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Influence of Foliar Top-Dressing on the Yield of Soybean Varieties

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Abstract. The use of complex microfertilisers on a chelated basis in agricultural technologies of the main crops is limited due to the lack of clear recommendations on the norm, methods, and timing of their use in particular production conditions and the levels of expected yield increase. Based on the rather specific mechanism of action of drugs, these recommendations are adjusted by investigating the level of reaction of plants and crops in particular zonal and weather conditions. The purpose of this study was to establish the reaction of soybean varieties to foliar top-dressing with complex Vuksal Microplant microfertiliser. Scientific research was conducted according to the field method during 2019-2021. According to the scheme of the experiment, the following varieties were investigated: Krynytsia, ES Hladiator, Melodiia, Korona, Feieriia, Etiud, Sava, Orfei, Everest, which are classified as early-maturing. The crop was fertilised according to the following variants: $N_{15}P_{30}K_{40}$; $N_{15}P_{30}K_{40}$+1 Vuksal Microplant top-dressing and $N_{15}P_{30}K_{40}$+2 Vuksal Microplant top-dressing. According to the tasks of experimental studies, the field germination rate of seeds was identified by calculating the density of plants in the phase of full germination for all repetitions of the experiment; phenological observations were made in variants of the experiment using the method of variety testing of agricultural crops; the leaf surface area was determined according to the clear-cutting method and the yield was established according to the weight method using direct combining of each site. Statistical processing of experimental data was performed using the Microsoft Excel and Statistica 10.0 application software package. A variant of the fertiliser system was established, which provides a substantial impact on soybean yield and a variety that formed stable productivity over years with changing weather conditions. Based on the results of the study, it is recommended to grow the Etiud soybean variety in production crops with culture fertilisation according to the system of applying macroelements at the rate of $N_{15}P_{30}K_{40}$ and performing two top-dressings with the Vuksal Microplant complex fertiliser on a chelate basis at the rate of 2 l/ha. The first spraying should be carried out in the phase of 2 ternate leaves (BBCH 13-14), and the second in the phase of bean formation (BBCH 70-71)

Keywords: legumes, cultivation technology, fertiliser system, microfertilisers

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INTRODUCTION

Normal growth and development and formation of the soybean grain crop is possible only involving secondary fertilising components (Vozhegova *et al.*, 2016). Studies conducted in various soil and climatic zones of Ukraine have determined that not all secondary fertilising components and not all soils need to be applied under agricultural crops (Gamajunova *et al.*, 2021). Microelements increase the yield of soybean grains, provided that they are applied on soils that are poor in fertility and content on the corresponding elements (Vozhegova *et al.*, 2018).

The relevance of the subject under study lies in the fact that important achievements in biology over the past century are proven facts of the need for trace elements for the active life of plant, animal, and human bodies. Considerable attention of the scientific community around the world is paid to establishing the role of secondary fertilising components in plant life. Microfertilisers have a positive effect on the processes of organogenesis of soybean plants.

Scientists confirm that the agrochemical and physiological role of microfertilisers is multifaceted (Shevnikov & Shevnikov, 2020). They improve the metabolic processes of substances in plants, activate their synthesising functions and contribute to the optimal course of physiological and biological processes (Tafij *et al.*, 2016). They have a positive effect on the process of chlorophyll synthesis and improve the intensity of photosynthesis (Kots *et al.*, 2022). The action of secondary fertilising components contributes to the resistance of plants to fungal and bacterial diseases (Pospielova *et al.*, 2021). It affects the increase in tolerance of such unfavourable environmental conditions as lack of productive moisture in the soil, short-term decrease or increase in air temperature, and other biotic factors (Gamayunova *et al.*, 2020). The most effective measures to influence the productivity of soybean varieties are the protection of crops from harmful organisms, the use of irrigation, a balanced fertiliser system, biologics, and regulators.

The purpose of the study was to establish the yield level of modern soybean varieties depending on the fertiliser system.

