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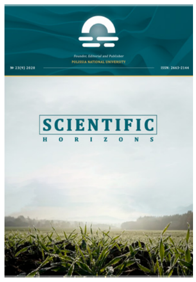

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Influence of Mineral Fertiliser and Foliar Dressing Rates on Buckwheat Yield

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Abstract. A significant problem in the cultivation of buckwheat is its low yield, therefore, it is relevant to improve the elements of the technology for growing this crop. The purpose of the study was to establish optimal norms and terms for applying mineral fertilisers and foliar dressing with chelated microfertilisers in the forest-steppe conditions of Western Ukraine, in a zone of sufficient moisture to obtain stable and high yields of buckwheat grain. For this purpose, a two-factor experiment was conducted on the experimental fields of the Lviv National Agrarian University on dark grey podzolized light loamy soil, which included fertiliser rates: $N_{20}P_{20}K_{20}$, $P_{20}K_{20}+N_{20}$ (foliar dressing), $N_{40}P_{40}K_{40}$, $P_{40}K_{40}+N_{40}$ (foliar dressing), $N_{60}P_{60}K_{60}$, $P_{60}K_{60}+N_{60}$ (foliar dressing) and foliar dressing: control (without foliar dressing), Vuksal Boron 2.0 l/ ha, Intermag Legumes 2.0 l/ha. Research methods: field studies – to determine the interaction of the object of research with weather factors and elements of the fertiliser system; calculation and weight – setting parameters of crop structure indicators and determining buckwheat yield; methods of mathematical statistics – dispersion, correlation, regressive and graphical display of findings. An increase in fertiliser rates from $N_{20}P_{20}K_{20}$ to $N_{60}P_{60}K_{60}$ provided an increase in all indicators of the buckwheat crop structure. Without foliar dressing, they reached the following values: the number of first-order branches – 1.56 pcs./plant, the number of inflorescences and flowers – 10.68 and 1,011 pcs, respectively, the number of full-size and undeveloped grains (pcs./plant) – 41.23 and 11.37, the weight of full-size grains – 1.15 g and the weight of 1,000 grains – 28.00 g. The introduction of nitrogen fertilisers in foliar dressing (at the beginning of flowering) has significant advantages over the introduction of nitrogen for pre-sowing cultivation. One of the proofs of this assumption is the increase in the number of grains, their weight, and the weight of 1,000 grains, respectively, from 35.43 pcs., 0.97 g, and 27.37 g (variant with $N_{40}P_{40}K_{40}$) up to 37.27 pcs., 1.03 g, 27.80 g (variant with $P_{40}K_{40}+N_{40}$). This trend is typical for all experiment designs. A positive effect of foliar dressing with microfertilisers on the elements of the crop structure was observed. The use of Vuksal Boron 2 l/ha was more effective. The maximum weight of full-size grains was in the variant $P_{60}K_{60}+N_{60}$ (foliar dressing) + Vuksal Boron 2 l/ha – 1.21 g, while the use of Intermag Legumes 2 l/ha on a similar background of mineral fertilisers provided this indicator at the level of 1.17 g. Studies have established the positive effect of nitrogen application by foliar dressing during the beginning of flowering on the yield level, and buckwheat yield also increased with an increase in the rate of mineral fertiliser application from $N_{20}P_{20}K_{20}$ to $N_{60}P_{60}K_{60}$ and under the influence of foliar dressing with microfertilisers. The maximum yield indicator on average for three years of research is obtained in variant $P_{60}K_{60}+N_{60}$ (foliar dressing) + Vuksal Boron 2.0 l/ha – 2.64 t/ha

Keywords: buckwheat, nutrition, microfertilisers, structure, productivity

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INTRODUCTION

The first priority of agro-industrial production has always been and will always be to provide food for the world's population (Olifir *et al*., 2021). Buckwheat is an important food crop, the main purpose of growing which is to produce cereals that are characterised by high taste and nutritional qualities and contain an average of 8.9% protein, 71% starch, 1.6% fat, and 0.3 % sugar (Ciesarova *et al*., 2016; Dębski & Horbowicz, 2020). Buckwheat can synthesise rutin, an antioxidant that stimulates the human cardiovascular system (Vojtíšková *et al*., 2012).

