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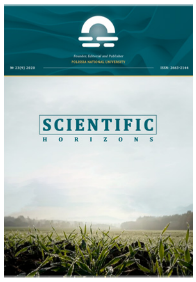

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Influence of sowing dates on the ecological stability, plasticity, and adaptability of lablab bean (*Dolichos lablab* L.)

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Abstract. Understanding the effects of soil and climatic conditions on agricultural crops forms the basis for developing and implementing innovative technologies and strategies aimed at minimising negative impacts on farming systems and agriculture as a whole. This study aimed to examine the impact of different sowing dates on lablab beans in order to expand the crop's cultivation potential in the conditions of the Right-Bank Forest-Steppe of Ukraine. The following methods were employed to investigate

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this issue: field trials to study the interaction of the research subject with biotic and abiotic factors and statistical analysis to evaluate the research results and determine the adaptability parameters of the lablab bean. It was established that the highest yield of green pods (2.1 t/ha)was achieved when sowing took place in the first ten-day period of May, which exceeded the control variant (the third ten-day period of April – 1.8 t/ha) by 0.3 t/ha (16.7%). The lowest yield (1.5 t/ha) was recorded when sowing occurred in the first ten-day period of June. The study also revealed that yield was influenced by the length of the growing season (r = 0.68), the sum of active temperatures (>10°C) (r = 0.72), and total precipitation (r = 0.74). A strong positive correlation was established between lablab bean yield and general adaptability (r = 0.99), plasticity (r = 0.67), homeostasis (r = 0.91), and breeding value (r = 0.71). Conversely, a negative correlation was observed between yield and the coefficient of variation (r = –0.75) as well as relative stability (r = –0.50). The relative yield stability (Sgi) ranged from 1.45% to 3.74%. The coefficient of variation in yield varied between 11.11% and 17.64%, depending on the sowing date. Under the agro-climatic conditions of the study, high plasticity was demonstrated in the sowing variants from the third ten-day period of April (control) to the third ten-day period of May. A low bi value was observed only when sowing took place in the first ten-day period of June, indicating that the lablab bean exhibited low ecological plasticity. The highest breeding value of the genotype (BVGi = 1.09 1.33) was recorded for sowings in the third ten-day period of April (control) and the first ten-day period of May, while the lowest value (BVGi = –0.275) occurred with sowing in the first ten-day period of June

Keywords: climatic factors; genotype; yield; food security; legumes

INTRODUCTION

The impact of climate change on agriculture has serious consequences for crop production, food security, and people's livelihoods (Huang *et al.*, 2020). Recent research suggests that a projected global average temperature rise of 1.8-4°C by the year 2100 is likely to lead to highly unpredictable precipitation patterns. It is also expected to significantly increase the frequency of extreme weather events, such as severe droughts, heat waves, cold spells, and floods (Bhattacharjee *et al.*, 2020). In 2010, it was estimated that out-of-season precipitation, hail, and floods caused damage across approximately 2.1 million hectares (González-Villagra *et al.*, 2023).

Changing climate conditions create favourable environments for the spread of pests and diseases, encourage the growth of weeds, and disrupt the balance of soil microorganisms. As noted by A. Shahzad *et al.* (2021), extreme weather events, particularly droughts, frosts, and heavy rainfall, place additional stress on plants, leading to reduced yields. Furthermore, the effects of climate change on agricultural productivity are not uniform across different geographical locations. Some regions are predicted to experience declines in yield, while others may see increases. As highlighted by T. Adamopoulos and D. Restuccia (2022), countries located in lower latitudes are more vulnerable to the negative impacts of climate change.

In this context, studying the agricultural potential of underutilised legume crops is particularly important. J. Minde *et al.* (2021) emphasise that growing lablab beans more widely could be a key factor in improving food and nutritional security, given their high nutritional value and ability to adapt to various climate conditions. According to P. Shashank *et al.* (2024), this versatile crop can be used as food in the form of immature seeds and pods, as well as a leafy vegetable. At the same time, lablab beans show significant environmental benefits, notably through their ability to fix atmospheric nitrogen within their own plant matter. As demonstrated in the research by L. Hernández-Herrerías *et al.* (2022), in mixed farming systems, lablab beans are often used as a cover crop alongside maize or sorghum. This helps to reduce water loss, improve soil fertility, and lower the risks of soil erosion.

