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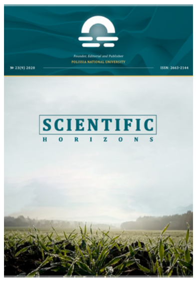

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Ecological stability, plasticity, and adaptability of cowpea varieties (*Vigna unguiculata* (L.) Walp. *subsp. sesquipedalis* (L.) Verdc.)

Iryna Bobos
PhD in Agricultural Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0001-5193-7192

Oleksandr Komar*
PhD in Agricultural Sciences
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0001-7511-4190

Ivanna Havrys
PhD in Agricultural Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0001-5965-9916

Oleksandr Shemetun
PhD in Agricultural Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0001-7129-9108

Vasyl Kokoiko
PhD in Agricultural Sciences, Senior Research Fellow
Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences
67667, 24 Mayatska Doroga Str., Khlybodarske Village, Ukraine
https://orcid.org/0000-0002-2528-7920

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Abstract. Determining the ecological plasticity and stability of varieties and hybrids of agricultural crops helps to comprehensively assess them, considering the productivity potential, qualitative technological indicators, and the level of resistance to stressful conditions. The purpose of this study was to investigate the development of the yield of beans of cowpea varieties with high ecological stability, plasticity, and adaptability. The leading methods of studying this problem are field-based – to determine the

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*Corresponding author

interaction of the research object with biotic and abiotic factors; statistical – to evaluate the results to determine the parameters of cowpea adaptability. Within the studied varieties, a direct and inverse correlation was established between the yield of cowpea and the sum of effective temperatures. For Groik (r = 0.36) and Kafedralna (Control) (R = 0.36), U-Cha-Kontou (r = -0.64) varieties, the correlation was average, while for Gasson (r = 0.96) and American improved (r = -0.98) varieties, it was strong. Based on the regression equations, an increase in the amount of precipitation by 1 mm can increase the yield of cowpeas by 3.4 kg/ha in the American improved variety and by 20.8 kg/ha – U-Cha-Kontou, and for the Gasson, Kafedralna (control), Groik varieties, there will be a decrease in yield by 6.4 kg/ha, 10.8 kg/ha, and 20.7 kg/ha, respectively. Varieties with high overall adaptive capacity, defined as the ability of genotypes to maximise the manifestation of traits under all environmental conditions, are valuable. High indicators of total adaptive capacity for plant yield were observed in the varieties Gasson (TAC = 5.16) and Groik (SAC = 2.16). The lowest value of this indicator was observed in the U-Cha-Kontou variety (TAC = -3.44). Varieties that produce high but unstable yields are not able to guarantee maximum yields in conditions of improper farming and difficult climatic conditions. The genotype breeding value is a complex indicator that determines the totality of productivity and stability of varieties. Studies have obtained such fluctuations in this indicator from 0.84 to 13.63. The best varieties in terms of genotype breeding value were Gasson (GBVi = 13.63) and Kafedralna (GBVi = 8.06). There is a relatively low yield stability and the ability to respond to improved growing conditions in the U-Cha-Kontou variety (GBVi = 0.84)

Keywords: legumes; seedpods; technical ripeness; yield, stability; adaptability; plasticity

INTRODUCTION

The population of the whole world, as in Ukraine, is changing approaches to nutrition, which consists in increasing the consumption of products from less common crops. More and more Ukrainians, along with traditional vegetables, require less well-known ones, which are valued for their medicinal properties and are safe for human health. Supermarkets and wholesale markets offer a small number of sparsely distributed vegetable crops. The main reason in Ukraine is the insufficient supply of new products. Over the past decades, the world's food system has experienced several crises, including climate change and the COVID-19 pandemic, war that has disrupted markets and supply chains, and raised concerns about food security. The military conflict between Russia and Ukraine also undermines important principles of food security, as Ukraine has long been known as the breadbasket of Europe (Rabbi *et al.,* 2023).

In this context, sparsely distributed vegetable legumes are a significant factor in meeting the needs of the population in a balanced diet. Vegetable legumes are a valuable source of carbohydrates, vitamins and minerals, and biologically active substances that promote health. Due to the growing awareness of consumers about a balanced diet, there is a constant increase in demand for fresh and processed legumes and vegetables. With this in mind, maintaining optimal yields of vegetable legumes is extremely important (Dhaliwal *et al.,* 2020; Fedosiy *et al.,* 2022).

Despite the significant impact of legumes on global food and food security, solving the problem of restoring and preserving soil fertility, there is also an opinion that their production volumes are still unsatisfactory, compared to the need for them, due to biotic and abiotic factors (Ojiewo *et al.,* 2019; Tanchyk *et al.,* 2021; Hnatiuk *et al.,* 2023). Among legumes, representatives of the genus Vigna unguiculata are becoming increasingly socio-economic, especially in countries where the local population cannot afford animal proteins. According to M. Guney *et al.* (2021), cowpea is a low-calorie source of protein, which makes it worth adding to the diet, especially for those who are vegetarian or prone to obesity. B. Abebe and M. Mulugeta (2022) and A. Quamruzzaman *et al.* (2022) noted that cowpea contains dietary fibre, a number of vitamins and minerals, and is also characterised by a high content of phytochemical antioxidants. It belongs to the category of healthy and high-quality food products.

The value of the crop is its high heat, drought and salt resistance, and the ability to grow it for vegetables, seeds, green manure, and feed. However, annual warming and rising air temperatures accelerate the growth and development of the crop, reducing the duration of phenological phases. Under stressful conditions, plants change their metabolism for optimal development, which is conditioned by increased respiration (Dehodyuk *et al.,* 2021). J. Barros (2021) pointed out that the crop reacts negatively to increased water scarcity and rising temperatures. It is the study of the ecological stability, plasticity, and adaptability of cowpea plants that can help producers change growing technologies to maintain sustainable crop production.

In 2008-2010, for the first time in the northern Forest-Steppe, cowpea varieties were studied and evaluated for early maturity, morphological characteristics, productivity, yield of seedpods and ripe seeds at the Department of Vegetable Crops and Indoor Greenhouse at the National University of Life and Environmental Sciences of Ukraine (Bobos *et al.*, 2022). The selected source material of varietal samples of cowpea was used in breeding work as parent forms. As a result of breeding, the first Kafedralna variety of cowpea was created, which in 2024 was listed in the State register of plant varieties (2024).

