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ORIGINAL ARTICLE

Effect of fertilizers for *Phaseolus vulgaris* L. productivity in Western Forest-Steppe of Ukraine

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The scientific article summarizes the improving the efficiency of growing legumes by selecting varieties, primary tillage mode, and optimization of plant nutrition in the Western Forest-Steppe. Studies have shown that legumes are the most demanding crops. In the Western Forest-Steppe, the Bukovynka variety of legumes became more productive when inoculating seeds with Rhizobophyte, applying mineral fertilizer (N30P60K60), foliar fertilization of crystallin, the grain yield of legumes was 2.69 t/ha. A high correlation is observed between the number of beans and the number of grains per plant (r = 0.98), the mass of grains from one plant and the mass of 1000 grains (r = 0.97), number of grains per 1 plant, and the mass of grains per plant (r = 0.96). The moderate correlation was between the number of grains in the bean (r = 0.63) and the weight of 1000 grains (r = 0.66). A low correlation (r = 0.45) was observed between the number of beans per plant and the bean's number of grains. Negative correlations we registered for the number of beans per plant and a mass of 1000 grains (r = -0.37) and the number of grains per one plant (r = -0.17). Thus, we revealed the Bukovynka variety provided the highest level of legume grain yield during inoculation of seeds with Rhizobophyte, applying mineral fertilizer at the dose of N30P60K60, and two foliar fertilization of crops with Kristalon.

Keywords: *Phaseolus vulgaris* L., productivity**,** variety, mineral fertilizers, foliar fertilization, grain yield.

Introduction

During the reform of the agro-industrial complex of Ukraine and animal production reduction, high-protein crop products' production became important. As a result, the demand for legume seeds has risen sharply in recent years. Legumes' particular importance in solving humankind's protein problem is determined primarily by the high protein content, a significant number of essential and critical amino acids, high solubility, and nutritional value.

Legumes contain an average of 24% protein, which in the amino acid composition is close to proteins of animal origin. We know these plants enrich the soil with valuable organic matter, nitrogen, replenish the arable layer with phosphorus, potassium, calcium, improve soil structure, and increase fertility. They are the best precursors for most crop rotation and the most valuable green manure; we can grow them without using nitrogen fertilizers, which account for up to 30% of energy consumption in intensive technologies. We can consider that the utilization rate of nitrogen from mineral fertilizers is only 50%, a significant part of them contaminates groundwater with nitrates, and living organisms entirely use biological nitrogen.

Recently, fundamental scientific research on technological methods of growing legumes and environmental and economic-environmental problems are the subjects of domestic and foreign scientists' special attention. In particular, these were the works of Petrychenko V.F., Mazur V.A., Kaminskyi V.F., Pantsyreva H.V., Shevchuk O.A., Didur I.M., Bakhmat O.M., Li J., Wang E., Chen W., Chen X. They established that the grain productivity of plants is one of the main elements of the structure of the crop, due to the interaction of many genes, the influence of soil-climatic and agronomic conditions.

Legumes are crops that requires high soil fertility. About 90-95% of P, K, and Ca is absorbed in a brief period – only 50-65 days from the moment of emergence. Legumes are the most demanding of all legumes. According to Stakanov F., legumes responded well to nitrogen fertilizers at a dose of N45 – yields increased by 11%. When growing legumes on chernozems, we need to use phosphorus and phosphorus and potassium fertilizers. After all, soil acidity and low phosphorus levels are critical limiting factors for increasing bean yields.

It is also essential to choose an effective bean inoculant. According to American scientists (Gepts P., Delgado-Salinas A, Bonet A., Gepts P., 1988), only six Rhizobium strains out of twelve were effective for Phaseolus vulgaris L. Thus, treatment of seeds with Glomus® and Rhizotorphin® increased the grain yield of legumes by 2.3-4.5 kg/ha. According to D. Shlyakhturova, the combination in the fertilizer system of ordinary nitrogen and mineral fertilizers created the best conditions for forming this culture's plant productivity. It is established that on the dark gray podzolic soil in the Lviv region conditions, the highest yield of legumes was obtained by applying mineral fertilizers in the pre-sowing cultivation in the dose N30P60K60.

In the conditions of the Northern Forest-Steppe of Ukraine, the maximum yield of legumes was obtained by inoculating seeds and applying N60P60K60. (Bakhmat O.M.,2016) In Bulgaria, the yield of legumes increased in all variants of the experiment with mineral fertilizers compared to the control (Oliveira, I.A.; Vasconcellos, M.J.; Seldin, L.; Paiva, E.; Vargas, M.A.; de Sá, N.M.H., 2000). In Brazil (Echeverrigaray S., Carvalho M.T.V., Pompeu A.S. and Derbyshire E., 1993), phosphorus and molybdenum's introduction has increased the yield of legumes, especially when inoculating seeds with nodule bacteria.

