant varieties on the pathogenic mycobiota of the rhizosphere and vegetative organs of plants at different stages of their development. But it is the pathogenic mycobiota that significantly reduces the quality and biological safety of raspberry products.

MATERIALS AND METHODS

The research was conducted at the Department of Agrobiological Resources and Environmentally Safe Technologies of the Institute of Agroecology and Nature Management of the National Academy of Agrarian Sciences of Ukraine and at the experimental field of Friendsbury LLC, located on typical chernozem in the Myronivskyi district of Kyiv Oblast and characterised by moderate agroclimatic conditions. The study was performed using raspberries of the Joan Jay (British selection) and Himbo-Top® (Swiss selection) remontant varieties cultivated according to the standard organic production technology (Polianchikov, S. & Kapitanska, O., 2017). Microbiological, phytopathological, mycological methods and methods of sampling raspberry plants during the growing season were used during the research (Bilay, V.I., *et al.*,1982, Parfeniuk, A.I., *et al.*, 2014, Zvyagintsev, D.G., 1991). Statistical analysis of the obtained results was performed using Microsoft Office Excel.

RESULTS AND DISCUSSION

The results of the study showed that the mycobiota of the rhizosphere and vegetative organs of raspberry plants of the varieties Joan J and Himbo-Top are dominated by fungi: *Septoria rubi,* West, *Botrytis cinerea,* Pers, *Aspergillus niger,* V. Tiegh, *Alternaria alternata,* (Fr.) Keissl., *Fusarium graminearum,* Schwabe, regardless of the phase of plant ontogeny, which are producers of mycotoxins. These micromycetes are producers of mycotoxins characterised by different mechanisms of action on living organisms and lead to biological contamination of agroecosystems and a decrease in crop quality (Table 1). Their mycotoxins can cause dangerous diseases in humans and animals.

Table 1. Species composition of phytopathogenic micromycetes of mycobiota of raspberry plants of Joan J and Himbo-Top varieties

Disease	Pathogen	Mycotoxins
Septoria	*Septoria rubi*	Properties only
Grey rot	*Botrytis cinerea*	Botrydial
Black mold	*Aspergillus niger*	Aflatoxin
Cladosporiosis	*Cladosporium herbarum*	Properties only
Alternariasis	*Alternaria alternata*	Tentotoxin

It is known that one of the important indicators characterising the physiological activity of phytopathogenic microsporidia is the average radial growth rate of fungal cultures on nutrient media (Parfeniuk, A.I., *et al.*, 2014). The results of the studies revealed that the identified phytopathogenic micromycetes have different rates of radial mycelial growth (Figs. 1, 2, 3).

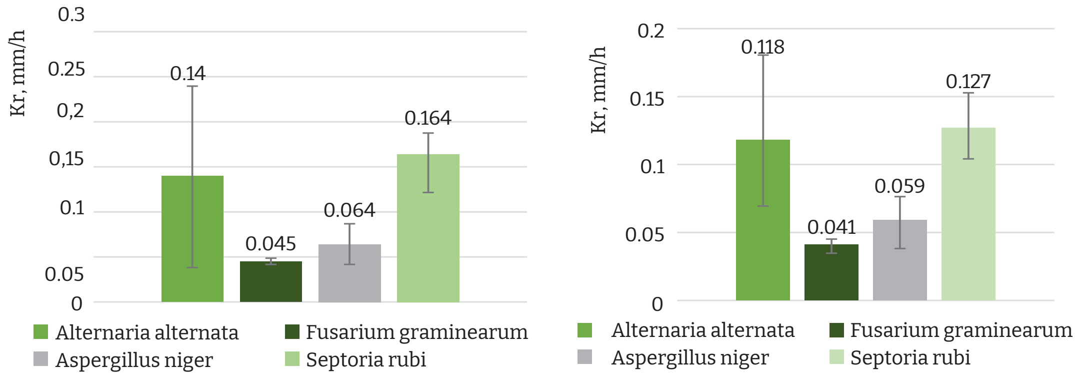

Figure 1. Radial growth rate *Kr* (mm/h) of fungal isolates isolated from rhizosphere soil and vegetative organs of raspberry plants in the phase of inflorescence extension (*left – raspberry variety Joan J, right – raspberry variety Himbo-Top*)

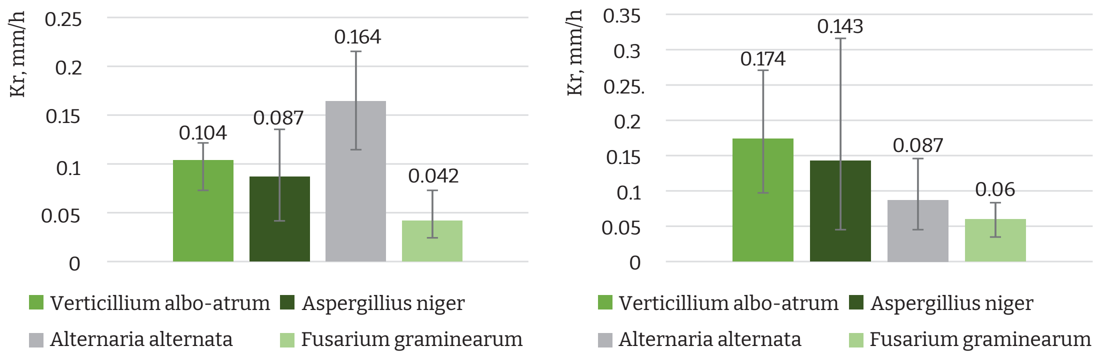

Figure 2. Radial growth rate Kr (mm/h) of fungal isolates isolated from rhizosphere soil and vegetative organs of raspberry plants of the studied varieties in the phase of bud separation in inflorescences (*left – raspberry variety Joan J, right – raspberry variety Himbo-Top*)

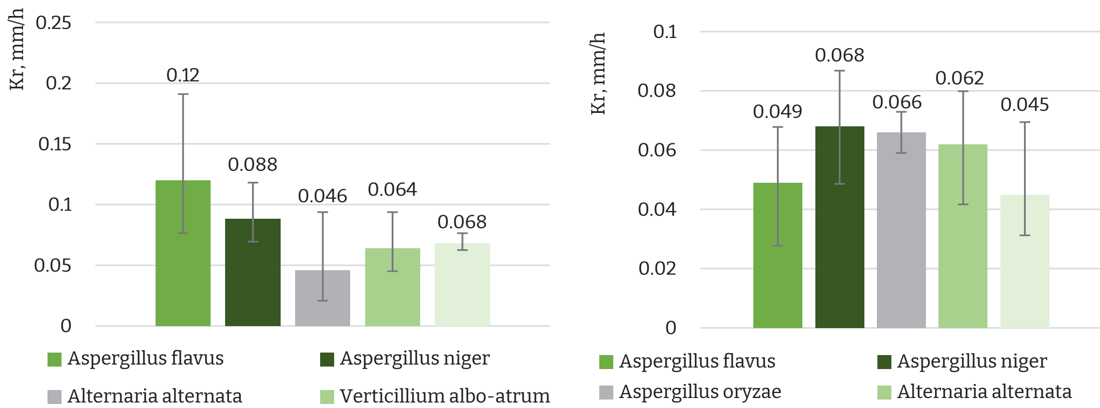

Figure 3. Radial growth rate *Kr* (mm/h) of fungal isolates isolated from rhizosphere soil and vegetative organs of raspberry plants of the studied varieties in the phase of intensive fruiting (*left – raspberry variety Joan J, right – raspberry variety Himbo-Top*)

According to the data presented in Fig. 1, the highest radial growth rate of mycelium (0.164 mm/h and 0.127 mm/h) was observed on isolates of *S. rubi* isolated from raspberry leaves of Joan J and Himbo-Top varieties in the phase of inflorescence extension. At the same time, the radial growth rate of *F. graminearum mycelium* isolated from both studied varieties was almost three times lower and averaged 0.045 mm/h and 0.041 mm/h, respectively. The results of the study suggest that during the phase of inflorescence in the rhizosphere soil mycobiota and on the vegetative organs of raspberry plants of the Joan J and Himbo-Top varieties, the isolates of *S. rubi* i *A. alternata* fungi are characterised by the highest competitive ability.

During the bud separation phase, a significant increase in phytopathogenic mycobiota was observed in the mycobioma of the rhizosphere and on the vegetative organs of raspberry plants of the studied varieties. According to the data shown in Figure 2, the highest rate of radial mycelium growth was observed in the culture of isolates of the species *A. alternata* (0.164 mm / h), isolated from rhizospheric soil and vegetative organs of raspberry plants of the Joan Jay variety. At the same time, on the variety Himbo-Top, the maximum radial growth rate of mycelium was observed in the culture of isolates of *A. flavus* (0.174 mm/h). During this period, the growth of the mycelium of *A. niger* fungi was almost unaffected by varietal differences in raspberry plants. The highest activity and diversity of phytopathogenic micromycetes was found in the inflorescences during the period of bud separation compared to other periods of raspberry plant ontogeny of the studied varieties. This may be due to weather conditions and characteristics of the physiological and biochemical properties of plants during this period. At the same time, the lowest rate of radial growth of fungal mycelium was observed in isolates of the species *F. dhamipeagim*, selected from both raspberry varieties (0.042 mm/h and 0.06 mm/h).

The results of the analysis of the rate of radial growth of fungal colonies of isolates isolated from the rhizosphere and leaves of raspberry plants in the phase of intensive fruiting (Fig. 3) showed that the highest rate of radial growth of mycelium was characterised by isolates of the species *A. flavus* (0.12 mm/h), isolated from the rhizosphere and leaves of raspberry plants of the raspberry variety Joan J. At the same time, the highest rate of radial mycelial growth was demonstrated by isolates of *A. niger* (0.068 mm/h), *A. oryzae* (0.066 mm/h) and *A. alternata* (0.062 mm/h) isolated from rhizosphere soil and leaves of plants of the Himbo-Top variety. They showed the highest competitiveness among the isolates of phytopathogenic microbial species. The lowest rate of radial growth of fungal mycelium during this period was observed in isolates of *A. alternata* isolated from plants of the raspberry variety Joan J (0.046 mm/h) and *F. graminearum* from plants of the variety Himbo-Top (0.045 mm/h).

CONCLUSIONS

In the phase of inflorescence extension in the mycobiota of rhizosphere soil and vegetative organs of raspberry plants, isolates of *S. rubi fungus showed the highest competitiveness on raspberry varieties Joan J and Himbo-Top.* During the period of bud separation in the inflorescences, the activity and diversity of phytopathogenic micromycetes significantly increase compared to other periods of raspberry plant ontogeny of the studied varieties. The raspberry varieties Joan J and Himbo-Top differ significantly in their effect on the competitiveness of phytopathogenic micro-microbes. In the mycobiota of rhizosphere soil and vegetative organs of raspberry plants of the variety Joan J during intensive fruiting of plants, the most competitive fungal isolates were *A. flavus*, and on the variety Himbo-Top, isolates of *A. niger*, *A. oryzae* та A. *alternata* showed high competitiveness.