Nowadays, there is a growing interest in the consumption of cowpea, but it remains sparsely distributed. Given the climatic conditions that change every year, there is a need for a comparative assessment of cowpea varieties by phenological, morphological, and economically valuable characteristics. With this in mind, comprehensive research on introduction, creation, and replenishment of the Ukrainian gene pool, and selection of promising samples for further breeding work will significantly expand the range of economically valuable plants aimed at developing the agricultural sector and ensuring a high quality of life for the population. That is why the purpose of this study was to investigate the development of the yield of seedpods of cowpea varieties with high ecological stability, plasticity, and adaptability.

MATERIALS AND METHODS

During 2014-2016, the following cowpea varieties were studied: Groik (Israel), Kafedralna (Ukraine), Gasson (Vietnam), American improved (USA), U-Cha-Kontou (China). Variety samples were obtained from the National Centre for Plant Genetic Resources of Ukraine (n.d.). The research was conducted in the training laboratory "Fruit and vegetable garden" at the collection plots of the Department of Vegetable Crops of the National University of Life and Environmental Sciences of Ukraine The plot was located on soddy-medium podzolic soils in the northern part of the Forest-Steppe region of Ukraine. The field study was conducted according to the methodology of one-factor experiments (Bondarenko & Yakovenko, 2001). Repeatability – three times with randomisation. The accounting area – 5 m^2. The control was the Kafedralna variety, which has been approved for use in Ukraine since 2014. The variety was created by the staff of the Department of Vegetable Crops of NUBiP of Ukraine (authors: I.M. Bobos, Z.D. Sych, I.O. Fedosiy, O.O. Komar).

Research continued in 2022-2023 within the framework of the state programme "Development of innovative technologies for growing sparsely distributed vegetable crops" (state registration number: 0122U001637). An examination of the new variety was carried out for the purpose of state registration of the variety for distribution in Ukraine and state registration of rights to it. In 2023, Certificate No. 230516 on state registration and Patent No. 230332 for the Kafedralna cowpea variety (*Vigna unguiculata* (L.) *Walp. subsp. sesquipedalis* (L.) Verdc.) were obtained.

Technology of growing cowpea varieties, adopted in production conditions. Sowing scheme – 70×25 cm. Seed embedding depth – 2-3 cm. Seeds of varieties together with the control were sown simultaneously on May 13 in all years of the study. Plant care consisted of mulching, systematic loosening, protection from weeds, diseases, and pests. During the field method, phenological phases were noted: full shoots, the beginning and full flowering, the beginning of harvesting ripeness of pods, and economic ripeness of pods. The beginning of maturation was noted for the maturation of the predominant number of pods (more than 75%). The duration of the growing season was determined from sowing to the date of economic ripeness. The period from sowing to germination in varieties ranged from 12 to 17 days and passed with an average sum of effective temperatures of 70.2-105.7°C and precipitation of 42.8-56.8 mm.

Harvesting of pods in technical ripeness was carried out weekly on all variants of the experiment simultaneously. Before harvesting, biometric measurements were made, namely, the length of the central stem was measured and the number of side shoots on the plants was counted. During harvesting, the length of the pod was measured and the number, weight of pods on the plant, and the number of seeds in one pod were determined. The response of a variety to growing conditions characterises the total adaptive capacity (TAC) – the average value of the trait in different environmental conditions, specific adaptive capacity (SAC) – a deviation from the total in a particular environment. Stability is characterised by the ability of a genotype to maintain a specific phenotype under various growing conditions as a result of regulatory mechanisms. Plasticity (bi-regression coefficient for the environment) is the response of a genotype primarily to changes in environmental conditions, expressed in phenotypic variability (Tyshchenko *et al.,* 2023).

A population study with n genotypes in m environments was used for the determination of TAC and SAC. The number of repetitions in this case is c:

$$x_{ikr} = U + V_i + d_k + (Vd)_{ik} + e_{ikr}, \quad (1)$$

where X_{ikr} – phenotypic value (*i*) of genotype grown in (*k*) environment in (*r*) repetition; *U* – total average of the entire set of phenotypes; V_i – effect of (*i*) genotype; d_k – effect of (*k*) environment; $(Vd)_{ik}$ – effect of interaction of (*i* genotype with (*k*) environment; e_{ikr} – effect caused by random causes and attributed to (*ekr*) phenotype.

Model elements have a set of the following restrictions:

$$\sum_i v_i = \sum_k d_k = \sum_k (vd)_{ik} = \sum_k (vd)_{ik} = \sum e_{ik} = 0. \quad (2)$$

At the first stage of evaluating the parameters of TAC and the stability of varieties, a two-factor analysis of variance was performed. The second stage of evaluation included the establishment of TAC, SAC, and stability of varieties. According to the definition, the effect of the total adaptive capacity of the TACi variety is Vi. Deviation from the sum of *U+Vi* is the effect of the specific adaptive capacity of the variety in the *R* medium – SAC_{iR}. This effect combines a linear (*R* medium effect) and a nonlinear part (interaction effect $(Vd)_{iR}$).

The SAC parameters of cowpea are defined as follows:

$$\sigma^2\ SAC_i\ = \frac{1}{m-1} * \sum_R (d_R + Vd_{iR})^2 - \frac{m-1}{m} * \sigma^2. \quad (3)$$

$$\sigma\ SAC_i\ = \sqrt{\sigma^2\ \text{CA3}_i}\ . \quad (4)$$

The values of relative stability S_{gi} used to compare the variability of different characteristics of varieties:

$$S_{gi} = \frac{\sigma \text{CA3}_i}{U + 3A3} * 100\ \%. \quad (5)$$

Regression coefficient b_i was defined:

$$b_i = \frac{\sum X_{iR} * d_R}{\sum_R d_R^2}. \quad (6)$$

The genotype breeding value (GBVi) was used to identify cowpea varieties that combine productivity and stability:

$$GBV_i = U + 3A3_i - p\sigma_{CA3_i}. \quad (7)$$

The sum of effective air temperatures was calculated by the formula:

$$\sum t_{ef} = (t_{avg} - B) * n, \quad (8)$$

where $\sum t_{ef}$ – sum of effective air temperatures for the period, °C; t_{avg} – average active air temperature for the period, °C; b – biological minimum, which in this study was taken as 10°C; n – number of days in the period.

