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INFLUENCE OF VARIETY, ELEMENTS OF THE FERTILIZATION SYSTEM, SOWING RATES OF SEEDS ON THE PEA YIELD (*Pisum sativum*)

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Abstract. The yield of pea varieties depending on the elements of the fertilizer system and sowing rates. In the first experiment, nine variants of the application of mineral fertilizers on the variety 'Madonna' were studied: 1. P_0K_0 – control; 2. P_0K_0 + Optimize Pulse; 3. $P_{60}K_{60}$; 4. $P_{60}K_{60}$ + N_{60}; 5. $P_{60}K_{60}$ + S_{30}; 6. $P_{60}K_{60}$ + N_{60} + S_{30}; 7. $P_{60}K_{60}$ + Mg_{20} + S_{30}; 8. $P_{60}K_{60}$ + N_{60} + + Mg_{20} + S_{30}; 9. $P_{60}K_{60}$ + N_{60} + Mg_{20} + S_{30} + Intermag beans (2 l/ha). In the second experiment, three varieties of 'Madonna', 'Gotivsky', and 'Otaman' were studied with six sowing rates of 0.9, 1.0, 1.1, 1,2, 1.3, 1.4 mln/ha.As a result of studies, it was found that the highest yield of pea grain was obtained in the 'Madonna' variety – 6.38 t/ha. As to the 'Gotivsky' variety the yield is lower and amounted 6.13 t/ha, which is by 0.25 t/ha less than the 'Madonna' variety. The lowest grain yield was in the 'Otaman' variety – 5.94 t/ha, which is by 0.44 t/ha less than the 'Madonna' variety and by 0.19 t/ha compared to the 'Gotivsky' variety.The highest yield of 'Madonna' pea grains (6.43 t/ha) was formed during the application of mineral fertilizers according to the following scheme: $P_{60}K_{60}$ + N_{60} + Mg_{20} + S_{30} + Intermagus beans (2 l/ha). Due to the improvement of the pea nutrition system, the yield increased by 2.43 t/ha or 60.7% compared to the control (P_0K_0). It has been investigated that the optimal sowing rate of the 'Madonna' pea variety is 1, 0 and 1.1 mln./ha, for the 'Gotivsky' variety –1.2 mln/ha and as to the 'Otaman' variety – 1.1 and 1.2 mln/ha. Improvement of elements of cultivation technology for conditions of sufficient moistening of the western forest-steppe of Ukraine allows to obtain stable yield of pea grain at the level of 6–7 t/ha.

Key words: peas, varieties, fertilizers, sowing rate, yield.

INTRODUCTION

In order to increase the grain yield to the level of 6–7 t/ha and to stabilize the production of peas over the years, it is necessary to investigate the following issues: selection of the variety and realization of its genetic potential by intensive cultivation technology; improvement of the fertilizer system, namely the study of the effect on the yield of pea grains of phosphorus and potassium, nitrogen, sulfur, magnesium, both individually and their joint application, taking into account the soil and climatic conditions of the growing zone; for the western forest-steppe, conditions of sufficient and excessive humidification have not been established economically proved the sowing rates for different varieties of peas, so there is a need to clarify this element of technology.

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Pea yield depends largely on the genetic potential of the variety (Lykhochvor et al. 2003; Petrichenko and Lykhochvor 2020). Varieties of pea developed and recommended for cultivation, but their biological features in cultivation technologies have not been used to full extent, so research is needed to determine the features of plant growth and development, formation of grain productivity of varieties of different morphotypes for their further implementation in advanced varietal technologies of cultivation (Pilipenko et al. 2016; Zhuikov and Lagutenko 2017).

The variety should have a high adaptive capacity, allowing the metabolism to be restored to the optimum level after the stress factor, which is especially important in the connection of climate change and instability. The main properties that determine the level of adaptability of peas are high harvest index, stem growth type, good ripening, disease resistance, resistance to shatter, high potential yield (Lopushniak et al. 2018; Telekalo 2019).

Morphological characteristics of modern varieties of peas (shorter internodes, tendrilness, compaction of the fruiting zone) provide high resistance to lodge of sowings and simultaneous grain ripening (Lykhochvor et al. 2008; Prysyazhnyuk et al. 2015). With the appearance of varieties of leafless (tendril) morphotype, it became possible to expand the acreage of peas (Petrichenko and Gonchar 2007; Cherenkov et al. 2014).

