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CHEMICAL COMPOSITION OF WINTER PEA PLANTS IN THE SOUTHERN STEPPE OF UKRAINE

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Topicality. *Introducing new crop varieties into production requires studying their chemical composition, as it depends on the climate conditions of the region and cultivation technologies. Therefore, the study of the peculiarities of the formation of macro- and microelements composition of a new variety of winter peas in the climatic conditions of the Southern Steppe is advisable.* ***Purpose****. To evaluate the chemical composition of winter pea and the distribution of macro- and microelements in the structural parts of plants depending on their development stages in the Southern Steppe of Ukraine.* ***Methods.*** *Samples of winter peas were selected by development stages in stationary and temporary experiments, as well as in production and testing crops of agricultural farms of the Odesa region. The following methods were used: laboratory method to determine content of nitrogen, phosphorus, potassium and microelements; statistical method to perform correlation, analysis of variance and statistical evaluation of research results.* ***Results.*** *The paper presents the data on the chemical composition of winter pea cultivated in the Southern Steppe of Ukraine. The peculiarities of accumulation and distribution of macro- and microelements by the leaf mass, grain and roots of winter pea are established. It was found that the rate of toxic elements accumulation in the vegetative mass of pea plants increased and decreased when they moved from plant leaves and stems to grain.* ***Conclusions.*** *The average content of nitrogen, phosphorus, potassium and microelements in grain and by-products of winter pea in the Southern Steppe of Ukraine were determined. We found significant changes in the microelement composition of the leaves and stems, grain and roots of winter pea. A higher variability of microelement content (12.7–70.7 %) was noted in contrast to the macroelement content (7.7–48.3 %). The low resistance of root barriers to the entry of Cd and Pb toxicants into the aboveground part of winter pea over the entire growing season and the high intensity of the leaf mass resistance to the absorption of these metals by grain were determined.*

Key words: *winter peas, microelements, nitrogen, phosphorus, potassium, content*

Introduction. The search for new crops or varieties of existing crops is part of adaptation of agriculture to climate change. In recent years, scientists and agricultural producers have turned their attention to winter pea varieties. According to research, plants of such varieties as NS Moroz, Enduro and Balltrap tolerate winter temperatures of up to -15 °C without snow cover and up to -25 °C with snow cover on the field surface [3].

In addition, autumn sowing of peas allows plants to more productively utilise winter-spring moisture reserves, avoid the negative effects of high temperatures in late spring and early summer, and harvest the yield of winter peas 10–15 days earlier than spring peas that allow the field to be cleared for the next crop in the rotation.

Today, technological elements of cultivation are being developed for winter peas and breeding research is underway. The issue of the influence of the cultivation zone on the chemical composition of this crop has not been addressed. Meanwhile, numerous studies have shown that climatic and soil conditions [8, 10–12], technological practices [2, 3, 7, 9, 13–16] significantly affect both the biological value of agricultural products, the variability of element content in grain, leaf mass and roots, the direction of these processes [5, 6, 11], and the bioavailability [14].

Research was aimed to evaluate the che-

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mical composition of winter pea plants and the distribution of macro- and microelements in the structural parts of plants and by development stages in the Southern Steppe of Ukraine.

Materials and Methods. In 2020–2022, observations and records were carried out on crops of winter peas of Balltrap, Enduro, NS Moroz varieties. The sowing date was 20–25 October; winter peas were sown in a solid method (row spacing 15 cm); the predecessor was winter wheat. Sampling the plants was carried out at the growth resumption, in the stages of flower-bud formation, podding and full maturity in stationary and temporary trials of the experimental field of the Odesa State Agricultural Experimental Station of the Institute of Climate-Smart Agriculture of NAAS of Ukraine, located in Odesa district, Odesa region. The plot area of the stationary trial was 240 square metres, and the temporary trial was 45 square metres, with a replication rate of 3 times. In addition, samples were taken from production and testing crops in the farms of Odesa region. Soil is southern low humus heavy loamy chernozem.