Variance (ANOVA) and correlation analysis were performed using the XLSTAT add-in in MS Excel software suite. The differences were considered significant for the validity of $\alpha = 0.95$ (Rao, 2018). The authors adhered to the standards of the Convention on Biological Diversity (1992) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1979).

RESULTS

As a result of a study of the yield of commercial seedpods in 5 cowpea varieties with 3 replications of the experiment and 3 replications in time (2014, 2015, 2016) with a sample size n = 45. The approximate number of groups was $\sqrt{45}$, so 7 groups were selected. In this case, the interval value will be 1.7. A visual representation of the frequency distribution is shown in Figure 1. A step graph (histogram) in the form of columns has a height proportional to the frequencies, and its width, equal to the class intervals, the distribution curve connects the average values of groups with a line.

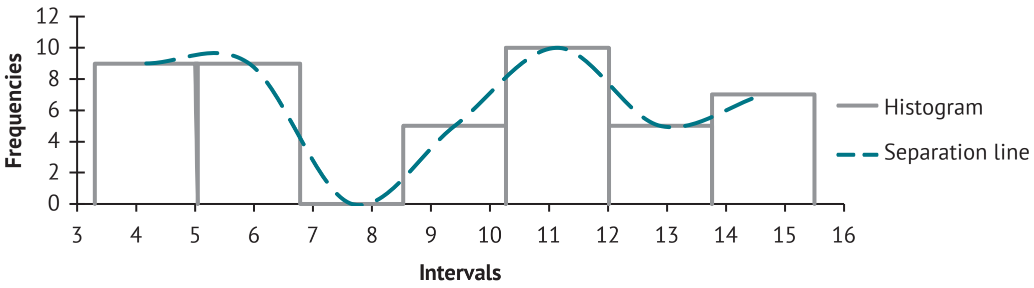

***Figure 1**. Histogram and yield distribution curve of commercial seedpods of cowpea varieties (2014-2016)*
***Source:** developed by the authors based on the conducted research*

Based on the obtained data of the variance analysis $F_{fact.} > F_{crit} = 459.684 > 3.47804$, which indicates the reliability of these differences at the level of $P_{0.95}$ (Table 1).

***Table 1**. Results of one-factor analysis of variance (2014-2016)*

Sourse of Variation	SS	df	MS	F	P-value	F crit
Bethwein Groups	209.616	4	52.404	459.684	2.76576 E-11	3.47804
Winter Groups	1.14	10	0.114			
Total	210.756	14				

***Source:** developed by the authors based on the conducted research*

Judging by the coefficient of determination (R^2 = 0.13-0.95), approximately 2% in the Groik variety, 17% – U-Cha-Kontou, 43% – Kafedralna (control), 84% – Gasson, and 91% – American improved) of changes in the yield of seedpods were conditioned by changes in the sum of effective air temperatures and only, respectively, by 98%, 83%, 57%, 16%, and 9% of the changes were conditioned by other factors. Within the variants under study, a direct and inverse correlation was established between the yield of cowpeas and the sum of effective temperatures. For Groik (r = 0.36) and Kafedralna (Control) (R = 0.36), U-Cha-Kontou (r = -0.64) varieties, the correlation was average, while for Gasson (r = 0.96) and American improved (r =v -0.98) varieties, it was strong.

Based on the regression equations presented in Figure 2, it can be assumed that an increase in the sum of effective temperatures by 1°C corresponds to both an increase in the yield of seedpods for the varieties Groik (2 kg/ha), Kafedralna (control) (2.5 kg/ha), Gasson (2.2 kg/ha), and a decrease – for the varieties American improved (2.0 kg/ha), U-Cha-Kontou (2.4 kg/ha). According to the coefficients of determination (R^2 = 0.02 - 0.96), about 2% of the yield variation in the varieties American improved, 25 % – Gasson, 65 % – Cathedral (control), 94% – Groik, and 96% – U-Cha-Kontou was due to a change in the amount of precipitation, but the rest 98%, 75%, 35%, 6%, and 4% of the variation, respectively, was due to the influence of other factors.

