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SOWING RATE EFFECT THE PERFORMANCE AND SEED QUALITY OF PEA CULTIVARS IN THE EASTERN FOREST-STEPPE OF UKRAINE

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The peculiarities of the performance and seed quality of pea cultivars depending on the sowing rate were established. On average for 2018–2021, because of the weather instability, with the sowing rates of 1.2 and 1.4 million seeds/ha, the grain yield from cultivar Oplot was by 0.35 and 0.41 t/ha or by 13.1 and 15.4 % higher than that with the sowing rate of 0.8 million seeds/ha. In cultivar Metsenat, the difference in the yield depending on the sowing rate was smaller, with its highest value at the sowing density of 1.2 million seeds/ha. The highest content of protein in seeds was recorded at the sowing rate of 0.8 million seeds/ha: 21.68% and 21.40% in Oplot and Metsenat, respectively. As the sowing rate was increased to 1.0 - 1.2 million seeds/ha, the protein content in seeds decreased by 0.20-0.37%, and at 1.4 million seeds/ha - by 0.65–0.67%. Regardless of the sowing rate, Oplot gave a higher yield and contained more protein in seeds than Metsenat.

***Key words**: pea, cultivar, sowing rate, performance, yield, seed quality*

Introduction. Analysis of the pea seed production in Ukraine indicated a downward trend in its croppage and yield as well as year-to-year instability of these indicators depending on environmental/climatic conditions [1]. Over the past 30 years, the sown area under this crop in Ukraine has decreased fivefold without a significant increase in the seed yield [2]. Thus, in 2020, the pea occupied 237,700 hectares, and its share was only 0.9% of the sown areas in all categories of farms [3]. The area reduction is attributed to a dereliction of the fodder basis of livestock, unfavorable weather/climate for pea growing and changes of the market reoriented to the cultivation of field crops of higher profitability. At the same time, significant differences in the pea performance between agrarian enterprises suggest various levels of resource provision and intensity of cultivation technologies.

Therefore, today, it is important to considerably boost and stabilize the pea production, which is of great food, fodder and agronomic importance [3]. Cultivation of high-yielding leafless cultivars with such economically valuable traits as determinant and short stems, resistance to diseases and lodging and suitability for direct harvesting should be the priority line to effectively restore sown areas and raise the pea seed production [4, 5]. Cultivars must be highly adaptable, which allows them to recover to the optimal levels of metabolic processes after stress factors, and it is especially important under climatic changes and instability. To enhance the realization of the biological potential of yield and to increase the seed quality, it is necessary to improve constituents of the cultivation technologies for growing modern pea cultivars [6, 7, 8].

Literature review and problem articulation. The farming techniques for the pea growing should provide favorable conditions for the plant growth and development at each stage of organogenesis [8, 9]. The plant nutrition area is an important factor in achieving high and stable pea yields. In this regard, among measures aimed at improving the performance of pea (*Pisum sativum* L.) cultivars, the optimal plant density is of importance. By choosing sowing rates for a cultivar, one can adjust the plant density and photosynthesis in the agrocenosis [10]. Sowing rates depend on forecrops, cultivars, soil fertility, fertilizers, timing and methods of sowing, seed quality and climatic conditions of cultivation. This is especially important in dry years, because water deficit in the first half of the growing period make upper buds fall, resulting in a sharp reduction in the pea performance [11]. According to L.P. Mikhailenko's data, the seed yields of cultivars vary significantly and depend on morphobiological characteristics, plant habitus, and, to a lesser extent, on sowing rates [12]. According to V.V. Hamaiunova and M.S. Tuz's data [13], the plant density significantly affects the plant weight and height, yield structure, timing of phenological phases, and photosynthesis productivity. In some cases, increased sowing rates positively affect the yield, and in others, the yield does not change significantly at different sowing rates. By increasing or decreasing the nutrition area, one can enhance the efficiency of mineral fertilizers. In thickened crops, the nutrient consumption is accelerated, especially it pertains to nitrogen. Plants mutually shade one another, stems grow excessively, assimilation capacity of plants reduces and, correspondingly, the numbers of fruit-bearing nodes, pods and seeds decline [14]. Here, the 1000-seed weight significantly decreases, negatively affecting both the pea yield and the seed quality [15].