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Фітопатогенна мікобіома в органічному виробництві малини (Rubus idaeus L.) сортів Джей Джей та Хімбо-Топ

Анотація. У статті представлено результати дослідження впливу сортів малини на видовий склад мікроміцетів у ризосферному ґрунті та на вегетативних органах рослин в умовах органічного виробництва. Проаналізовано мікобіоту сортів малини Джоан Джей та Хімбо-Топ протягом онтогенезу рослин та визначено видовий склад фітопатогенних мікроміцетів у ризосфері та на листках рослин. Встановлено, що в популяції домінують гриби: Septoria rubi, West, Botrytis cinerea, Pers, Aspergillus niger, V. Tiegh, Alternaria alternata, (Fr.) Keissl., Fusarium graminearum, Schwabe, незалежно від фази онтогенезу рослин, які є продуцентами мікотоксинів. Результати дослідження свідчать, що у фазу цвітіння в мікобіоті ризосфери ґрунту та на вегетативних органах рослин малини сортів Джоан Дж і Хімбо-Топ найвищою конкурентною здатністю характеризуються ізоляти грибів Septoria rubi та Alternaria alternata. Дослідження сортів малини показало значну диференціацію впливу на мікобіоту ризосферного ґрунту та вегетативних органів під час інтенсивного плодоношення. Встановлено, що ізоляти Aspergillus flavus, Aspergillus niger, Aspergillus oryzae та Alternaria alternate, які паразитують на рослинах сорту Хімбо-Топ, характеризуються вищою швидкістю радіального росту міцелію та конкурентною здатністю порівняно з тими, що паразитують на рослинах малини сорту Джоан Дж

Ключові слова: малина, ризосфера, мікобіота, радіальний ріст, вегетативні органи рослин, ізоляти, фітопатогени, органічне виробництво

Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en
Plant and Soil Science, 12(1), 102-111
Received xx.xx.2020 Revised xx.xx.2021 Accepted xx.xx.2021

UDC [635.262"324":631.526.3]:631.528(477.5)

DOI: 10.31548/agr2021.01.0102

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Productivity of Winter Garlic in the Left-Bank Forest-Steppe of Ukraine and Molecular Genetic Polymorphism of the Studied Varieties by ISSR Loci

Abstract. In Ukraine, the areas allocated to garlic cultivation are expanding and as of 2020 amounted to 1,100 hectares, which is driven by high profitability and steady demand in both domestic and foreign markets. At the same time, the evaluation of current and new varieties of winter garlic is important for further yield increase in this valuable crop. The purpose of the study is to evaluate the genetic diversity of the studied varieties of winter garlic by ISSR loci and determine the most productive ones in the conditions of the Left-Bank Forest-Steppe of Ukraine. Winter garlic varieties Dyushes, Lyubasha and Ugorskyi (line 20-16) were used for the research. The largest marketable

Suggested Citation:

Yaroviy, G.I., Filimonova, O.I., Romanov, O.V., & Hordiienko, I.M., (2021). Productivity of Winter Garlic in the Left-Bank Forest-Steppe of Ukraine and Molecular Genetic Polymorphism of the Studied Varieties by ISSR Loci. *Plant and Soil Science*, 12(1), 102-111. doi: 10.31548/agr2021.01.102.

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yield (14.1 t/ha) was obtained by growing winter garlic of the Lyubasha variety. The Ugorskyi variety (line 20-16) provided a yield of 12.9 t/ha, the Dyushes variety 9.4 t/ha. The formation of the yield of winter garlic by 12.3% depended on the characteristics of the variety, the impact of the growing season made up 87.3%. The variety of winter garlic Ugorskyi (line 20-16) with *As* = 73.8% was agronomically stable (As > 70%). Based on the above studies, allelic formulas (molecular genetic passports) of winter garlic varieties Ugorskyi (Line 20-16), Lyubasha and Dyushes were formed. The studied varieties of winter garlic contained several amplicons unique within the group under investigation. In the Dyushes variety, the unique loci were UBC812725 and UBC 812902, and in the Lyubasha variety UBC 812791 and UBC 842702. The 20-16 line had the most unique loci: UBC 812460, UBC812997, UBC826682, UBC8341283, and UBC846920. The calculated Nei-Li similarity coefficients indicate a close genetic distance between studied varieties of winter garlic. The varieties Lyubasha and Dyushes are genetically closer to one another compared to Ugorskyi (line 20-16)

Keywords: garlic, variety, Lyubasha, Dyushes, Ugorskyi, yield, polymorphism

RELEVANCE

Garlic (*Allium sativum* L.) is an annual, herbaceous, cold-resistant plant that is distributed throughout the Eastern Hemisphere, but most of all in Asia Minor and Central Asia (Kovarovič *et al.*, 2019) Almost 10 million tons of garlic are grown annually. The world's largest producers are China and South Korea (Etana, 2018), as well as Egypt, India, Turkey and Spain (Malik Geetika, 2017).

Due to its valuable properties, garlic is widely used for food and medicinal purposes (Shah Faraz, 2018). In Ukraine, the increase in production of this crop is mainly due to an expansion of the crop cultivation areas. The cause of the weak increase in winter garlic yields is its high conservatism and poor adaptability to growing conditions due to the vegetative type of reproduction, which results in a limited production area for the varieties created so far. For this reason, local varieties of garlic, which are well adapted to the ecological conditions of the region, are grown in Ukraine and other countries. Evaluation of existing and new varieties of winter garlic is important for further increase of production of this valuable crop both for the Left Bank Forest-Steppe zone and for the whole of Ukraine.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

In Ukraine, the area of garlic cultivation amounted to 1,100 hectares as of 2020. Its primary production (about 49% of the crops) is concentrated in Vinnytsia, Chernivtsi, Zaporizhzhia and Donetsk Oblasts. The yields and total harvests of seed and food garlic in the country are still low – 8.6 tons per hectare (Mogylna *et al.*, 2018).

There are about 600 cultivated varieties of garlic in the world (Anonymus, 2018). Most of them originated from a few basic types that grew in different environments and acquired unique characteristics over the centuries. At the same time, varieties play an extremely important role in increasing and stabilising garlic production. Their optimal selection can significantly increase gross production, improve product quality, and reduce the risk of plant damage by pests and diseases (Pinto *et al.*, 2000; Kyryk, Pikovskyi, Azaiki, 2012; Kyryk, Pikovskyi, Azaiki, 2016). For areas with more favourable natural conditions, it is important to introduce varieties with the appropriate genetic characteristic that can form a high level of yield and product quality.

The purpose of the research is to evaluate the genetic diversity of the studied varieties of winter garlic by ISSR loci and to determine the most productive cultivars within the conditions of the Left-Bank Forest-Steppe of Ukraine.

MATERIALS AND METHODS

The research was conducted during 2016-2020 in the experimental field of the Department of Fruit and Vegetable Growing and Storage of the V.V. Dokuchayev Kharkiv National Agrarian University, as well as at the Laboratory of Agrochemistry and Analytical Measurements of the Institute of Vegetable and Melon Growing of the NAAS of Ukraine. Winter garlic varieties Dyushes, Lyubasha and Ugorskyi (line 20-16) were used for the research. Field studies were conducted in accordance with generally accepted methods (era methodology, 2001). The experiment included 2 biometric measurements. The first measurement was carried out during the bulb formation period, and the second during the winter garlic harvest. The harvesting of garlic was carried out once. Each plot brought in a harvest that was weighed and counted.

The study of garlic DNA polymorphism using the polymerase chain reaction (PCR) method was carried out on the basis of the testing laboratory "AGROGEN NOVO" in 2020.

DNA was extracted by the solid-phase method using the Diatom DNA Prep100 DNA extraction kit. A lysis reagent with guanidine chloride was used to solubilize the cellular debris and denature cellular nucleases. In the presence of a lysis reagent, DNA was sorbed onto a silica sorbent and washed from proteins and salts with an alcohol solution. DNA extraction was performed according to the protocol described in the instructions for the commercial kit "Diatom DNA Prep100" (http://www.galartdiag.ru/files/diatom_dna_prep_100.pdf). The purity of the isolated DNA concentration was determined using a Shimadzu UV-1280 spectrophotometer (Japan) at a wavelength of 260 nm.

ISSR (Intersimple Sequence Repeats) primers. The DNA polymorphism of garlic varieties was studied using primers for intermicrosatellite sequences developed at the University of British Columbia (UBC, Canada) (Table 1).

Table 1. Nucleotide sequences of ISSR primers

Primer	Nucleotide sequence 5'-3'	Primer	Nucleotide sequence 5'-3'
UBC 803	$(AT)_8C$	UBC 825	$(AC)_8T$
UBC 804	$(TA)_8A$	UBC 826	$(AC)_8C$
UBC 807	$(AG)_8T$	UBC 834	$(AG)_8YT$
UBC 810	$(GA)_8T$	UBC 842	$(GA)_8YG$
UBC 812	$(GA)_8A$	UBC 846	$(CA)_8RT$

Note: Y = pYrimidine (C or T); R = puRine (A or G)

DNA amplification was performed using GenePaktm PCR core kits (Isogen, Russia). In tubes from these kits containing lyophilised dry reaction mixtures for PCR, 20 ng of extracted DNA, 0.2 µM primer was added, and then the reaction mixture was brought to 20 µL with the solvent from the PCR kits.

PCR was performed in a TP4-PCR-01-"Tertsik" thermocycler (Russia) under the following conditions: initial denaturation of DNA at 94°C for 5 min; 40 amplification cycles under the following conditions for each cycle: denaturation at 94°C – 40 s, hybridisation – 45 s – at 50°C (for primers UBC 803, UBC 804, UBC 807, UBC 810, UBC 812 and UBC 825), 52°C (for primers UBC 826, UBC 834 and UBC 846) or 54°C (for primer UBC 842), elongation at 72°C – 2 min; final elongation at 72°C – 7 min.

Amplification products were electrophoresed in a 1.5% ethidium bromide agarose gel for 1.5 h at 120 V. The Tris-EDTA-borate buffer system used in the study was 0.09 M Tris, 0.09 M H3PO3, 0.0031 M EDTA (pH 8.3). Visualisation of the spectra of amplified DNA regions was performed using a TCR-20 MS transilluminator (France) followed by photographing the gels. M combi (fragment sizes: 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1200, 1400, 1600, 1800, 2000 bp) was used as a marker for determining the size of amplicons.

The polymorphism of the spectra, as well as the presence/absence of amplification products, was assessed visually. Each amplification product was considered as a marker of the corresponding locus in the genomic DNA with a dominant type of inheritance.

Amplicon sizes were calculated using a demo version of the TotalLab TL120 software package (http://www.totallab.com).

The level of polymorphism for each primer was defined as the proportion of polymorphic loci of the total number of loci per primer, expressed as a percentage. The level of genetic diversity of varieties was assessed using the Nei-Li similarity coefficient (Dij), which was calculated using the Phylip-3.69 software package (Nei and Li, 1979). The matrix of Nei-Li similarity coefficients was used for cluster analysis by the Neighbor-joining method (NJ).