To fulfil the stated purpose, the following *tasks* were identified:

- to calculate the density of plants in the germination phase and determine the field germination rate of soybean seeds depending on the variety;
- to conduct phenological observations of the onset of growth and development phases of soybean varieties and record the duration of the entire vegetation season;
- to determine the leaf surface area of soybean plants depending on the fertiliser system;
- to determine the influence of the properties of varieties and the fertiliser system on the yield of soybean seeds.

MATERIALS AND METHODS

Scientific research was conducted during 2019-2021 in the conditions of the central forest-steppe of Ukraine.

The object under study was varieties of the early-maturing group: Krynytsia, ES Hladiator, Melodiia, Korona, Feieriia, Etiud, Sava, Orfei, Everest.

In the field experiment, the system of fertilisation of soybean varieties was used according to the following variants:

1. $N_{15}P_{30}K_{40}$;
2. $N_{15}P_{30}K_{40}$ + 1 top-dressing with Vuksal Microplant;
3. $N_{15}P_{30}K_{40}$ + 2 top-dressings with Vuksal Microplant.

Mineral fertilisers for soybeans were applied in the norm — $N_{15}P_{30}K_{40}$. During the main tillage, 30 kg of active agent/ha of phosphorus and 40 kg of active agent/ha of potassium were added. For this purpose, 150 kg/ha of physical weight of simple granular superphosphate and 100 kg/ha of physical weight of potassium salt were used. During sowing, a seeder applied 15 kg of active agent/ha of full mineral fertiliser in the form of ammonium nitrate phosphate fertiliser, in the norm of 100 kg/ha of physical weight of fertiliser. For foliar top-dressing, Vuksal Microplant was used — a mineral fertiliser, the components of which are chelated complexes (%): N — 5; K_2O — 10; MgO — 3; SO_3-13; B — 0.3; Cu — 0.5; Fe — 1; Mn — 1.5; Mo — 0.01; Zn — 1.

On the variants where 1 top-dressing was used, the crops were sprayed with a working solution in the phase of 2 ternate soybean leaves (BBCH 13-14) with 2 l/ha of Vuksal Microplant.

On the variants where 2 top-dressings were used, soybean crops were sprayed with a working solution in the geminate leaf phase (BBCH 13-14) with 2 l/ha of Vuksal Microplant and in the bean formation phase (BBCH 70-71) — with the same fertiliser at 2 l/ha.

In total, 27 variants were investigated in the experiment: nine varieties (Factor A) and three variants of the fertiliser system (Factor B). The experiment repeatability — three times. Site placement — randomised (Yeshchenko *et al.*, 2005). The area of the experimental plot was 36 m^2, accounting area — 25 m^2. Soybeans were sown in the usual drills with a row spacing of 15 cm. According to the scheme of the experiment, the cultivation technology in the variants was the same, only the fertiliser system under study differed.

The main type of soil of the experimental sites is typical heavy loamy chernozem. Humus content in the soil at a depth of 0-20 cm was 3.8-4.5%; easily hydrolysed nitrogen (according to Tiurin) — 8.6-12.2 mg/100 g of soil; P_2O_5 (according to Chyrykov) — 15.8-20.1 mg/100 g of soil; K_2O (according to Maslova) — 10.3-12.1/100 g of soil. During the three years of research, weather conditions had deviations compared to the long-term average. In terms of humidity and temperature conditions, the best conditions for soybeans were during the growing season of 2019 and 2021, but the increased air temperature combined with the drought, due to the lack of precipitation during the second half of July and throughout August, limited the synthesis of organic matter, which adversely affected the development of crop productivity. The worst weather conditions were recorded during 2020, especially the lack of moisture was characteristic.

RESULTS AND DISCUSSION

Scientists have found that upon working to increase the adaptive potential of soybean varieties, it is possible to increase the annual collections of vegetable protein and oil by 10-15% or more (Vozhegova *et al.*, 2019).