Numerous experimental studies showed that sowing rates depended on soil and climatic conditions of cultivation and were associated with major elements of cultivation technologies, ranging 0.8 million to 1.8 million seeds/ha. L.I. Haidukevych thought that there should be at least 120 pea plants per square meter [16]. According to A.D. Hyrka et al.' and O.V. Ilienko' results of studies in the Northern Steppe of Ukraine, the pea yield significantly depends on productive precipitation amount and distribution during the growing period as well as on the adaptability of cultivars to growing conditions. For the studied pea cultivars, the optimal sowing rate was 1.4 million germinable seeds/ha [17, 18]. Increasing the sowing rate to 1.6 million germinable seeds/ha led to a drop in the maximum yield due to plant self-shading, lack of productive moisture in the soil and a decline in the numbers of pods and seeds.

V.V. Lykhochvor and M.O. Andrushko experimentally established that under sufficient water supply in the Western Forest-Steppe the economically feasible sowing rate was 1.0 million seeds/ha for Madonna, 1.1 million seeds/ha for Otaman, and 1.2 million seeds/ha for Hotivskyi [19].

Therefore, the above data indicate the need for further research to optimize the sowing rates for new pea cultivars, with due account for growing conditions.

Our purpose was to assess the sowing rate effect on the performance and seed quality of pea cultivars in the Eastern Forest-Steppe of Ukraine.

Materials, methods, meteoconditions. The study was conducted in the stationary crop rotation of the Plant Production Institute named after V.Ya. Yuriev of NAAS in 2018–2021 using the split plot design on basic mineral fertilization at a dose of $N_{30}P_{30}K_{30}$ in compliance with the field experimentation methods described by B.A. Dospekhov and the state variety trial methods. The soil was typical mid-humus slightly-leached chernozem. The gross content of readily hydrolyzed nitrogen per 1 kg of soil in the arable layer was low or medium (132−178 mg); the phosphorus and potassium contents were high: 160−165 mg and 130-133 mg, respectively.

Zoned pea cultivars Oplot and Metsenat (factor A) were investigated in the experiments. The sowing rate was 0.8 million, 1.0 million, 1.2 million, and 1.4 million germinable seeds/ha (factor B). The sowing rate range for the pea cultivars was based on the analysis of guidelines and literature. The expediency of choosing these cultivars was justified by the prospect of their dissemination and various lengths of the growing period: 79−85 and 73−78 days, respectively. The farming techniques, except for the issues under investigation, were conventional the zone. The forecrop was spring cereals. Seeds were sown with a Klen-1,5M seeder. The field experiments were carried out in accordance with the multifactor split plot design used in the field experimentation methods described by B.A. Dospekhov and the state variety trial methods. The plots were arranged systematically in three replications. The total area of the plot was 37.5 m^2; the record area was 25.0 m^2. The crop was harvested by direct threshing the plots with a Samro-130 combine. The seed quality was determined in the Laboratory of Grain Quality. The data were processed by analysis of variance.

The hydrothermal conditions in the study years were characterized by insufficient rainfall and increased temperatures compared to the average long-term values. Thus, in May−July 2018 the precipitation amount (113.4 mm) was twice less and the average monthly air temperature was by 2.4–4.5°C higher than the average long-term value. Such arid conditions led to shortened phenological phases of the growing period, deteriorated plant biometrics, premature ripening, and reduced weight of seeds. In April 2019, the air temperature and precipitation were similar to the long-term averages, but in May they exceeded the average values by 10% and 60%, respectively. The abnormally hot weather was observed in June: the temperature (23.8ºC) was by 4.3 ºC higher than the average value and the precipitation amount (25.4 mm) was only 60% related to the average level. Soil and air droughts suspended the plant biomass growth and shortened the periods of seed setting and filling. In July and August, the precipitation amount was only 27.4 mm and 10.6 mm, or 38% and 23% of the long-term average, respectively. April 2020 was dry and cool. However, 176.1 mm fell in May, which is as 4 times as much as the average. The average monthly temperature (13.1ºC) was by 3.0 ºC lower, promoting the plant development. In June, the average daily temperature (21.3ºC) was by 1.1 ºC higher than the long-term average in combination with a precipitation deficit. In July, the precipitation amount was 107.8 mm at elevated temperatures, which had a positive effect on the seed filling.

The weather in 2021 was favorable in terms of moisture supply of crops. The precipitation amount in April and May was 40.0 mm and 116.0 mm, respectively, but the cool weather somewhat slowed down the plant development. The first 10 days of June were by 4.6ºC cooler and rainier (38.0 mm fell), while during the second and third 10 days there was no rain and the temperature rose. There was no precipitation in July and the average temperature was by 3.4 ºC higher than the corresponding average.

