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INFLUENCE OF PREDECESSORS, MINERAL FERTILISERS AND SEEDING RATES ON PEA GRAIN YIELD IN THE NORTHERN STEPPE OF UKRAINE

A. D. Gyrka [1], O. V. Bochevar [1], V. S. Malook [1], Yu. Ya. Sydorenko [2], O. V. Ilienko [2], Ya. V. Aleksieiev [2]
[1]State Enterprise Institute of Grain Crops of NAAS, 14 Volodymyr Vernadskyi St., Dnipro, 49009, Ukraine
[2]Erastivska Experimental Station of the SE Institute of Grain Crops of NAAS, Vyshneve village, Kamianske district, Dnipropetrovsk region, 52150, Ukraine

Topicality. *The plant density per unit area is one of the most important agronomic indicators, which depends on both the seeding rate and the soil water regime. This is especially important for the Steppe zone of Ukraine, given the constant water scarcity in this region. The analysis of literature sources revealed limited scientific data regarding the response of modern pea varieties to seeding rates depending on the predecessors and mineral nutrition of plants in the unstable weather and climatic conditions of the Steppe region of Ukraine.* ***Purpose.*** *To establish the optimal seeding rate for peas of Haiduk variety, depending on the predecessors and mineral fertilizers.* ***Materials and Methods.*** *During 2021–2022, the scientific study was carried out at the Erastivska Experimental Station of the SE Institute of Grain Crops of NAAS, which is located in the Northern Steppe of Ukraine. In the area of the experimental station, the temperate continental climate is characterised by aridity and unstable moisture conditions. The soil cover of the experimental plots is ordinary low-humus heavy loamy chernozem. The humus content in the topsoil (0–30 cm) is 4.0–4.5 %, total nitrogen – 0.23–0.26 %, phosphorus – 0.11–0.16 %, potassium – 2.0–2.5 %, pH of the soil-water extract – 6.5–7.0. The experiment was laid out after winter wheat and maize for grain as predecessors on the background of mineral fertilizers at rates of* $N_{30}P_{30}K_{30}$ *and* $N_{45}P_{45}K_{45}$ *under pre-sowing cultivation. Leafless peas of the Haiduk variety, bred by the Yuriev Plant Production Institute, were sown at seeding rates of 1.2, 1.4, 1.6 and 1.8 million germinated seeds/ha. Generally accepted agricultural techniques were used in the experiment.* ***Results.*** *The seeding rate and the level of mineral nutrition of pea plants after different predecessors had a significant effect on the yield attributes and grain yield of the Haiduk variety. On average, over two years of research (2021–2022), the application of mineral fertilisers at a rate of* $N_{45}P_{45}K_{45}$ *under pre-sowing cultivation, compared to the background* $N_{30}P_{30}K_{30}$*, increased the pea grain yield of Haiduk variety after maize for grain by 0.18–0.51 t/ha, after winter wheat – by 0.16–0.32 t/ha, depending on the seeding rate under study.* ***Conclusions.*** *In the pea cultivation technology, the effect of the predecessors (winter wheat and maize for grain) on grain yields of the Haiduk variety was almost equivalent in the case of pre-sowing application of mineral fertilisers at a rate of* $N_{45}P_{45}K_{45}$ *and a seeding rate of 1.4 million germinated seeds/ha.*

Key words: *pea, predecessor, fertiliser background, seeding rate, plant density, yield attributes, plant productivity, grain yield*

Introduction. The value of pea (*Pisum sativum*) as a high-protein crop has long been known. It is the main legume crop in Europe [1, 2]. Compared to cereal spiked crops, peas have a number of advantages, especially in terms of valuable vegetable protein. Thus, pea grains contain up to 24.5 % protein, which allows this crop to be widely used in the food industry and for feed purposes [3]. In addition, the green mass of peas used for animal feed contains 18–22 % of protein, 3–4 % of fat and 20–22 % of fibre [4].