The content of Mn, Zn, Cu, Co, Pb and Cd in the leaf mass, roots, grain and by-products (straw) of winter peas was determined using an atomic absorption spectrophotometer C-115 M 1 with atomisation in an air-acetylene flame. The content of nitrogen, phosphorus, and potassium was determined in the same objects using standard methods. The experimental data were processed using the mathematical statistics software Excel 2007 and Statistica 6. An array of analytical data on macro- and microelement composition of winter pea plants obtained over three years in stationary and temporary experiments of the Odesa State Agricultural Experimental Station, production and testing crops in farms of the Odesa region, which reflect the climatic features of the southern Steppe, was subjected to statistical processing.

In order to compare the ability of the pea plant (leaf and stem mass, roots, seeds) to accumulate chemical elements, the relative accumulation coefficient (Acropetal Coefficient – AC) was calculated as the ratio of concentrations in different parts of the plant.

Results. Studies have shown significant variability in the macrocomposition of pea plants by the growth and development stages (Table 1). In the early spring growth resumption, the highest content of nitrogen and potassium was observed in the aboveground part of plants, which gradually decreased by 4.2 and 3.0 times, respectively, until the pea was fully ripe. The phosphorus content was generally low and varied within 0.070–0.044 % by growth stages. There were also significant deviations from the average value, especially for nitrogen and potassium, which were significant (19.5 and 48.3 %) in the full maturity, and the phosphorus content from the growth resumption to full maturity ranged from 17.0 % to 54.1 %. The minimum deviations from the average values were observed in the concentration of phosphorus in

Table 1. Content of main macronutrients in winter pea plants sowing by growth stages, % on dry matter (n=162)

Parts of plant	Nitrogen			P_2O_5			K_2O		
	M ± m	Fluctuation interval	V, %	M ± m	Fluctuation interval	V, %	M ± m	Fluctuation interval	V, %
Spring regrowth									
LM*	4.25±0.40	3.31-5.02	9.4	0.110±0.026	0.070-0.177	23.5	2.17±0.19	1.74-2.65	8.9
Roots	2.81±0.32	2.06-3.52	11.4	0.122±0.038	0.069-0.231	31.0	2.42±0.24	2.00-3.24	9.8
Flower-bud formation									
LM	3.83±0.29	3.21-4.50	7.7	0.064±0.035	0.027-0.196	54.1	1.72±0.12	1.48-1.96	6.8
Roots	3.55±0.38	2.80-4.56	10.7	0.066±0.021	0.035-0.121	31.9	1.57±0.11	1.37-1.77	6.8
Podding									
LM	2.42±0.24	2.07-2.89	9.1	0.057±0.010	0.045-0.080	17.0	1.20±0.10	1.10-1.50	8.0
Pods	3.46±0.20	3.06-3.97	5.8	0.318±0.046	0.230-0.465	14.6	1.01±0.09	0.74-1.20	9.1
Roots	2.85±0.64	1.93-4.12	14.8	0.071±0.015	0.058-0.088	18.8	1.36±0.25	1.20-2.06	11.3
Full maturity									
Grain	3.34±0.43	2.47-4.39	22.7	0.264±0.032	0.175-0.362	12.0	0.83±0.08	0.72-1.11	11.3
Straw	1.01±0.20	0.78-1.29	19.5	0.099±0.066	0.044-0.230	37.1	1.05±0.51	0.58-2.13	48.3
Roots	2.06±0.48	1.75-2.44	18.6	0.084±0.057	0.056-0.087	24.8	1.67±0.33	0.88-2.52	30.1

*Note. *LM – leaf mass.*

the grain (12.0 %).

The dynamics of NPK content in pea roots was similar to its dynamics in the leaf mass. The acropectral coefficients show (Fig. 1) that nitrogen was accumulated in the leaf mass before the pod formation stage. Subsequently, more nitrogen was supplied to the pods and grain, and its concentration in the leaf mass relative to the roots decreased and the coefficients of relative accumulation decreased from 1.51 (spring regrowth) to 0.49 (full maturity).