Plants use only a fraction of the mineral elements introduced into the soil (Arbačauskas *et al.*, 2021). Thus, for most brands of mineral fertilisers, the average utilisation rates of the active agent range from 40-60% nitrogen, phosphorus 10-20%, potassium 20-40% (Taranenko *et al.*, 2021). Furthermore, the level of nutrient absorption depends on the structural parameters and quality of the soil, as well as on the development of the plant's root system (Hanhur *et al.*, 2020). According to the data provided in most reference books (Shepilova *et al.*, 2021) the formation of one hundredweight of soybean seeds requires 4.5-9.5 kg of nitrogen, 1.5-3 kg of phosphorus, 3.5-6 kg of potassium. Rather wide limits of variation of coefficients indicate the presence of factors that contribute to or, conversely, reduce the level of assimilation of soil minerals (Punchyshyn *et al.*, 2019).

One of the first tasks of the study was to establish the field germination of seeds by counting plants in the phase of full soybean germination.

According to the results of calculating the number of plants by variants in the phase of full germination, it was found that the germination rate of soybean seeds was influenced by weather conditions of the year and biological characteristics of varieties (Table 1). Depending on the conditions of the year, the best field germination of seeds was in 2019, on average for variants. Depending on the varieties, the highest density of plants in the full germination phase was in the Etiud variety. Field germination of seeds of this variety, on average, was 91.2%.

Table 1. *Field germination rate of soybean seeds, % (2019-2021)*

Item No.	Experiment variants	$N_{15}P_{30}K_{40}$	$N_{15}P_{30}K_{40}$ + 1 top-dressing with Vuksal Microplant	$N_{15}P_{30}K_{40}$ + 2 top-dressing with Vuksal Microplant
1	Krynytsia	75.1	77.8	76.3
2	ES Hladiator	84.3	87.7	85.1
3	Melodiia	82.1	84.5	83.6
4	Korona	85.6	87.1	85.9
5	Feieriia	86.1	87.2	86.5
6	Etiud	90.3	92.5	90.9
7	Sava	80.5	82.6	80.9
8	Orfei	81.4	83.1	82.3
9	Everest	83.4	85.3	84.1

The duration of the growing season is an indicator that describes the conditions of crop formation of field crops.

As for the duration of the soybean growing season, it is not a constant value. It varies for several reasons, primarily the temperature of the soil and air, the intensity and duration of lighting, the level and nature of moisturising (Vozhegova *et al.*, 2020). The level of response depends on the specific features of the genotype, dosage, and ratio of these factors (Gamayunova & Panfilova, 2020).

A critical review of scientific sources on the influence of abiotic and biotic factors on the duration of soybean vegetation indicates considerable differences in opinions on their role and place in changing the duration of vegetation. Thus, M. Galytska *et al.* (2021) emphasise that the intensity of plant organogenesis mainly depends on the temperature regime of the environment, and the water regime affects only the duration of certain interphase periods. Namely, for the following periods: sowing — germination and flowering — maturation. The complex influence of factors on the development of agricultural plants is indicated by O.V. Tryhub *et al.* (2020), noting that the duration of each of the phases of ontogenesis mainly depends on the level of accumulation of organic compounds at apical growth points. The data on the close correlation between the duration of the soybean growing season, the intensity and spectral composition of sunlight are quite convincing (Miladinov *et al.*, 2020).

According to the results of phenological observations, it was found that in all variants of the experiment, the longest growing season of soybeans was in the Melodiia variety (Table 2). The soybean fertiliser system had differing effects on the formation of vegetative and generative organs and the maturation of the crop in particular. The use of foliar top-dressing with complex Vuksal Microplant microfertiliser affected the lengthening of the growing season from 2 to 7 days, on average, according to the experiment.

***Table 2**. Duration of the growing season of soybean plants, days (2019-2021)*

Item No.	Experiment variants	$N_{15}P_{30}K_{40}$	$N_{15}P_{30}K_{40}$ + 1 top-dressing with Vuksal Microplant	$N_{15}P_{30}K_{40}$ + 2 top-dressing with Vuksal Microplant
1	Krynytsia	110	114	116
2	ES Hladiator	109	112	115
3	Melodiia	110	113	117
4	Korona	108	110	116
5	Feieriia	105	107	108
6	Etiud	101	103	105
7	Sava	109	114	115
8	Orfei	106	108	109
9	Everest	102	105	106

Spraying of crops with Vuksal Microplant microfertiliser twice during the growing season lengthened the growing season by 3-8 days, compared to variants where foliar top-dressing of plants was not carried out at all.