The need of any agricultural crop, including buckwheat, for nutrition elements, depends on its chemical composition and the removal of nutrients with the harvest. According to Rubin (1970), buckwheat requires 88 kg of nitrogen, 51 kg of phosphorus, and 151 kg of potassium to produce a yield of 2 t/ha. Before flowering, it consumes up to 60% nitrogen and potassium, 40% phosphorus, and the remaining nutrients – during the flowering-maturation period (Petrychenko & Lykhochvor, 2022). The root system of buckwheat is able to absorb phosphates in a hard-to-dissolve form, which should be taken into account when setting fertiliser application standards.

Analysing the studies by Ukrainian and foreign researchers, there is a significant difference in the recommended standards and methods of application B. Parkhuts (2018) studied the buckwheat fertiliser system in the conditions of the Western forest-steppe of Ukraine on dark grey light loamy soil. The maximum yield was recorded in the variant with $N_{60}P_{45}K_{45}$ – 1.87 t/ha. Application of fertilisers in the amount of $N_{45}P_{60}K_{45}$ and $N_{45}P_{45}K_{60}$ has led to a decrease in the yield to 1.76 and 1.62 t/ha, respectively. Yu.V. Mashchenko (2010) recommends applying fertilisers in the amount of $N_{80}P_{115}K_{120}$ in the conditions of the Kirovohradska oblast on ordinary, light loamy chernozems with low humus content I.D. Tkalich & Y.V. Tkalich (2019) emphasise the importance of observing the economic feasibility of the proposed fertiliser options and consider the amount of $N_{60}P_{30}$ and $N_{60}P_{60}$ to be optimal, because they provide the cheapest grain. O.F. Tymchyshyn & V.V. Lykhochvor (2009) in the conditions of the western forest-steppe, studying the effect of mineral and biological fertilisers on buckwheat productivity, recommend applying mineral fertilisers in the amount of $N_{60}P_{60}K_{60}$ in combination with the use of nitrogen-fixing and phosphorus-mobilising preparations, which contributes to an increase in leaf surface area by 71%, net photosynthetic productivity by 20 %, and an increase in yield by 118% (up to 2.59 t/ha). The retail method of applying nitrogen in the form of foliar dressing is supported by V.F. Kaminsky & R.I. Grishchenko (2011) and V.Ya. Bilonozhko & A.P. Berezovsky (2010). The first dressing of buckwheat is carried out in the budding phase (stage VI of organogenesis) with a rate of up to 25% of the total demand and mainly on wide-row crops, the second – at stage IX of organogenesis during the mass flowering phase at a rate of 15-20 kg/ha, while the yield increase is up to 0.3 t/ha and a larger grain with a high core yield is formed.

The issue of buckwheat fertiliser also attracts the attention of foreign researchers, in particular F. Xiaomei (2018), studying the nitrogen fertiliser system of the Youqiao 2 variety in China, came to the conclusion that the maximum stem thickness, the number and weight of 1,000 grains, the yield of the buckwheat plant is formed with fertilisation rate of N_{30}, increasing it to N_{90} led to a decrease in the yield. Ya. Wang (2018), growing buckwheat variety Ningqiao 01 in Japan, concluded that an increase in nitrogen fertiliser rates does not lead to an increase in yield, but contributes to plant lodging. M.R. Sobhani (2014) recommends nitrogen application rates of 100 kg/ha in the Arak region (Iran), which provides a yield of 2.5 t/ha and protein content of 15.24%. G. Podolska (2011) conducted a study in the fields of the IUNG-PIB experimental station and claims that buckwheat does not require more than 30 kg/ha of nitrogen to form high yields.

The physiological role of trace elements is revealed by B.A. Rubin (1970), V.V. Lykhochvor & V.F. Petrichenko (2021), P.I. Anspok (1990), M.L. Tyrus (2018), V.M. Katelevsky (2017) *et al*. The theory and practice of using microfertilisers has gone through a rather long evolutionary path from the use of metal salts in fertilisers that were introduced into the main fertiliser, seed treatment, to leaf dressing with chelated highly effective microfertiliser suspensions (Dębski & Horbowicz, 2020; Olifir *et al*, 2018; Priadkina, 2020).