Thus, the weather conditions of 2018–2021 differed not only in temperature, but also in the precipitation amount and distribution during the pea growing period, making it possible to comprehensively study the effects of the studied factors.

Results and discussion. The various hydrothermal conditions had a significant impact on the biomass formation and productive processes in the pea, which was adequately reflected in the yield and seed quality of the cultivars, especially in the dry years. We observed clear difference between the sowing rates from the initial stages of the plant development to the seed setting phase. Subsequently, there was no visual difference between the variants with different plant densities.

The yield parameters over the years allowed us to establish the peculiarities of the plant performance formation and to trace the dependence of these processes on the studied factors. It is known that in thickened fields the plant growth and development worsen due to accelerated use of nutrients, especially nitrogen [14].

Our results showed that in the thickened plots the growth processes in pea plants were somewhat suppressed. With increasing the sowing rate from 0.8 million to 1.4 million seeds/ha, pea plants become shorter in the both cultivars (Table 1). Thus, in Oplot the difference between these variants was 6.8 cm, or 9.9%; Metsenat − 7.9 cm, or 10.2%. At the same time, there was no significant difference in the plant height between the plots sown at the rates of 1.0 million and 1.2 million seeds/ha.

The yield constituents are determined by the total potential of pea crops. The highest numbers of pods per plant, seeds per pod and seeds per plant were observed in the both cultivars at the sowing rates of 0.8 million seeds/ha: in Oplot the figures were 3.5, 3.7, and 12.5, respectively; in Metsenat − 4.6, 3.7, and 16.9, respectively. With the increase in the sowing rate to 1.4 million seeds/ha, these parameters decreased, depending on the cultivar, to 0.4–0.5, 0.3−0.6, 2.0−3.1 or by 10.9–11.4%, 8.1–16.2%, and 16.0–18.3%, respectively. The plots sown at the rates of 1.0 million and 1.2 million seeds/ha in these parameters occupied an intermediate position and did not differ significantly from each other. Thus, compared to 0.8 million seeds/ha, Oplot decreased the numbers of pods and seeds per plant in these variants by 2.9−5.7% and 5.6-7.2%, respectively; Oplot – by 2.2–4.3% and 8.9–10.1%, respectively. Previously, we found that, with increasing the sowing rate from 0.8 million to 1.4 million seeds/ha, the absolutely dry weight of peas in the phases of budding, flowering, pod formation, and full ripeness of seeds decreased regardless of nutrition [20]. Here, there was a decrease in the main indicators of the yield structure and seed weight, which across the years significantly depended on the total moisture supply during the growing period, distribution of precipitation over time, and single rainfall amounts.

We observed a dependence of the 1000-seed weight on varietal characteristics of pea plants. Thus, on average across the years, the increase in the sowing rate from 0.8 million to 1.4 million seeds/ha led to a significant reduction in the 1000-seed weight in Oplot (by 18.4 g or by 7.8%) and Metsenat (by 11.0 g or by 5.3%). In the both cultivars, this parameter was higher at the rate of 0.8 million seeds/ha and amounted to 237.1 g and 209.6 g in Oplot and Metsenat, respectively. The difference in the 1000-seed weight between 1.0 million and 1.2 million seeds/ha only was 2.3–2.4 g; it was increased to 4.1–9.5 g when the rate was increased from 1.2 million to 1.4 million seeds/ha, though not reaching statistical significance either. We revealed that the pre-harvest plant density was almost the same regardless of the sowing rates: in Oplot, it was within 0.75−1.12 million plants/ha and in Metsenat − 0.74−1.11 million plants/ha. At the same time, the pea plant survival largely depended on the hydrometeorological conditions of the year and sowing rate.

Table 1

Yield structure in the pea cultivars depending on the sowing rate, 2018−2021

Sowing rate, mln seeds/ha(facto r B)	Plant height, cm	Number			1000-seed weight, g	Pre-harvest plant densi-ty, mln plants/ha	Plant survival, %
		pods per plant	seeds per pod	seeds per plant			
Cv. Oplot (factor A)							
0.8	68.9	3.5	3.7	12.5	237.1	0.8	68.9
1.0	66.3	3.4	3.5	11.8	230.5	1.0	66.3
1.2	64.2	3.4	3.4	11.6	228.2	1.2	64.2
1.4	62.4	3.1	3.4	10.5	218.7	1.4	62.4
Cv. Metsenat (factor A)							
0.8	70.2	4.6	3.7	16.9	209.6	0.8	70.2
1.0	67.4	4.5	3.4	15.5	205.1	1.0	67.4
1.2	66.2	4.5	3.4	15.2	202.7	1.2	66.2
1.4	64.8	4.1	3.1	12.8	198.6	1.4	64.8
LSD_{05}, for the factors: A		0.08	0.07	0.67	9.4	0.02	−
B		0.11	0.09	0.86	8.1	0.04	−
AB		0.30	0.26	2.49	16.3	0.07	−