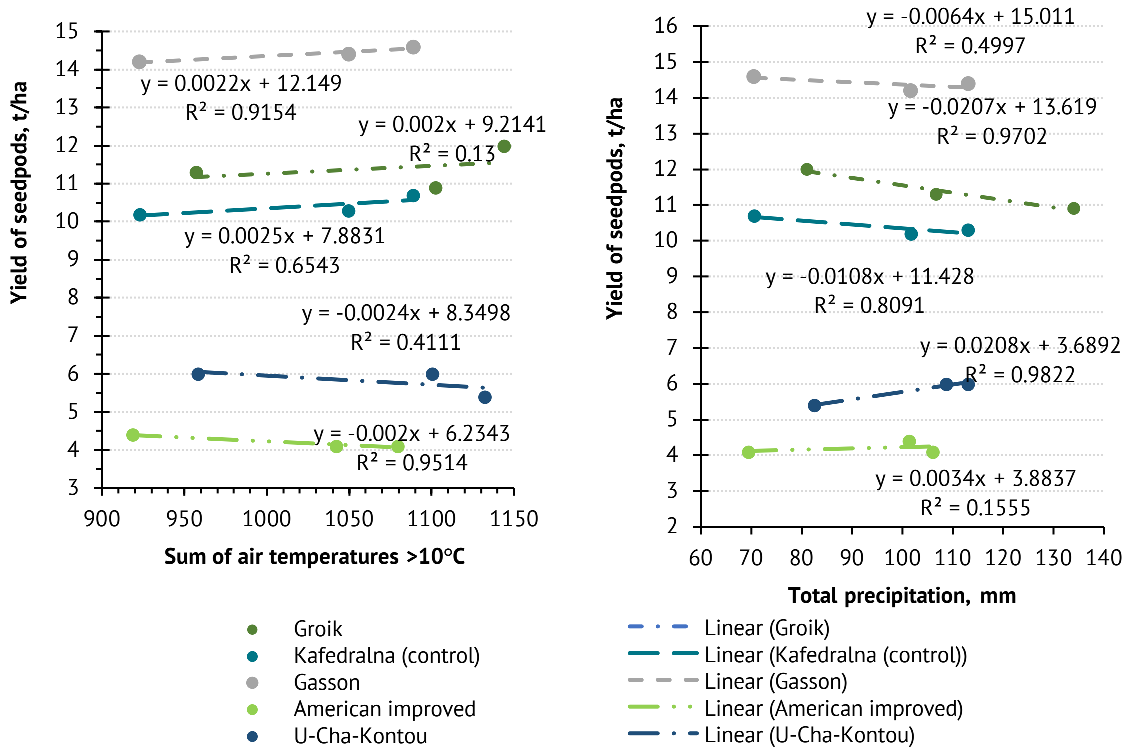

***Figure 2**. Dependence of the yield of cowpea seedpods between the sum of effective air temperature (left) and precipitation (right) (2014-2016)*
***Source:** eveloped by the authors based on the conducted research*

It turned out that among the varieties under study, the yield directly and inversely depended on the amount of precipitation. The correlation was average for the American improved variety (r = 0.39), and strong for the Gasson (r = 0.71), Kafedralna (control) (r = -0.90), Groik (r = -0.98), and U-Cha-Kontou (r = 0.99) varieties. Based on the regression equations, an increase in the amount of precipitation by 1 mm can increase the yield of cowpeas by 3.4 kg/ha in the American improved variety and by 20.8 kg/ha – U-Cha-Kontou, and for the Gasson, Kafedralna (control), Groik varieties, there will be a decrease in yield by 6.4 kg/ha, 10.8 kg/ha, and 20.7 kg/ha, respectively.

The range of feature variability allows assessing a certain influence of the environment on the expression of quantitative parameters. A higher scope means a greater environmental impact. Samples that have a low range of variations, regardless of the growing environment, are more stable. This means that the degree of influence of the genotype on the severity of the trait in them is greater than the influence of the environment. The smallest yield range of seedpods was found in the varieties American improved (0.3 t/ha) and Gasson (0.4 t/ha). This indicates that the boundaries in which the value of the trait changes narrow when the growing conditions of these varieties worsen. The largest range of variation of this trait was observed in the Groik variety (1.1 t/ha) (Fig. 3). Varieties with high overall adaptive capacity, defined as the ability of genotypes to maximise the manifestation of traits under all environmental conditions, are valuable. High indicators of total adaptive capacity according to plant yield was observed in the varieties Gasson (TAC = 5.16) and Groik (TAC = 2.16). The lowest value of this indicator was observed in the U-Cha-Kontou variety (TAC = -3.44) (Fig. 4). The specific adaptive capacity allows assessing the level of stability of varieties – the lower the value of this indicator, the more stable the variety. The Gasson (SAC = 0.015) and American improved (SAC = 0.005) varieties were the most stable in the study.