The study of buckwheat leaf dressing with trace elements has become widespread in the world agronomic science, so, in particular, Y. Jiang (2015) investigated the effect of selenium on buckwheat growth processes during 2012-2013 in the fields of the Chifeng Academy of Sciences. T. Knapowski & E. Majcherczak (2016) recommend using Vigor fertiliser, which contains 90% S in a tank mixture with Micro Plus fertiliser – (B – 0.3%, Cu – 0.15%, Fe – 2.4%, Mn – 1.0%, Mo – 0.06%, Zn – 0.4%). R. Tobiasz-Salach & B. Krochmal-Marczak (2018) recommend applying Herbagreen at a rate of 2 kg/ha in different phases of vegetation: BBCH 33, BBCH 59, BBCH 67. The use of microfertilisers is an element of the technology of growing agricultural crops, which, with a small investment, provide an additional crop (Veremeenko *et al*., 2020)

The purpose of the study was to clarify the norms and methods of applying mineral fertilisers and the features of foliar dressing of buckwheat in the forest-steppe conditions of Western Ukraine.

MATERIALS AND METHODS

In order to improve the buckwheat fertiliser system in the experimental fields of Lviv National Agrarian University (Pasmove Pobuzhya 49°53'46" N 24°05'33" E) a two-factor experiment was carried out according to generally accepted methods and in compliance with: the principle of unified logical declension, the typicality of the experiment, the ability to reproduce research results in identical conditions, the availability of necessary documentation (field journals), and statistical processing of experiment data. Structural analysis was carried out according to the "Methodology of state variety testing of agricultural crops, 2000". The weight of 1,000 grains was determined according to the state standard 10842-82. Buckwheat yield was recorded in the full ripeness phase by threshing with a Sampo-500 combine and weighing from each accounting area.

The soil of the experimental sites is dark grey podzolic and light loamy. In the soil layer of 0-20 cm, the humus content according to the Tyurin method in the Nikitin modification (DSTU 4289:2004) is 2.2-2.3%, easily hydrolysed nitrogen according to the Kornfield method (DSTU 7863:2015) – 98 mg/kg, phosphorus and potassium according to the Chirikov method (DSTU 4115-2002), respectively, 116-134 mg/kg and 125-135 mg/kg of soil, hydrolytic acidity according to the Kapen method (DSTU 7537:2014) is 5.8-6.0, the content of mobile sulphur is low, and other trace elements are at a sufficient level.

The hydrothermal conditions of the research years were characterised by certain differences both among themselves and in comparison with the long-term average data, mostly favourable and were not a limiting factor for the formation of the buckwheat crop. In 2018, it was warm – an average of 9.1°C per year, which is 1.3°C higher than the long-term data. The annual precipitation also exceeded the norm by 146 mm and amounted to 818 mm in 2020.

In 2020, the annual temperature also exceeded the long-term temperature by 1.0°C. Yields in 2020 decreased due to uneven precipitation distribution. If in April-May the amount of precipitation was 36 mm less, then in June it fell 153 mm, which is 69 mm more than normal. This led to the displacement of air from the soil, created a lack of oxygen for the root system, and a decrease in grain yield.

In 2021, the annual temperature exceeded the long-term one by 0.8°C. Precipitation fell evenly throughout the growing season. Hydrothermal conditions were favourable for buckwheat harvest.

The field experiment was based on the study of the action and interaction of two factors:

- factor A (mineral fertiliser rate);
- factor B (foliar dressing).

Variants were placed by the method of split sites. The accounting area of the elementary plot – 50 m^2, three-fold repetition. Method of sowing buckwheat – row with spacing of 15 cm The seeding rate is 3.5 million tonnes of seeds of the Oranta variety per hectare (originators – NSC Institute of Agriculture of the National Academy of Sciences and TOV NVMP Antaria). The technology of buckwheat cultivation corresponds to the recommended one for this zone, with the exception of agricultural measures, the influence of which was studied in this paper.

In the experimental plots, winter wheat was the precursor during the years of research. After harvesting, BDT-3 + T-150 stubbles were peeled to preserve moisture and provoke the growth of weeds. After the regrowth of weeds, they were destroyed using glyphosate at a rate of 5 l/ha, then phosphorus-potassium fertilisers (potassium chloride and superphosphate) were applied under ploughing (MTZ-82+PN-3-35) with a depth of 20-22 cm according to the experiment scheme.

In the spring, when the soil was physically ripe, harrowing was carried out with heavy harrows BZTS-1.0 across the ploughing direction to preserve moisture. Further tillage included two cultivations with the MTZ-82+ KPS-4 cultivator. Before carrying out the second (pre-sowing) cultivation, nitrogen fertilisers were applied according to the experiment design in the form of ammonium nitrate. Sowing was carried out with a SN 4B seed drill at a given seeding rate.