Peas are also of great value in crop rotation. Pea plants are able to fix air nitrogen in the amount of 100–150 kg/ha of nitrogen, which is equivalent to 300–400 kg of

Author information:

Anatolii D. Gyrka, *Doctor of Agricultural Sciences, Professor, Chief Researcher of the Laboratory of Agbiological Resources of Winter and Spring Crops,* e-mail: adgyrka@gmail.com, https://orcid.org/0000-0002-2521-502X

Olha V. Bochevar, *Candidate of Agricultural Sciences, Senior Researcher, Leading Researcher at the Laboratory of Agribiological Resources of Winter and Spring Crops*, e-mail: olgamedodessa@ukr.net, https://orcid.org/0000-0001-5549-7681

Vadym S. Malook, *PhD candidate,* e-mail: mvs@gmail.com, https://orcid.org/0009-0000-3508-5735

Yurii Ya. Sydorenko, *Candidate of Agricultural Sciences, Senior Researcher, Head of the Grain Crops Laboratory,* e-mail: zernovik_1@ukr.net, https://orcid.org/0000-0003-0695-3956

Oleksandr V. Ilenko, *Candidate of Agricultural Sciences, Senior Researcher, Senior Researcher of the Grain Crops Laboratory,* e-mail: soyewod1@ukr.net, https://orcid.org//0000-0002-3660-1268

Yaroslav V. Aleksieiev, *Candidate of Agricultural Sciences, Senior Researcher at the Grain Crops Laboratory,* e-mail: ayv7709@gmail.com, https://orcid.org/0000-0002-5757-8044

ammonium nitrate. The results of the research showed that with sufficient soil moisture, peas are the best early predecessor for winter crops and allow us to sow them in the optimal dates. In addition, peas can effectively control weeds [5]. Inclu-ding peas in the crop rotation also allows farmers to significantly save money on mineral fertili-sers, improve soil health and its mechanical composition [6, 7, 8]. That is why peas are one of the best predecessors for winter wheat, millet, buckwheat and other crops. Thus, gro-wing peas in crop rotations contributes to redu-cing the total cost of crop production, improves the phytosanitary condition of crops and increases arable land productivity.

Peas differ from other pulses in that their stems do not branch and elongate mainly in height. In favourable years, pea crops lodge severely due to excessive plant growth, which requires two-phase harvesting and leads to grain yield losses [9, 10]. The priority for effective area renewal and increase in pea grain production is the cultivation of high-yielding varieties of leafless morphological type with high potential productivity, tolerance to environmental stress factors, lodging and suitable for direct harvesting [11, 12]. In order to increase the yields of this crop, there is a need to improve the cultivation technology of the newest pea varieties of the leafless morphological type tolerant to lodging. The analysis of the literature showed that in the system of agronomic practices aimed at increasing pea productivity, great importance should be given to the rational use of fertilisers and seeding rates [13–15].

At the same time, pea plants are susceptible to the effects of the predecessor and their productivity forms differently depending on this factor. According to the results of research, the best grain yields of peas are obtained in the subzone of unstable moisture when peas are sown after maize for grain and silage, winter wheat, buckwheat, and barley. The data also suggests that crops such as maize for grain, sunflower and spring barley are almost equally valuable predecessors for peas [1, 4]. Thus, given the comprehensive economic importance of pea, the issue of expanding its area in the steppe zone is relevant, and therefore, agrotechnical methods of growing this crop should be constantly improved.

The research was aimed at studying the peculiarities of pea growth, development and grain yield formation of Haiduk variety depending on the predecessors, mineral fertilizers and seeding rates.

Materials and Methods. The field research was conducted at the Erastivka Experimental Station of SE IGC NAAS located in the Northern Steppe of Ukraine during 2021–2022. The climate of the research station is temperate continental, characterised by aridity and unstable moisture conditions. The soil cover of the experimental plots was ordinary low-humus heavy loamy chernozem. The humus content in the topsoil (0–30 cm) is 4.0–4.5 %, total nitrogen content is 0.23–0.26 %, phosphorus is 0.11–0.16 %, potassium is 2.0–2.5 %, and the pH of the soil-water extract is 6.5–7.0. The experiment was laid out after winter wheat and maize for grain. A mid-ripening pea of leafless morphological type of Haiduk variety developed by the Yuriev Plant Production Institute was sown. Agrotechnology in the experiment was generally accepted for the zone. The primary tillage in the autumn period included double stubble breaking of the predecessor and moldboard ploughing to a depth of 20–22 cm. Spring tillage included early spring harrowing and pre-sowing cultivation with the application of mineral fertilisers ($N_{16}P_{16}K_{16}$) in rates of $N_{30}P_{30}K_{30}$ and $N_{45}P_{45}K_{45}$ according to the experimental design. Various pea seeding rates of 1.2, 1.4, 1.6 and 1.8 million germinated seeds/ha were studied. Sowing was conducted with a SN-16 seeder followed by rolling with sprocket packers. Integrated plant control against weeds, diseases and pests was also applied during the pea growing season. The arrangement of the experimental variants in the field was systematic, repeated three times, and the plot area was 25 m^2.