In academic discussion, it is becoming increasingly accepted that climate change is a factor that encourages the development of innovative technologies and management approaches. O. Zavadska *et al.* (2021) and E. Elahi *et al.* (2022) highlight the need to put adaptive strategies in place to reduce the vulnerability of the agricultural sector to the challenges posed by the changing climate. Furthermore, the results of modelling carried out by I. Fedosiy *et al.* (2022) and A. Aboltins *et al.* (2024) suggest that adjusting farming schedules – particularly the timing of sowing and harvesting – is an effective way to adapt to climate change. Using data on crop development over two decades, X. Cui and W. Xie (2022) show that both sowing dates and the length of the growing season are significantly influenced by current temperature and precipitation levels. Their calculations indicate that adjusting the growing season could lead to sowing dates being shifted by 2-6 days and the growing season being shortened by 3-6 days by the end of this century. These changes could offset up to 9% of the yield losses associated with climate change.

The growth and potential yield of agricultural crops are determined by the environmental conditions experienced throughout the growing season. A lack of sufficient understanding about how lablab bean plants interact with their environment limits the ability to achieve maximum yields, as practical results show. To optimise the positive effects of environmental factors on the growth and yield of the lablab bean, information on the best sowing time is needed. This research aimed to analyse the impact of different sowing dates for lablab beans in order to identify the best farming practices for expanding its cultivation in the Right-Bank Forest-Steppe region of Ukraine.

MATERIALS AND METHODS

The experimental research was carried out over three years (2016-2018) at the National University of Life and Environmental Sciences of Ukraine (NULES, Ukraine). The soil at the research site is classified as dark grey podzolic soil with a medium level of leaching and a light loamy texture, with a soil pH of 6.1. The humus-rich topsoil layer was 24-28 cm deep. The research area is characterised by a low humus content, ranging from 1.5% to 2.2%, a medium nitrogen content of 26 to 38 mg/kg, phosphorus levels of 43 to 61 mg/kg, and potassium levels of 28 to 34 mg/kg.

During the period of 2016-2018, precipitation was distributed very unevenly throughout the year, ranging from 881 mm in 2018 to 939 mm in 2016 (Fig. 1). The period from November to March is considered the coldest time of the year. This is because temperatures often drop below 0°C during this time. In the colder months (November-March), 38.5%-44.5% of the total annual precipitation occurred. The highest monthly precipitation during the cold period reached 190.4 mm (December 2017), while the lowest was 24.8 mm (March 2017). The coldest months of the year were January (-4.3°C) and February (-1.5°C). Based on observations, the minimum air temperature recorded was −18.8°C on 4 January 2016 at 08:00, 2016. Air temperatures crossed the 10°C mark in the first ten-day period of April and the 15°C mark in the first ten-day period of May. Analysis of temperature data from 2016-2018 shows that the duration of the period with positive temperatures above 5°C was 217-241 days, above 10°C was 173-195 days, and above 15°C was 128-149 days. The total accumulated temperature above 5°C was 2,494°C-2,754°C, above 10°C was 1,475°C1,714°C, and above 15°C was 709°C-860°C. An extremely high temperature of +34.6°C was recorded on 17 July 2016 at 14:00.