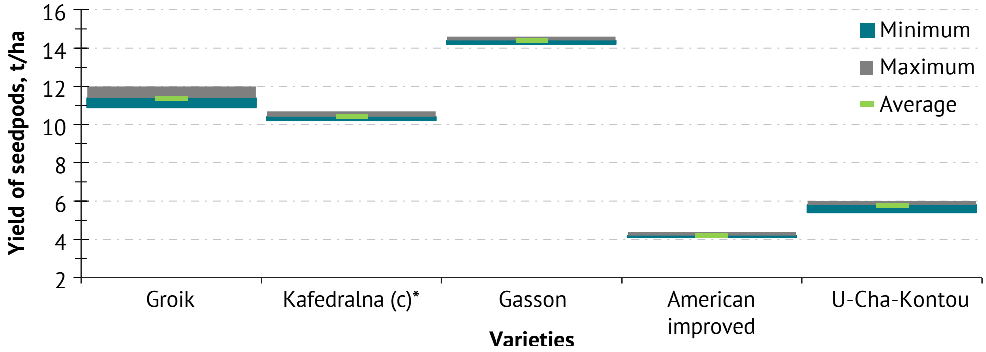

***Figure 3**. Yield of seedpods of cowpea varieties, t/ha (2014-2016)*

***Note:** (c)* – control*

***Source:** developed by the authors based on the conducted research*

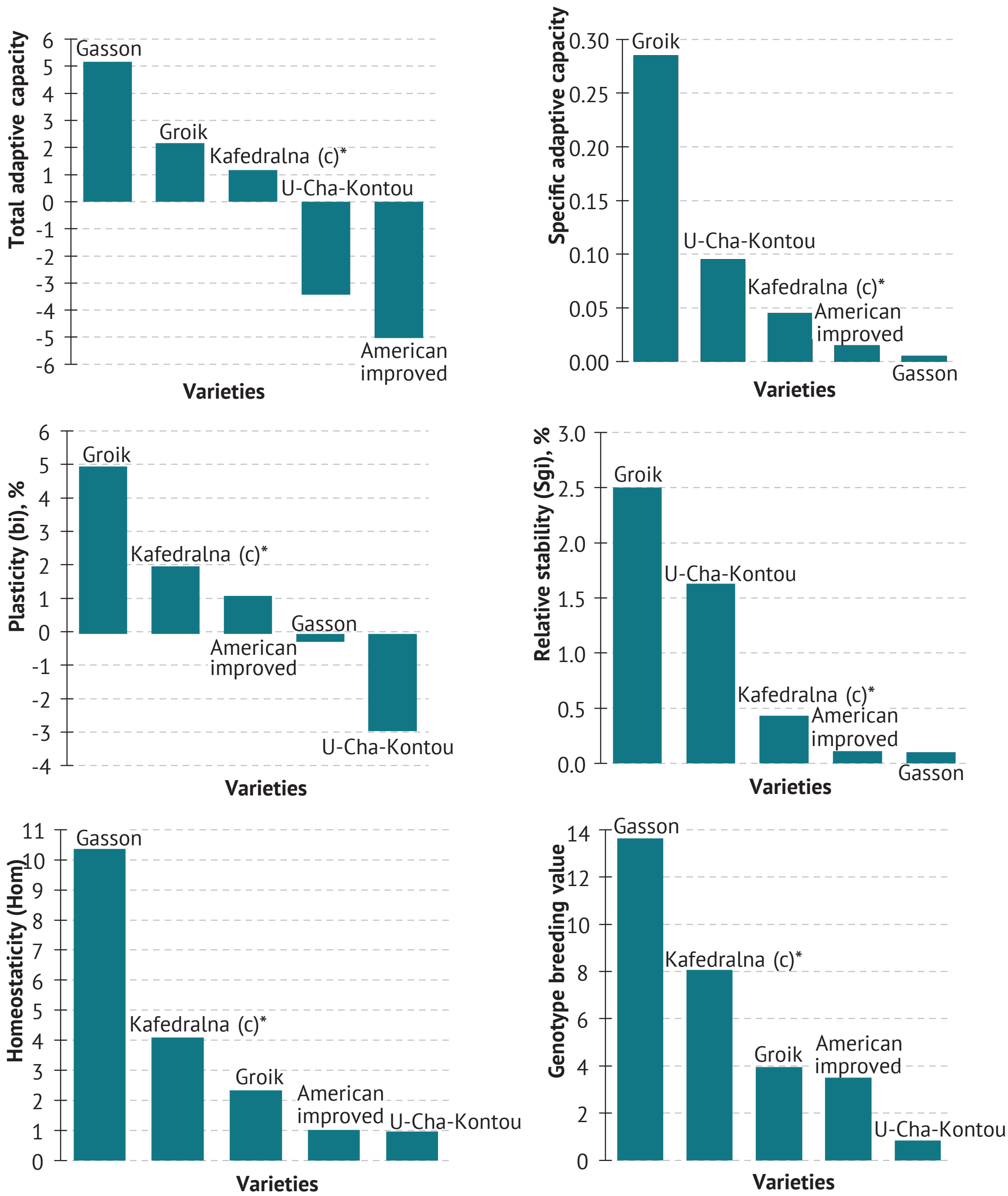

***Figure 4**. Parameters of adaptive capacity and stability of cowpea varieties: (2014-2016)*

***Note:** A) total adaptive capacity; B) specific adaptive capacity; C) relative stability (Sgi); D) plasticity (bi); E) homeostasis (Hom); F) genotype breeding value (GBVi); (c)* – control*

***Source:** developed by the authors based on the conducted research*

When assessing relative stability (Sgi), it was found that all the varieties have a high stability in the range of 0.10 to 2.50 %. The plasticity coefficient is a measure of adaptive ability. The higher the coefficient, the more sensitive the variety is to improved growing conditions, and this may indicate its ability to make the best use of favourable environmental conditions. At the same time, it is less stable in the event of deterioration of growing conditions. A coefficient value of less than 1 indicates both greater stability of the variety and a worse ability to respond to better growing conditions with an increase in the quantitative trait. The variety does not respond to changes in environmental conditions when bi = 0. The Groik variety had the highest regression coefficient (5.0), therefore, it has a high sensitivity to growing conditions. A value close to 1 was observed in the Gasson variety (bi = 1.13). Varieties American improved and U-Cha-Kontou had a bi coefficient in the range from -0.24 to -0.29, therefore, they have a low level of sensitivity to any changes in the environment (stable). Such a variety provides a guaranteed high yield in any growing conditions.

A higher homeostatic index, compared to the control, was observed in the Gasson variety (Hom = 10.37). Varieties that produce high but unstable yields are not able to guarantee maximum yields in conditions of improper farming and difficult climatic conditions. The genotype breeding value is a complex indicator that determines the totality of productivity and stability of varieties. In this study, this indicator ranged from 0.84 to 13.63. The best varieties in terms of genotype breeding value were Gasson (GBVi = 13.63) and Kafedralna (GBVi = 8.06). There is a relatively low yield stability and the ability to respond to improved growing conditions in the U-Cha-Kontou variety (GBV_i = 0.84).

Using the correlation calculation, a direct strong relationship was established between the average yield and genotype breeding value (GBVi) (r = 0.77), homeostasis (Hom) (r = 0.84), total adaptive capacity (TAC) (r = 0.99); between the range of variation and relative stability (Sgi) (r = 0.94), specific adaptive capacity (SAC) (r = 0.99); between the coefficient of variation and relative stability (Sgi) (r = 0.71); between total adaptive capacity (TAC) and homeostasis (Hom) (r = 0.84), genotype breeding value (GBVi) (r = 0.77); between specific adaptive capacity (SAC) and relative stability (Sgi) (r = 0.94); between homeostasis (Hom) and genotype breeding value (GBVi) (r = 0.96).

An inverse strong correlation was found between the average yield and the coefficient of variation (r = -0.68); between the coefficient of variation and total adaptive capacity (TAC) (r = -0.68), homeostaticity (Hom) (r = -0.87), and the genotype breeding value (GBVi) (r = -0.97). The presence of a direct average relationship was established: between the average yield and plasticity (bi) (r = 0.62); between the range of variation and the coefficient of variation (r = 0.46), plasticity (bi) (r = 0.62); between the coefficient of variation and specific adaptive capacity (SAC) (r = 0.51); between total adaptive capacity (TAC) and plasticity (bi) (r = 0.62); between specific adaptive capacity (TAC) and plasticity (bi) (r = 0.62); between specific adaptive capacity (SAC) and plasticity (bi) (r = 0.61).

An inverse average correlation was found: between the range of variation and the genotype breeding value (GBVi) (r = -0.38); between specific adaptive capacity (SAC) and the genotype breeding value (GBVi) (r = -0.44); between relative stability (Sgi) and homeostaticity (Hom) (r = -0.46), and the genotype breeding value (GBVi) (r = -0.62).