RESULTS

In 2017, according to the results of research, the yield of winter Garlic of the Lyubasha variety was 9.2 t/ha (Table. 2), which is 1.9 t/ha or 26.0% more than the control variant and is a significant difference (LSD_{05} = 0.65). The Ugorskyi variety had a yield of 10 t/ha, which is significantly different from the control variant and exceeded it by 3.2 t/ha or 43.8%. In 2018, the yield of winter garlic of the Lyubasha variety was 16.1 t/ha, which is significantly higher than the control variant. The difference between the yield of the control variant and the Lyubasha variety was 7.9 t/ha (LSD_{05} = 3.42). The yield of the Ugorskyi winter garlic variety was 13.4 t/ha, which is 5.2 t/ha more than the Dyushes variety, which is a significant difference.

On average, over the three years of research, a higher level of marketable yield was observed in the Lyubasha variety (14.1 t/ha), in the Ugorskyi variety 12.9 t/ha and 9.4 t/ha in the Dyushes variety (control variant) (Table 2).

The analysis of the weather conditions over the years of research shows that fluctuations in air temperature and uneven precipitation during the growing season largely caused fluctuations in the yield of winter garlic. In 2017, The HTC of the growing season of winter garlic was 0.69, which can be considered slightly arid. According to the results of this year's research, the yield of winter garlic averaged 9.0 t/ha. The vegetation period of 2018 has not been sufficiently moist (HTC = 0.38). Under such conditions, the average yield of winter garlic was

12.6 t/ha. The weather conditions of 2019 can be described as dry (HTC = 0.65). According to the study results, the yield of winter garlic under these conditions was 14.84 t/ha (Table 2).

The analysis of variance found that the formation of winter garlic yields by 12.3% depended on the characteristics of the variety (factor A), the influence of the growing season conditions (factor B) was 87.3%, the combined effect of factors AB – 0.5%, other factors (elements of cultivation technology, etc.). According to the research, only the Ugoskyi variety is stable: *As* = 83.3%. The coefficients of agronomic stability of the Lyubasha and Dyushes varieties are 69.4 and 55.2%, respectively (Table. 2). These varieties of winter shooting garlic are unstable. Thus, the value of these indicators confirmed that the adaptive capacity influenced the yield during the years of cultivation. Furthermore, the yield of underground bulbs of winter garlic showed significant dependence on both the variety and the weather conditions of the year.

Table 2. The yield of bulbs in winter arrow garlic varieties

Cultivar	Yield, t/ha			Average	Yield increase		Coefficient of stability, SF	Agronomic stability As
	2017	2018	2019		t/ha	%		
Dyushes (control)	7.3	8.2	12.7	9.4	0.0	0.0	1.74	55.2
Lyubasha	9.2	16.1	17.1	14.1	4.7	50.0	1.88	69.4
Ugorskyi (line 20-16)	10.5	13.4	14.7	12.9	3.5	37.2	1.40	83.3
LSD_{05}	0.65	3.42	2.84					

These data are also confirmed by the coefficient of agronomic stability (*As*), which was proposed by V.V. Hangildin. It characterises the resistance of varieties to adverse conditions of the growing season. A variety is considered stable if *As* is over 70%. Over the years, the yield level of the Dyushes variety ranged from 7.3 to 12.7 t/ha, which caused a lower phenotypic stability coefficient compared to other variants. These data are also confirmed by the coefficient of agronomic stability (*As*), which characterises the resistance of hybrids to unfavourable conditions of the growing season (Sych, 2005; morphological..., 2006).

As a result of molecular genetic analysis of winter garlic varieties Dyushes, Lyubasha and Ugorskyi (line 20-16) using 10 ISSR primers, 65 loci were identified, 23 of which were polymorphic. The number of detected amplicons varied depending on the primer and variety (Table 3). Thus, 48 out of 65 possible loci were detected in Line 20.16, and 57 loci each in varieties Lyubasha and Dyushes.

The studied loci were found to be low polymorphic. The polymorphism level averaged 28.6% and ranged from none for primers UBC 810 and UBC 825 to 58.3% for primer UBC 812.

Table 3. Molecular genetic polymorphism of garlic varieties revealed by ISSR analysis

Primer	The number of detected loci, pcs.	Polymorphism level, %	Amplicon size, minimum - maximum, bp.
UBC 803	no amplicons detected		
UBC 804	no amplicons detected		
UBC 807	8	25.0	354–1076
UBC 810	6	0.0	396–983
UBC 812	12	58.3	262–997
UBC 825	1	0.0	665
UBC 826	7	28.6	348–1020
UBC 834	11	36.4	206–1283
UBC 842	11	36.4	218–1265
UBC 846	9	44.4	336–1192
Total	65	On average 28.6	

In the studied garlic varieties, the amplicons in the electrophoretic spectra differed in number, size, and level of expression. Figures 1 and 2 show the electropherograms obtained.

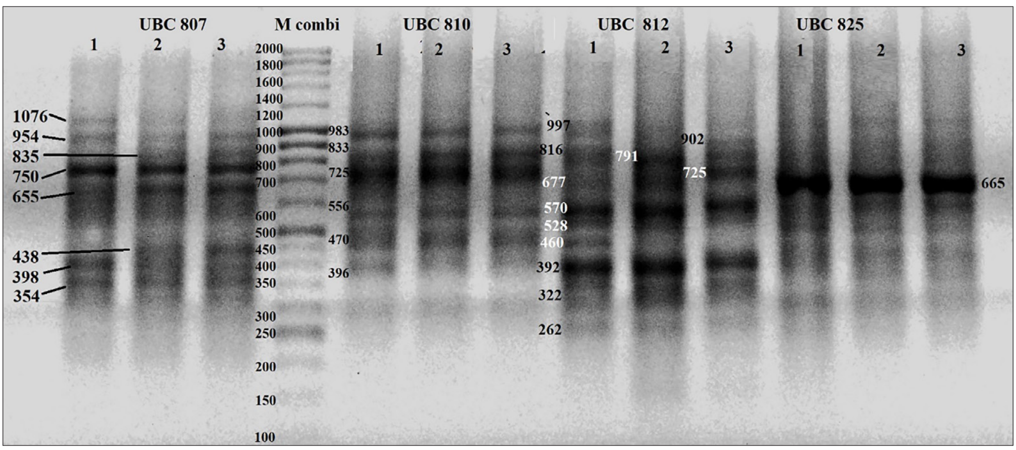

Figure 1. Electropherogram of garlic DNA amplification products with primers UBC 807, UBC 810, UBC 812, and UBC 825. M combi is a marker for determining the size of amplicons: 1 – Ugorskyi (Line 20-16), 2 – Lyubasha variety, 3 – Dyushes variety

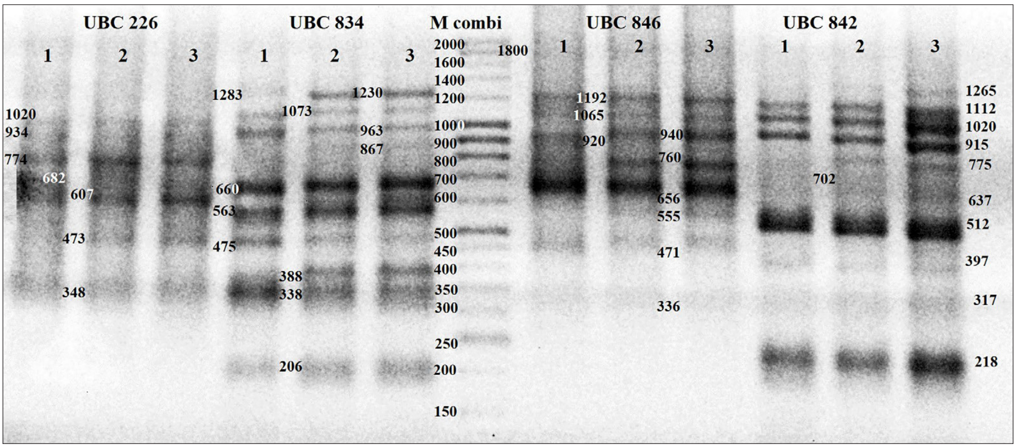

Figure 2. Electropherogram of garlic DNA amplification products with primers UBC 826, UBC 834, UBC 842 i UBC 846. M combi is a marker for determining the size of amplicons: 1 – Ugorskyi (Line 20-16), 2 – Lyubasha variety, 3 – Dyushes variety

The use of primers UBC 803 and UBC 804 failed to produce amplification products. This may be due to the fact that in the genomes of the analysed garlic varieties, microsatellites with sequences $(AT)_8C$ and $(TA)_8A$, respectively, are rare or absent, or the distance between inverted repeats is too large for amplification in the mode used here, i.e., more than 2000 bp.

The identification of 65 loci of intermicrosatellite DNA repeats in winter garlic made it possible to form allelic formulas of the studied varieties that can be used as their molecular genetic passports. To develop these passports, loci were labelled with capital Latin letters, next to which the size of the amplicon was indicated as a lower index. Loci were labelled as follows:

A – UBC 807	**E – UBC 826**
B – UBC 810	**F – UBC 834**
C – UBC 812	**G – UBC 842**
D – UBC 825	**H – UBC 846**

The resulting passports are shown in Table 4.

Table 4. Molecular genetic passports of winter garlic varieties

No.	Cultivar	Genetic passport
1	Ugorskyi (Line 2016)	$A_{354, 398, 655, 750, 954, 1076}$ $B_{396, 470, 556, 725, 833, 983}$ $C_{262, 322, 392, \mathbf{460}^{*}, 528, 570, 677, 816, \mathbf{997}}$ D_{665} $E_{348, 607, \mathbf{682}, 774, 934, 1020}$ $F_{206, 338, 475, 563, 660, 963, 1073, \mathbf{1283}}$ $G_{218, 317, 397, 512, 915, 1020, 1112}$ $H_{336, 471, 656, \mathbf{920}, 1065, 1192}$
2	Lyubasha	$A_{354, 398, 438, 655, 750, 835, 954, 1076}$ $B_{396, 470, 556, 725, 833, 983}$ $C_{262, 322, 392, 528, 570, 677, \mathbf{791}}$ D_{665} $E_{348, 473, 607, 774, 934, 1020}$ $F_{206, 338, 388, 475, 563, 660, 867, 963, 1073, 1230}$ $G_{218, 317, 397, 512, 637, \mathbf{702}, 775, 915, 1020, 1112, 1265}$ $H_{336, 471, 555, 656, 760, 940, 1065, 1192}$
3	Dyushes	$A_{354, 398, 438, 655, 750, 835, 954, 1076}$ $B_{396, 470, 556, 725, 833, 983}$ $C_{262, 322, 392, 528, 570, \mathbf{725}, 816, \mathbf{902}}$ D_{665} $E_{348, 473, 607, 774, 934, 1020}$ $F_{206, 338, 388, 475, 563, 660, 867, 963, 1073, 1230}$ $G_{218, 317, 397, 512, 637, 775, 915, 1020, 1112, 1265}$ $H_{336, 471, 555, 656, 760, 940, 1065, 1192}$

Note: * – amplicons unique to the respective variety are highlighted in bold. A – UBC 807; B – UBC 810; C – UBC 812; D – UBC 825; E – UBC 826; F – UBC 834; G – UBC 842; H – UBC 846

Notably, several amplicons unique within the studied group were detected in the winter garlic varieties presented in this study (Figs. 1 and 2, Table 3). In the Dyushes variety, the unique loci were UBC812_{725} and UBC 812_{902}, and in the Lyubasha variety UBC 812_{791} and UBC 842_{702}. Ugorskyi (line 20-16) had the most unique loci: UBC 812_{460}, UBC 812_{997} UBC 826_{682}, UBC 834_{1283} UBC 846_{920}. These plots can be used to develop more specific markers of the corresponding varieties.