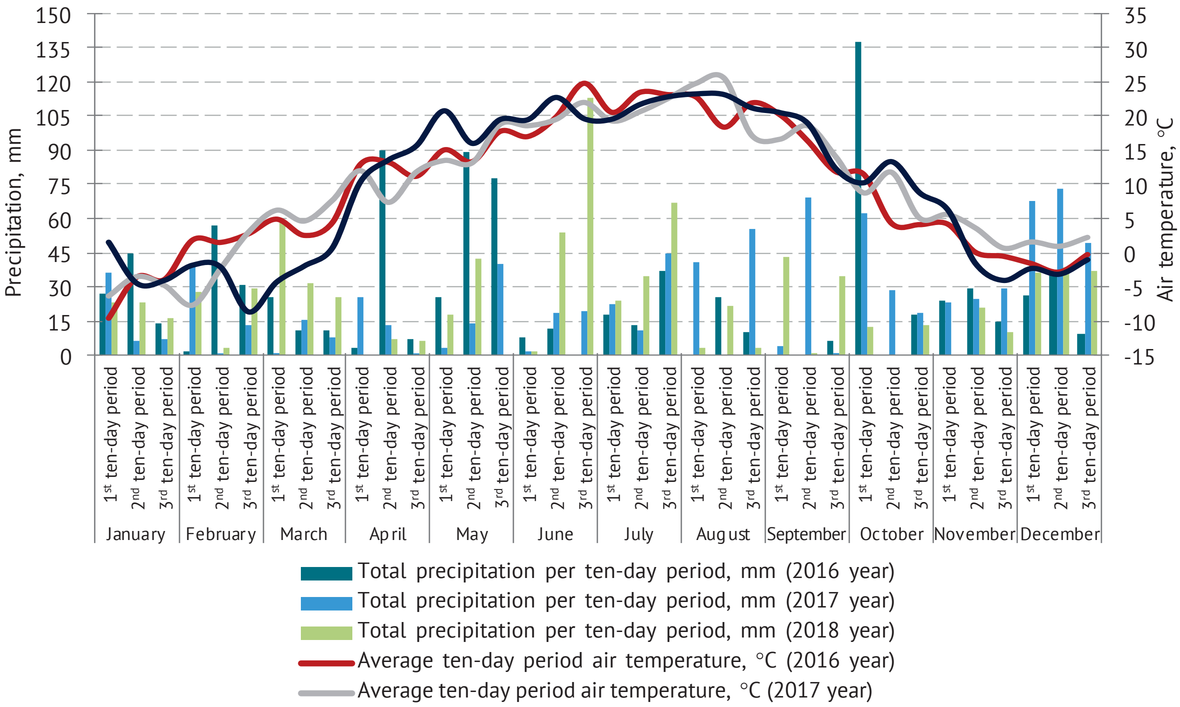

***Figure 1**. Dynamics of air temperature and precipitation, 2016-2018*
***Source:** compiled by the authors based on the conducted research*

The average monthly temperature in April was 12°C, with precipitation of 50.7 mm, which is 5.6% of the average annual amount. May was characterised by warm weather, with an average air temperature of 16.4°C. During this month, precipitation was highest for the period with positive temperatures, reaching 103.3 mm, or 11.4% of the average annual total. In June, the average monthly temperature noticeably increased, reaching 20.4°C. Simultaneously, 76 mm of precipitation, represents 8.4% of the average annual amount. July had an average temperature of 21.5°C, with 90.7 mm of precipitation, which is 10.1% of the average annual total. August was the hottest month across all the years of observation, with an average temperature of 22.0°C. The total precipitation for August was 52.8 mm, accounting for 5.9% of the average annual average. September had moderate weather with an average temperature of 16.6°C. Precipitation amounted to 53.0 mm, which is 5.9% of the average annual rainfall. October saw a significant drop in temperature, reaching 8.6°C. At the same time, 96.5 mm of precipitation, represents 10.7% of the average annual total.

The Department of Vegetable Crops at the National University of Life and Environmental Sciences of Ukraine studied four sowing dates for lablab bean (*Dolichos lablab* L. or *Lablab purpureus* (L.) Sweet) during the years 2016-2018: A) the third ten-day period of April; B) the first ten-day period of May; C) the third ten-day period of May; and D) the first ten-day period of June. The third ten-day period of April was used as the control sowing date. For all experimental groups, the same planting pattern was used – 70 × 20 cm, which resulted in a plant density of 71,000 plants per hectare. Seeds were sown at a depth of 2-3 cm. Each plot measured 5 square metres. Within these plots, 10 plants were selected for detailed study. The space allocated to each plant was controlled by the number of plants in a row, and the distance between rows was the same for all treatment groups. The width of the buffer zones was the same as the width of the plot on both sides of each experimental area.