This parameter was the lowest at the sowing rate of 1.4 million seeds/ha: 80.0% and 79.3% in Oplot and Metsenat, respectively. When the sowing rate was reduced to 1.0 million and 1.2 million seeds/ha, the plant survival amounted to 85.0–87.0%. The highest pre-harvest survival of plants (92.5−93.8%) was achieved at the rate of 0.8 million seeds/ha in the both cultivars. That is, at different sowing rates, pea plants were ably to self-regulate their density depending on the hydrothermal conditions during the growing period and sowing rate.

The seed yield is an integral indicator of the plant performance; it reflects relationships between quantitative traits and environment. We demonstrated that the pea yields depended not only on the cultivar variety and external conditions, but also on the crop density. Thus, on average across four years, the seed yield from Oplot was 2.67 t/ha at the sowing rate 0.8 million seeds/ha (Table 2). With the increase in the sowing rate to 1.0 million seeds/ha, Oplot produced more by 0.17 t/ha. Further increase in the sowing rate to 1.2 million and 1.4 million seeds/ha led to a rise in the yield to 3.02 and 3.08 t/ha, respectively, which was by 0.35 and 0.41 t/ha or by 13.1 and 15.4%, respectively, higher than at the sowing rate of 0.8 million seeds/ha. At the same time, the thickening of crops to 1.4 million seeds/ha did not provide a significant gain in the seed yield, which only was 0.06 t/ha compared to the ‘1.2 million seeds/ha’ variant.

In Metsenat, the difference in the yield depending on the sowing rate was smaller: on average across the study years it ranged 2.51 to 2.75 t/ha. While Oplot gave the biggest yield at the sowing rate of 1.4 million seeds/ha, Metsenat − at 1.2 million seeds/ha (2.75 t/ha). Here, the gain in the seed yield was 0.04 t/ha related to the '1.4 million seeds/ha' variant, ie, in Metsenat, there was a downward trend in the performance when its crops were thickened (Table 2).

Table 2

Yields of the pea cultivars depending on the sowing rate, t/ha, 2018–2021

Factor		Year				Average, t/ha	Gain in the seed yield	
Cultivar (factor A)	Sowing rate, mln seeds/ha (factor B)	2018	2019	2020	2021		t/ha	%
Oplot	0.8	2.73	1.10	3.58	3.27	2.67	–	–
	1.0	3.09	1.22	3.72	3.34	2.84	0.17	6.4
	1.2	3.01	1.34	4.09	3.65	3.02	0.35	13.1
	1.4	3.11	1.38	4.20	3.63	3.08	0.41	15.4
Metsenat	0.8	3.03	0.82	3.57	2.60	2.51	–	–
	1.0	3.10	0.98	3.59	2.76	2.61	0.10	4.0
	1.2	3.04	1.30	3.77	2.89	2.75	0.24	9.6
	1.4	2.87	1.32	3.69	2.94	2.71	0.20	8.0
$LSD_{0.05}$ t/ha for the factors: A – cultivar; B – sowing rate		A – 0.11 B – 0.16 AB – 0.21	A – 0.12 B – 0.19 AB – 0.22	A – 0.14 B – 0.20 AB – 0.26	A – 0.11 B – 0.14 AB – 0.23	–	–	–

Thus, further increase in the sowing rate was not associated with a significant rise in yield in Oplot and it was even associated with a decrease yield from Metsenat. Under the most favorable weather conditions in 2020 and 2021, the highest yields from the studied cultivars were achieved at the sowing rates of 1.2 million and 1.4 million seeds/ha, without significant differences between the values. The maximum yield was harvested in 2020: Oplot produced 4.09 and 4.20 t/ha, respectively, which is by 14.2% and 17.3% higher than that obtained with the rate of 0.8 million seeds/ha (Table 2). It should be noted that this cultivar's response to favorable conditions was weaker. When the sowing rate was increased from 1.0 million to 1.4 million seeds/ha, the yield was 3.59–3.77 t/ha, and a significant gain in the seed yield of 0.20 t/ha or 5.6% was obtained only at the rate of 1.2 million seeds/ha. In unfavorable 2018 under the arid conditions, there was no significant difference in the yields between the cultivars. However, in Oplot the increase in the sowing rates, compared to the '0.8 million seeds/ha' variant, contributed to a significant rise in the seed yield of 0.28-0.38 t/ha or 10.2−13.9%, while the yield from Metsenat sown at the rate of 1.4 million seeds/ha even decreased by 0.16 t/ha or by 12.9%.