The calculated Nei-Li similarity coefficients indicate a close genetic distance between studied varieties of garlic. It should be noted that the varieties Lyubasha and Duchesne were genetically closer to one another (*Dij* = 0.0009), compared to Hungarian (Line 20-16) – *Dij* between this line and each of the varieties was 0.0035. The genetic similarity of the studied varieties may be the result of the use of genetically uniform source material during the creation of these varieties.

CONCLUSIONS

The largest marketable yield (14.1 t/ha) was obtained by growing winter garlic of the Lyubasha variety. The Ugorskyi variety (line 20-16) provided a yield of 12.9 t/ha, the Dyushes variety 9.4 t/ha.

The formation of the yield of winter garlic by 12.3% depended on the characteristics of the variety, and the impact of the growing season made up 87.3%.

The variety of winter garlic Ugorskyi (line 20-16) with *As* = 73.8% was agronomically stable (*As* > 70%).

Based on the above studies, allelic formulas (molecular genetic passports) of winter garlic varieties Ugorskyi (Line 20-16), Lyubasha and Dyushes were formed.

The studied varieties of winter garlic contained several amplicons unique within the group under investigation. In the Dyushes variety, the unique loci were UBC 812725 and UBC 812_{902}, and in the Lyubasha variety, the loci were UBC 812_{791} and UBC 842_{702}. The 20-16 line had the most unique loci: UBC 812_{460}, UBC 812_{997}, UBC 826_{682}, UBC 8341_{283}, and UBC 846_{920}.

The calculated Nei-Li similarity coefficients indicate a close genetic distance between studied varieties of winter garlic. The varieties Lyubasha and Dyushes are genetically closer to one another compared to Ugorskyi (line 20-16).

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Продуктивність часнику озимого в лівобережному лісостепу України та молекулярно-генетичний поліморфізм досліджуваних сортів за ISSR-локусами

Анотація. В Україні площі, відведені під вирощування часнику, розширюються і станом на 2020 рік склали 1100 га, що зумовлено високою рентабельністю та стійким попитом як на внутрішньому, так і на зовнішньому ринках. Водночас оцінка існуючих та нових сортів часнику озимого має важливе значення для подальшого підвищення врожайності цієї цінної культури. Мета роботи – оцінити генетичне різноманіття досліджуваних сортів часнику озимого за ISSR-локусами та визначити найбільш продуктивні з них в умовах Лівобережного Лісостепу України. Для досліджень використовували сорти часнику озимого Дюшес, Любаша та Угорський (лінія 20-16). Найбільшу товарну врожайність (14,1 т/га) було отримано при вирощуванні часнику озимого сорту Любаша. Сорт Угорський (лінія 20-16) забезпечив урожайність 12,9 т/га, сорт Дюшес – 9,4 т/га. Формування врожайності часнику озимого на 12,3% залежало від особливостей сорту, вплив вегетаційного періоду становив 87,3%. Сорт часнику озимого Угорський (лінія 20-16) з *As* = 73,8% був агрономічно стабільним (As > 70%). На основі проведених досліджень сформовано алельні формули (молекулярно-генетичні паспорти) сортів часнику озимого Угорський (лінія 20-16), Любаша та Дюшес. Досліджувані сорти часнику озимого містили декілька ампліконів, унікальних у межах досліджуваної групи. У сорту Дюшес унікальними локусами виявилися UBC812725 та UBC 812902, а у сорту Любаша - UBC 812791 та UBC 842702. Найбільше унікальних локусів мала лінія 20-16: UBC 812460, UBC812997, UBC826682, UBC8341283 та UBC846920. Розраховані коефіцієнти подібності Nei-Li свідчать про близьку генетичну відстань між досліджуваними сортами озимого часнику. Сорти Любаша та Дюшес генетично ближчі один до одного порівняно з сортом Угорський (лінія 20-16)

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

Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en
Plant and Soil Science, 12(1), 112-119
Received xx.xx.2020 Revised xx.xx.2021 Accepted xx.xx.2021

UDC 635.2:635.03

DOI: 10.31548/agr2021.01.0112

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The Efficiency of Different Methods of Growing Sweet Potato (*Ipomoea batatas*) Planting Material

Abstract. The purpose of the study was to determine the efficiency of different methods of obtaining sweet potato planting material (through potted seedlings or unrooted cuttings) in the conditions of the Left-Bank Forest-Steppe of Ukraine. Research methods: field, laboratory, calculation and statistical. The potting method facilitates the formation of more developed plants (with an increased number of shoots per plant and their total length). Slips as a method of obtaining planting material for sweet potatoes provides more intensive growth rates, the formation of tuber yields at the level of 14.8 t/ha with a high content of dry matter (13.8%), starch (10.7%) and vitamin C (5.33 mg/100 g). When using potted seedlings, some sweet potato bushes are found to have deformed tubers (3.5%), but the proportion of bushes that do not form tubers at all decreases (8.3% compared to 10.0% when using slips)

Keywords: sweet potatoes, method of growing planting material, yield, product quality, slips, potted seedlings

Suggested Citation:
Kuts, O.V., Mykhailyn, V.I., Semenenko, I.I., & Shevchenko, S.V., (2021). The efficiency of different methods of growing sweet potato (*Ipomoea batatas*) planting material. *Plant and Soil Science*, 12(1), 112-119. doi: 10.31548/agr2021.01.112.

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RELEVANCE

Sweet potato is a fairly widespread crop in the world, cultivated in more than 100 countries across an area of more than 8.5 million hectares. Annual global production reaches 106.5 million tons, which ranks third among tuberous plants after potatoes and cassava (Woolfe, 2008; Ramirez R., 1991).

In African countries, it is cultivated as a crop preventing hunger and for vitamin A deficiency (Ankumah, Khan, Mwamba, Kpomblekou, 2003), which makes it a valuable dietary food product, sometimes as a staple, but usually as an alternative food (Nicanor, George, Michael, 2015; Heritier *et al*, 2018). Sweet potatoes are characterized by high yields and pleasant taste; they contain a large amount of potassium, antioxidants, vitamins A and C, group B (B_1, B_2, B_3, B_6, folic acid), phosphorus, and magnesium. Sweet potato tubers are high in complex carbohydrates and fibre (Rees *et al*, 1998; Rosas-Ramirez, Pereda-Miranda, 2013; Sochinwechi, Dilip, Ramasamy, 2017; Dinu, Soare, Babeu, Hoza, 2018).

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Sweet potatoes are propagated both generatively and vegetatively. The first method is of interest only to geneticists and breeders. Vegetative propagation using slips (cuttings or unrooted shoots) is the most common form of propagation. Slips (cuttings) are planted immediately or no later than four days after cutting; the material for planting should be undamaged by diseases and pests to prevent their transfer to the main crop area (Youg, 1961; Lencha, Birksew, Dikale, 2016; Zebarth, Arsenaut, Sanderson, 2006).

The results of studies conducted in Ghana have shown that the use of sweet potato tubers with 5-6 nodes results in a positive trend towards an increase in the number and weight of marketable tubers and tuber length compared to cuttings with 4 nodes. A significant increase in the biometric parameters of sweet potato plants and yield was also achieved using apical cuttings compared to cuttings obtained from semi-lignified shoots (Essilfie, Dapaah, Tevor, Darkwa, 2016). The advantage of apical (non-lignified) cuttings as planting material for sweet potato has been proven in other studies (Belehu, 2003; Ravi and Indira, 2010; Atu, 2014; Lencha, 2016).

According to F.M. Amoah (1997), with sufficient potassium nutrition ($K_{60\text{-}120}$), it is effective to use sweet potato blinds with 5-7 nodes as planting material, the use of which provides a significant increase in leaf surface area, leaf weight per plant, yield of marketable tubers, etc. Research by Ethiopian scientists showed that cuttings with 9 nodes (compared to cuttings with 5 and 7 nodes) were more preferable for planting, which ensured an increase in the number of tubers in the bush, an increase in the total yield and a yield of marketable tubers (Nebiyu &Getachew, 2015). According to the results of research by D. Markos & G. Loha (2016), using sweet potato cuttings of 30-40 cm in size together with other technological measures results in a tuber yield of 50-60 t/ha.

To obtain the maximum number of cuttings (slips) in Ukraine, sweet potato tubers are germinated in greenhouses starting in January and February. To maximise shoot growth, a hot, humid environment is created in the greenhouse (temperature in the range of 22-28°C, air humidity – 85-90%). There are two methods of obtaining planting material: gradual cutting (apical shoots with 5-6 nodes) and planting them in pots or cassettes with a volume of at least 250 ml, or the formation of longer shoots of sweet potatoes and their cutting on the day of planting. In the Forest-Steppe of Ukraine, sweet potatoes are planted in the second or third decade of May, when the threat of frost has passed. At the same time, the air temperature is expected to be at least 15-17°C (Potopalsky and Yurkevich, 2005).

Each of the above methods of obtaining planting material has its own advantages and disadvantages. For growing sweet potato seedlings through pots or cassettes, more cuttings can be obtained from one tuber, but this method is more resource- and labour-intensive and often causes the formation of more deformed tubers (bending of roots in a small volume of the substrate). The second method is much less expensive, but the yield of planting material is reduced by 20-40%.

The purpose of the study is to determine the efficiency of different methods of obtaining sweet potato planting material (through potted seedlings or unrooted cuttings) in the conditions of the Left-Bank Forest-Steppe of Ukraine.

MATERIALS AND METHODS

The research was conducted during 2019-2020 in the laboratory of agrochemical research and product quality of the Institute of Vegetable and Melon Growing of the National Academy of Sciences of Ukraine. The soil of the experimental plot is a typical low-humus light loamy chernozem on loess loam (the arable layer (0-25 cm) contains 4.3% humus; hydrolysable nitrogen – 139.0 mg/kg; mobile phosphorus – 106-119 mg/kg and exchangeable potassium – 93 mg/kg of soil; hydrolytic acidity – 2.8 mEq per 100 g of soil; pH of salt extract – 5.7; the sum of absorbed bases – 26.0 mEq per 100 g of soil).

Sweet potato tubers were placed in boxes with a substrate for growing seedlings in the first and second ten-day period of February, submerged halfway into the substrate. The temperature in the greenhouse was maintained at 22-24°C, the humidity was 75-85%, and the substrate was regularly irrigated. Periodically (once every 20-25 days), plants were treated with biological products to optimise nutrition and prevent the development of diseases (HelpRost vegetable, 10 ml/l; Phytohelp, 15 ml/l; Liposam, 5 ml/l).

