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THE EFFECT OF VARIED FERTILIZATION ON THE YIELD AND CHEMICAL COMPOSITION OF CHICKPEA SEED (*CICER ARIETINUM* L.)

The researches results on the yield of the chickpea Pamyat (Cicer arietinum L.*) in the conditions of sufficient humidity in the Western Forest-Steppe are presented in the article. Results showed that the mass of seeds produced by a single plant increased from 6.97 g on the control to 7.94 g when macro and micro fertilizers were applied, as well as the mass of 1,000 seeds grew from 267.0 g to 286.2 g, respectively. The highest yield of chickpea (3.09 t/ha) was observed when $P_{40}K_{60}$ + Intermag Legumes + $MgSO_4$ were applied. The fertilizers also affected the amount of proteins in the seeds, which increased to 26.3%, while the amount of ashes decreased from 4.3% to 3.5%. However, the amount of fats and fibres remained stable.*

Key words: chickpea, fertilizers, yield, structure, quality

I. INTRODUCTION

Modern agriculture cannot be imagined without sustainable use of fertilizers. The use of fertilizers allows to increase the yield and to improve the quality of seeds. In addition, application of fertilizers increases the resistance of plants against diseases, accelerates ripening, improves the usage of moisture, etc. [Polskyi 1977]. The main conditions for increasing the chickpea yield are: the selection of highly productive native varieties, application of modern technologies into growing and seeding processes, and improvement of seed production. These issues in the practice of chickpea growing still remain unsolved [Bushulian and Sichkar 2009]. The chickpea is an effective nitrogen-fixing plant improving the nitrogen balance of the soil. This is why chickpea is considered one of the best precursors in crop rotation offering the opportunity of obtaining organic products [Yadava et al. 2000].

Usually no natural aborigine tuber bacteria associated with the chickpea can be found in soils. Legume-ryzobial symbiosis is the result of genotype compliance between the macro and micro symbiont [Bushulian and Sichkar 2009]. In the result of long-term studies researchers found that the level of mineral nutrition of plants along with predecessor substances, varieties characteristics, and climatic conditions are regulatory factors in the yield formation with high quality parameters [Saiko and Boiko 2002, Lykhochvor 2008].

The most favourable conditions for obtaining high productivity of plants, as well as for maintaining soil fertility on the required level are created at full provision of plants by nutrition elements [Golik 2001].

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According to the summarized data of the former All-Union Geographical Network of Field Experiments with Fertilizers, patterns of impact of nutrition elements on the productivity of crops were found. The most important element is nitrogen, the second is phosphorous, and the third is potassium [Pidhotovka 2004]. Phosphorous is in the composition of nucleic acids and nucleotides, enzymes and intermediate products of the Calvin cycle, which is the energetic base and energetic reserve of plant cells, and also participates in all of the most important biochemical processes (photosynthesis, respiration, and growth) [Khomenko 1991]. Optimization of phosphorous nutrition leads to acceleration of plant development, increase of cold and drought durability, firmness of grain and legume crops against lodging. Optimal phosphorous nutrition improves the development of the root system, which is especially important in arid conditions [Ivanov 1971].

Potassium also has a significant role in the chickpea nutrition balance. Its deficit in the plant decreases photosynthetic activity, violates carbohydrate metabolism, enhances fungal infectious diseases, and also negatively influences the amount of proteins in seeds [Chub 1980].

Notably the deficit of several microelements decreases the effectiveness of nitrogen, phosphorous, and potassium fertilizers. As a result, obtaining high yields is impossible even at rich nutrition of macroelements [Zhednetskyi 2009, Hospodarenko and Prokopchuk 2013].

The aim of the present research is to study the impact of mineral fertilizers on the chickpea's productivity. Under conditions of the western forest steppe, the chickpea is an uncommon crop thus research data on the effectiveness and norms of using micro and macro elements in its cultivation are scarce. Therefore, this issue is topical especially when it comes to developing highly productive technologies of cultivation of new chickpea cultivars.

Currently, the main problems that arise before farmers growing chickpea are the ignorance of scientifically grounded technologies of growing along with consideration of the plant’s biological features, the use of low productive local varieties and outdated growing technologies, which do not provide high yields. Under conditions of the Western Forest-Steppe of Ukraine, the chickpea is an uncommon cultivated plant species hence there are no research data on the expediency and rates of applying fertilizers and microelements in its growing. This issue becomes especially relevant in developing highly productive technologies of growing new varieties.