The foliar dressing was carried out during the budding phase according to the experiment scheme Vuksal Boron – 2 l/ha (produced by Aglukon Spezialdünger GmbH & Co KG) and Intermag Legumes – 2 l/ha (produced by Intermag). Spraying was carried out with a satchel sprayer at the rate of 200 litres of working solution per 1 ha, in the first half of the day in calm weather, to avoid spraying of drugs to neighbouring areas. In variants where foliar dressing was not used, spraying was carried out with water. At the beginning of the flowering phase, nitrogen was fed in the form of ammonium nitrate in the corresponding variants of the experiment.

Sheaf samples were taken the day before harvesting plants from sites with an area of 1 m^2, which were arranged to determine the density of plants. During the analysis of the sheaf material, the following parameters were measured: the number of first-order branches (pcs.); number of inflorescences and flowers (pcs.); number of grains (pcs.), including developed and underdeveloped; the weight of full-size grains from 1 plant (g); the weight of 1,000 grains (g). Harvesting was carried out separately when 70-80% of the grains were disturbed and the plants were previously mowed into swaths. After 4-6 days, with the grain humidity of 16-18%, harvesting was carried out by a combine harvester. After threshing, the grain was cleaned and dried to a humidity of 14-15%.

Mathematical processing of results was performed using Statistica and MS Office Excell software suites.

RESULTS

Methods of achieving an increase in buckwheat yield in the zone of sufficient moisture in the forest-steppe of Western Ukraine by increasing only fertiliser rates are considered ineffective. Therefore, the authors proposed an experiment design where nitrogen fertilisers were applied both for pre-sowing cultivation and during the beginning of flowering. In addition, the effect of mineral fertilisers is studied in combination with foliar dressing, while special attention is paid to the boron trace element.

The results of studies on the influence of mineral fertilisers and foliar dressing standards on the development of the buckwheat crop structure allow establishing the following regularities (Table 1).

***Table 1**. Influence of mineral fertilisers and foliar dressing on the elements of the buckwheat crop structure (on average for 3 years)*

Fertiliser variant	Number of first-order branches, pcs./plant	Quantity pcs./plant		Number of grains, pcs./plant		Weight of full-size grains, g/plant	Weight of 1,000 grains, g
		Inflorescences	Flowers	Full-size	Underdeveloped		
Without foliar dressing							
$N_{20}P_{20}K_{20}$	1.51	9.57	891	27.70	12.30	0.75	26.93
$P_{20}K_{20}+N_{20}$ (foliar dressing)	1.44	8.81	833	30.83	13.13	0.83	27.03
$N_{40}P_{40}K_{40}$	1.53	10.41	980	35.43	11.13	0.97	27.37
$P_{40}K_{40}+N_{40}$ (foliar dressing)	1.46	8.90	868	37.27	12.63	1.03	27.80
$N_{60}P_{60}K_{60}$	1.56	10.68	1,011	39.23	9.93	1.08	27.67
$P_{60}K_{60}+N_{60}$ (foliar dressing)	1.48	9.04	903	41.23	11.37	1.15	28.00
Intermag Legumes 2 l/ha							
$N_{20}P_{20}K_{20}$	1.52	9.58	891	28.37	12.07	0.76	26.93
$P_{20}K_{20}+N_{20}$ (foliar dressing)	1.44	8.81	833	31.57	12.87	0.85	27.03
$N_{40}P_{40}K_{40}$	1.53	10.41	981	36.20	10.87	0.99	27.37
$P_{40}K_{40}+N_{40}$ (foliar dressing)	1.46	8.92	868	38.17	12.40	1.06	27.80
$N_{60}P_{60}K_{60}$	1.56	10.68	1012	40.17	9.70	1.11	27.67
$P_{60}K_{60}+N_{60}$ (foliar dressing)	1.48	9.05	904	42.07	11.10	1.17	28.00
Vuksal Boron 2 l/ha							
$N_{20}P_{20}K_{20}$	1.51	9.59	892	29.53	11.60	0.79	26.93
$P_{20}K_{20}+N_{20}$ (foliar dressing)	1.44	8.83	834	32.83	12.37	0.89	27.03
$N_{40}P_{40}K_{40}$	1.52	10.41	980	37.43	10.80	1.03	27.37
$P_{40}K_{40}+N_{40}$ (foliar dressing)	1.47	8.91	868	39.43	11.93	1.10	27.80
$N_{60}P_{60}K_{60}$	1.57	10.69	1012	41.40	9.37	1.15	27.67
$P_{60}K_{60}+N_{60}$ (foliar dressing)	1.50	9.05	904	43.47	10.63	1.21	28.00