The research studied two ways to obtain planting material:

1) through potted seedlings – gradual (during March - April) cutting of apical shoots with 5 nodes and planting them in 400 ml pots, where the cuttings are then rooted and grown (irrigation and fertilisation according to the system used on mother plants);

2) through slips (unrooted cuttings) – long shoots are formed in half of the boxes with uterine tubers, which are cut into slips with 5 knots on the day of planting seedlings in the field.

Planting of both potted seedlings and slips was carried out in the third ten-day period of May according to the planting scheme (90 + 50) x 25 cm (58 thousand pcs/ha) with the background use of fertilisers ($N_{370}P_{370}K_{450}$), drip irrigation and mulching of the soil with straw. The research was performed using the sweet potato variety Slobozhansky Rubin following generally accepted methods (Dospekhov, 1985; Bondarenko and Yakovenko, 2001). The total area of the plot was 33.6 m^2, the accounting area was 21 m^2, and the replication was four times.

RESULTS AND DISCUSSION

It was established that in terms of biometric parameters in the first half of the growing season, sweet potato plants grown from unrooted cuttings ("slips") were inferior to plants from potted seedlings (Table 1). Thus, in the middle of the period of development of sweet potato plants (July), the number of shoots on plants grown from the slips was 2.1 pcs./plant with a total shoot length of 78.3 cm/plant. On sweet potato plants grown from potted seedlings, the number of shoots was 3.2 pcs./plant, the total length of shoots was 96.9 pcs./plant. A similar pattern is observed over the years of research. During the period of active formation and growth of tuber mass (August), this trend persists, but the difference between the variants decreases, indicating a more intensive development of plants from non-rooted cuttings.

Table 1. Biometric parameters of sweet potato plants by different methods of seedling production (2019-2020)

Method of obtaining sweet potato seedlings	Biometric parameters of plants					
	Number of shoots, pcs./plant			Total length of shoots on the plant, cm		
	2019	2020	average	2019	2020	average
First ten-day period of July						
Potted seedlings	1.45	5.0	3.2	75.6	275.2	96.9
Slips	1.20	3.0	2.1	48.1	145.6	78.3
$LSD_{0,95}$	0.09	0.22		3.55	9.67	
First ten-day period of August						
Potted seedlings	2.05	9.0	5.5	166.0	691.0	428.5
Slips	1.70	8.0	4.9	134.6	633.0	383.8
$LSD_{0,95}$	0.11	0.43		11.5	34.7	

In terms of tuber yield, the methods of obtaining seedlings did not differ significantly (Fig. 1). Over the years of research, there has even been a positive trend towards an increase in the yield of sweet potato tubers when grown through slips; the difference over the years of research ranged from 0.2-1.0 t/ha). There was a positive tendency towards an increase in sweet potato yield (16.9 t/ha) when using slips.

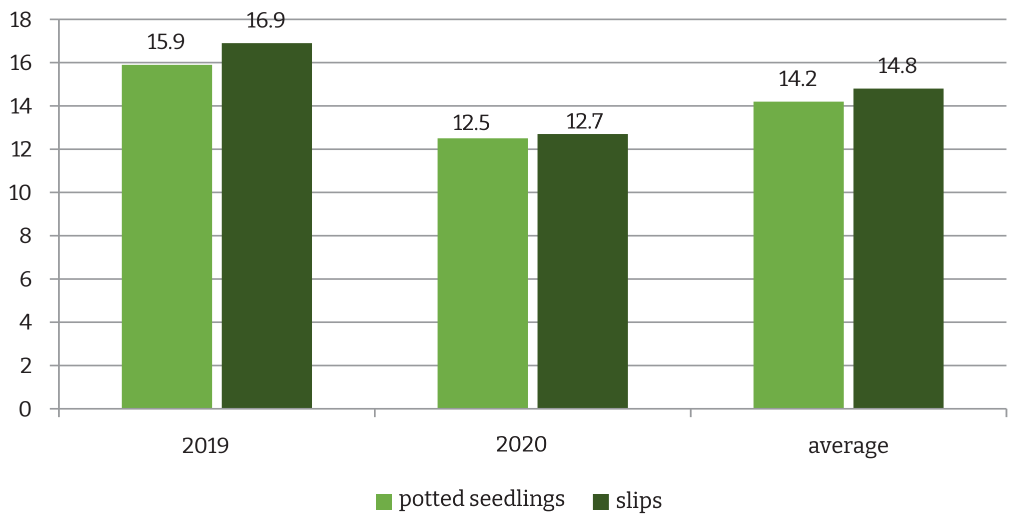

Figure 1. The yield of sweet potato tubers by different methods of seedlings production (2019-2020):
LSD0,95 (2019) = 3.8 t/ha; LSD0,95(2020) = 1.04 t/ha

Furthermore, the use of potted seedlings leads to the formation of sweet potato bushes with deformed tubers (up to 3.5% of the total number of plants), which is associated with a certain bending of the roots at the stage of their growth in a limited space of pots (Fig. 2). It was also found that some plants did not form full tubers at all: 8.3% when using potted seedlings, and 10.0% when using slips. This fact is attributed to the stressful reaction of sweet potato plants to various abiotic factors, primarily to temperature. The temperature minimum for sweet potato plants ranges from 12-15°C. Since during the summer in the Left-Bank Forest-Steppe zone of Ukraine, the air temperature at night can briefly drop below this threshold, some plants cannot withstand the stress load and do not form tubers.

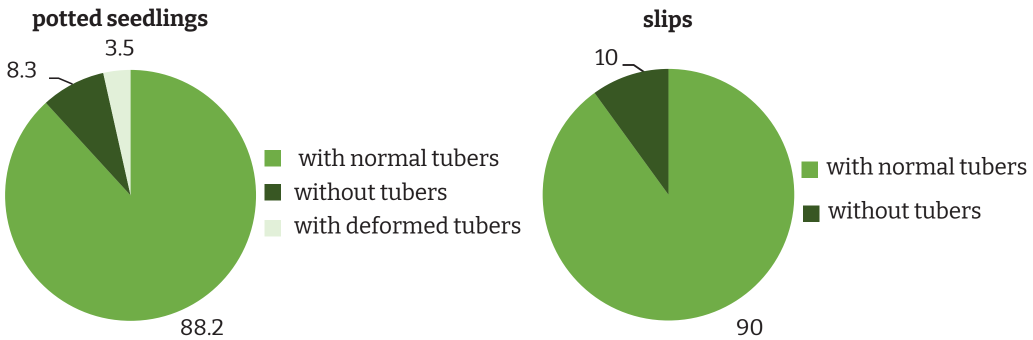

Figure 2. The ratio of plants with different quality of tubers depending on the methods of obtaining seedlings, %

According to the basic parameters of the biochemical composition of tubers, there were no significant differences between different methods of obtaining planting material for sweet potato (Table 2).But there is a positive trend towards an increase in the content of dry matter in tubers (by 0.7%), vitamin C (0.26 mg/100 g) and starch (0.3%) when growing sweet potatoes from slips. A negative factor in the use of slips is a significant increase in nitrate content in sweet potato tubers to 133 mg/kg of fresh weight against 22.4 mg/kg of fresh weight in tubers grown from pot seedlings.

Table 2. The influence of different methods of seedling preparation on the biochemical composition of sweet potato tubers (average for 2019-2020)

Method of obtaining sweet potato seedlings	Content in tubers, %				
	dry matter	total sugar	vitamin C, mg/100 g	starch	nitrates, mg/kg
Potted seedlings	13.1	3.47	5.07	10.4	22.4
Slips	13.8	3.46	5.33	10.7	113.0
$LSD_{0,95}$ (by year)	1,12; 0,98	0,32; 0,29	0,57; 0,62	0,94; 0,88	7,8; 5,7

CONCLUSIONS

The potting method of producing sweet potato planting material provides for the formation of more developed plants (with a greater number of shoots per plant and their total length). However, plants grown from unrooted cuttings (blinds) are characterised by a more intensive growth rate, resulting in a decrease in the difference in the indicated biometric parameters in the second half of the sweet potato growing season.

Slips as a method of obtaining planting material for sweet potatoes provide the formation of tuber yields at the level of 14.8 t/ha with a high content of dry matter (13.8%), starch (10.7%) and vitamin C (5.33 mg/100 g).

When using potted seedlings, some sweet potato bushes are found to have deformed tubers (3.5%), but the proportion of bushes that do not form tubers at all decreases (8.3% compared to 10.0% when using slips).

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Ефективність різних способів вирощування садивного матеріалу батату (*Ipomoea batatas*)

Анотація. Мета дослідження – визначити ефективність різних способів отримання садивного матеріалу батату (через горщечкову розсаду або невкорінені живці) в умовах Лівобережного Лісостепу України. Методи досліджень: польовий, лабораторний, розрахунково-статистичний. Метод горщикування сприяє формуванню більш розвинених рослин (зі збільшеною кількістю пагонів на рослині та їх загальною довжиною). Розсада як спосіб отримання садивного матеріалу батату забезпечує більш інтенсивні темпи росту, формування врожайності бульб на рівні 14,8 т/га з високим вмістом сухої речовини (13,8%), крохмалю (10,7%) та вітаміну С (5,33 мг/100 г). При використанні горщечкової розсади частина кущів батату має деформовані бульби (3,5%), але частка кущів, які взагалі не формують бульб, зменшується (8,3% порівняно з 10,0% при використанні розсади)

Ключові слова: батат, спосіб вирощування садивного матеріалу, урожайність, якість продукції, сліпи, розсада в горщиках

Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en
Plant and Soil Science, 12(1), 120-128
Received xx.xx.2020 Revised xx.xx.2021 Accepted xx.xx.2021

UDC 634.1.054:634.722

DOI: 10.31548/agr2021.01.0120

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Qualitative indicators of redcurrant varieties (*Ribes rubrum* L.) selected by the Professor V.L. Symyrenko Department of Horticulture of NULES of Ukraine

Abstract. This study presents the findings on the qualitative indicators of seven varieties of redcurrant (Ribes rubrum L.), five of which are selected by the Professor V.L. Symyrenko Department of Horticulture of NULES of Ukraine. The largest average weight of berries had the varieties "Buzhanska" (0.58 g) and "Polyana Holosiivska" (0.59 g). These varieties also stand out among others in terms of maximum berry weight. In certain years of research, the fruits of "Buzhanska" weighed 1.05 g. The "Lebidka" variety had the largest cluster weight (6.98 g) due to the large number of berries in it (17 pcs.). The uniformity of berries in the cluster of the studied varieties is average (from 63 to 73% depending on the variety). The highest yields per bush were achieved by "Buzhanska" (4.20 kg/bush), "Kyianochka" (4.42 kg/bush) and "Polyana Holosiivska" (4.0 kg/bush). The varieties "Jonkheer van Tets" (c.), "Polyana Holosiivska", "Buzhanska" and "Snizhanka" are rich in vitamin C. The highest dry soluble solids content was found in the "Lebidka" variety (12.94%). The most sugars in the fruit were accumulated by the varieties "Snizhanka" (5.40%), "Buzhanska" (5.23%) and "Malva" (5.13%). The white-fruited varieties "Snizhanka" and "Lebidka" are particularly notable for their dessert flavour, as they have the best sugar to total acidity ratio (TAR) among the varieties studied – 4 and 3, respectively, and the highest flavour score (9 points)

Keywords: berry weight, cluster, bush, biochemical composition, taste assessment, berry quality, taste

Suggested Citation:

Andrusyk, G.S., & Andrusyk, Y.Y., (2021). Qualitative indicators of redcurrant varieties (*Ribes rubrum* L.) selected by the Professor V.L. Symyrenko Department of Horticulture of NULES of Ukraine. *Plant and Soil Science*, 12(1), 120-128. doi: 10.31548/agr2021.01.120.