DISCUSSION

Cowpeas perform well in semi-arid tropics, where other legumes cannot thrive. Due to its ability to grow in extreme conditions, cowpea is a suitable choice in the face of climate change (Ayalew & Tarek, 2022). Q. Cui *et al.* (2023) reported that 4 drought-tolerant samples were identified among 36 Arkansas cowpea lines. O. Olorunwa *et al.* (2022) confirmed that the UCR 369 genotype can develop adventitious roots and provide biomass accumulation during waterlogging. The photosynthetic response to waterlogging varied between tolerant and sensitive cowpea genotypes. According to the study, excessive precipitation was observed in May 2016, where the difference between the average long-term precipitation was 102 mm. Waterlogging led to an increase in the concentration of CO_2 in the root zone of plants, and to a decrease in hydraulic conductivity, which as a result, caused rapid closure of stomata.

The study of the effect of temperature stress on pollen is extremely important, as the viability of pollen grains is one of the key indicators for assessing plant tolerance to temperature stress (Havryliuk *et al.,* 2022). In San Francisco, the cowpea variety BRS Gurguéia has proven itself well, which under conditions of temperature stress maintained greater pollen viability with a lower level of flower abortivity and, as a result, provided a higher yield (Barros *et al.,* 2024). Our research also confirms that high temperatures affected the metabolism of cowpea plants, causing changes in plant growth. However, the varieties had different physiological responses due to each variety's different need for thermal energy.

Soil salinity is one of the key abiotic factors limiting the productivity of cowpea plants. For the most part, salinity negatively affects growth processes, reproductive characteristics such as the number of flowers, bean development, seed yield and size, thus affecting the final yield (Le *et al.,* 2021). W. Ravelombola *et al.* (2019) found that PI582438 variety had a lower percentage of dead plants, increased chlorophyll content, and a lower rate of leaf damage.

In recent years, heavy metal toxicity has become one of the most serious threats to agricultural production, which may become even more urgent in the coming decades (Tonkha *et al.,* 2020). In particular, the effect of heavy metal toxicity on cowpea is evident in almost all plant tissues and at all stages from seed germination to ageing, although these effects are strongest during seed germination and root system growth (Riyazuddin *et al.,* 2021). A. Ahmad *et al.* (2023) proved that the use of rhizobacteria is an effective tool for improving the growth and physiological parameters of cowpea in conditions of lead contamination. Some of the most serious bacterial infections of cowpea are *Xanthomonas axonopodis pv. vignicola (Xav)* and *Xanthomonas citri pv. glycines (Xcg)*, causing serious damage to crops (Mahmoud, 2021). Depending on the time and intensity of infection, viral diseases can cause crop losses from 10% to 100% (Mekonnen *et al.,* 2022). In August, a summer drought was observed, and intense dews at the end of August led to the development of diseases (bacteriosis, anthracnose), which reduced the marketability of products.

Cowpea is damaged by insects at all stages of growth and development. Aphids are the first major pest to settle in the early stages of development (Mofokeng & Gerrano, 2021). According to the study, dry weather was often observed in May, which led to intensive infestation of plants by bean aphids. Plants inhabited by aphids were distinguished by the presence of sticky honeydew, which is a favourable environment for the development of mould. In such plants, a decrease in the effective leaf area was observed, which significantly reduced the level of photosynthesis.

Cowpea is one of the most valuable leguminous crops that ensures food and food safety. Due to its nutritional value, it is in demand all over the world. Although the climatic conditions prevailing in Ukraine are not so difficult in terms of drought and high temperatures, in contrast to the tropical climate, in which cowpea is mainly grown, it is exposed to numerous abiotic and biotic influences, and other factors that reduce its yield. However, the genetic resources of cowpea in most cases remain unexploited. Therefore, to further unlock its potential, it is necessary to create highly productive varieties with a variety of purposes, high nutritional value and adapted to the climatic and soil conditions of the region.

CONCLUSIONS

According to the results of studies on cowpea in the conditions of the northern forest-steppe of Ukraine, it was established that the maximum level of yield of seedpods was provided by the Gasson variety (14.4 t/ha), the minimum – by the American improved variety (4.2 t/ha). The maximum range of yield variation (Max-Min) ranged from 0.3 to 1.1 t/ha. A low value of linear yield regression (bi < 1) was found only in the varieties American improved and U-Cha-Kontou, therefore, such varieties respond less to changes in environmental conditions than on average the entire set of varieties under study. The Groik variety was the most responsive to changes in environmental conditions for this feature (bi > 1).

The relative stability index of the varieties under study ranged from 0.1 to 2.5. Thus, all the studied varieties belong to a highly stable group. However, the American improved and U-Cha-Kontou varieties do not have high productivity (average yield 4.2-5.8 t/ha), so they are not economically valuable. Kafedralna and Gasson varieties are distinguished, which are characterised by a combination of high yield parameters (10.4-14.4 t/ha), adaptability, and genotype breeding value (8.06-13.63). Marketing of little-known legumes is complicated by the fact that they are mostly less well-known to consumers, so a promising area of further research is to investigate the mechanisms of popularisation and widespread inclusion of them in the human diet.

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None.

CONFLICT OF INTEREST

The authors of this study declare no conflict of interest.

REFERENCES

[1] Abebe, B.K., & Alemayehu, M.T. (2022). A review of the nutritional use of cowpea (*Vigna unguiculata* L. Walp) for human and animal diets. *Journal of Agriculture and Food Research*, 10, article number 100383. doi: 10.1016/j.jafr.2022.100383.

[2] Ahmad, A., Mushtaq, Z., Nazir, A., Jaffar, M. T., Asghar, H. N., Alzuaibr, F. M., Alasmari, A., & Alqurashi, M. (2023). Growth response of cowpea (*Vigna unguiculata* L.) exposed to *Pseudomonas fluorescens*, *Pseudomonas stutzeri*, and *Pseudomonas gessardii* in lead contaminated soil. *Plant Stress*, 10, article number 100259. doi: 10.1016/j.stress.2023.100259.

[3] Ayalew, T., & Yoseph, T. (2022). Cowpea (*Vigna unguiculata* L. Walp.): A choice crop for sustainability during the climate change periods. *Journal of Applied Biology and Biotechnology*, 10(3), 154-162. doi: 10.7324/JABB.2022.100320.