High-yield technology is based on an advanced pea fertilizer system (Sukhova 2014). For the formation of 0.1 t of seeds and the corresponding amount of straw peas uses 45–60 kg of nitrogen, 17–20 kg of phosphorus, 38–40 kg of potassium, 25–30 kg of calcium, 8–13 kg of magnesium and sulfur and microelements primarily molybdenum and boron (Babich and Babich-Poberezhnaya 2010; Dvoretska and Lyubchich 2016; Buchinskiy and Lykhochvor 2018).

There are very diverse recommendations regarding to the rate of application of mineral fertilizers when growing peas. The discrepancy in the parameters of the rates is explained by different soil and climatic conditions of cultivation, varietal features, models of cultivation technologies.

It is important to establish the optimal sowing rate for pea varieties for certain soil and climatic conditions (Sichkar et al. 2012). The sowing rate should ensure the optimum sowing density. Sowing rates are set depending on the biological characteristics of the variety and soil and climatic zone of cultivation (Kostina 2015). It ranges from 0.8 to 1.4 million similar seeds per hectare (Dvoretskaya et al. 2016). In arid conditions, the seeds are sown less, in the area of sufficient moisture more.

According to German breeding stations, 0.7–0.8 mln/ha is the optimum sowing rate for German conditions. And only when delayed with sowing it should be increased to 0.80–0.85 mln/ha. In Poland, 0.80–1.0 million hectares are sown (Bilski et al Kajdan--Zysnarska 2019). For Czech conditions it is proposed to sow 0.9–1.1 mln/ha (Hýbl 2014). Significantly higher sowing rates of 1.0–.2 mln/ha are recommended in Ukrainian sources (Girka 2018). Studies of sowing rates of 0.6 mln/ha, 0.8 mln/ha and 1.0 mln/ha have shown that in the conditions of the Skvyrsky district of the Kiev region at varieties of Madonna, Salamanca and Astronaut the highest yield is formed by sowing of 1.0 mln/ha. Reducing the sowing rate to 0.8 mln/ha leads to a decrease of the yields by 0.19–0.56 t/ha (Girka et al. 2018).

The analysis of literature sources on the subject of research indicates the possibility of improving both individual elements of the technology of pea cultivation, and technology as a whole in order to increase the grain yield to the level of 6–7 t/ha and to stabilize the production of peas over the years.

MATERIAL AND METHODS

In order to optimize the investigated elements of the technology of pea cultivation in 2017–2019 field studies were conducted at the experimental field of the Lviv National Agrarian University on dark gray podzolized light loamy soil. The soil was characterized by such indicators. The content of total humus is average and is 2.2–2.3%. The reaction of the soil solution is slightly acidic, the salt pH is 6.0–6.1. Lightly hydrolyzed nitrogen is 101–112 mg/kg of soil and by the degree of provision refers to the low class. Mobile phosphorus compounds 124–128 mg/kg of soil, potassium exchange 95–110 mg/kg of soil. According to the grouping of soils by the content of mobile phosphorus and potassium, these two elements are of high provision.

The total area of the elementary plot was 60 m^2, the accounting area of the plots was 50 m^2, the repetition of the experiment was threefold, the placement of the plots was systematized.

In the first experiment, the effect of fertilizers on the yield of the Madonna pea variety was studied. The aim of the research was to determine the efficiency of application of phosphorus, potassium, nitrogen, sulfur and magnesium fertilizers. The scheme is presented in Table 1.

In the second experiment, three varieties of Madonna, Gotivsky, and Otaman peas were studied with six sowing rates of 0.9, 1.0, 1.1, 1.2, 1.3, 1.4 mln/ha. The expediency of studying these varieties is justified by the most widespread use in the western forest-steppe. The range of sowing rates was chosen based on the analysis of recommendations from literature. The scheme of the experiment is presented in Table. 2. Statistical analysis was performed by anova using applied computer program Statistika.

Peas were grown by intensive technology, which required compliance with all elements of technology. The seeds were treated with Maxim XL (flutioxonil, 25 g/l + metalaxyl-M, 10 g /l) [235] with a rate of 1.0 l/t and treated by the bacterial fertilizer Optimaiz Pulse.

The fertilizer system was as follows. Triple superphosphate (P46), potassium chloride (K60) and sulfur fertilizers (Vigor, S90) were applied into plowing in the fall. Magnesium (magnesium sulfate, S30 Mg20) and nitrogen (ammonium nitrate, N34) in the spring in pre-sowing tillage. Intermag bean microfertilizer was applied at the beginning of the budding phase of the pea at the same time as the Fox fungicide.