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RELEVANCE

To provide the population with nutritious food and vitamins, it is necessary to develop and improve the present selection of berry crops, including redcurrants (*Ribes rubrum L.*). The fruits of redcurrants have great taste and consumer qualities, as well as a rich chemical composition, so the prospects for their cultivation are quite high (Cristina *et al.*, 2013). This berry crop is characterised by high yields, winter hardiness, resistance to terry and bud mites, and is relatively uncomplicated to maintain (Makarkina, 2013). Therefore, with the correct selection of varieties to suit the conditions of cultivation, it is possible to obtain environmentally friendly, high-quality products (Karhu *et al.*, 2020).

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Purslane (red and white) is a common crop in Ukraine and the rest of the world, with the largest scale of production in the United States (Heijerman & Gessel, 2020) It is also common in Europe: The Netherlands, the United Kingdom, the Czech Republic, France, Germany, Belgium, and Russia (Zdunic *et al.*, 2016). In Ukraine, redcurrants are not as popular as currants, but they are in demand among gardeners because of their drought and winter hardiness, resistance to pests and diseases, high yield and durability of branches and bushes (Kopan', 2005; Tarapata, 2005). Because of all its properties, this crop is becoming more and more common in industrial plantations, as demand for red berry products is growing (Salina *et al.*, 2020). The fruits are used for consuming fresh, making juices, wine, jelly, marmalade, and jam. Unlike black currants, redcurrants have no essential oils, but the berries accumulate a large amount of coumarin (up to 4.4 mg/100 g of berry weight), which is used in the perfumery, soap, and confectionery industries as an aromatic substance. A derivative of coumarin, decoumarin, is used in medicine to treat patients with increased blood clotting (Gündeşli *et al.*, 2019). Due to the high content of organic acids, its juice quenches thirst, eliminates nausea, improves appetite and is a good tonic for recuperating from serious illnesses. Due to the content of salicylic acid, consumer of berries helps to reduce the body temperature of patients and thin the blood, which is important for people with high blood pressure. The juice accelerates the release and removal of harmful salts from the human body (Sherenhovyi, 2011).

Since the 1980s, more than 20 varieties of redcurrants have been developed in Ukraine (Yareshchenko *et al.*, 2012). The main centres of black currant and redcurrant selection in Ukraine are the Institute of Horticulture of the National Academy of Agrarian Sciences and its regional structural units, and the Professor V.L. Symyrenko Department of Horticulture of the National University of Life and Environmental Sciences (NULES) of Ukraine. During this period, a number of competitive redcurrant varieties were developed at the university under the guidance of PhD in Biology P.Z. Sherengovyi (Mezhenskyj *et al.*, 2020). As of February 5, 2021, 12 varieties of redcurrant were included in the State Register of Plant Varieties Suitable for Distribution in Ukraine for 2021: "Rovada" – Dutch selection; "Vatra", "Svyatomykhailivska", "Troitska", "Darnytsia", "Samburska" and "Lasunia" – IH NAAS selection; and five varieties of NULES of Ukraine selection – "Lebidka", "Buzhanska", "Polyana Holosiivska", "Kyianochka" and "Olha" (Derzhavnyi reiestr, 2021).

The purpose of the study is to investigate the quality indicators of fruits of redcurrant varieties selected by NULES of Ukraine (characteristics of berries, clusters, yield, the content of basic organic substances in fruits and tasting evaluation of berries), to identify the best varieties according to these characteristics.

MATERIALS AND METHODS

The study was conducted in the plantations of redcurrants of the educational laboratory (EL) "Fruit and Vegetable Garden" of the Professor V.L. Symyrenko Department of Horticulture of NULES of Ukraine, which is located in the right-bank zone of the Western Forest-Steppe of Ukraine. The climate is temperate continental with warm, moderately humid summers, the warmest month is July with an average monthly temperature of +19.3°C. The winters are cloudy, with frequent thaws and only in some years with severe frosts; the coldest month is January with an average monthly temperature of 5.9°C.

The soil of the experimental plot is soddy-medium podzolic coarse-dusty light loam. It is characterised by a humus content of 1.48% in the topsoil.

Overall, the soil and climatic conditions of the research area are suitable for growing berry crops, in particular redcurrants.

The experiment was established in 2008 in accordance with the Methodology for State Testing of Varieties of Fruit and Berry Crops. The subject of the study is seven varieties of redcurrants, including five selected by NULES of Ukraine. The well-known variety of the Dutch selection "Jonkheer van Tets" was used as a control. The plants were planted according to a 3 × 0.75 m pattern, 5 plants each in three replications. The variants were arranged randomly.

The tests and observations were carried out according to the above-mentioned methodology and the "Programme and methodology of the varietal study of fruit, berry and nut crops" (Sedov & Ogoltsova, 1999). The content of basic organic substances in redcurrant fruits was determined by the following methods: dry matter content in fruits – DSTU EN 12143:2003 Fruit and vegetable juices. Determination of soluble solids content. Refractometric method; sugar content – in accordance with DSTU 4954:2008 Fruit and vegetable processing products. Methods for determining sugars; vitamin C content – in accordance with GOST 24556-89 Fruit and vegetable processing products; acidity determination – in accordance with DSTU 4957:2008 Fruit and vegetable processing products. Methods for determining titrated acidity. Statistical processing of the data was carried out using Microsoft Excel® computer programmes.

RESULTS AND DISCUSSION

The fruits of redcurrants have great taste and consumer properties, so the prospects for their cultivation are quite high. Today, the market is filled with a diverse range of varieties, but an important sign of their competitiveness is the marketability and taste qualities of berries (Metodyka, 2012).

Temperature and precipitation during the period of berry growth and ripening are the factors that affect the weight of berries, the accumulation of dry soluble substances and sugars, and therefore the taste and nutritional value of berries (Sherenhovyi, 2011).

The varieties "Buzhanska" and "Polyana Holosiivska" have the highest average berry weight among the studied varieties, which is 6 and 7% more than the control, respectively. The average weight of Lebidka berries is the same as that of the control variety, while Malva, Kyianochka and Snizhanka are 2-7% less than the control.

The weight of the berry depends to some extent on soil and air moisture, and the age of the bush; on older branches, the weight of the berry decreases. When describing a variety, attention is paid to determining the maximum mass of berries, which is an important indicator, but not a determining one (Sedov & Ogoltsova, 1999).

The varieties "Buzhanska" and "Polyana Holosiivska" have a higher maximum berry weight than the control. According to the methodology, berries over 0.85 g are considered very large.

It is important to note that during the research, individual Buzhanska berries reached a weight of 1.05 g. On average, the maximum weight of berries varies from 0.70 g in "Snizhanka" to 0.92 g in "Buzhanska", which is 11% more than the control.

The average and maximum berry weight of the cultivar, as well as the number of berries per cluster, affect the cluster weight (Mikulic-Petkovsek *et al.*, 2016). In 2015, the "Lebidka" variety had an average of 17 berries per cluster, while the control had 13. In some years of research, the number of "Lebidka" berries reached 22 pieces per cluster. It is worth noting that an important marketable feature of the variety is the uniformity of the berries. According to the methodology, the uniformity of berries in the bunches of the studied varieties is average, ranging from 63 to 73%. The "Lebidka" variety has the largest weight of clusters, which is 2.54 g more than in the control. In 2015, the average weight of the cluster of the studied varieties was in "Buzhanska" (9.19 g) and "Lebidka" (9.16 g).

It is impossible to draw conclusions about the potential yield of a variety based only on the weight of the berry and the cluster, it is also necessary to determine the number of clusters per plant. Each variety has its own fruiting characteristics. In particular, the "Kyianochka" variety has an average berry weight and cluster weight, but due to the bouquet branches having a large number of multi-cluster nodes, the yield per branch, and thus per bush, is the highest. The varieties "Buzhanska" and "Polyana Holosiivska" also have a large number of multi-clustered nodes, with bouquet branches occupying 2/3 of the branch and located on the upper part of the bush. The varieties "Kyianochka", "Buzhanska" and "Polyana Holosiivska" have the highest yield per bush, 23, 17 and 11% more than the control, respectively.

Table 1. Characteristics of yield components of redcurrant varieties (average for 2013-2015)

Cultivar name	Berry weight, g		Cluster weight, g	Yield per 1 bush, kg
	average	the highest		
"Jonkheer van Tets" (k.)	0.55	0.83	4.44	3.60
"Buzhanska"	0.58	0.92	5.60	4.20
"Kyianochka"	0.51	0.78	5.08	4.42
"Lebidka"	0.55	0.81	6.98	3.84
"Malva"	0.54	0.75	4.78	2.86
"Polyana Holosiivska"	0.59	0.85	5.17	4.00
"Snizhanka"	0.51	0.70	4.68	3.39
LSD_{05}	0.064	0.093	0.708	0.387

One of the main indicators of consumer quality of fresh fruits is vitamin C. Redcurrant fruits are significantly (3-5 times or more) inferior to currants in terms of ascorbic acid content (Djordjević *et al.*, 2014). The berries of the control variety are rich in vitamin C (43.00 mg/100 g of fresh weight), as well as "Polyana Holosiivska", "Snizhanka" and "Buzhanska" (42.24...42.93 mg/100 g of fresh weight).

The content of dry soluble substances varies from year to year, due to weather conditions, specifically the amount of rainfall and soil moisture at harvest time (Djordjević *et al.*, 2020). The largest amount of dry soluble substances (12.00-12.94%) is accumulated by berries of the varieties "Polyana Holosiivska", "Snizhanka" and "Lebidka". The flavour of red berries is more influenced by the acid content than by sugars. However, the sugar content also matters. The varieties "Buzhanska", "Malva" and "Snizhanka" accumulated the highest amount of sugars among the studied varieties, which was 9%, 7% and 13% more than in the berries of the control variety, respectively. "Polyana Holosiivska" has the lowest sugar content (19% less than the control), while "Lebidka" and "Kyianochka" are almost at the control level.

The fewer acids berries accumulate, the tastier they are. Redcurrant fruits are typically characterised by an acid content of 1.2-3.9% (Golyayeva, 2010). White-fruited varieties "Snizhanka" and "Lebidka" had the lowest values of total acids (1.26 and 1.27%, respectively), and "Buzhanska" had the highest. All berries of the studied varieties were characterised by low total acidity.