The aim of this paper was to discuss the impact of different fertilization regimes applied to chickpea on the effectiveness and costs of seed production under conditions of the Ukraine Western Forest-Steppe.

II. MATERIAL AND METHODS

Researches on the influence of fertilizing elements on the yield of chickpea variety Pamyat were carried out in 2016-2017 on experimental fields of the Laboratory of Plant cultivation at the Institute of Agriculture of the Carpathian Region, NAAS in Ukraine.

The soil of the experimental plot is grey, forest, surface clay which is characterized by the following agrochemical parameters: humus amount in the 0-20 cm layer (after Turin) is 2.1 %, and Ph 5.8. Additionally, the amount of slightly hydrolysed nitrogen (after Kornfield) is 112.7 mg/kg, of movable forms of phosphorous (after Kirsanov) is 111.0 mg/kg, and of potassium (after Kirsanov) is 109.0 mg/kg.

The following factors were considered:

Variant 1. Control N_0 P_0K_0; Variant 2. $P_{20}K_{30}$; Variant 3. $P_{40}K_{60}$; Variant 4. $P_{60}K_{90}$;
Variant 5. $N_{30}P_{20}K_{30}$; Variant 6. $P_{40}K_{60}$ + Intermag Legumes at the early phase of budding;
Variant 7. $P_{40}K_{60}$ + $MgSO_4$ (10 kg ha^{-1}), at the early phase of budding;
Variant 8. $P_{40}K_{60}$ + Intermag Legumes + $MgSO_4$ (10 kg ha^{-1}).

Leaf application of micro fertilizers and magnesium sulphate were carried out at the early phase of budding on the background of $P_{40}K_{60}$. Microfertilizers Intermag Legumes, magnesium sulphate in a concentration of 5 %, namely 5 kg per 100 dm^3 of water, or 10 kg ha^{-1}. On Variant 8, both micro fertilizers and magnesium sulphate were applied on the same terms as in case of their separate use.

Phosphorous and potassium fertilizers were applied in autumn as superphosphate and potassium chloride, respectively, before ploughing. Meanwhile, nitrogen fertilizers were applied as ammonium nitrate before pre-sowing ploughing. The norm diapason of fertilizers was selected based on the analysis of recommendations and literature sources.

The area of the experimental plot was 60 m^2, while the accounting area was 50 m^2. The research was conducted according to generally recognized approaches [Pidhotovka 2004].

The ANOVA test was used to determine the significance of the differences between the parameter mean values. Probability level was $\alpha=0.05$.

III. RESULTS AND DISCUSSION

Research data show that parameters of the yield structure changed under the influence of phosphorous and potassium fertilizers. The number of legumes increased from 24.1 to 28.4 (Table 1). The fertilizers almost had no effect on the number of seeds in the legume. Legumes of the chickpea usually contained a single or, occasionally, two pods.

Table 1 – *Tabela 1*

Features affecting the yield of chickpea seeds / *Cechy kształtujące wielkość plonu nasion ciecierzycy*

Fertilization variants *Wariant nawożenia*	Number of pods per plant *Liczba strąków na roślinie*	Number of seeds per pod *Liczba nasion w strąku*	Weight of seeds per plant / *Masa nasion z rośliny* [g]	Weight of 1000 seeds / *Masa 1000 nasion* [g]	Biological productivity *Wydajność biologiczna* [t/ha]
$N_0P_0K_0$ Control / *Kontrola*	24.1	1.10	6.97	267,0	2.79
$P_{20}K_{30}$	26.0	1.12	7.36	278,1	3.16
$N_{30}P_{20}K_{30}$	27.2	1.12	7.46	282,2	3.28
$P_{40}K_{60}$	27.1	1.12	7.75	280,0	3.49
$P_{60}K_{90}$	27.2	1.11	7.50	284,2	3.22
$P_{40}K_{60}$ + Intermag Legumes	28.0	1.13	7.93	285,0	3.65
$P_{40}K_{60}$ + $MgSO_4$	28.0	1.12	7.88	285,1	3.62
$P_{40}K_{60}$ + Intermag Legumes + $MgSO_4$	28.4	1.12	7.94	286,2	3.73
$SD_{0.05}$	ns	ns	ns	ns	0.23

n.s. not significant differences at the 0.05 probability level / *różnice statystycznie nieistotne przy poziomie prawdopodobieństwa 0.05*

The weight of seed produced by a single plant increased from 6.97 g on the control to 7.94 g without fertilizers, on Variant 8 where $P_{40}K_{60}$ + Intermag Legumes + $MgSO_4$ were applied by 0.97 g. With the increased rates of fertilizers, the mass of 1,000 seeds increased as well, particularly from 267.0 g on the control to 286.2 g on the variant with maximum application of fertilizers. On the contrary, N_{30} had no significant effect on the growth of yield structure elements and biological productivity.