1. The maximum number of first-order branches (pcs./plant), the number (pcs.) of inflorescences and flowers are provided by options with the introduction of nitrogen fertilisers in pre-sowing cultivation $N_{20}P_{20}K_{20}$ – 1.51, 9.57, 891; $N_{40}P_{40}K_{40}$ – 1.53, 10.41, 980; $N_{60}P_{60}K_{60}$ – 1.56, 10.68, 1,011, respectively. The use of nitrogen fertilisers on similar phosphorus-potassium backgrounds in foliar dressing during the phases of the beginning of flowering reduces the indicators mentioned above, and this trend is observed in all variants of the experiment.

2. The use of Vuksal Boron and Intermag Legumes in foliar dressing at the rate of 2 l/ha did not significantly affect the number of first-order branches, inflorescences, and flowers.

3. A positive effect of foliar dressing on the indicators of the buckwheat crop structure was observed, while the use of Vuksal Boron 2 l/ha was more effective compared to the introduction of Intermag Legumes 2 l/ha. Thus, the number of full-size grains (43.47 pcs.), their weight (1.21 g) was the largest when combined with the application of mineral fertilisers $P_{60}K_{60}+N_{60}$ (foliar dressing) and foliar dressing with Vuksal Boron 2 l/ha. This is 1.40 pcs., and 0.04 g more compared to the variant $P_{60}K_{60}+N_{60}$ (foliar dressing) + Intermag Legumes 2 l/ha and 2.24 pcs., and 0.46 g more compared to the same variant for applying mineral fertilisers, where the foliar dressing was not carried out. Notably, the foliar dressing did not affect the weight index of 1,000 grains;

4. Elements of the buckwheat crop structure increase with an increase in the fertiliser application rate from $N_{20}P_{20}K_{20}$ to $N_{60}P_{60}K_{60}$ and at the same time they vary widely: the weight of 1,000 grains is in the range of 26.93-28.00 g; the weight of full-scale grains – 0.75-1.21 g; the number of full-scale grains – 27.70-43.47 pcs.

The level of buckwheat yield is the result of a complex interaction of the genetic potential of plants with a complex of environmental conditions, which includes hydrothermal conditions and factors that were studied: fertiliser rates and foliar dressing (Table 2).

Table 2. Yield, t/ha of buckwheat depending on the norms of mineral fertilisers and foliar dressing

Fertiliser variant	Years			Average for 3 years
	2018	2020	2021	
Without foliar dressing				
$N_{20}P_{20}K_{20}$	1.63	1.29	1.63	1.52
$P_{20}K_{20}$ + N_{20} (foliar dressing)	1.79	1.47	1.79	1.68
$N_{40}P_{40}K_{40}$	2.17	1.72	2.24	2.05
$P_{40}K_{40}$ + N_{40} (foliar dressing)	2.29	1.86	2.36	2.17
$N_{60}P_{60}K_{60}$	2.47	1.98	2.53	2.33
$P_{60}K_{60}$ + N_{60} (foliar dressing)	2.63	2.15	2.68	2.49
Intermag legumes 2 l/ha				
$N_{20}P_{20}K_{20}$	1.68	1.32	1.69	1.57
$P_{20}K_{20}$ + N_{20} (foliar dressing)	1.84	1.50	1.87	1.74
$N_{40}P_{40}K_{40}$	2.24	1.78	2.31	2.11
$P_{40}K_{40}$ + N_{40} (foliar dressing)	2.36	1.94	2.45	2.25
$N_{60}P_{60}K_{60}$	2.53	2.04	2.63	2.40
$P_{60}K_{60}$ + N_{60} (foliar dressing)	2.70	2.21	2.75	2.55
Vuksal boron 2 l/ha				
$N_{20}P_{20}K_{20}$	1.71	1.34	1.81	1.62
$P_{20}K_{20}$ + N_{20} (foliar dressing)	1.87	1.58	1.97	1.81
$N_{40}P_{40}K_{40}$	2.28	1.88	2.44	2.20
$P_{40}K_{40}$ + N_{40} (foliar dressing)	2.40	2.00	2.58	2.33
$N_{60}P_{60}K_{60}$	2.60	2.14	2.74	2.49
$P_{60}K_{60}$ + N_{60} (foliar dressing)	2.77	2.28	2.88	2.64
$LSD_{0.05}$ t/ha A	0.06	0.15	0.07	
$LSD_{0.05}$ t/ha B	0.04	0.11	0.05	
$LSD_{0.05}$ t/ha A+B	0.10	0.23	0.12	