The sugar-to-acid ratio (SAR) determines the flavour of red berries. A high index is typical for berries of dessert flavour, which have an excellent tasting score. They are intended primarily for fresh consumption, and the lowest score is assigned to varieties with average flavour qualities (Berk, *et al.*, 2020). The varieties "Snizhanka", "Polyana Holosiivska", "Malva" and "Lebidka" stand out positively by this indicator. The varieties Buzhanska and Kyianochka have the lowest sugar-acid index, although they have a high sugar content in berries.

Table 2. Content of basic organic substances in fruits of redcurrant varieties (average for 2013-2015)

Cultivar name	Vitamin C, mg %	Dry soluble substances, %	Total sugar, %	Total acidity, %	SAI
"Jonkheer van Tets" (k.)	43.00	11.60	4.80	1.47	3
"Buzhanska"	42.24	10.85	5.23	2.38	2
"Kyianochka"	31.58	11.10	4.93	2.10	2
"Lebidka"	20.40	12.94	4.22	1.27	3
"Malva"	36.50	11.27	5.13	1.69	3
"Polyana Holosiivska"	42.93	12.00	3.90	1.50	3
"Snizhanka"	42.34	12.27	5.40	1.26	4

Redcurrant clusters can be stored in the refrigerator for a long period of time without losing their appearance and shape. The content of organic matter is also preserved after defrosting, which makes it popular in cooking, for making desserts, marmalades, and jellies (Paprstein *et al.*, 2016). The berries of redcurrants exhibit different berry colours; they can be red, dark red, white, yellow, or flesh-coloured (Milošević, 2018).

Among the varieties studied, five have red berries, and two: "Snizhanka" and "Lebidka" have white berries. The berries of all the varieties studied have a certain shade, for example, the fruits of "Malva" are dark red, while those of "Kyianochka" are light red. The fruits of "Snizhanka" are white, transparent; "Lebidka" are white with stripes, and transparent when ripe.

Table 3. Taste assessment of redcurrant berries (average for 2013-2015)

Cultivar name	Colour	Appearance	Flavour	Overall score
"Jonkheer van Tets" (k.)	red	5.0	7.0	7.0
"Buzhanska"	red	9.0	7.5	8.1
"Kyianochka"	light red	9.0	8.5	7.8
"Lebidka"	white	9.0	9.0	8.5
"Malva"	dark red	6.5	7.0	5.9
"Polyana Holosiivska"	red	6.5	7.0	7.4
"Snizhanka"	white	8.5	9.0	7.7

"Buzhanska", "Kyianochka", and "Lebidka" varieties were rated the highest for their attractive appearance. The clusters of these varieties are dense, full, uniform, the berries have a rich colour, the skin of the fruit is translucent; the separation of the berries from the stem is dry. The powdery mildew damage negatively affected the assessment of the appearance of clusters of "Jonkheer van Tets" (k.), "Malva" and "Polyana Holosiivska". The white-fruited varieties "Lebidka" and "Snizhanka" have the best (dessert) taste. They have a sweet and sour taste, delicate due to the optimal ratio of sugars and total acids. Other varieties had a sweet and sour taste, which negatively affected the score. The aroma of redcurrant berries is barely noticeable. The best overall score, considering all organoleptic characteristics, was given to the varieties "Lebidka" and "Buzhanska".

CONCLUSIONS

The varieties "Buzhanska" and "Polyana Holosiivska" can be singled out as large-fruited varieties, as they had the highest average and maximum berry weights. In particular, in some years of research, the weight of the fruit of the variety "Buzhanska" reached 1.05 g. The best indicators in terms of cluster weight (6.98 g) and number of berries per cluster (17) are those of the "Lebidka" variety.

The uniformity of berries of all varieties is average. The most productive varieties under study are "Buzhanska", "Kyianochka" and "Polyana Holosiivska", with an average yield of 4.00-4.42 kg per bush.

"Jonkheer van Tets" (c.), "Polyana Holosiivska", "Buzhanska" and "Snizhanka" accumulated the highest amount of ascorbic acid. The highest dry soluble solids content was found in the fruits of "Lebidka" (12.94%). Berries of "Snizhanka" (5.40%), "Buzhanska" (5.23%) and "Malva" (5.13%) are rich in sugar. The white-fruited varieties "Snizhanka" and "Lebidka" have a distinctive dessert flavour due to their low organic acid content. They have a sugar-to-total acidity ratio of 4 and 3 points, respectively, and they also received the highest (9 points) flavour score. The red-fruited varieties "Buzhanska" and "Kyianochka" and the white-fruited variety "Lebidka" were rated the highest in terms of appearance.

The clusters of these varieties are dense, full, uniform, the berries have a rich colour, the skin of the fruit is translucent; the separation of the berries from the stem is dry.

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Якісні показники сортів порічок (*Ribes rubrum* L.) селекції кафедри садівництва імені професора В.Л. Симиренка НУБІП України

Анотація. У роботі наведено результати вивчення якісних показників семи сортів порічок (*Ribes rubrum* L.), п'ять з яких селекції кафедри садівництва ім. професора В.Л. Симиренка НУБіП України. Найбільшу середню масу ягід мали сорти "Бужанська" (0,58 г) та "Поляна Голосіївська" (0,59 г). Ці сорти також виділяються серед інших за максимальною масою ягоди. В окремі роки досліджень плоди сорту "Бужанська" мали масу 1,05 г. Сорт "Лебідка" мав найбільшу масу грона (6,98 г) за рахунок великої кількості ягід у ньому (17 шт.). Вирівняність ягід у гроні досліджуваних сортів середня (від 63 до 73% залежно від сорту). Найвищої врожайності з куща досягли сорти "Бужанська" (4,20 кг/кущ), "Кияночка" (4,42 кг/кущ) та "Поляна Голосіївська" (4,0 кг/кущ). Сорти "Jonkheer van Tets" (с.), "Поляна Голосіївська", "Бужанська" та "Сніжанка" багаті на вітамін С. Найвищий вміст сухих розчинних речовин виявлено у сорту "Лебідка" (12,94%). Найбільше цукрів у плодах накопичили сорти "Сніжанка" (5,40%), "Бужанська" (5,23%) та "Мальва" (5,13%). Білоплідні сорти "Сніжанка" та "Лебідка" особливо вирізняються десертним смаком, оскільки мають найкраще серед досліджуваних сортів співвідношення цукру до загальної кислотності (ЗК) – 4 та 3 відповідно, а також найвищу оцінку смаку (9 балів)

Ключові слова: маса ягід, гроно, кущ, біохімічний склад, дегустаційна оцінка, якість ягід, смак

Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en
Plant and Soil Science, 12(1), 129-135
Received xx.xx.2020 Revised xx.xx.2021 Accepted xx.xx.2021

UDC 631.527:633.367: 631.524

DOI: 10.31548/agr2021.01.0129

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Correlation of Seed and Vegetative Productivity Elements in Collection Samples of White Lupine

Abstract. The purpose of the study was to establish the strength and general pattern of correlations between quantitative traits that form vegetative and seed productivity in white lupine. Research methods used included field, weighing and measuring, and mathematical and statistical methods. A significant positive correlation was found between the average strength of seed productivity and such traits as plant height, number of lateral shoots, number of beans from central and lateral clusters, etc. A strong positive correlation was detected with the vegetative development of plants, and a weak one with the number of seeds per bean and the weight of 1000 seeds. A significant strong positive correlation of vegetative productivity with such quantitative traits as the weight of beans from the central cluster and the weight of leaves and stems was established. A positive correlation of average strength was found with the number of beans from central and lateral clusters, weight of beans from lateral shoots, root weight, etc. It was found that the seed productivity of white lupine plants is mainly conditioned by the development of such traits as the number of beans from lateral clusters, weight of leaves and roots, number of seeds and weight of seeds from the central and lateral clusters. The formation of vegetative productivity primarily depends on the weight of beans from the central cluster and the weight of leaves and stems. The

Suggested Citation:

Golodna, A., & Baidiuk, T., (2021). Correlation of seed and vegetative productivity elements in collection samples of white lupine. *Plant and Soil Science*, 12(1), 129-135. doi: 10.31548/agr2021.01.129.

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use of the established regularities of productivity formation will enhance the effectiveness of the selection of selective material according to the specified parameters

Keywords: correlations, central and lateral clusters, seed weight, number of beans and seeds, number of seeds per bean, the weight of 1000 seeds

RELEVANCE

The method of correlation analysis is widely used to determine the relationship between quantitative traits, the variability of which is caused by phenotypic and genotypic factors. The correlation coefficients between the same traits can vary depending on the species and even the variety of plants and growing conditions. Such patterns of variability in the correlation between individual traits are fully consistent with the basic principles of the genetics of quantitative traits and their phenotypic manifestation in the genotype-environment interaction (Litun *et al.*, 2004). Selection of high-yielding genotypes requires extensive knowledge on the patterns of plant productivity. This fully applies to white lupine, the yield level of which is determined by indicators that form seed and vegetative productivity.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Correlation analysis has been used by many scientists to evaluate the selection material of different crops (Usyk, 2009; Kobyzieva, 2009; Tryhub, 2002; Katsan, 2014; Bulintsev *et al.*, 2015; Marchenko *et al.*, 2019; Carpici & Celic, 2012). It has been established that the formation of lupine yields depends to a greater extent on such components as the number of beans and seeds per plant, the number of seeds per bean, the weight of seeds per plant, and the number of productive shoots (Friehiwot *et al.*, 2019; Sozinov & Khalimullina, 2019; Vitko & Vanga, 2015). Thus, the study of the interrelationships of various plant productivity traits with each other is a topical issue, since on the basis of the established patterns it is possible to determine the direction of the selection of selective breeding material to create new varieties that can meet modern production requirements. This will allow predicting of the selection process and increase its efficiency.

Purpose of the study. To establish the strength and direction of correlations between quantitative traits that form vegetative and seed productivity in white lupine.

MATERIALS AND METHODS

Field and laboratory studies were conducted in 2016-2019 at the Institute of Agriculture of the National Academy of Sciences of Ukraine. The fields of selection crop rotation are located in the Fastiv district of Kyiv Oblast. The years of the research differed in temperature and moisture availability, which made it possible to evaluate the manifestation of seed productivity traits in white lupine under different growing conditions. The weather conditions in 2016 were generally relatively favourable for the growth and development of lupine plants and the formation of good seed productivity. The hot and dry weather during the growing season in 2017, and especially the drought during flowering and bean setting, led to a significant decrease in plant productivity. Sufficient moisture and optimal temperature conditions in 2018 contributed to the good development of lupine plants and high seed yields. The lack of moisture during the period of flowering, seeding, and filling of beans in 2019 led to accelerated maturation and reduced seed productivity.

The subject of the research was 50 collection samples of white fodder lupine. The field experiments were conducted using the standard technology of lupine cultivation. Winter grain crops preceded the lupine sowing. Sowing was done in wide rows (row spacing was 45 cm). The plot area was 6.0 m^2, the repetition is fourfold. The study used field, weighing and measuring, and mathematical and statistical methods. The correlation analysis was carried out according to the relevant methods described by B.O. Dospekhov (Dospekhov, 1985).