For control of dicotyledonous and monocotyledonous in the phase of 3 triplicate leaves was applied herbicide Pulsar 40 (imazamox, 40 g/l) with a rate of 1 l/ha. In the spring, sowings were sprayed with fungicides to protect against disease twice: in the start of budding phase, the fungicide Fox (trifloxystrobin, 150 g/l + prothioconazole, 175 g/l) at the rate of 0.5 l/ha, and in the flowering phase Amistar Extra (cyproconazole, 80 g/l + azoxystrobin, 200 g/l) at the rate of 0.5 l/ha were applied. Insecticides were applied twice against the pests: Fastak (alpha-cypermethrin, 100 g/l) in the flowering phase with a rate of 0.20 l/ha and Enzhio (thiamethoxam, 141 g/l + lambda-cyhalothrin, 106 l/ha) in the phase flowering rate of 0.18 l/ha.

Yield accounting was determined by threshing the grain in the full ripening phase with the SAMPO-500 combine. Yields from the plot resulted in standard 14% humidity and 100% purity.

RESULTS AND DISCUSSION

An important reserve for increasing the yield of pea grains is the fullest possible realization of the potential productivity of the varieties by optimizing the elements of cultivation technology. Fertilizers have a significant impact on pea yields. The yield of pea varieties changes under the influence of fertilizers in the range from 1.16 to 5.46 t/ha (Ishchenko et al.2018).

Our studies have shown the possibility of increasing the yield of peas to the level of 6.5–7.0 t/ha (Andrushko et al. 2019). Grain yield on the control without fertilizers was relatively high and amounted to 4.00 t/ha (Table 1). On the variant with seed treatment by the inoculant Optimaize Pulse the yield increased to 4.68 t/ha, which is higher than the control by 0.68 t/ha or 17.0%. This is due to the intensification of symbiotic activity of pea plants. Increasing the rate of fertilizers from P_0K_0 to $P_{60}K_{60}$ provided the yield increase by 1.12 t/ha. If the inoculant yield increased by 0.68 t/ha, the increase from the application of phosphorus and potassium fertilizers is less and amounts 0.44 t/ha. Phosphorus and potassium fertilizers contributed to the better development of the root system and had a positive effect on the formation of tubers

The inclusion of nitrogen fertilizers (N_{60}) in the system of pea nutrition contributed to the further increase of grain yield. Thus, the yield in the fourth variant is 5.50 t/ha, which is higher than the control by 1.50 t/ha or by 37.5%. From the application of mineral nitrogen N_{60}, the yield increased by 0.38 t/ha compared to the variant $P_{60}K_{60}$, which is less than the increase from seed inoculation by 0.30 t/ha.

Table 1. The yield of the 'Madonna' pea grain depending on the elements of the fertilizer system

No.	Fertilizer variant	Yield [t/ha]				The increase of the yield	
		2017	2018	2019	average	t/ha	%
1	P_0K_0 – Control	4.55	3.93	3.52	4.00	–	–
2	P_0K_0 + Optimize Pulse	5.18	4.58	4.28	4.68	0.68	17.0
3	$P_{60}K_{60}$ – background	5.44	5.10	4.82	5.12	1.12	28.0
4	$P_{60}K_{60}$ + N_{60}	5.95	5.39	5.17	5.50	1.50	37.5
5	$P_{60}K_{60}$ + S_{30}	5.88	5.32	4.98	5.39	1.39	34.7
6	$P_{60}K_{60}$ + N_{60} + S_{30}	6.42	5.66	5.52	5.87	1.87	46.7
7	$P_{60}K_{60}$ + Mg_{20} + S_{30}	5.86	5.50	5.10	5.49	1.49	37.2
8	$P_{60}K_{60}$ + N_{60} + Mg_{20} + S_{30}	6.68	5.88	5.80	6.12	2.12	53.0
9	$P_{60}K_{60}$ + N_{60} + Mg_{20} + S_{30} + + Intermag bean (2 l/ha)	6.91	6.27	6.10	6.43	2.43	60.7
The average for the years		5.87	5.29	5.03	–	–	–
NIR_{05}, for yield		0.12	0.13	0.12	–	–	–

Sulfur fertilizers also had a positive effect on the pea yield formation. The increase from the application of S_{30}, compared to the third variant, was 0.27 t/ha. This can be explained by the fact that peas belong to crops that are quite demanding for sulfur. It is also important that sulfur promotes better absorption of nitrogen.