The response of the pea cultivars to the sowing rate was slightly different in abnormally arid 2019. Thus, during the extended soil drought, the yields from Oplot and Metsenat were the lowest (1.10 and 0.82 t/ha, respectively) in the '0.8 million seeds/ha' variant; the raise in the sowing rate to 1.2 million and 1.4 million seeds/ha was the most appropriate, especially for Metsenat. In these variants, the most significant gains in the seed yields were achieved: 0.24–0.28 t/ha or 21.8–25.4% in Oplot and 0.48–0.50 t/ha or 58.5–61.0% in Metsenat. The results indicate that cultivars individually response to sowing rates, so one should determine sowing rates more carefully for each cultivar, with due account for their biological characteristics, to more fully reveal their yield potentials.

In addition to high pea seed yields, it is important to achieve appropriate indicators of its quality [5, 22]. Our four-year study showed that the protein content in pea seeds varied depending on the weather and sowing rates. The seed quality was also found to differ between the cultivars. On average across the experimental variants of sowing rates, the highest protein content in seeds was recorded in Oplot (21.35%); it was by 0.26% higher than that in Metsenat seeds (Table 3). The highest protein content in seeds of the studied cultivars was observed in

2019 and 2020. In Oplot, this figure was higher in 2020, amounting to 23.12% with fluctuations within 22.67-23.53%; in Metsenat - in 2019 (23.22% and 22.42–23.96%, respectively).

Table 3

Protein content in pea seeds depending on the sowing rate,%, 2018−2021

Sowing rate, mln seeds/ha (factor B)	Protein content in seeds (%)				Average	Gain, %
	2018	2019	2020	2021		
Cv. Oplot (factor A)						
0.8	21.40	22.09	23.53	19.68	21.68	–
1.0	20.60	21.81	23.16	19.99	21.39	–0.29
1.2	19.89	22.76	23.13	19.47	21.31	–0.37
1.4	19.84	22.61	22.67	19.01	21.03	–0.65
Average	20.43	22.32	23.12	19.53	21.35	–
Cv. Metsenat (factor A)						
0.8	19.58	23.96	3.17	1.88	21.40	–
1.0	19.66	23.36	23.03	18.76	21.20	–0.20
1.2	19.69	23.15	22.88	18.42	21.03	–0.37
1.4	19.97	22.42	22.53	18.02	20.73	–0.67
Average	19.73	23.22	22.90	18.52	21.09	
LSD_{05}, % for the factors: A – cultivar; B – sowing rate	A – 0.09 B – 0.14 AB – 0.16	A – 0.11 B – 0.14 AB – 0.20	A – 0.12 B – 0.15 AB – 0.22	A – 0.09 B – 0.19 AB – 0.26	–	–

The lowest protein content in pea seeds was accumulated in 2018 and 2021: it averaged 20.43 and 19.3%, respectively, across the sowing rates in Oplot, which was by 0.70% and 1.01% higher than that in Metsenat, respectively. On the average across the four years, the highest protein content in seeds was recorded at the sowing rate of 0.8 million seeds/a: 21.68% and 21.40% Oplot and Metsenat, respectively. As the sowing rate was increased, this parameter dropped significantly. Thus, in the '1.0 million seeds/ha' and '1.2 million seeds/ha' variants, the protein content in seeds was lower by 0.20-0.37% (depending on the cultivar) and at the rate of 1.4 million seeds/ha it reduced by 0.65-0.67%. Regardless of the sowing rate, Oplot gave a higher yield and contained more protein in seeds than Metsenat.