Phosphorus accumulation coefficients vary

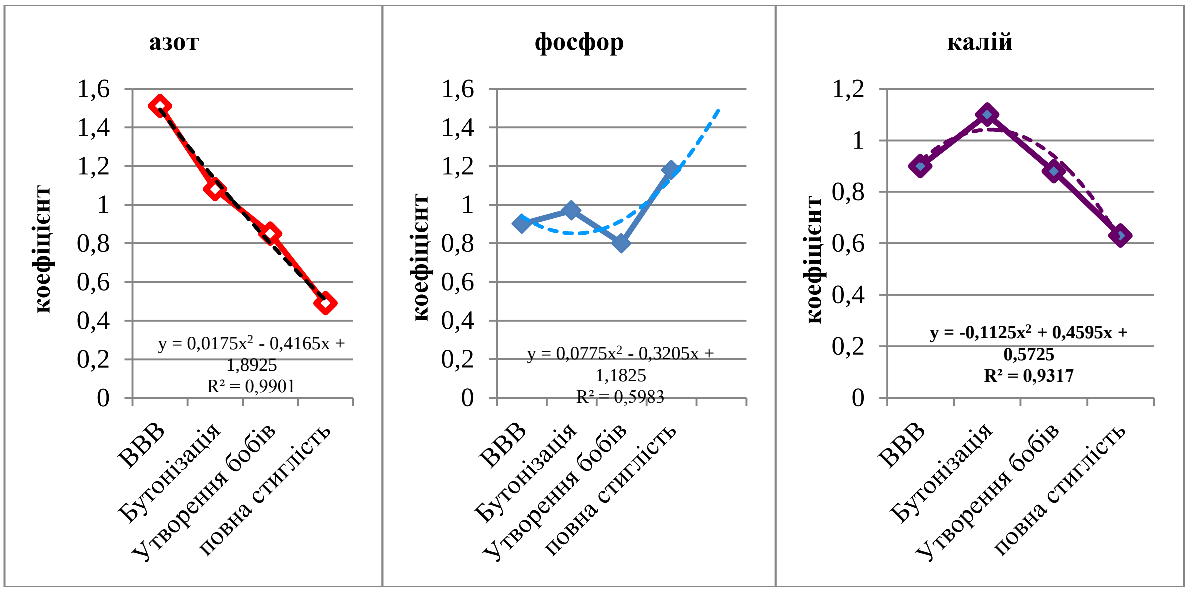


Fig. 1. Acropetal coefficients for nitrogen, phosphorus, potassium (leaf mass : roots) by the main growth and development stages of winter pea plants

within a rather narrow range (0.90...1.18), but tend to increase by the time of full maturity, i.e. at the time of harvesting its concentration in the leaf mass (straw) is higher than in the root. Acropectal coefficients for potassium decreased for all the growing season, except for the flower-bud formation stage, when the potassium content in the leaf mass exceeded its concentration in the roots by 10.0 %. Figure 1 additionally shows the trend lines and approximation coefficients, which show that the probability of such a mechanism of nitrogen and potassium accumulation in the leaf mass and roots of winter pea is very high (R^2 = 0.99 and 0.93, respectively), and for phosphorus the probability is 60 %.

The calculated coefficients of correlation between the nitrogen content in the leaf mass during the growth resumption and the flower-bud formation stage and in the grain of winter pea showed a lower than average degree of correlation, r = 0.26 and 0.36, respectively, which does not yet give grounds to define these stages as optimal for nitrogen nutrition. In this case, we should be guided by the results of a scientific experiment to study the rates and dates of fertilisation of peas. At the same time, the correlation between the nitrogen and potassium intake in grain is high (r = 0.69–0.70), and the correlation between the crop yield and nitrogen content of the vegetative mass in the stages of growth resumption and flower-bud formation is also quite high (r = 0.56 and 0.65), and between the yield and potassium content is 0.34 and 0.44, respectively.

The average concentration of microelements in pea grains is as follows: Mn – 8.11 mg/kg; Zn – 33.87; Cu – 4.72; Co – 0.39; Cd – 0.015; Pb – 0.19 mg/kg of dry matter (Table 2). The highest content is characteristic of zinc (71.6 %), and the highest deviations from the average values were noted for Co – 50.0 % and Pb – 70.0 %. However, it should be noted that even the highest lead content (0.45 mg/kg) did not exceed the maximum permissible level of this element (0.50 mg/kg).