The experimental design involved three replicates in the field, meaning three identical plots for each treatment, and three replicates over the three years (2016, 2017, and 2018). The field replicates allowed for a more comprehensive representation of the variability within the experimental site for each treatment, leading to more stable and accurate average results. The replicates over time established the influence, interaction, or carry-over effects of the factors being studied under different weather conditions. Overall, this resulted in a sample size of 36 observations (4 treatments × 3 repetitions per field × 3 repetitions over time). To ensure optimal quality, the green pods were harvested at the appropriate stage of maturity. This period is characterised by the pods reaching a typical size and the seeds developing a tender texture (Fig. 2). Harvesting was done manually when the pods in the plot reached harvest maturity (BBCH 77-79) (Meier *et al.*, 2009).

Figure 2. *Simultaneous flowering and fruiting of lablab bean plants*
Source: *authors' photo*

The assessment of general and specific adaptive capacity was based on studying the genetic type (n) in different environments (m) with several experimental repeats (c). Thus:

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

where x_{ikr} is the phenotypic value of trait (*i*) of the genotype when grown in environment (*k*) and replication (*r*); *U* is the overall mean of the entire set of phenotypes; V_i is the effect of genotype (*i*); d_k is the effect of environment (*k*); $(Vd)_{ik}$ is the interaction effect of genotype (*i*) with environment (*k*); e_{ikr} is the effect caused by random factors and associated with phenotype (*ikr*).W

The following constraints were applied to the components of the model:

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

Effects of specific adaptive capacity:

$$SAC_i = V_i = X_i - u. \quad (3)$$

The parameters for the species' adaptability were as follows:

$$\sigma^2\ SAC_i = \frac{1}{m-1} * \sum_R (d_R + Vd_{iR})^2 - \frac{m-1}{m} * \sigma^2. \quad (4)$$

$$\sigma\ SAC_i = \sqrt{\sigma^2\ SAC_i}. \quad (5)$$

To compare the variability of different characteristics of lablab across different environments, the relative stability index Sgi was used:

$$S_{gi} = \frac{\sigma_{SAC_i}}{U+GAC} * 100\%. \quad (6)$$

The regression coefficient b_i was used to determine the response of the lablab bean to improvements in environmental conditions:

$$b_i = \frac{\sum x_{iR} * d_R}{\sum_R d_R^2}. \quad (7)$$

To identify the optimal sowing dates for lablab beans that combine productivity and stability, the breeding value of the genotype was used:

$$BVG_i = U + GAC_i - p\sigma_{SAC_i}. \quad (8)$$

The application of the Growing Degree Days method allowed for the determination of the cumulative effective air temperatures during the interphase development period of the lablab bean based on actual temperature data:

$$\sum t_{eff} = (t_{avg} - B) * n, \quad (9)$$

where $\sum t_{eff}$ is the sum of effective air temperatures over the period, °C, t_{avg} is the average air temperature for the period, °C, *B* is the value of the biological minimum, which in this analysis is taken to be 10°C, and *n* is the number of days in this period.

Statistical analysis of the research data was performed using the Statistica 13.1 software package (StatSoft, Inc., Tulsa, OK USA). Differences between the treatments were determined using Tukey's test, with significance considered at $p < 0.05$ (with Bonferroni correction applied). To establish the direction and strength of the relationship between the studied variables, the correlation coefficient was calculated (Nageswara, 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