RESULTS AND DISCUSSION

The number of lateral shoots is the main factor determining the formation of seed and vegetative productivity of white lupine due to the development of lateral clusters. It has a strong correlation with lateral cluster traits such as the number of beans, the number and weight of seeds, and the average bean weight. A weak negative correlation was found with the number and weight of seeds from the central cluster, and with the number of seeds per bean from both the central and lateral clusters. Thus, the enhanced development of lateral shoots can lead to a decrease in the productivity of the central cluster and also reduce the size of the seeds.

The number of beans from the central cluster primarily determines its productivity, so it is closely positively correlated with the weight of shiny beans, number, and weight of seeds. The correlation of average strength was established with the traits of leaf, stem, and root weight. The number of beans from lateral shoots showed strong correlations with the weight of shiny beans, the number and weight of seeds from lateral clusters.

For lupine as a feed crop used for green fodder for animals, it is important to determine the features of vegetative mass formation, including correlations between the elements of its productivity. A strong correlation was established between the weight of shiny beans from the central shoot and the number and weight of seeds from the central clusters, between the weight of beans from the lateral shoots and the number and weight of seeds from the lateral clusters, and between the weight of leaves and stems. Positive correlations of medium strength were found between most of the other traits (Table 1).

The analysis of the relationships between the structural elements of seed productivity revealed a weak correlation in most cases, with both positive and negative values. The weight of the seeds from the central and lateral clusters directly depends on the number of seeds formed on them, so the value of the correlation strength is close to one. The value of the correlation coefficients between the number of seeds from the central clusters and the number and weight of seeds from the lateral clusters was almost zero, which proves the possibility of creating varieties with seed yields achieved by the development of both lateral and central clusters.

Establishing patterns of productivity formation based on determining its correlations with the constituent structural elements will help to increase the accuracy of evaluation and the effectiveness of the selection of selective material according to specified parameters. It was found that seed productivity with most traits (plant height, number of lateral shoots, number of beans from the central clusters and lateral clusters, etc.) had an average positive significant correlation (Fig. 1). A strong positive correlation was detected with the vegetative development of plants, and a weak one with the number of seeds per bean and the weight of 1000 seeds.

Table 1. Matrix of paired correlation coefficients between traits of seed and vegetative productivity of white lupine plants, 2016-2019

No.	General plant structure			Green mass productivity structure (shiny bean phase)					Seed productivity structure					
	number of lateral shoots	number of beans		beans		leaves	stems	roots	number of seeds		weight of seeds		number of seeds per 1 bean	
		central cluster	lateral clusters	central cluster	lateral clusters				central cluster	lateral clusters	central cluster	lateral clusters	central cluster	lateral clusters
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2	-0.04													
3	0.78	-0.02												
4	0.16	0.78	0.22											
5	0.67	0.12	0.88	0.28										
6	-0.01	0.36	0.09	0.39	0.21									
7	0.10	0.37	0.16	0.41	0.27	0.79								
8	0.27	0.38	0.38	0.38	0.44	0.57	0.67							
9	-0.14	0.84	-0.08	0.70	0.09	0.56	0.49	0.43						
10	0.77	0.02	0.94	0.29	0.86	0.19	0.25	0.44	-0.02					
11	-0.24	0.82	-0.21	0.72	0.03	0.58	0.52	0.38	0.91	-0.15				
12	0.78	0.04	0.93	0.33	0.84	0.25	0.30	0.46	-0.01	0.97	-0.11			
13	-0.17	-0.25	-0.08	-0.05	-0.01	0.44	0.30	0.11	0.25	-0.02	0.25	0.03		
14	-0.17	0.21	-0.22	0.24	-0.08	0.46	0.37	0.19	0.29	0.05	0.28	0.04	0.14	

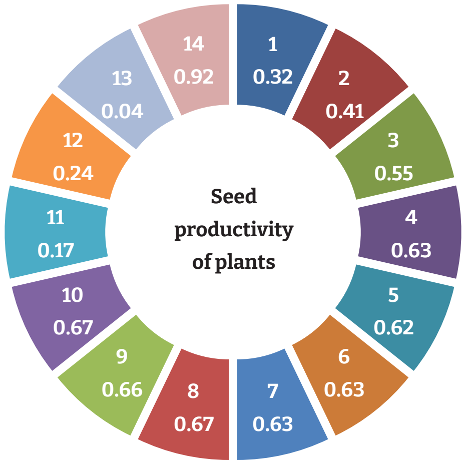

Figure 1. Correlation of seed productivity of plants with elements of its structure and other traits

Note: *1 – plant height, 2 – number of lateral shoots, 3 – number of beans from the central cluster, 4 – number of beans from the lateral clusters, 5 – leaf weight, 6 – root weight, 7 – number of seeds from the central cluster, 8 – number of seeds from the lateral clusters, 9 – weight of seeds from the central cluster, 10 – weight of seeds from lateral clusters, 11 – number of seeds in 1 bean from the central cluster, 12 – number of seeds in 1 bean from lateral clusters, 13 – weight of 1000 seeds, 14 – vegetative productivity of plants*

The established average correlations between seed productivity and leaf weight indicate that increased photosynthetic activity associated with the development of the leaf surface contributes to its growth. Besides, a well-developed root system of plants ensures the formation of increased seed productivity. The high correlation of seed productivity with a green mass of plants proves that good overall plant development leads to the formation of increased seed productivity.

The high correlation of seed productivity with a green mass of plants proves that favourable overall plant development contributes to the generation of higher seed productivity. A significant strong positive correlation of vegetative productivity with such quantitative traits as the weight of beans from the central cluster and the weight of leaves and stems was established (Fig. 2). The weight of the beans from the central cluster during the shiny bean phase, which is the best for harvesting lupine for green fodder, has a stronger correlation with vegetative productivity compared to the beans of the lateral clusters, because the latter are not yet sufficiently developed during this period. A strong correlation with the weight of leaves and stems determines their influence on the formation of productivity and fodder qualities of green mass.

A positive correlation of average strength was found with plant height, number of lateral shoots, number of beans from the central and lateral clusters, weight of beans from lateral shoots, and root weight. A weak positive correlation was established with the dry matter content. An important feature is the almost complete absence of a correlation between vegetative productivity and protein content, which suggests that research should be directed toward creating forms that can combine high yields of green mass with high protein content.

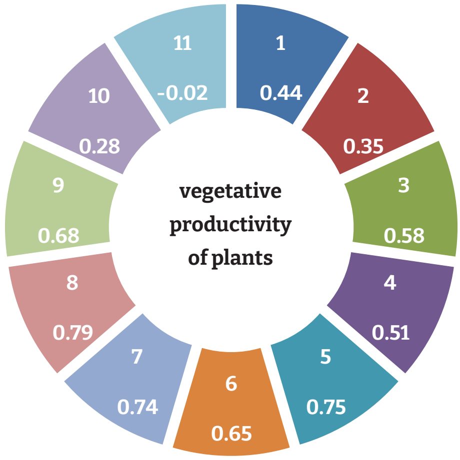

Figure 2. Correlation of vegetative productivity of plants with elements of its structure and other traits

Note: *1 – plant height, 2 – number of lateral shoots, 3 – number of beans from the central cluster, 4 – number of beans from the lateral clusters, 5 – weight of beans from the central cluster, 6 – weight of beans from the lateral clusters, 7 – weight of leaves, 8 – weight of stems, 9 – weight of roots, 10 – dry matter content, 11 – protein content*

The study of correlations between quantitative traits in white lupine was also conducted by scientists from the Institute of Fodder Crops (Bulgaria) and the Lupine Research Institute (Russian Federation) (Kosev & Vasileva, 2020 (a); Kosev & Vasileva, 2020 (b); Zaharova *et al.*, 2014). Bulgarian scientists have found a strong positive correlation between seed productivity and the number of seeds per plant and plant height, and a close relationship between vegetative productivity and plant height, number and weight of leaves, and root weight. According to the data collected by Russian scientists, there is a strong correlation between seed weight and bean weight, plant weight, and number of seeds, and a weak correlation with the weight of 1000 seeds. The conclusions of these authors are consistent with the results of this study and validate its findings.

CONCLUSIONS

The seed productivity of white lupine plants is largely determined by the development of such traits as the number of beans per lateral cluster, weight of leaves and roots, number of seeds per central and lateral cluster, and weight of seeds per central and lateral cluster. Therefore, when evaluating selection material, it is especially relevant to consider the values of these traits, which will facilitate the targeted selection of highly productive genotypes. When evaluating the vegetative productivity of white lupine plants, selection should be based on higher values of such traits as the weight of beans from the central cluster and the weight of leaves and stems. The second most important traits in the formation of green mass are the number of beans per plant, the weight of beans from the lateral clusters and the weight of roots. The application of the established patterns of productivity formation will contribute to the efficiency of the selection of selective material according to the specified parameters.

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Співвідношення елементів насіннєвої та вегетативної продуктивності у колекційних зразків люпину білого

Анотація. Метою досліджень було встановлення сили та загального характеру кореляційних зв'язків між кількісними ознаками, що формують вегетативну та насіннєву продуктивність люпину білого. Методи дослідження включали польовий, вагово-вимірювальний та математично-статистичний методи. Виявлено достовірну позитивну кореляцію між середньою силою насіннєвої продуктивності та такими ознаками, як висота рослин, кількість бічних пагонів, кількість бобів з центральної та бічних китиць тощо. Сильну позитивну кореляцію виявлено з вегетативним розвитком рослин, а слабку - з кількістю насінин у бобі та масою 1000 насінин. Встановлено достовірну сильну позитивну кореляцію вегетативної продуктивності з такими кількісними ознаками, як маса бобів з центральної китиці та маса листя і стебел. Позитивний кореляційний зв'язок середньої сили виявлено з кількістю бобів з центральної та бічних китиць, масою бобів з бічних пагонів, масою коренів тощо. Встановлено, що насіннєва продуктивність рослин люпину білого в основному обумовлена розвитком таких ознак, як кількість бобів з бічних пагонів, маса листя і коренів, кількість насінин і маса насіння з центральних і бічних пагонів. Формування вегетативної продуктивності в першу чергу залежить від маси бобів з центральної китиці та маси листя і стебел. Використання встановлених закономірностей формування продуктивності дозволить підвищити ефективність добору селекційного матеріалу за вказаними параметрами

Ключові слова: кореляційні зв'язки, центральна та бічні китиці, маса насіння, кількість бобів і насінин, кількість насінин у бобі, маса 1000 насінин

РОСЛИННИЦТВО ТА ҐРУНТОЗНАВСТВО

Науковий журнал

Том 12, № 1. 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:
Д. Кокра

Редагування англомовних текстів:
С. Воровський, К. Касьянов

Комп'ютерна верстка:
О. Глінченко

Підписано до друку 15 квітня 2021 р.
Формат 60*84/8
Умов. друк. арк. 11,5
Наклад 50 прим.

Адреса видавництва:

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PLANT AND SOIL SCIENCE

Scientific Journal

Volume 12, No. 1. 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:
D. Kokra

Editing English-Language Texts:
S. Vorovsky, K. Kasianov

Desktop Publishing:
O. Glinchenko

Signed for print of April 15, 2021.
Format 60*84/8
Conventional printed pages 11.5
Circulation 50 copies

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