The foliar top-dressing factor had an accumulative effect, which provided a gradual increase in the difference between the indicators of vegetative development of plants from juvenile to generative stages of soybean organogenesis. The same conclusions were obtained in the study by S.Y. Kots *et al.* (2022) but using other solutions for foliar top-dressing.

A substantial difference between the control and the experimental variants in terms of leaf surface area was recorded starting from the "budding" phase. Such a mechanism of variation in the indicators of vegetative development of plants, according to the variants of the experiment using microfertilisers for top-dressing, indicates the physiological reaction of a certain variety, which expands the agrotechnical possibilities of increasing the photosynthetic apparatus of plants.

The development of the assimilation surface of soybean plants, within the framework of the experiment, was influenced by the weather conditions of the year, the characteristics of the variety and the complex use of macro- and microfertilisers with different effects on the physiological and biochemical processes in soybean plants (Table 3). According to the results of the experiment, the maximum leaf surface area is 0.905 m^2/ the plant was formed in the Etiud variety with the fertiliser system of culture $N_{15}P_{30}K_{40}$ + 2 top-dressings with Vuksal Microplant.

***Table 3**. Leaf surface area in the soybean seed filling phase, m^2/ plant (2019-2021)*

Item No.	Experiment variants	$N_{15}P_{30}K_{40}$	$N_{15}P_{30}K_{40}$ + 1 top-dressing with Vuksal Microplant	$N_{15}P_{30}K_{40}$ + 2 top-dressing with Vuksal Microplant
1	Krynytsia	0.695	0.701	0.713
2	ES Hladiator	0.792	0.794	0.799
3	Melodiia	0.732	0.735	0.738
4	Korona	0.806	0.809	0.845
5	Feieriia	0.85	0.851	0.858
6	Etiud	0.898	0.903	0.905
7	Sava	0.733	0.739	0.751
8	Orfei	0.781	0.784	0.79
9	Everest	0.771	0.788	0.811

The results of phenological observations, measurements and calculations during the field experiment indicate a fairly high level of reaction of soybean plants to the use of microfertilisers for foliar top-dressing during the growing season of the crop. However, in agronomy, the effectiveness of the elements of field crop cultivation technology under study can be analysed only based on the main indicator, namely the yield of the main products.

The most favourable weather conditions for the formation of soybean yields were in 2019. The yield of varieties differed substantially (Table 4). The maximum yield of soybean seeds of 3.11 t/ha was obtained from crops of the Etiud variety on the variant of a combination of mineral fertilisers application in the norm $N_{15}P_{30}K_{40}$ and two foliar top-dressings with the Vuksal Microplant complex microfertiliser on a chelated basis.

***Table 4**. Soybean yield depending on the variety and fertiliser system, t/ha (2019-2021)*

Item No.	Experiment variants	$N_{15}P_{30}K_{40}$	$N_{15}P_{30}K_{40}$ + 1 top-dressing with Vuksal Microplant	$N_{15}P_{30}K_{40}$ + 2 top-dressing with Vuksal Microplant
1	Krynytsia	2.19	2.22	2.31
2	ES Hladiator	2.47	2.48	2.58
3	Melodiia	2.45	2.49	2.53
4	Korona	2.69	2.73	2.8
5	Feieriia	2.78	2.81	2.87
6	Etiud	2.99	3.02	3.11
7	Sava	2.46	2.51	2.59
8	Orfei	2.6	2.62	2.67
9	Everest	2.62	2.64	2.69
Least significant difference $_{0.05}$ t/ha		$A_{(variety)}$ – 0.03; $B_{(fertiliser\ system)}$ – 0.01		

According to the results of the studies by Z. Miladinov *et al*. (2020) it was also found that foliar spraying with fertiliser solutions had a considerable impact on soybean yields. And the year factor, namely the availability of moisture, affected the productivity of the crop and the effectiveness of top-dressing solutions.