The application of nitrogen and sulfur fertilizers on the background of $P_{60}K_{60}$ allowed to increase the yield to 5.87 t/ha, which is higher than the control by 1.87 t/ha, or by 46.7%. Compared to the $P_{60}K_{60}$ background, the yield from nitrogen and sulfur application increased by 0.75 t/ha.

In the seventh variant, during the application of sulfur and magnesium (magnesium sulfate, $S_{30}Mg_{20}$) the yield was 5.49 t/ha, i.e. the yield increase was lower by 0.38 t/ha than from the application of sulfur and nitrogen. It should be noted that under the influence of magnesium, the yield increased by only 0.10 t/ha.

In the eighth variant, the application of P, K, N, S, Mg in the nutrition system of pea the yield increased by 6.12 t/ha, which is higher than the control by 2.12 t/ha, or by 53.0%. The increase of the yield from the application of nitrogen, sulfur and magnesium is 1.00 t/ha.

The highest yield of pea grain was in the ninth variant with the application of micro elements: $P_{60}K_{60}$ + N_{60} + Mg_{20} + S_{30} + Intermag beans (2 l/ha), where it was 6.43 t/ha. Due to the improvement of the pea nutrition system, the yield increased by 2.43 t/ha compared to the control (P_0K_0) or by 60.7%. Yield increase from the application of micro-fertilizers Intermag beans is 0.31 t/ha.

Pea yields in our studies also relied heavily on the weather of the year. The highest yield was obtained in the first year of research (from 4.55 t/ha to 6.91 t/ha), on the average, it was 5.87 t/ha. In the next years, grain yields were lower. In 2018 it has decreased to 5.29 t/ha, which is 0.58 t/ha less compared with the previous year. The main reason for this was hydrothermal conditions, in particular less than normal rainfall in April and May and waterlogging in June (153 mm, which is higher than the norm by 69 mm). In 2019, the yield was lowest 5.03 t/ha, or by 0.84 t/ha less than in 2017. This is due to the excessive rainfall in May (161 mm), which resulted in the soil being wetted for almost a month, which limited the absorption of nutrients and symbiotic activity of the plants.

An important factor influencing the level of yield and its stability is the optimal combination of all agro-measures and selection of varieties in accordance with their requirements for the soil and climatic conditions of cultivation (Khukhlaev et al. 2014).

According to the results of our research, it was found that the highest yield of pea grain in the average of three years research was obtained in the variety ‘Madonna’ – 6.38 t/ha (Table 2). The ‘Gotivsky’ yield was 6.13 t/ha, which is by 0.25 t/ha less than the Madonna variety. The lowest grain yield was obtained in the ‘Otaman’ variety – 5.94 t/ha, which is less by 0.44 t/ha than the ‘Madonna’ variety and by 0.19 t/ha compared to the ‘Gotivsky’ variety. In the ‘Madonna’ variety, depending on the year of research, the yield varied within 6.00–6.87 t/ha, in the ‘Gotivsky’ variety in the range 5,84–6,54 t/ha and in the ‘Otaman’ variety varied from 5.56 t/ha to 6.40 t/ha.

The best hydrothermal conditions for the formation of grain yield of all varieties of peas occurred in 2017. The yield of the ‘Madonna’ variety was 6.87 t/ha on the average in the first year of research according to the studied sowing rates. In 2018, the yield decreased to 6.25 t/ha, or 0.62 t/ha, and in 2019 it was the lowest – 6.00 t/ha, which is lower by 0.87 t/ha compared to 2017. Similar changes as to the grain yield of pea varieties were observed in – 6.02 t/ha and the least one in 2019 – 5.84 t/ha. In the ‘Otaman’ variety, yields varied from 6.40 t/ha in 2017 to 5.86 t/ha in 2018 and 5.56 t/ha in 2019.

The yield of the pea grain varied not only depending on the variety and the conditions of the year, but also under the influence of the studied seed sowing rates. In the variant of ‘Madonna’, at the rate of sowing of 0.9 mln/ha on the average for three years was 6.34 t/ha. As the sowing rate increased to 1.0 and 1.1 mln/ha, the yield increased and was the highest, respectively, 6.52 and 6.55 t/ha, which is higher than the variant with sowing rate of 0.9 mln/ha by 0.21 t/ha (Table 2).