[4] Barros, J.R.A., dos Santos, T.C., Silva, E.G.F., da Silva, W.O., Guimarães, M.J.M., & Angelotti, F. (2024). Pollen viability, and the photosynthetic and enzymatic responses of cowpea (*Vigna unguiculata* (L.) Walp., Fabaceae) in the face of rising air temperature: A problem for food safety. *Agronomy*, 14(3), article number 463. doi: 10.3390/agronomy14030463.

[5] Barros, J.R.A., Guimarães, M.J.M., Simões, W.L., Melo, N.F. de., & Angelotti, F. (2021). Water restriction in different phenological stages and increased temperature affect cowpea production. *Ciência E Agrotecnologia*, 45, article number e022120. doi: 10.1590/1413-7054202145022120.

[6] Bobos, I., Fedosiu, I., Zavadskaya, O., Komag, O., Topkha, O., Furduha, M., & Addlfs, R. (2022). Imp of sowingdates op the variabilitu of different trails of fenugreek. *Rural Sustainabilitu Research*, 47(342), 37-46. doi: 10.2478 / plua-2022-0006.
[7] Bondarenko, G.L., & Yakovenko, K.I. (2001). *Methodology of experimenting in vegetable farming and melon growing*. Kharkiv: Osnova.
[8] Convention on Biological Diversity. (1992, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_030#Text.
[9] Convention on International Trade in Endangered Species of Wild Fauna and Flora. (1979, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_129#Text.
[10] Cui, Q., Xiong, H., Yufeng, Y., Eaton, S., Imamura, S., Santamaria, J., Ravelombola, W., Mason, R.E., Wood, L., Mozzoni, L.A., & Shi, A. (2020). Evaluation of drought tolerance in Arkansas cowpea lines at seedling stage. *HortScience*, 55(7), 1132-1143. doi: 10.21273/HORTSCI15036-20.
[11] Dehodyuk, E., Dehodiuk, S.E., Borko, Yu., Litvinova, O., Ihnatenko, Yu., & Mulyarchuk, A. (2021). Long-term monitoring of aridization in agriculture before and after climate change in Ukraine. *Plant and Soil Science*, 12(4), 102-114. doi: 10.31548/agr2021.04.0102.
[12] Dhaliwal, S.K., Talukdar, A., Gautam, A., Sharma, P., Sharma, V., & Kaushik, P. (2020). Developments and prospects in imperative underexploited vegetable legumes breeding: A review. *International Journal of Molecular Sciences*, 21(24), article number 9615. doi: 10.3390/ijms21249615.
[13] Fedosiy, I., Bobos, I., Zavadska, O., Komar, O., Tonkha, O., Furdyha, M., PolishchukS., Arak, M., & Olt, J. (2022). Research into properties of blue melilot and fenugreek cultivated using different sowing times. *Agronomy Research*, 20(1), 103-123. doi: 10.15159/AR.22.005.
[14] Guney, M., Gündesli, M.A., Karci, H., & Topcu, H. (2021). The effect of cowpea (*Vigna unguiculata*) on human health. In *III Balkan agriculture congress* (pp. 325-332). Turkey: Edirne. doi: 10.5555/20220174067.
[15] Havryliuk, O., Kondratenko, T., Mazur, B., Tonkha, O., Andrusyk, Y., Kutovenko, V., Yakovlev, R., Kryvoshapka, V., Trokhymchuk, A., & Dmytrenko, Y. (2022). Efficiency of productivity potential realization of different-age sites of a trunk of grades of columnar type apple-trees. *Agronomy Research*, 20(2), 241-260. doi: 10.15159/AR.22.031.
[16] Hnatiuk, T., Kravchenko, O., Abarbarchuk, L., Churilov, A., & Chobotar, V. (2023). Influence of drugs produced by electropulse ablation methods on the development of soybean phytopathogenic bacteria. *Plant and Soil Science*, 14(3), 22-34. doi: 10.31548/plant3.2023.22.
[17] Le, L.T.T., Kotula, L., Siddique, K.H., & Colmer, T.D. (2021). Na+ and/or Cl− toxicities determine salt sensitivity in soybean (*Glycine max* (L.) Merr.), mungbean (*Vigna radiata* (L.) R. Wilczek), cowpea (*Vigna unguiculata* (L.) Walp.), and common Bean (Phaseolus vulgaris L.). *International Journal of Molecular Sciences*, 22(4), article number 1909. doi: 10.3390/ijms22041909.
[18] Mahmoud, G.A.E. (2021). Biotic stress to legumes: Fungal diseases as major biotic stress factor. *Sustainable Agriculture Reviews*, 51, 181-212. doi: 10.1007/978-3-030-68828-8_7.
[19] Mekonnen, T.W., Gerrano, A.S., Mbuma, N.W., & Labuschagne, M.T. (2022). Breeding of vegetable cowpea for nutrition and climate resilience in Sub-Saharan Africa: Progress, opportunities, and challenges. *Plants*, 11(12), article number 1583. doi: 10.3390/plants11121583.
[20] Mofokeng, M.A., & Gerrano, A.S. (2021). Efforts in breeding cowpea for aphid resistance: A review. *Acta Agriculturae Scandinavica, Section B-Soil & Plant Science*, 71(6), 489-497. doi: 10.1080/09064710.2021.1923797.
[21] National center for plant genetic resources of Ukraine. (n.d.). Retrieved from https://yuriev.com.ua/ua/pro-institut/nacionalnij-centr-genetinchih-resursiv-roslin-ukraini/.
[22] Ojiewo, C., *et al.* (2019). Genomics, genetics and breeding of tropical legumes for better livelihoods of smallholder farmers. *Plant Breeding*, 138(4), 487-499. doi: 10.1111/pbr.12554.
[23] Olorunwa, O.J., Adhikari, B., Brazel, S., Shi, A., Popescu, S.C., Popescu, G.V., & Barickman, T.C. (2022). Growth and photosynthetic responses of cowpea genotypes under waterlogging at the reproductive stage. *Plants*, 11(17), article number 2315. https://doi.org/10.3390/plants11172315.
[24] Quamruzzaman, A.K.M., Islam, F., Akter, L., Khatun, A., Mallick, S.R., Gaber, A., Laing, A., Brestic, M., & Hossain, A. (2022). Evaluation of the quality of yard-long bean (*Vigna unguiculata* sub sp. *sesquipedalis* L.) cultivars to meet the nutritional security of increasing population. *Agronomy*, 12(9), article number 2195. doi: 10.3390/agronomy12092195.
[25] Rabbi, M.F., Ben Hassen, T., El Bilali, H., Raheem, D., & Raposo, A. (2023). Food security challenges in Europe in the context of the prolonged Russian-Ukrainian conflict. *Sustainability*, 15(6), article number 4745. doi: 10.3390/su15064745.
[26] Rao, N.G. (2018). Statistics for agricultural sciences (3rd Ed). Hyderabad: BS Publications.
[27] Ravelombola, W., Qin, J., Weng, Y., Mou, B., & Shi, A. (2019). A simple and cost-effective approach for salt tolerance evaluation in cowpea (*Vigna unguiculata*) seedlings. *HortScience*, 54(8), 1280-1287. doi: 10.21273/HORTSCI14065-19.