Conclusions. Under the instable weather in 2018–2021, on average, the largest numbers of pods and seeds per plant and the highest 1000-seed weight in the pea cultivars were recorded at the sowing rate of 0.8 million seeds/ha. The increase in the rate to 1.4 million seeds/ha resulted in a significant decline in these parameters: by 10.9−11.4%, 16.0–18.3% and 5.3–7.8%, respectively. The plant survival lowered with as the sowing density was increased: it was 79.3−80.0% at the sowing rate of 1.4 million seeds/ha and 85.0−87.0% at rates of 1.0 million and 1.2 million seeds/ha vs. 92.5−93.8% at the rate of 0.8 million seeds/ha. Thus, at the various sowing rates plants of the pea cultivars were able to self-regulate their density depending on the sowing rate and hydrothermal conditions during the growing period.

On average in 2018–2021, in the '1.2 million seeds/ha' and '1.4 million seeds/ha' variants, the seed yield from Oplot amounted to 0.35 t/ha and 0.41 t/ha, respectively, or by 13.1% and 15.4% higher than the yield at the rate of 0.8 million seeds/ha. Then the crops were thickened to 1.4 million seeds/ha, we observed no significant rise in the seed yield compared to the rate of 1.2 million seeds/ha. In Metsenat, the difference in the yield depending on the sowing rate was smaller; the yield reached its maximum at 1.2 million seeds/ha (2.75 t/ha).

On average across the four years, the highest protein content in seeds was accumulated at the sowing rate of 0.8 million seeds/ha: 21.68% and 21.40% in Oplot and Metsenat, respectively. As the sowing rate was increased to 1.0 million and 1.2 million seeds/ha, the protein content in seeds decreased by 0.20–0.37%; when it was increased to 1.4 million seeds/ha, the protein content decreased by 0.65– 0.67%. Regardless of the sowing rate, Oplot produced a higher yield and accumulated more protein in seeds than Metsenat.

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ФОРМУВАННЯ ПРОДУКТИВНОСТІ ТА ЯКОСТІ ЗЕРНА СОРТІВ ГОРОХУ В ЗАЛЕЖНОСТІ ВІД НОРМИ ВИСІВУ В УМОВАХ СХІДНОГО ЛІСОСТЕПУ УКРАЇНИ

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Мета дослідження – встановити вплив норми висіву на продуктивність і якість зерна сортів гороху в умовах східної частини Лісостепу України.

Матеріали і методи. Польові дослідження проводили в 2018–2021 рр. у стаціонарній сівозміні Інституту рослинництва імені В.Я. Юр’єва НААН на фоні основного внесення мінеральних добрив у дозі $N_{30}P_{30}K_{30}$ згідно методики дослідної справи Б.А. Доспехова та методики кваліфікаційної експертизи. Ґрунт – чорнозем типовий середньогумусний слабковилугований. Попередник – ярі колосові. Вихідним матеріалом були внесені в Державний реєстр сорти горохуОплот і Меценат, норми висіву схожого насіння 0,8; 1,0; 1,2; 1,4 млн шт./га. Технологія вирощування, за виключенням чинників, які вивчалися, загальноприйнята для зони.Статистичний обробіток експериментальних даних проводили методом дисперсійного аналізу.

Обговорення результатів. В умовах 2018–2021 рр. у сортів гороху кількість бобів та насіння на одну рослину та маса 1000 насінин були найбільшими за норми висіву 0,8 млн. шт./га. Підвищення норми висіву до 1,4 млн шт./га приводило до істотного зниження згаданих показників на 10,9–11,4%; 16,0–18,3% та 5,3–7,8% відповідно. Маса 1000 насінин у сортів гороху в залежності від норми висіву змінювалася неістотно, а саме: при нормах висіву 1,0 і 1,2 млн. шт./га, а також 1,2 і 1,4 млн. шт./га різниця складала 2,3–2,4 г та 4,1–9,5 г відповідно. Перед збиранням урожаю густота рослин в залежності від норми висіву була практично однаковою – 0,75–1,12 млн шт./га у сорту Оплот та 0,74–1,11 млн шт./га – у сорту Меценат. При цьому збереженість рослин до збирання знижувалася зі збільшенням густоти та складала в залежності від сорту за норми 1,4 млн. шт./га від 79,3 до 80,0%, а за норми 1,0 і 1,2 млн. шт./га – від 85,0 до 87,0%. Найбільш високою (92,5–93,8 %) збереженість в обох сортів була за норми 0,8 млн шт./га. Таким чином, у гороху за різних норм висіву відмічено здатність до саморегулювання густоти рослин.