A box plot, shown in Figure 3, is a useful tool for visualising the distribution of output data, particularly for identifying outliers, the median, and quartiles. The current study gives a clear picture of the distribution of green pod yield over the period 2016-2018. The box itself represents the interquartile range, which contains 50% of the middle values. The bottom edge of the box shows the first quartile (the 25^{th} percentile), and the top edge shows the third quartile (the 75^{th} percentile). In the current case, the majority of yields for sowing in the third ten-day period of April (control) were between 1.65 and 1.90 t/ha, for the first ten-day period of May between 1.82 and 2.30 t/ha, for the third ten-day period of May between 1.53 and 1.94 t/ha, and for the first ten-day period of June between 1.31 and 1.74 t/ha. The line inside the box represents the median, which is the value that exactly divides the data into two equal halves. In the context of this study, the median yield was found to be around 1.78 t/ha for the third ten-day period of April (control), 2.06 t/ha for the first tenday period of May, 1.58 t/ha for the third ten-day period of May, and 1.40 t/ha for the first tenday period of June. The mode is defined as the value that appears most frequently within a dataset. In this study, it is worth noting that all values are unique, as each value occurs only once. The absence of any number appearing more often than others indicates that there is no mode.

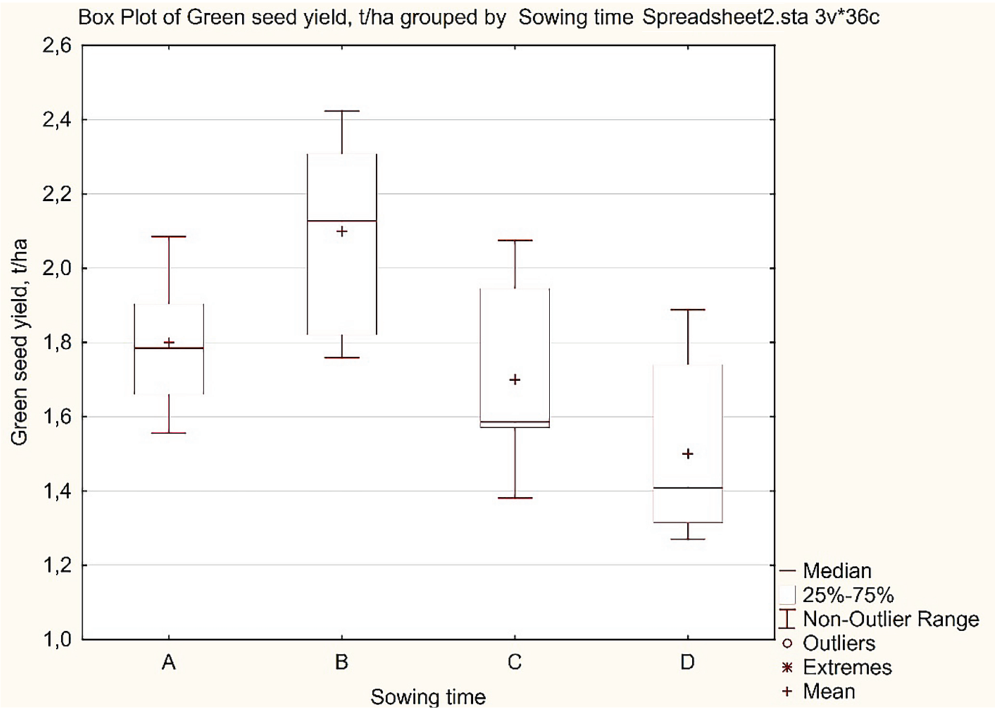

***Figure 3**. Box plot illustrating the yield of green pods of lablab bean*
***Note:** the x-axis represents the sowing date, where A) the third ten-day period of April (control); B) the first ten-day period of May; C) the third ten-day period of May; D) the first ten-day period of June (2016-2018)*
***Source:** developed by the authors based on the conducted research*

As shown in the graph, the mean value is indicated by a "+" symbol. This symbol was located within the box plot, which represents the interquartile range. A high yield of green pods of lablab bean (2.1 t/ha) was obtained when sown in the first ten-day period of May, an increase of 0.3 t/ha or 16.7% compared to the control. The worst yield results for the lablab bean were seen with sowing in the first ten-day period of June, resulting in a decrease of 0.3 t/ha or 16.7% compared to the control. It is worth noting the sowing date in the third ten-day period of May, where the yield was similar to the control (1.7 t/ha). For the control sowing date in the third ten-day period of April, a green pod yield of 1.8 t/ha was recorded.