The field germination remained stable and was little affected by the rates of fertilizers. Nevertheless, the highest field germination was observed on the control variant without fertilizers (81.4 %), while the lowest germination (78.6 %) was on the variant, where $P_{60}K_{90}$ was applied (Table 2). Respectively, the fertilizers had no relevant effect on the number of plants during germination, which almost did not change and was 55-57 plants/m^2.

Table 2 – *Tabela 2*

Plant density depending on fertilization / *Gęstość roślin w zależności od nawożenia*

Fertilization variants *Wariant nawożenia*	Field germination / *Polowa zdolność wschodów [%]*	Plant density after emergence [No. /m^2] *Obsada roślin po wschodach [szt./m^2]*	Number of plants before harvesting [No. / m^2] *Liczba roślin przed zbiorem [szt./m^2]*
$N_0P_0K_0$ (Control / *Kontrola*)	81.4	57	40
$P_{20}K_{30}$	80.0	56	43
$P_{40}K_{60}$	80.0	56	44
$P_{60}K_{90}$	78.6	55	45
$N_{30}P_{20}K_{30}$	80.0	56	43
$P_{40}K_{60}$ + Intermag Legumes	80.0	56	46
$P_{40}K_{60}$ + $MgSO_4$	80.0	56	46
$P_{40}K_{60}$ + Intermag Legumes + $MgSO_4$	80.0	56	47
$LSD_{0.05}$	0.5	1.7	1.3

Note: sowing rate was 0.7 mln/ha / *Uwaga: obsada roślin 0,7 mln / ha*

Mineral fertilizers mainly affected the survival of plants during vegetation and their density before harvesting. Research results show that the survival was the lowest on the control with no fertilizers (71.9%), while on the variant where $P_{40}K_{60}$ + Intermag Legumes + $MgSO_4$ were applied the survival of plants increased to 83.9% or by 12%. The number of plants before harvesting grew from 40 plants/m^2 on the control up to 47 plants/m^2 on Variant 8. The increased survival of plants can be explained by better development of vegetative parts and of the root system of plants, higher competing ability, and more effective utilization of solar energy. The productivity of the chickpea variety Pamyat was the lowest on the control with no fertilizers (2.42 t/ha). On the variant where $P_{20}K_{30}$ was applied, the productivity increased to 2.60 t/ha or by 0.18 t/ha (Table 3). When the rate of fertilizers was doubled ($P_{40}K_{60}$), the productivity grew by 0.14 t/ha and it was 2.74 t/ha.

Table 3 – *Tabela 3*

Seed yield of chickpea variety Pamyat depending on the fertilization [t/ha]
Plon nasion ciecierzycy odmiany Pamyat w zależności od nawożenia [t/ha]

Fertilization variants *Wariant nawożenia*	2016	2017	Mean *Średnio*	Yield increase *Przyrost plonu*	
				t ha^{-1}	%
$N_0P_0K_0$ (control/ *kontrol*a)	2.30	2.54	2.42	–	–
$P_{20}K_{30}$	2.51	2.69	2.60	0.18	7.4
$P_{40}K_{60}$	2.73	2.85	2.74	0.32	13.2
$P_{60}K_{90}$	2.75	2.89	2.82	0.40	16.5
$N_{30}P_{20}K_{30}$	2.52	2.70	2.61	0.19	7.9
$P_{40}K_{60}$ + Intermag Legumes	2.89	3.01	2.95	0.53	21.9
$P_{40}K_{60}$ + $MgSO_4$	2.86	2.96	2.91	0.49	20.2
$P_{40}K_{60}$ + Intermag Legumes + $MgSO_4$	3.04	3.14	3.09	0.67	27.7
$LSD_{0.5}$	0.48	0.38	ns	ns	ns

n.s. differences not significant at the 0.05 probability level / *różnice statystycznie nieistotne przy poziomie prawdopodobieństwa 0.05*

Regarding phosphorous and potassium fertilizers, the highest seed yield was obtained on the variant with $P_{60}K_{90}$, where the yield increased to 2.82 t/ha. The application of nitrogen fertilizers (N_{30}) on the background of $P_{20}K_{20}$ did not lead to growth of the chickpea's yield.