Results and Discussion. Weather conditions during the pre-sowing period of peas varied significantly over the years of research, which affected the sowing dates and, consequently, the further plant development. Thus, during April 2021, rainfall of varying intensity was frequent, exceeding the monthly norm by 17.7 mm; the average daily air temperature decreased by 1.3 °C compared to long-term data, and the average monthly relative humidity increased by 6 % compared to long-term data. Such weather conditions delayed the start of spring sowing campaign and postponed the sowing of spring spiked cereals and peas by two weeks later than the long-term average. The beginning of spring in March 2022 was characterised by low air temperatures, frosts in the first and second ten-day periods of the month, and a rapid rise in temperatures (up to 3.9–12.0 °C) in the third ten-day period, which exceeded long-term data by 2.5 °C In March, the relative humidity was 67 %, which was 12 % lower than the long-term average. Precipitation was primarily recorded in early March, but its amount was almost twice (14 mm) less than long-term data. Thus, the weather conditions of the spring of 2022 contributed to the timely conduct of field operations and pea was sown in the trial on 29 March.

Phenological observations showed that full pea seedlings of Haiduk variety emerged 16 days after sowing both when sown at the optimal date in 2022 and with a two-week delay in sowing (Table 1).

Table 1. Dates of the main growth and development stages of pea plant of Haiduk variety during the growing season, 2021−2022

Year	Plant growth and development stages						
	sowing	seedling	5^{th} leaf	flower bud formation	flowering	pod formation	full grain maturity
2021	17.04	03.05	17.05	07.06	13.06	20.06	10.07
2022	29.03	14.04	27.04	05.06	08.06	15.06	09.07

However, the plant development period from the formation of the 5th leaf to flower bud formation varied by year and was 21 days in 2021, and in 2022 it increased to 39 days due to cooler conditions in May. Subsequent periods of plant growth and development were almost the same duration by years of research. In general, the growing season in pea plants of the Haiduk variety was 84 days in 2021, and 102 days – in 2022. According to the results of the research, we have also found that the predecessors, rates of mineral fertilizers and seeding rates had no practical effect on the occurrence and duration of the main stages of pea growth and development.

According to the pea yield attributes, on average for two years, the highest plants were and 87.3–87.8 cm, which formed after winter wheat as a predecessor, with the application of $N_{45}P_{45}K_{45}$ fertiliser and a seeding rate of 1.2–1.4 million germinated seeds/ha (Table 2).

Table 2. Yield attributes and grain yield of peas depending on the predecessor, nutritional background and seeding rates, 2021−2022

Fertiliser background (factor B)	Seeding rate, million germinated seeds/ha (factor C)	Plant height, cm	Number of pods per plant, pcs	Number of seeds per plant, seeds	Seed weight per plant, g	1000 seed weight, g	Grain yield, t/ha
Predecessor (factor A) – winter wheat							
$N_{30}P_{30}K_{30}$	1.2	82.9	4.6	19.0	4.1	214.9	2.50
	1.4	81.8	4.8	18.8	3.9	210.7	2.74
	1.6	81.5	4.6	18.0	3.6	207.7	2.68
	1.8	75.1	4.4	16.2	3.3	205.4	2.63
$N_{45}P_{45}K_{45}$	1.2	87.8	5.5	20.0	4.6	220.5	2.82
	1.4	87.3	5.5	19.1	4.9	218.5	3.03
	1.6	86.6	4.8	18.2	3.8	215.9	2.92
	1.8	82.5	4.5	17.0	3.5	211.3	2.79
Predecessor (factor A) − maize for grain							
$N_{30}P_{30}K_{30}$	1.2	74.9	4.3	16.4	3.2	209.5	2.31
	1.4	74.2	4.5	16.5	3.6	209.3	2.66
	1.6	70.2	3.8	15.5	3.0	207.3	2.62
	1.8	69.0	3.5	14.5	2.8	207.2	2.53
$N_{45}P_{45}K_{45}$	1.2	80.1	4.9	16.8	3.3	215.5	2.82
	1.4	80.3	4.8	16.6	3.4	216.2	3.00
	1.6	79.2	4.1	15.0	3.2	212.5	2.81
	1.8	71.6	3.9	14.3	3.0	209.7	2.71
LSD_{05}, t/ha for factor: A – 0.03−0.05; B – 0.03−0.04; C – 0.04−0.05; AB −0.05−0.07; AC −0.08-0.09; BC − 0.07−0.08; ABC − 0.10−0.11.							