У середньому за чотири роки у варіанті 0,8 млн шт./га врожайність сорту Оплот складала 2,67 т/га, а за умови збільшення норми висіву до 1,2 і 1,4 млн шт./га – підвищувалася на 0,35 та 0,41 т/га (13,1 та 15,4 %) відповідно. При цьому різниця врожайності у варіантах з нормами висіву 1,2 та 1,4 млн/га була неістотною. Урожайність сорту Меценат в залежності від норми висіву змінювалася значно менше – від 2,51 до 2,75 т/га, найвищого рівня досягала за норми висіву 1,2 млн/га, а при збільшенні густоти рослин було відмічено тенденцію до зниження врожайності.

За сприятливих погодних умов 2020 і 2021 рр. урожайність гороху була найбільш високою у варіантах 1,2 і 1,4 млн шт./га, без істотних відмінностей між сортами. Максималь-

ну врожайність мав сорт Оплот у 2020 р., 4,09 та 4,20 т/га у залежності від норми висіву, що на 14,2% і 17,3% перевищує норму 0,8 млн шт./га. У сорту Меценат реакція на зміну погодних умов більш слабка. В залежності від норми висіву (1,0−1,4 млн шт./га) урожайність складала 3,59–3,77 т/га, а підвищення врожайності зерна на 0,20 т/га (5,6%) відмічено за норми 1,2 млн шт./га.

Установлено відмінності за якістю зерна в залежності від погодних умов та норми висіву. Вміст білка у сорту Оплот складав 21,35%, що на 0,26% вище, ніж у Мецената. В залежності від норми висіву вміст білка є вищим за норми 0,8 млн шт./га – 21,68% у сорту Оплот та 21,40% – у сорту Меценат.

Висновки.За різних погодних умов більш високими показники структури врожайності незалежно від сорту були за норми висіву 0,8 млн. шт/га. Збільшення норми висіву призводило до істотного зниження кількості бобів та насіння на одну рослину. При цьому мінливість маси 1000 насінин була неістотною, що свідчить про значно сильнішу залежність цього показника від сорту, аніж від умов вирощування. Передзбиральна густота рослин у обох сортів була однаковою, але збереженість знижувалася зі збільшенням норми висіву та була найбільшою у варіанті 0,8 млн шт./га – 92,5–93,8 %. Тобто, у гороху відмічено здатність до саморегуляції густоти рослин.

За чотири роки середня врожайність була вищою у сорту Оплот та складала 2,67 т/га за норми 0,8 млн шт./га, тоді як у Мецената – 2,51 т/га. При цьому сорт Оплот більш сильно реагував на зміну умов вирощування, ніж Меценат. Різниця за врожайністю в обох сортів у варіантах з нормами висіву 1,2 та 1,4 млн/га була неістотною, тому з урахуванням вартості насіння рекомендованою можна визнати норму 1,2 млн шт./га.

Незалежно від норми висіву вміст білка в насінні був вищим у сорту Оплот – 21,35%, що на 0,26% вище, ніж у Мецената. Максимальним вміст білка в обох сортів був у варіанті 0,8 млн шт./га – 21,68% у сорту Оплот та 21,40% – у сорту Меценат.

Таким чином, незалежно від умов вирощування сорт Оплот має вищу врожайність та вміст білка в зерні, ніж сорт Меценат. При цьому сорт Оплот має більш сильну позитивну реакцію на покращання умов вирощування, що може характеризувати його як сорт інтенсивного типу.

Ключові слова: *горох, сорт, норма висіву, врожайність, якість зерна*

SOWING RATE EFFECT THE PERFORMANCE AND SEED QUALITY OF PEA CULTIVARS IN THE EASTERN FOREST-STEPPE OF UKRAINE

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Purpose. To assess the sowing rate effect on the performance and seed quality of pea cultivars in the Eastern Forest-Steppe of Ukraine.

Materials and methods. The study was conducted in the stationary crop rotation of the Plant Production Institute named after V.Ya. Yuriev of NAAS in 2018–2021 on basic mineral fertilization at a dose of $N_{30}P_{30}K_{30}$. The soil was typical mid-humus slightly-leached chernozem. The forecrop was spring cereals. Zoned pea cultivars Oplot and Metsenat were investigated in the experiments. The sowing rate was 0.8 million, 1.0 million, 1.2 million, and 1.4 million seeds/ha. The farming techniques, except for the issues under investigation, were conventional the zone. The data were processed by analysis of variance.