Table 2. Yield of pea varieties depending on sowing rates, t/ha[a]

Varieties	Sowing rate [mln/ha]	2017	2018	2019	Average for three years	Decrease of the yield[b]	
						t/ha	%
‘Madonna’	0.9	6.85	6.21	5.95	6.34	–0.21	–2.75
	1.0	7.05	6.38	6.12	**6.52**	–0.03	–0.46
	1.1	7.10	6.40	6.15	**6.55**	–	–
	1.2	6.90	6.25	6.04	6.40	–0.15	–2.29
	1.3	6.75	6.20	5.92	6.29	–0.26	–3.97
	1.4	6.58	6.07	5.80	6.15	–0.40	–6.11
Average for the variety		6.87	6.25	6.00	**6.38**		
‘Gothic’	0.9	6.40	5.80	5.68	5.96	–0.36	–5.70
	1.0	6.50	5.92	5.80	6.07	–0.25	–3.95
	1.1	6.62	6.10	5.91	6.21	–0.11	–1.74
	1.2	6.72	6.21	6.02	**6.32**	–	–
	1.3	6.58	6.12	5.88	6.19	–0.13	–2.06
	1.4	6.42	5.98	5.76	6.05	–0.27	–4.27
Average for the variety		6.54	6.02	5.84	**6.13**		
‘Otaman’	0.9	6.34	5.65	5.48	5.82	–0.23	–3.80
	1.0	6.45	5.78	5.55	5.93	–0.12	–1.98
	1.1	6.54	5.90	5.67	**6.04**	–0.01	–0.17
	1.2	6.48	6.00	5.68	**6.05**	–	–
	1.3	6.37	5.97	5.57	5.97	–0.08	–1.32
	1.4	6.25	5.84	5.40	5.83	–0.22	–3.64
Average for the variety		6.40	5.86	5.56	**5.94**		

[a]$P_{60}K_{60}$ + N_{60} + Mg_{20} + S_{30} + Intermag bean (2 l/ha).
A – variety, B – sowing rate, AB – interaction.
NIR_{05}, t/ha 2017: A – 0.09, B – 0.13, AB – 0.23.
2018: A – 0.05, B – 0.07, AB – 0.14.
2019: A – 0,10 B – 0,13; AB – 0,22.
[b]related to optimum sowing rate.

Further increase of sowing rate to 1.2, 1.3 and 1.4 mln/ha led to a regular decrease of yield. On the variant with a sowing rate of 1.4 mln/ha, the crop density caused the yield to 6.15 t/ha, which is by 0.40 t/ha less compared with the variant of sowing 1.1 mln/ha.

It should be noted that for the studied varieties, the optimal sowing rates were different. Thus, if the ‘Madonna’ variety had the optimal sowing rate of 1.0 and 1.1 mln/ha, then the Gotivsky variety had the highest productivity at the slightly higher sowing rate of 1.2 mln/ha. The yield of this variant is the highest – 6.32 t/ha. Increasing and decreasing the rate of sowing led to a decrease of grain yield of this pea variety.

In the ‘Otaman’ pea variety, the optimum sowing rate is wider, similar to the ‘Madonna’ variety. But if the highest productivity of the ‘Madonna’ variety was formed at the sowing rates of 1.0 and 1.1 mln/ha, then in the ‘Otaman’ variety – by sowing rates of 1.1 and 1.2 mln/ha. Yields on these variants were 6.04 and 6.05 t/ha.

CONCLUSIONS

1. The highest yield of pea grain was obtained in the ‘Madonna’ variety – 6.38 t/ha. The ‘Gotivsky’ yield was 6.13 t/ha, which is 0.25 t/ha less than the ‘Madonna’ variety. The lowest grain yield was in the ‘Otaman’ variety – 5.94 t/ha, which is 0.44 t/ha less than the ‘Madonna’ variety and 0.19 t/ha compared to the ‘Gotivsky’ variety.
2. The highest grain yield of the ‘Madonna’ pea (6.43 t/ha) is formed by the application of mineral fertilizers according to the following scheme: $P_{60}K_{60}$ + N_{60} + Mg_{20} + S_{30} + + Intermag beans (2 l/ha). Due to the improvement of the pea nutrition system, the yield increased by 2.43 t/ha or 60.7% compared to the control (P_0K_0). The yield increase from the application of micro-fertilizer Intermag beans is 0.31 t/ha.
3. The optimal sowing rate of the ‘Madonna’ variety is 1, 0 and 1.1 mln/ha, for the ‘Gotivsky’ variety 1.2 mln/ha, and for the ‘Otaman’ variety – 1.1 and 1.2 mln/ha.

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