Materials and methods

Scientific research was performed by conducting field and laboratory experiments. The research was conducted following generally accepted methods Scientific research was performed by conducting field and laboratory experiments. The research was conducted following generally accepted methods. The soil of the experimental field is leached black soil, low humus, on carbonate loam. The humus content in the soil layer is 0-30 cm (according to Tyurin is 3.86-4.11%; easily hydrolyzing nitrogen (according to Cornfield) – 111-121 mg/kg, mobile phosphorus and metabolic potassium (according to Chirikov) – 90 and 179 mg/kg of soil, respectively. The absorption capacity and the number of absorbed bases vary, respectively, between 33-36 and 30-33 mg-eq/100 g of soil. Hydrolytic acidity is 0.76-0.87 mg-eq/100 g soil, the degree of saturation of the basics – 94.7-99.0%.

The solid phase density is 2.58 g/cm^3, the density of the soil structure is 1.14-1.25 g/cm^3, the total porosity is 52-59%. The maximum soil hygroscopicity is 5.2%; the lowest moisture content is 23.4%, the total field capacity is 41.2%.

The climate of the southwestern part of the Forest-Steppe of Ukraine is warm, with sufficient moisture. The average radiation balance in the region for the year is 43.3 kcal/cm², and for the growing season of sugar sorghum – 137.73 kJ /cm². Most of PAR come in June and July. From May to September, 3/4 of the annual amount of heat comes to the soil surface. Annual precipitation ranges from 550-700 mm, 3/4 of which falls during the warm season. The hydrothermal coefficient in the region is 1.4. The weather conditions of the sugar sorghum vegetation period in 2017-2019 years had the following features: with the average long-term rainfall and the sum of temperatures respectively 345 mm and 2903 °C, during the years these indicators fluctuated within such limits.

During the research period, two experiments were conducted. The study examined the effect of fertilizers on grain yield of common bean varieties. Varieties of common beans, entered in the State Register of varieties allowed for distribution in Ukraine Nadiya, Bukovynka.

Results and discussion

We found that the average yield of legumes under control in 2015-2019 (Nadiya variety without fertilizer) was 2.07 t/ha. Among the studied varieties in the variant without the use of fertilizers, the highest grain yield was in the variety of legumes Bukovynka - 2.33 t/ha. Our application of fertilizers significantly increased the yield of legumes. Thus, when applying $P_{60}K_{60}$, the yield fluctuated in the range of 2.24-2.49 t/ha or 8.2-9.4% more than the control. According to the control, the application of N30P60K60 contributed to a further increase in yield to 2.29-2.62 t/h a, which was 11.1-12.4% more.

To a lesser extent, legumes' productivity was affected by inoculation of seeds with Rhizobophyte: grain yield of Nadiya variety increased by 0.1 t/ha or 4.8%, Bukovynka variety – by 0.05 t/ha. The combination of inoculation of seeds with Rhizobophyte and application of phosphorus and potassium fertilizers ($P_{60}K_{60}$) created more optimal conditions for the formation of high productivity of bean varieties. It should be noted that the combination of biological (Rhizobophyte) and mineral (N_{30}) nitrogen on the background of $P_{60}K_{60}$ contributed to increased grain yield of legumes. Thus, the average grain yield of legumes of the Nadiya variety was 2.31 t/ha, and the Bukovynka variety – 2.51 t/ha. Foliar fertilization of bean crops with Cristalon was also adequate.

In Nadiya variety, treatment with Crostalon provided an increase in yield of 0.17 t/ha, or as much as the application of phosphorus and potassium fertilizers at a dose of $P_{60}K_{60}$ (Table 1).

Table 1. Grain productivity of bean varieties, depending on power supply systems, t/ha.