Results and discussion. Under the instable weather in 2018–2021, on average, the largest numbers of pods and seeds per plant and the highest 1000-seed weight in the pea cultivars were recorded at the sowing rate of 0.8 million seeds/ha. The increase in the rate to 1.4 million seeds/ha resulted in a significant decline in these parameters: by 10.9−11.4%, 16.0–18.3% and 5.3–7.8%, respectively. The differences in the 1000-seed weight between the ‘1.0 million seeds/ha’ and ‘1.2 million seeds/ha’ variants as well as between ‘1.2 million seeds/ha’ and ‘1.4

million seeds/ha' variants were insignificant: 2.3−2.4 g and 4.1−9.5 g, respectively. The pre-harvest plant density was vary similar regardless of the sowing rates: 0.75−1.12 million plants/ha in Oplot and 0.74−1.11 million plants/ha in Metsenat. At the same time, the pre-harvest plant survival decreased when the sowing rate was raised: 79.3−80.0% (depending on the cultivar) at 1.4 million seeds/ha vs. 85.0−87.0% at 1.0 million and 1.2 million seeds/ha. The highest pre-harvest plant survival (92.5−93.8%) was recorded when the both cultivars were sown at the rate of 0.8 million seeds/ha. Thus, pea cultivars were able to self-regulate their plant density at different sowing rates.

On the average across the four years in the '0.8 million seeds/ha' variant, the performance of Oplot amounted to 2.67 t/ha. When the sowing rate was increased to 1.2 million and 1.4 million seeds/ha, the performance rose by 0.35 t/ha and 0.41 t/ha or by 13.1% and 15.4%, respectively. At the same time, the increase in the sowing density to 1.4 million seeds/ha did not significantly boost the seed yield compared to the '1.2 million seeds/ha' variant. In Metsenat, the differences in the yield depending on the sowing rate were smaller (2.51−2.75 t/ha).The biggest yield was noted at the sowing rate of 1.2 million seeds/ha and there was a downward trend in the plant performance as the plant density was increased.

Under the most favorable weather in 2020 and 2021, the highest yields were obtained when the cultivars were sown at the rates of 1.2 million and 1.4 million seeds/ha, without any significant difference between them. In 2020, the maximum yield was given by Oplot (4.09 and 4.20 t/ha, respectively, which was by 14.2% and 17.3% higher than that in the '0.8 million seeds/ha' variant). Metsenat responded more weakly to the favorable weather. When the sowing density was raised from 1.0 million seeds/ha to 1.4 million seeds/ha, the yield was 3.59–3.77 t/ha; the desirable gain in the seed yield of 0.20 t/ha or 5.6% was provided at the rate of 1.2 million seeds/ha. In unfavorable 2018, there was no significant difference in the yields from the cultivars between the studied variants.

There were differences in the seed quality of the cultivars depending on weather and sowing rate. On average across the sowing rates, Oplot had a higher content of protein in seeds: 21.35%, which was by 0.26% higher than in Metsenat. On average across the study years, a higher content of protein in seeds were noted with the sowing rate of 0.8 million seeds/ha: 1.68% in Oplot and 21.40% in Metsenat. As the sowing rate was increased to 1.0 million and 1.2 million seeds/ha, the protein content in seeds reduced by 0.20–0.37%; when the rate was increased to 1.4 million seeds/ha - by 0.65– 0.67%. Regardless of the sowing rate, Oplot produced a higher yield and accumulated more protein in seeds than Metsenat.

Conclusions. On average under the unstable weather in 2018−2021, the highest indicators of the pea performance were recorded at the sowing rate of 0.8 million seeds/ha, and its increase to 1.4 million seeds/ha led to their reduction. The pre-harvest plant density differed insignificantly between the cultivars related to the sowing rates, plant survival rates decreased with increasing sowing density. The pre-harvest highest survival of plants was achieved at the rate of 0.8 million seeds/ha − 92.5−93.8%. The pea cultivars were able to self-regulate their plant density. On the average across the four years in the '0.8 million seeds/ha' variant, the yield from Oplot was 2.67 t/ha, increasing by 0.35 and 0.41 t/ha or by 13.1 and 15.4% at the sowing rates of 1.2 million and 1.4 million seeds/ha, respectively. 1.2 million seeds/ha turned out to be the optimal sowing rate, and an increase in the sowing density led to a reduction in the plant performance.

There were differences in the seed quality of the cultivars depending on the weather and sowing rate, in particular, the highest content of protein in seeds was detected in Oplot sown at the rate of 0.8 million seeds/ha.

Key words: *pea, cultivar, sowing rate, performance, yield, seed quality*