At the period of full maturity, the microelement content in the leaf mass of winter peas (straw) was as follows: Mn – 13.50 mg/kg; Zn – 20.79; Cu – 4.22; Co – 1.52; Cd – 0.040; Pb – 0.674 mg/kg of dry matter. The fact that the content of Co, Cd and Pb in straw is 3.9, 2.7 and 3.5 times higher than in grain is noteworthy. Perhaps, winter peas have a good protective barrier on the straw-grain line, which allows these

Table 2. Microelements content in winter pea plants by growth stages, mg/kg dry matter (n=162)

	Leaf mass			Roots		
Spring regrowth						
	M ± m	Fluctuation interval	V, %	M ± m	Fluctuation interval	V, %
Mn	35.22±9.83	19.23–51.59	28.0	51.02±11.40	32.64–76.55	22.3
Zn	37.20±12.27	10.79–60.34	33.0	36.52±8.26	18.47–51.47	22.6
Cu	14.06±6.53	7.00–39.03	46.4	15.95±5.58	7.73–32.87	35.0
Co	4.15±0.85	2.91–6.18	20.4	2.90±1.16	1.03–5.24	40.0
Flower-bud formation						
Mn	48.35±10.05	28.70–67.80	20.8	55.89±16.12	20.57–876.13	28.8
Zn	30.95±6.07	19.95–49.65	19.6	31.48±7.54	20.94–50.01	24.0
Cu	20.55±9.28	7.37–38.00	45.1	22.61±6.41	11.02–39.24	28.4
Co	3.86±0.81	2.21–5.81	21.1	4.14±1.56	2.11–6.82	37.7

Podding

	Leaf mass			Pods			Roots		
	M ± m	Fluctuation interval	V, %	M ± m	Fluctuation interval	V, %	M ± m	Fluctuation interval	V, %
Mn	27.31±5.04	16.27–59.56	18.5	19.72±2.37	13.72–25.08	12.0	18.36±1.70	15.13–32.17	19.7
Zn	18.60±1.65	12.45–25.12	19.3	15.35±4.68	10.34–17.46	24.2	26.03±3.32	19.83–31.64	18.8
Cu	7.64±1.29	6.02–10.64	16.9	5.24±2.25	2.78–12.90	43.0	5.25±0.85	3.79–10.12	26.8
Co	5.02±0.64	3.70–6.42	12.7	2.00±0.71	0.88–3.59	35.2	4.30±1.21	2.90–6.81	29.1

Full maturity

	Grain				Straw		
	M ± m	Fluctuation interval	V, %	МДР*	M ± m	Fluctuation interval	V, %
Mn	8.11± 0.67	6.68–9.12	8.3	-	13.50± 1.41	9.16–18.91	25.2
Zn	33.87± 4.60	26.31–42.62	13.6	50/50	20.79±4.20	15.75–29.51	20.2
Cu	4.72± 0.59	3.83–5.81	12.6	10/30	4.22±0.84	3.26–5.61	20.0
Co	0.39± 0.19	0.15–0.69	50.0	-	1.52±0.36	1.19–2.06	23.6
Cd	0.015±0.003	0.011–0.021	21.2	0.1/0.3	0.040±0.026	0.016–0.078	65.5
Pb	0.190±0.034	0.020–0.450	70.7	0.5/5.0	0.674±0.171	0.370–0.876	25.3

*Note. *MPL – maximum permissible level (DSTU4523:2006); numerator - grain for food purposes, denominator - grain for feed purposes [1].*

elements to enter the grain in lower concentrations.

At the same time, the transfer of cadmium and lead from the root to the leaf mass of pea during the main spring and summer periods of