The application of the micro fertilizer Intermag Legumes (3 l/ha) on the background of $P_{40}K_{60}$ at the early phase of budding led to the increase of yield by 0.21 t/ha, while magnesium sulphate (10 kg/ha) caused only 0.17 t/ha. The simultaneous application of micro fertilizers and $MgSO_4$ increased the yield to 3.09 t/ha. Thus, due to optimization of the fertilizing system, the yield grew from 2.42 t/ha on the control variant without fertilizers to 3.09 t/ha, or by 0.67 t/ha, on the variant where $P_{40}K_{60}$ + Intermag Legumes + $MgSO_4$ were applied.

The fertilizers used in the experiment also influenced the chemical composition of the seeds.The protein content in chickpea seeds decreased slightly when phosphate and potassium fertilizers were used.

The application of microelements, magnesium, and sulphur led to the increase of protein amount. However, the amount of fat was almost not affected by fertilizer elements and it varied in the range of 5.6-6.0% (Table 4). The content of fibre increased due to the fertilizers from 5.0% to 5.6%, while the content of ash decreased from 4.3 % to 3.5-3.3%.

Table 4 – *Tabela 4*

Content of organic components and ash in the chickpea seeds (mean for 2016 -2017) [% DM]

Zawartość składników organicznych i popiołu w nasionach ciecierzycy (średnio za lata 2016-2017) [% s.m.]

Fertilization variants / *Warianty nawożenia*	Total protein *Białko ogółem*	Crude fat *Tłuszcz surowy*	Crude fibre *Włókno surowe*	Ash *Popiół*
$N_0P_0K_0$ (Control / *Kontrola*)	23.8	5.8	5.0	4.3
$P_{20}K_{30}$	23.0	5.7	5.2	4.0
$P_{40}K_{60}$	22.8	5.7	5.3	3.9
$P_{60}K_{90}$	22.5	5.7	5.3	3.9
$N_{30}P_{20}K_{30}$	24.0	5.5	5.2	3.3
$P_{40}K_{60}$ + Intermag Legumes	24.5	5.8	5.4	3.5
$P_{40}K_{60}$ + $MgSO_4$	25.8	5.8	5.4	3.4
$P_{40}K_{60}$ + Intermag Legumes + $MgSO_4$	26.3	6.0	5.6	3.5

IV. CONCLUSIONS

1. The application of phosphorous and potassium fertilizers in the cultivation of Pamyat chickpeas had no influence on the density of plants after emergence, but modified the density of plants before harvesting. The density of plants fertilized with P40K60 + Intermag Legumes + MgSO4 was then higher by 7 plants / m^2 compared to the control.
2. The fertilizers had no effect on the number of pods produced by a single plant and the number of seeds in a single pod.
3. The highest seed yield (3.09 t/ha) was obtained after applying P40K60 + Intermag Legumes + MgSO4. In this variant, the weight of seeds per one plant and the weight of 1000 seeds increased respectively by 0.97g and 19.2g compared to the control. These fertilizers also influenced the increase of the protein content in the seeds by 2.5% and the decrease of ash by 0.8% dry mass compared to the control, while the content of fat and fibre remained stable.

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WPŁYW ZRÓŻNICOWANEGO NAWOŻENIA NA PLON I SKŁAD CHEMICZNY NASION CIECIERZYCY *(CICER ARIETINUM* L.)

Streszczenie

W pracy przedstawiono wyniki doświadczenia polowego nad wpływem zróżnicowanego nawożenia na plon i skład chemiczny nasion ciecierzycy (*Cicer arietinum* L.) odmiany Pamyat. Badania prowadzono w latach 2016-2017 w warunkach lasostepu zachodniego, w Instytucie Rolnictwa Regionu Karpat, NAAS (Ukraina). Po zastosowaniu nawozów zawierających makro- i mikroskładniki, masa nasion z rośliny wzrosła z 6,97 g do 7,94 g, a masa 1000 nasion z 267,0 g do 286,2 g. Wykazano, że najwyższy plon nasion ciecierzycy (3,09 t ha) można uzyskać stosując $P_{40}K_{60}$ + Intermag + $MgSO_4$. Pod wpływem tych nawozów zawartość białka ogółem w nasionach wzrosła z 22,5 do 26,3% s.m., zawartość popiołu zmniejszyła się z 4,3 do 3,5% s.m., natomiast zawartość tłuszczu i włókna pozostała stabilna.

Słowa kluczowe: ciecierzyca, nawożenie, plon, cechy morfologiczne roślin, skład chemiczny nasion