After analysing the obtained research data, it can be argued that:

1. The maximum yield levels were provided by hydrothermal conditions of 2021. The yield varied depending on the variant in the range of 1.63-2.88 t/ha. In 2018 and 2020, the yield indicators ranged from 1.63-2.77 and 1.29-2.28 t/ha, respectively.

2. An increase in the norms of nitrogen and phosphorus-potassium fertilisers leads to an increase in buckwheat yields, which reach maximum values in variants $N_{60}P_{60}K_{60}$ (2.33 t/ha) and $P_{60}K_{60}$ + N_{60} (foliar dressing) (2.49 t / ha);

3. The use of nitrogen fertilisers in the flowering phase ensured an increase in the yield and reached its maximum values on average for three years of research in the following variants: $P_{60}K_{60}$+N_{60} (foliar dressing) – 2.49 t/ha; $P_{60}K_{60}$+N_{60} (foliar dressing) + Intermag Legumes 2 l/ha – 2.55 t/ha; $P_{60}K_{60}$+N_{60} (foliar dressing) + Vuksal Boron 2 l/ha – 2.64 t/ha. The yield increase in variants where nitrogen fertilisers were applied at different rates during the flowering phase is 0.16-0.97 t/ha (without foliar dressing), with the use of microfertilisers, this growth was even more significant (Fig. 1).

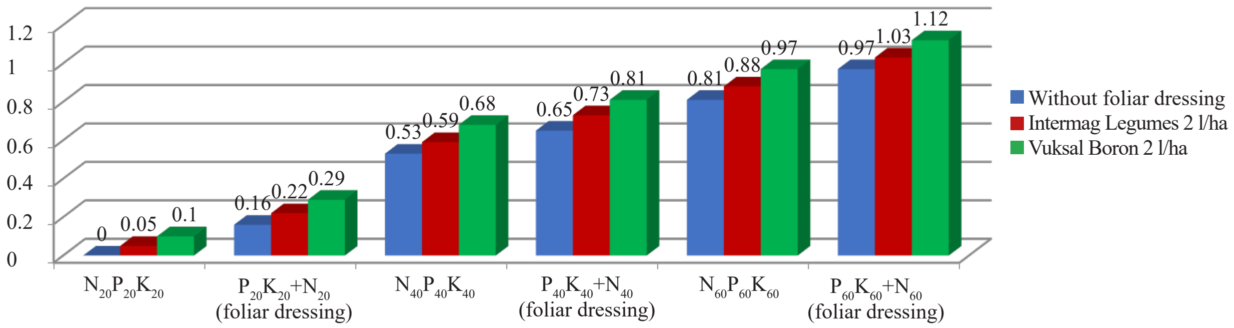

***Figure 1.** Increase in buckwheat yield depending on the norms of fertilisers and foliar dressing in comparison with option $N_{20}P_{20}K_{20}$ (without foliar dressing)*

4. A positive effect of using foliar dressing with chelated microfertilisers in the budding phase was noted. Thus, the option of applying mineral fertilisers in the amount $N_{40}P_{40}K_{40}$ on average, during three years of research, provided 2.05 t/ha of buckwheat. The use of mineral fertiliser Intermag Legumes 2 l/ha allowed additionally obtaining 0.06 t/ha, and the yield increase for the use of Vuksal Boron 2 l/ha was 0.15 t/ha, that is, the introduction of Vuksal Boron 2 l/ha is more effective than the introduction of Intermag Legumes 2 l/ha.

The relationship between buckwheat yield and weight of 1,000 grains is described by the regression equation:

$$Y=252496+1,0516X$$

where Y – yield t/ha, X – weight of 1,000 seeds, pcs.

Coefficient of determination R^2=0.9049. Strong correlations between these indicators R=0.9513 were noted. The relationship between buckwheat yield and the number of full grains is described by the regression equation:

$$Y=-0,5461+0,07324X$$

where Y – yield t/ha, X – number of full-size grains, pcs.

Coefficient of determination R^2=0.9966. Strong correlations between these indicators R=0.9983 were noted.