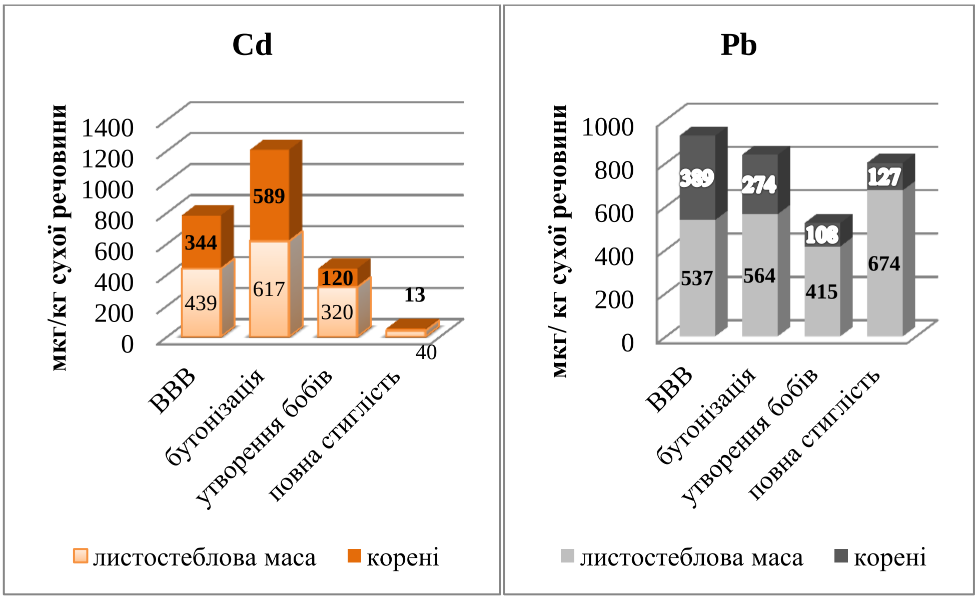


Fig. 2 Dynamics of toxic metals content in leaf mass and roots of winter peas

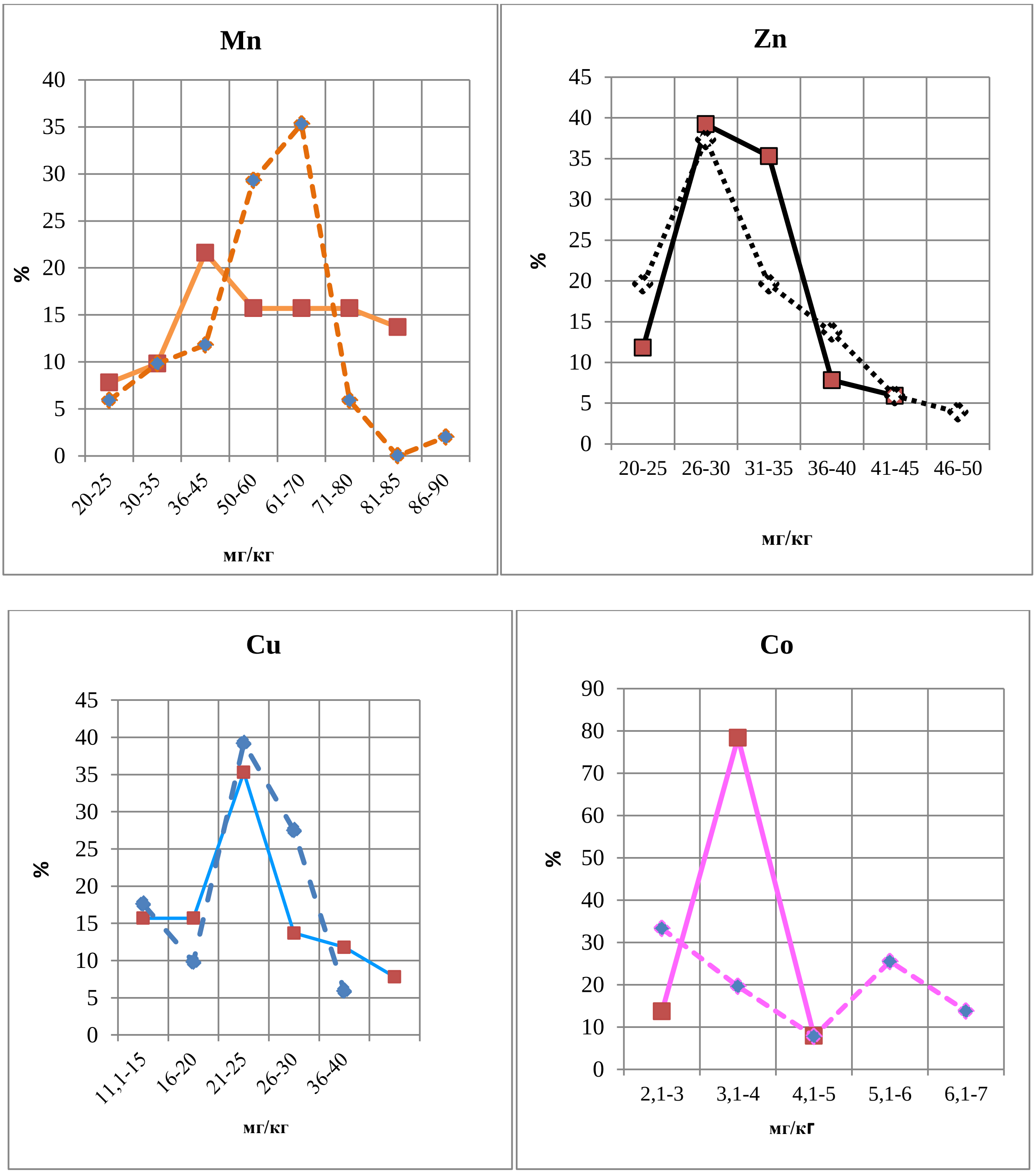
plant growth is easy, since the concentration of Cd and Pb in the aboveground mass exceeds their content in the roots (Fig. 2). The accumulation coefficients of Cd in the leaf mass relative to the root are in the range of 1.3–1.1–2.7–3.1, and Pb: 1.4–2.1–3.8–5.3, which indicates a low intensity of root barriers to the flow of toxicants to the ground organs of winter pea during the growth and development stage.