Fertilizers (factor A)	Yield by year					
	2015	2016	2007	2018	2019	average
grade (factor B) – Nadiya						
No fertilizers (c.)	2.24	1.71	2.16	2.14	2.07	2.07
$P_{60}K_{60}$	2.35	2.09	2.27	2.25	2.24	2.24
$N_{30}P_{60}K_{60}$	2.46	2.12	2.33	2.29	2.30	2.30
Rhizobophyte	2.38	1.76	2.23	2.31	2.17	2.17
$P_{60}K_{60}$ + Rhizobophyte	2.44	2.02	2.42	2.35	2.31	2.31
$N_{30}P_{60}K_{60}$ + Rhizobophyte	2.46	2.12	2.43	2.36	2.32	2.34
Cristalon	2.36	1.99	2.28	2.33	2.24	2.24
$P_{60}K_{60}$ + Cristalon	2.57	2.11	2.25	2.39	2.33	2.33
$N_{30}P_{60}K_{60}$ + Cristalon	2.59	2.24	2.37	2.44	2.41	2.41
Rhizobophyte + Cristalon	2.42	1.83	2.35	2.40	2.25	2.25
$P_{60}K_{60}$ + Rhizobophyte + Cristalon	2.51	2.19	2.38	2.48	2.39	2.39
$N_{30}P_{60}K_{60}$ + Rhizobophyte + Cristalon	2.64	2.32	2.42	2.54	2.48	2.48
grade (factor B) – Bukovynka						
No fertilizers	2.57	1.82	2.43	2.50	2.33	2.33
$P_{60}K_{60}$	2.77	1.96	2.52	2.71	2.49	2.49
$N_{30}P_{60}K_{60}$	2.84	2.06	2.56	2.82	2.62	2.57
Rhizobophyte	2.65	1.86	2.47	2.54	2.38	2.38
$P_{60}K_{60}$ + Rhizobophyte	2.81	1.95	2.54	2.74	2.51	2.51
$N_{30}P_{60}K_{60}$ + Rhizobophyte	2.87	2.08	2.62	2.83	2.60	2.60
Cristalon	2.81	1.91	2.68	2.76	2.54	2.54
$P_{60}K_{60}$ + Cristalon	2.91	2.09	2.75	2.89	2.66	2.66
$N_{30}P_{60}K_{60}$ + Cristalon	2.92	2.13	2.78	2.89	2.68	2.68
Rhizobophyte + Cristalon	2.84	1.90	2.71	2.79	2.56	2.56
$P_{60}K_{60}$ + Rhizobophyte + Cristalon	2.93	2.12	2.73	2.90	2.67	2.67
$N_{30}P_{60}K_{60}$ + Rhizobophyte + Cristalon	2.93	2.15	2.78	2.91	2.69	2.69

HIP_{05}: 2015 A – 0,07; B – 0,09; AB – 0,19; 2016 A – 0,09; B – 0,10; AB – 0,23; 2017 A – 0,09; B – 0,10; AB – 0,20; 2018 A – 0,10; B – 0,12; AB – 0,22; 2019 A – 0,08; B – 0,07; AB – 0,14; average A – 0,07; B – 0,03; AB – 0,09; Note: (c.) – control.

Against the background of $P_{60}K_{60}$, the increase in grain yield in this variety was 0.13 t/ha, against the background of $N_{30}P_{60}K_{60}$ – 0.11

t/ha. The soil nutrition of plants, especially with the application of mineral fertilizer at a dose of $N_{30}P_{60}K_{60}$, reduced the increase from the use of only Crystalon. With the joint use of Rhizobophyte and Crystalon, the yield increase was 0.18 t/ha, while Rhizobophyte alone was 0.1 t/ha. In our opinion, this is due to the fact that after receiving an additional source of nitrogen nutrition, bean plants spent less nutrients on the functioning of the legume-rhizobial apparatus, and more was spent on the formation of grain yields. Two-factor analysis of variance obtained data showed that the share of the factor «grade» on the yield of legumes was 52%, the factor «fertilizer» −35%, and the interaction of factors such as «grade» and «fertilizer» −1%. Other unaccounted for factors were 12%.

The correlation analysis of grain growing indicators of Bukovynka legumes showed a high density of the relationship between grain yield and grain weight per plant (r = 0.91), there is also a high level of relationship between yield indicators and the number of grains in legumes (r = 0.89), as well as the number of grains per plant (r = 0.81). The average relationship between the yield of Bukovynka legumes and the number of legumes per plant is slightly weaker (r = 0.70), and the relationship between the value of yields and the weight of 1000 grains is 0.33 (Table 2).

Table 2. Coefficients of correlation between indicators of structural elements and grain yield of Bukovynka legumes (average for 2015-2019).

Indexes	Number of beans per one plant, pcs.	Number of grains in beans, pcs.	Number of grains per one plant, pcs.	Mass of grains from one plants, g	Mass 1000 grains, g	Yield, t/ha
Number of beans per plant, pcs.	1.00	-	-	-	-	-
Number of grains in beans, pcs.	0.45*	1.00	-	-	-	-
Number of grains per plant, pcs.	0.98*	0.63*	1.00	-	-	-
Mass of grains on one plant,	0.89*	0.81*	0.96*	1.00	-	-
Mass 1000 grains, g	-0.37*	0.66*	-0.17*	0.97*	1.00	-
Yield, t/ha	0.70*	0.89*	0.81*	0.91*	0.33*	1.00

A high correlation is observed between the number of beans and the number of grains per plant (r = 0.98), the mass of grains from one plant and the mass of 1000 grains (r = 0.97), number of grains per 1 plant, and the mass of grains per plant (r = 0.96). The moderate correlation was between the number of grains in the bean (r = 0.63) and the weight of 1000 grains (r = 0.66). A low correlation (r = 0.45) was observed between the number of beans per plant and the bean's number of grains. Negative correlations we registered for the number of beans per plant and a mass of 1000 grains (r = -0.37) and the number of grains per one plant (r = -0.17). Thus, we established the Bukovynka variety provided the highest level of legume grain yield during inoculation of seeds with Rhizobophyte, applying mineral fertilizer at the dose of N30P60K60, and two foliar fertilization of crops with Kristalon.

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