DISCUSSION

The nutritional value of buckwheat and the increase in yield under the influence of fertilisers are noted in many sources. Buckwheat groats (Fagopyrum esculentum Moench) are an excellent source of nutrients, as they contain high levels of essential amino acids, minerals, and B vitamins compared to other cereals (Linh *et al.*, 2014). Microorganisms and trace elements effectively affect the yield of buckwheat (Jaroszewska *et al.*, 2019).

One of the technological problems in growing buckwheat is its relatively low resistance to lodging. This feature is especially important to consider in conditions of sufficient and excessive moisture in the western forest-steppe. Increased fertilisation rates, especially nitrogen fertilisers, can increase the risk of lodging. Therefore, it is promising to improve the technology of growing buckwheat to find ways to increase the resistance of plants to lodging.

In this study, the yield of buckwheat increased under the influence of fertilisers by more than a tonne (Table 2). Most of all, crop growth was affected by the weight of grain from the plant and the weight of 1,000 grains (Table 1). Under the influence of fertilisers, the weight of 1,000 grains also increased in studies conducted in Iran (Fallah *et al.*, 2016) and India (Maruti *et al.*, 2018). According to the data (Bunchak, 2018), the application of organic fertilisers in the Elena variety provided an increase in field germination by 4.4-8.1% and plant density by 0.184-0.324 million pcs./ha.

In Turkey, five types of fertilisers were studied for buckwheat varieties Aktash and Gunesh, the highest yield was provided by the introduction of mineral fertiliser urea, enriched with trace elements of copper, iron, and manganese (Çürük *et al.*, 2020). According to Indian researchers (Hulihalli & Shantveerayya, 2018), the highest yield of buckwheat grain was formed when mineral fertilisers were applied at the rate of $N_{35}P_{20}K_{20}$.

According to Italian researchers (Mariotti *et al.*, 2016), in the Mediterranean, buckwheat is only an alternative crop. Only in very early spring sowing periods can 2 t/ha of seeds be collected. Later sowing dates are unsuitable for growing buckwheat due to the negative impact of high summer temperatures on the setting and germination of seeds. Due to global warming, in some years similar climatic conditions are also typical for Ukraine. Therefore, certain elements of technology, especially the nutrition system, should be used to create conditions for intensive buckwheat development and fruiting before the onset of heat. This is confirmed by studies conducted in Serbia (Kolarić *et al.*, 2021), where four fertiliser rates were investigated ($N_0P_0K_0$, $N_{30}P_{30}K_{30}$, $N_{60}P_{60}K_{60}$, $N_{90}P_{90}K_{90}$) when growing the Novosadska variety. The maximum yield of buckwheat grain was obtained by applying $N_{90}P_{90}K_{90}$. Yield significantly positively correlated with such structural indicators as the number of seeds per plant, the weight of seeds per plant, the height of plants, and the number of side branches.

CONCLUSIONS

Increasing the rate of application of mineral fertilisers from $N_{20}P_{20}K_{20}$ to $N_{60}P_{60}K_{60}$ helps to increase the amount and weight of full-scale grains, respectively, from 27.70 to 41.23 pcs., and from 0.75 to 1.15 g, the weight of 1,000 grains – from 26.93 to 28.00 g. When nitrogen fertilisers are applied to dressing (the beginning of the flowering phase), the number of first-order branches, inflorescences, and flowers decreases, but the number and weight of full-size grains and the weight of 1,000 grains increases, which reach their maximum with fertiliser variant of $P_{60}K_{60}$+N_{60} (foliar dressing) – 41.23 pcs., 1.15 g, and 28.00 g, respectively.

The use of foliar dressing has a positive effect on the development of elements of the buckwheat structure, while this growth is more significant than the introduction of Vuksal Boron at a rate of 2 l/ha. The largest number of full-size grains (43.47 pcs.), their weight (1.21 g), and weight of 1,000 grains (28.00 g) were obtained in variant $P_{60}K_{60}$+N_{60} (foliar dressing) + Vuksal Boron 2 l/ha.

Increasing the norms of mineral fertilisers, applying nitrogen fertilisers to foliar dressing (the beginning of the flowering phase) and applying foliar dressing (the budding phase) have a positive effect on the buckwheat yield indicator. The maximum yield on average for three years of research was obtained in the variant where nitrogen fertilisers are in the norm of N_{60} was applied to foliar dressing (the phase of the beginning of flowering) on a phosphorus-potassium background of $P_{60}K_{60}$ for the use of Vuksal Boron 2 l/ha – 2.64 t/ha. Such a fertiliser system is recommended for production.