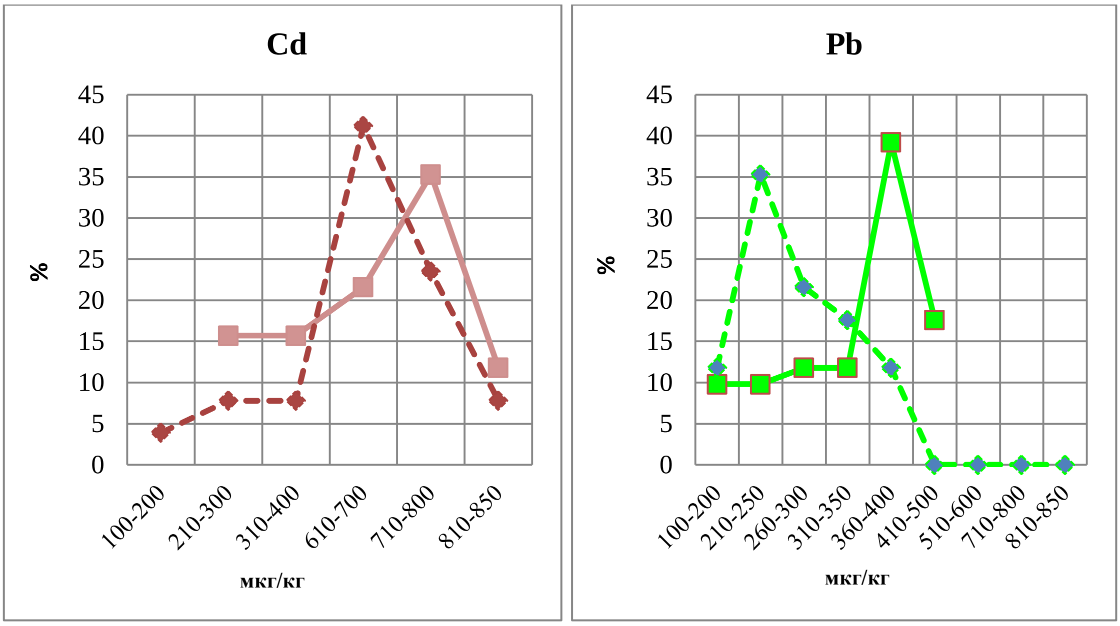
The maximum Cd content in leaf mass was observed in the flower-bud formation stage (617 μg/kg). In fact, Cd has a high rate of penetration into plants, especially in dry years [10, 12]. Such observations are confirmed by our data, since the three years of sampling (2020–2022) were characterised by severe drought.

In general, the content indicators and coefficients of variation indicate a higher variability of the microelement composition of all structural parts of winter pea (V=12.7–70.7 %) than the macroelement composition (V = 7.7–48.3 %).

For a visual representation of the size characteristics of the studied pea samples, empirical curves of the frequency distribution of microelements in the Southern Steppe were constructed. As an example, we took the distribution of microelements in the leaf mass and roots of pea in the flower-bud formation stage, which are shown in Fig. 3.