The plant height of peas was by 4.9–5.5 cm less when peas were sown with similar seeding rates after winter wheat on the background of $N_{30}P_{30}K_{30}$ fertilisation. The lowest pea plants of 74.2–74.9 cm were obtained after the maize for grain and with moderate rates of mineral fertiliser ($N_{30}P_{30}K_{30}$). The increase in plant height of peas to 80.1–80.3 cm was due to the improvement of mineral nutrition by fertilising with $N_{45}P_{45}K_{45}$ after maize for grain.

The level of mineral nutrition of plants significantly affected the formation of the number of pods and their grain content in peas. Thus, pre-sowing introduction of mineral fertiliser $N_{45}P_{45}K_{45}$ after the predecessor winter wheat resulted in an increase of these indicators by 0.2–0.9 pods and 0.3–1.0 grains, respectively, compared to the fertiliser $N_{30}P_{30}K_{30}$. These parameters grew less intensively under improved mineral background after maize for grain and increased by 0.3–0.6 pods and 0.1–0.5 grains, respectively. The largest grain weight per pea plant was obtained under sowing with seeding rates of 1.2–1.4 million germinated seeds/ha after the predecessor winter wheat: 4.6–4.9 g in variants with the maximum amount of mineral fertilisers and 3.9–4.1 g – with moderate application of $N_{30}P_{30}K_{30}$. Sowing peas after maize for grain resulted in a decrease in the plant productivity in the best experimental variants by 1.3–1.5 g and 0.3–0.9 g, respectively, depending on the nutrition background.

According to the results of the research, 1000 grain weight of Haiduk variety peas increased significantly after the predecessor winter wheat and the application of mineral fertiliser $N_{45}P_{45}K_{45}$. A greater 1000 grain weight of peas was provided by variants with seeding rates of 1.2–1.4 million germinated seeds/ha – 218.5–220.5 g, respectively. Thickening of pea crops by increasing the seeding rate from 1.2 to 1.8 million germinated seeds/ha led to a decrease in 1000 grain weight by 2.0–9.5 g, depending on the predecessor and the mineral fertiliser background.

The average grain yield of Haiduk variety was higher on two years of research, when mineral fertiliser $N_{45}P_{45}K_{45}$ was applied for pre-sowing cultivation and was practically unchanged depending on the predecessor. The maximum grain yield of 3.00–3.03 t/ha of pea was obtained in variants with a seeding rate of 1.4 million germinated seeds/ha both after winter wheat and after maize for grain. Increasing the seeding rate of peas to 1.6–1.8 million germinated seeds/ha resulted in a decrease in the best grain yield by 0.11–0.29 t/ha, depending on the predecessor. In the variant with fertilizer $N_{30}P_{30}K_{30}$, a similar response to grain yield formation was observed depending on the seeding rate, but under such nutrition conditions, the level of plant productivity in variants with a seeding rate of 1.4 million germinated seeds/ha after whiter wheat decreased by 0.29, after maize for grain – by 0.34 t/ha, compared to fertilizer $N_{45}P_{45}K_{45}$. Thus, the effect of the predecessor on the pea plant productivity of Haiduk variety was more significant in variants with moderate application of mineral fertilizers than in the case of pre-sowing fertilizer application $N_{45}P_{45}K_{45}$.

Conclusions

The two-year research findings were used to establish the following:

1.Seeding rates of 1.2, 1.4, 1.6, and 1.8 million germinated seeds/ha after winter wheat and maize for grain with the introduction of mineral fertilisers $N_{30}P_{30}K_{30}$ and $N_{45}P_{45}K_{45}$ under pre-sowing cultivation did not affect the dates of occurrence and duration of the main stages of pea growth and development of Haiduk variety plants.

2. The best indicators of the pea yield attributes were formed by sowing with seeding rates of 1.2–1.4 million germinated seeds/ha. The thickening of pea crops to 1.6–1.8 million plants/ha after the predecessor winter wheat, depending on the fertiliser background, reduced the plant height by 0.3–7.8 cm, the number of pods per plant by 0.4–1.0 pcs, grain content of pods – by 0.8–3.0 seeds, 1000 grains weight – by 3.0–9.5 g, and after maize for grain – by 0.7–8.5 cm, 0.5–1.0 pcs, 0.1–0.8 seeds and 2.0–6.5 g, respectively.