CONCLUSIONS

It is established that production conditions necessitate the use of several varieties with differing biological characteristics, ratio to environmental factors, protein content, oil content, sensitivity to fertilisers, resistance to diseases, and crop density. It should also be considered that even in agroclimatic zones, where varieties can be grown with a longer vegetating season, it is necessary to select genotypes described by different maturation periods. This approach will reduce the impact of possible adverse abiotic factors (rainy summers, low air temperatures), simplifying the optimisation of sowing and harvesting terms. Agrotechnical elements of cultivation technology in modern conditions do not sufficiently contribute to the realisation of the genetic potential of modern soybean morphobiotypes in terms of productivity indicators, which is associated with the low compliance of agricultural measures with the ecological and biological features of intensive varieties. Proceeding from this, there is a problem of improving the elements of cultivation technology to adapt them to the biological characteristics of soybeans, which contributes to the maximum use of its yield potential. The most effective measures to influence the productivity of soybean varieties are the use of a balanced fertiliser system. Therefore, for the central forest steppe zone of Ukraine, the authors of this study recommend growing the Etiud soybean variety using the fertiliser system $N_{15}P_{30}K_{40}$+ 2 top-dressings with Vuksal Microplant, with the norm of 2 l/ha. The first top-dressing should be carried out in the phase of 2 trifoliate leaves (BBCH 13-14), the second in the phase of bean formation (BBCH 70-71).

Prospects for further research lie in the study of the complex application of elements of technology for growing soybean varieties of different ripeness groups.

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Вплив позакореневого підживлення на врожайність сортів сої

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Анотація. Застосування комплексних мікродобрив на хелатній основі у агротехнологіях основних культур обмежене через відсутність чітких рекомендацій щодо норми, способів та строків їх використання у конкретних виробничих умовах і рівнів очікуваної прибавки врожаю. Виходячи із досить специфічного механізму дії препаратів, коригування цих рекомендацій проводиться шляхом вивчення рівня реакції рослин і посівів у цілому в конкретних зональних та погодних умовах. Метою досліджень було встановити реакцію сортів сої на позакореневе підживлення комплексним мікродобривом Вуксал Мікроплант. Наукові дослідження проводили польовим методом упродовж 2019–2021 років. За схемою досліду вивчали сорти: Криниця, ЕС Гладіатор, Мелодія, Корона, Феєрія, Етюд, Сава, Орфей, Еверест, які класифікують як ранньостиглі. Удобрення культури проводили за такими варіантами: $N_{15}P_{30}K_{40}$; $N_{15}P_{30}K_{40}$+1 підживлення Вуксал Мікроплант та $N_{15}P_{30}K_{40}$ + 2 підживлення Вуксал Мікроплант. Згідно з завданнями експериментальних досліджень було визначено польову схожість насіння, шляхом підрахунку густоти рослин у фазі повних сходів по всіх повтореннях досліду; проведено фенологічні спостереження у варіантах досліду за методикою сортовипробування сільськогосподарських культур; визначено площу листкової поверхні методом «висічок» та встановлено рівень урожайності ваговим методом за допомогою прямого комбайнування кожної ділянки. Статистичну обробку експериментальних даних проведено з використанням пакету прикладних програм Microsoft Excel і Statistica 10.0. Установлено варіант системи удобрення, що забезпечує істотний вплив на врожайність сої та сорт, який формував стабільну продуктивність по роках з мінливими погодними умовами. За результатами досліджень рекомендовано у виробничих посівах вирощувати сорт сої Етюд із удобренням культури за системою внесення макроелементів у нормі $N_{15}P_{30}K_{40}$ та проведення двох підживлень комплексним добривом на хелатній основі Вуксал Мікроплант у нормі 2 л/га. Перше обприскування потрібно проводити у фазі 2-х трійчастих листків (ВВСН 13-14), а друге у фазі формування бобів (ВВСН 70-71)

Ключові слова: зернобобові, технологія вирощування, система удобрення, мікродобрива