[28] Riyazuddin, R., Nisha, N., Ejaz, B., Khan, M.I.R., Kumar, M., Ramteke, P.W., & Gupta, R. (2021). A comprehensive review on the heavy metal toxicity and sequestration in plants. *Biomolecules*, 12(1), article number 43. doi: 10.3390/biom12010043.
[29] State Register of Plant Varieties Suitable for Distribution in Ukraine. (2024). Retrieved from https://minagro.gov.ua/file-storage/reyestr-sortiv-roslin.
[30] Tanchyk, S., *et al*. (2021). Fixed nitrogen in agriculture and its role in agrocenoses. *Agronomy Research,* 19(2), 601-611. doi: 10.15159/AR.21.086.
[31] Tonkha, O., Menshov, O., Bykova, O., Pikovska, O., & Fedosiy, I. (2020). Magnetic methods application for the physical and chemical properties assessment of Ukraine soil. In *XIV international scientific conference "Monitoring of geological processes and ecological condition of the environment"* (pp. 1-5). Kyiv: European Association of Geoscientists & Engineers. doi: 10.3997/2214-4609.202056027.
[32] Tyshchenko, A., Tyshchenko, O., Konovalova, V., Fundirat, K., & Piliarska, O. (2023). Methods of determining the adaptability and ecological stability of plants. *Scientific Collection "InterConf+",* 33 (155), 324-342. doi: 10.51582/interconf.19-20.05.2023.029.

Екологічна стабільність, пластичність та адаптивність сортів вігни спаржевої (*Vigna unguiculata* (L.) Walp. *subsp. sesquipedalis* (L.) Verdc.)

Ірина Бобось
Кандидат сільськогосподарських наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0001-5193-7192

Олександр Комар
Кандидат сільськогосподарських наук
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0001-7511-4190

Іванна Гаврись
Кандидат сільськогосподарських наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0001-5965-9916

Олександр Шеметун
Кандидат сільськогосподарських наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0001-7129-9108

Василь Кокойко
Кандидат сільськогосподарських наук, старший науковий співробітник
Інститут кліматично орієнтованого сільського господарства
Націоанальної Академії Аграрних Наук України
67667, вул. Маяцька дорога, 24, смт. Хлібодарське, Україна
https://orcid.org/0000-0002-2528-7920

Анотація. Визначення екологічної пластичності та стабільності сортів і гібридів с/г культур дає можливість комплексно оцінити їх з урахуванням потенціалу продуктивності, якісних технологічних показників та рівня стійкості до стресових умов. Метою даного дослідження було вивчення формування врожаю бобів-лопаток сортів вігни спаржевої з високою екологічною стабільністю, пластичністю та адаптивністю. Провідними методами дослідження даної проблеми є польовий – для визначення взаємодії об'єкта дослідження з біотичними та абіотичними факторами, статистичний – для оцінки результатів досліджень з метою визначення параметрів адаптивності вігни. В межах досліджуваних варіантів встановлено пряму та зворотню кореляцію між урожайністю вігни та сумою ефективних температур. Для сортів Гроік (r = 0,36) і Кафедральна (контроль) (r = 0,36), У-Тя-Контоу (r = -0,64) кореляція була середньою, а для сортів Гассон (r = 0,96), Американська поліпшена (r=-0,98) – сильною. Виходячи з рівнянь регресії підвищення суми опадів на 1 мм може збільшувати урожайність бобів-лопаток вігни спаржевої на 3,4 кг/га у сорту Американська покращена та на 20,8 кг/га – У-Тя-Контоу, а для сортів Гассон, Кафедральна (контроль), Гроік спостерігатиметься зменшення врожайності на 6,4 кг/га, 10,8 кг/га та 20,7 кг/га відповідно. Сорти з високою загальною адаптивною здатністю, яка визначається як здатність генотипів до максимального прояву ознак за будь-яких умов навколишнього середовища, є цінними. Високі показники загальної адаптивної здатності за урожайністю рослини спостерігалися у сортів Гассон (ЗАЗ = 5,16) та Гроік (ЗАЗ = 2,16). Найменше значення даного показника спостерігали у сорту У-Тя-Контоу (ЗАЗ = -3,44). Сорти, які дають високі, але нестабільні врожаї, не здатні гарантувати отримання максимальної врожайності за умов неналежного землеробства та складних кліматичних умов. Селекційна цінність генотипу – це комплексний показник, який визначає сукупність продуктивності та стабільності сортів. У дослідженнях отримано такі коливання цього показника від 0,84 до 13,63. Кращими за показниками селекційної цінності виявилися сорти Гассон (СЦГі = 13,63) і Кафедральна (СЦГі = 8,06). Спостерігається відносно низька стабільність врожайності та здатність реагувати на покращення умов вирощування у сорту У-Тя-Контоу (СЦГі = 0,84)

Ключові слова: бобові культури; боби-лопатки; технічна стиглість; урожайність; стабільність; адаптивність; пластичність