In the leaf mass of pea during the budding





______ – microelement content in leaf mass; _ _ _ _ – in root

Fig. 3 Distribution curves of microelements concentrations in the root and leaf mass of winter peas in the flower-bud formation stage

period, 23 % of Mn concentrations were in the interval of 36–45 mg/kg, and 53 % were in the interval of 50–80 mg/kg; in the roots, the majority of values (67 %) were in the interval of 50–70 mg/kg. The peaks of Zn content in the leaf mass and roots practically coincide in the interval of 26–30 mg/kg; 75 % of its values in the aboveground mass are in the interval of 26–35 mg/kg. A similar pattern of peaks is typical for Cu: 35–39% of the values lie in the interval of 21–25 mg/kg; in the roots, 67 % of the total values belong to 21–30 mg/kg. The maximum of Co values of leaf mass (80 %) corresponds to concentrations from 3.1 to 4.0 mg/kg, and the frequency of repeated content of this element in pea roots has two small peaks: in the interval of 2.1–3.0 mg/kg (32 %) and 5.1–6.0 mg/kg (28 %).

The leaf mass of winter peas is characterised by rather high frequencies of Cd concentrations (35 %) in the interval of 710–800 µg/kg, and in pea roots most of the values (42 %) are in the interval of 610–700 µg/kg. The frequency of Pb distribution in pea plants is as follows: in the leaf mass 45 % is in the interval of 100–350 µg/kg, and 40 % – 360–400 µg/kg; in the roots 56 % – 210–300 µg/kg, including 35 % – 210–250 µg/kg.

Conclusions. The average values of nitrogen, phosphorus, potassium and microelements in grain and by-products of winter pea, which are background for the Southern Steppe of Ukraine, were found.

The microelement composition in leaf mass, grain and roots of winter pea is subject to significant fluctuations. A higher variability of microelement composition (12.7–70.7 %) was noted in contrast to the NPK content (7.7–48.3 %).

It was found that root barriers have low resistance to the entry of toxicants Cd and Pb into the ground organs of winter pea over the entire growing season and high intensity of leaf mass resistance to the absorption of these metals by grain.

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Одеська державна сільськогосподарська дослідна станція Інституту кліматично орієнтованого сільського господарства НААН, вул. Маяцька дорога,24, смт. Хлібодарське, Одеська обл., 67667, Україна

Актуальність. Інтродукція у виробництво нових різновидів чи сортів сільськогосподарських культур потребує вивчення їх хімічного складу, оскільки останній залежить від кліматичних умов регіону та технологій вирощування. Тому є доцільним вивчення особливостей формування макро- та мікроелементного складу нового різновиду гороху: гороху підзимової сівби (озимого) в погодно-кліматичних умовах Південного Степу. **Мета** – оцінка хімічного складу рослин гороху підзимової сівби та особливості розподілу макро- і мікроелементів за структурними частинами рослин і фазами їх розвитку в Південному Степу України. **Матеріали і методи.** Матеріалом були зразки гороху підзимової сівби, відібрані за фазами росту в стаціонарному і тимчасових дослідах та виробничих і апробаційних посівах агроформувань Одеської області; використовували: лабораторний метод – визначення азоту, фосфору, калію та мікроелементів; статистичний – виконання кореляційного, дисперсійного аналізу та статистичної оцінки результатів досліджень. **Результати.** Наведені результати досліджень хімічного складу рослин гороху підзимової сівби в умовах південно-степової зони України. Встановлено особливості акумуляції та розподілу макро- і мікроелементів листостебловою масою, зерном та корінням гороху озимого. Спостерігається тенденція до підвищення швидкості находження токсичних елементів до вегетативної маси рослин гороху та зниження – при переході із листостеблової маси до зерна. **Висновки.** Визначено середні значення вмісту азоту, фосфору, калію та мікроелементів в зерні та побічній продукції гороху підзимової сівби, які є фоновими для зони південного Степу України. Мікроелементний склад листостеблової маси, зерна та коренів гороху озимого зазнає суттєвих змін. Відмічена більш висока варіабельність мікроелементного складу (12,7–70,7 %) на відміну від вмісту NPK (7,7–48,3). Визначено низьку протидію кореневих бар’єрів надходженню токсикантів Cd і Pb до наземних органів гороху підзимової сівби протягом всього періоду вегетації та високу інтенсивність протидії листостеблової маси поглинанню цих металів зерном.

Ключові слова: *горох, підзимова сівба, мікроелементи, азот, фосфор, калій, вміст*