The use of nitrogen fertilisers in foliar dressing during the beginning of flowering (and not for pre-sowing tillage) will be of practical importance, since the vegetative mass and the risk of lodging plants are reduced. In addition, "late nitrogen" will be used to form the regenerative part of the plant, which will ensure a higher grain yield.

Increasing the application rates of phosphorous, potash and, especially, nitrogen mineral fertilisers in the cultivation of buckwheat will be economically impractical. Further study on improving the buckwheat fertiliser system will be aimed at investigating the effectiveness of applying sulphur and magnesium fertilisers.

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Вплив норм мінеральних добрив та листкових підживлень на урожайність гречки

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Анотація. Значною проблемою у вирощуванні гречки є низька врожайність, тому актуальним є удосконалення елементів технології вирощування цієї культури. Метою досліджень було установити оптимальні норми та строки внесення мінеральних добрив та листкових підживлень хелатними мікродобривами в умовах Лісостепу західної України, в зоні достатнього зволоження для отримання стабільних та високих врожаїв зерна гречки. Для цього на дослідних полях Львівського Національного аграрного університету на темно-сірому опідзоленому легкосуглинковому ґрунті був закладений двофакторний дослід, який включав норми добрив: $N_{20}P_{20}K_{20}$, $P_{20}K_{20}+N_{20}$ (підживлення), $N_{40}P_{40}K_{40}$, $P_{40}K_{40}+N_{40}$ (підживлення), $N_{60}P_{60}K_{60}$, $P_{60}K_{60}+N_{60}$ (підживлення) та листкові підживлення: контроль (без листкового підживлення), Вуксал Борон 2,0 л/га, Інтермаг Бобові 2,0 л/га. Методи дослідження: польовий – для визначення взаємодії об'єкта досліджень з погодними факторами та елементами системи удобрення; розрахунково-ваговий – встановлення параметрів показників структури врожаю та визначення врожайності гречки; методи математичної статистики – дисперсійний, кореляційний, регресивний та графічне відображення результатів досліджень. Зростання норм добрив від $N_{20}P_{20}K_{20}$ до $N_{60}P_{60}K_{60}$ забезпечило збільшення усіх показників елементів структури врожаю гречки. Без листкових підживлень вони досягали таких значень: кількість гілок першого порядку – 1,56 шт/рослину, кількість суцвіть та квіток відповідно 10,68 та 1011 шт, кількість повноцінних зерен та рудяку (шт/рослину) відповідно 41,23 та 11,37, маса повноцінних зерен – 1,15 г та маса 1000 зерен – 28,00 г. Варто відмітити, що внесення азотних добрив у підживлення (фаза початку цвітіння) має суттєві переваги порівняно з внесенням азоту під передпосівну культивацію. Одним із доказів цього судження є зростання показників кількості зерен, їх маси та маси 1000 зерен відповідно від 35,43 шт., 0,97 г та 27,37 г (варіант внесення $N_{40}P_{40}K_{40}$) до 37,27 шт., 1,03 г, 27,80 г (варіант внесення $P_{40}K_{40}+N_{40}$). Така тенденція характерна для усіх варіантів досліду. Спостерігався позитивний вплив листкових підживлень мікродобривами на елементи структури врожаю. Більш ефективним виявилось застосування Вуксал Борону 2 л/га. Маса повноцінних зерен максимальною була у варіанті $P_{60}K_{60}+N_{60}$ (підживлення) + Вуксал Борон 2 л/га – 1,21 г, тоді як застосування препарату Інтермаг Бобові 2 л/га на аналогічному фоні мінеральних добрив забезпечило цей показник на рівні 1,17 г. Дослідженнями установлено позитивний вплив внесення азоту методом підживлення за фази початку цвітіння на рівень врожаю, також врожайність гречки зростала зі збільшенням норми внесення мінеральних добрив від $N_{20}P_{20}K_{20}$ до $N_{60}P_{60}K_{60}$ та під впливом листкових підживлень мікродобривами. Максимальний показник урожаю у середньому за три роки досліджень, отриманий у варіанті $P_{60}K_{60}+N_{60}$ (підживлення) + Вуксал Борон 2,0 л/га – 2,64 т/га

Ключові слова: гречка, живлення, мікродобрива, структура, продуктивність