3. The introduction of mineral fertiliser $N_{45}P_{45}K_{45}$ under pre-sowing cultivation, compared to the background $N_{30}P_{30}K_{30}$, increased the grain yield of Haiduk variety after the predecessor maize for grain by 0.18–0.51 t/ha, after winter wheat – by 0.16–0.32 t/ha, depending on the seeding rate under study.

4. The maximum grain yield (3.0–3.03 t/ha) of peas was obtained in variants with a seeding rate of 1.4 million seeds/ha. Increa-

sing or decreasing the seeding rate of 1.4 million germinated seeds/ha showed the inexpediency of such an agronomic practice.

5. In the pea cultivation technology of the Haiduk variety, winter wheat and maize for grain were almost equivalent, thus they can be recommended for use in crop rotations in the Northern Steppe of Ukraine under pre-sowing application of mineral fertilizers at a rate of $N_{45}P_{45}K_{45}$ and a seeding rate of 1.4 million germinated seeds/ha.

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Гирка А. Д.[1], Бочевар О. В. [1], Малоок В. С. [1], Сидоренко Ю. Я. [2], Ільєнко О. В. [2], Алєксєєв Я. В[2].

Вплив попередників, мінеральних добрив та норм висіву насіння на врожайність зерна гороху в Північному Степу України. *Зернові культури. 2024. 8 (1). 72–77.*

[1]Державна установа Інститут зернових культур НААН, вул. Володимира Вернадського, 14, м. Дніпро, 49009, Україна
[2]Ерастівська дослідна станція Державної установи Інститут зернових культур НААН, смт Вишневе, Кам'янський район, Дніпропетровська область, 52150, Україна

Актуальність. Густота рослин на одиниці площі відноситься до найважливіших агротехнічних показників, який залежить від норми висіву насіння та корегується водним режимом ґрунту. Це має особливе значення для умов степової зони України, де волога знаходиться у постійному дефіциті. Аналіз літературних джерел виявив обмежену кількість наукових даних щодо реакції сучасних сортів гороху на норми висіву насіння залежно від попередників та мінерального живлення рослин за нестабільних погодно-кліматичних умов степового регіону. **Мета досліджень** полягала у встановленні оптимальних норм висіву насіння гороху сорту Гайдук залежно від попередників та мінеральних добрив. **Матеріали та методи.** Наукова робота проводилась упродовж 2021–2022 рр. на Ерастівській дослідній станції ДУ ІЗК НААН, яка розташована у Північному Степу України. Клімат зони розміщення дослідної станції помірно-континентальний, характеризується посушливістю та нестійкими умовами зволоження. Ґрунтовий покрив дослідних ділянок – чорнозем звичайний малогумусний важкосуглинковий. Вміст гумусу в орному шарі ґрунту (0–30 см) становить 4,0–4,5 %, загального азоту – 0,23–0,26 %, фосфору – 0,11–0,16 %, калію – 2,0–2,5 %, pH водної витяжки – 6,5–7,0. Дослід закладали після попередників пшениця озима та кукурудза на зерно на фоні внесення під передпосівну культивацію мінеральних добрив у дозах $N_{30}P_{30}K_{30}$ та $N_{45}P_{45}K_{45}$. Вирощували горох вусатого морфологічного типу сорту Гайдук селекції Інституту рослинництва ім. В. Я. Юр'єва з нормами висіву 1,2; 1,4; 1,6 та 1,8 млн схожого насіння/га. Агротехніка у досліді – загальноприйнята для зони. **Результати.** Норма висіву насіння та рівень мінерального живлення рослин за сівби після різних попередників суттєво впливали на елементи структури врожаю та врожайність зерна гороху сорту Гайдук. У середньому за два роки досліджень (2021−2022) внесення під передпосівну культивацію мінеральних добрив у дозі $N_{45}P_{45}K_{45}$, порівняно з фоном $N_{30}P_{30}K_{30}$, забезпечило підвищення врожайності зерна гороху сорту Гайдук після попередника кукурудза на зерно на 0,18−0,51 т/га, після пшениці озимої − на 0,16−0,32 т/га залежно від норм висіву насіння, які досліджувались. **Висновки.** У технології вирощування гороху сорту Гайдук попередники (пшениця озима та кукурудза на зерно) виявились майже рівнозначними за умов використання передпосівного внесення мінеральних добрив $N_{45}P_{45}K_{45}$ та норми висіву 1,4 млн схожого насіння/га, що дає змогу рекомендувати їх для використання у сівозмінах зони Північного Степу України.

Ключові слова: *горох, попередник, фон удобрення, норма висіву насіння, елементи структури врожаю, продуктивність рослин, урожайність зерна*