On the graph, the whiskers outline the boundaries of the main body of the data and represent the entire range of values, excluding any outliers. For the control group (third ten-day period of April), the lower limit indicated by the whisker was approximately 1.56 t/ha, and the upper limit was 2.08 t/ha. Accordingly, for the other sowing dates, the ranges are as follows: first ten-day period of May – 1.76-2.42 t/ha, third ten-day period of May – 1.38-2.07 t/ha, and first ten-day period of June – 1.27-1.89 t/ha. Outliers are defined as data points that fall outside the whiskers. These points suggest the presence of anomalies or extreme values. The occurrence of outliers can be linked to various factors, including specific weather conditions, pest or disease infestation, or unique characteristics of the location. In the context of this research, no such deviations were identified. Therefore, based on the box plot, it can be concluded that the distribution of green pod yield in the experimental groups did not contain any outliers. The mean and median values are located at different points within the distribution. Yield is the most agronomically important element of a plant's phenotype, resulting from the interaction between genotype, environment, and cultivation technology. Physiological principles and agricultural data indicate that the duration, rate of growth, and maturation of the pods are the key factors determining the yield of lablab beans. From a physiological perspective, variations in the length of the growing season are most often linked to variations in the duration of the different phenological stages of growth and development. Statistical analysis showed a direct correlation (r = 0.68) between the length of the growing season and the yield of green pods (Fig. 4). This correlation coefficient indicates a strong relationship between the two studied variables. The regression equation, based on the data, allows for the prediction of yield dynamics with changes in the growing season's length. For example, an increase of 10 days in the growing season is predicted to lead to an increase in green pod yield of 207.3 kg/ha.

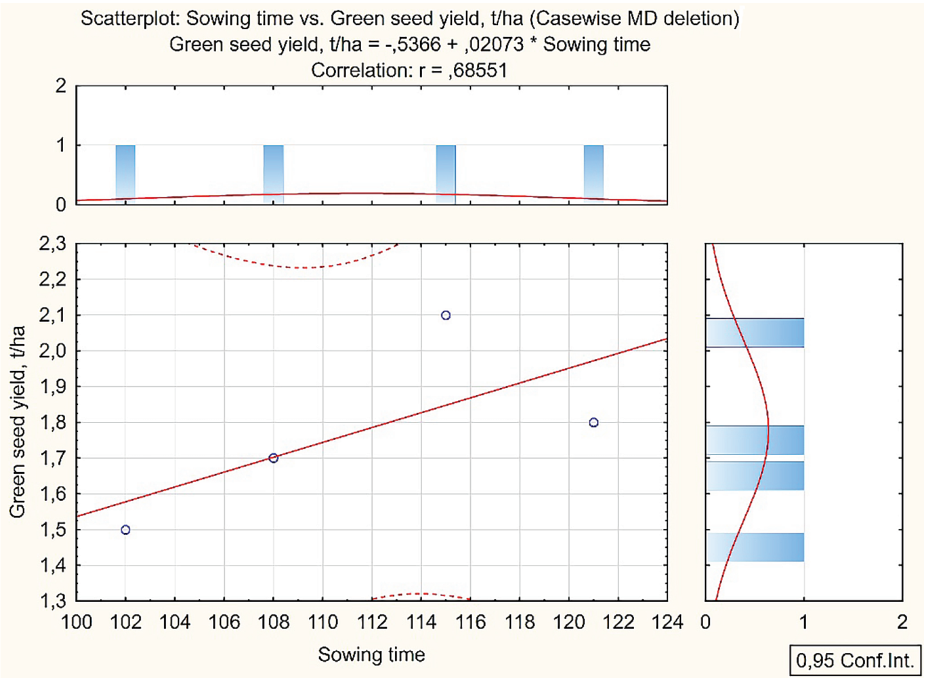

***Figure 4**. Relationship between green pods of lablab bean yield and the duration of the growing season (average for 2016-2018)*
***Source:** developed by the authors based on the conducted research*

The growth and development of the lablab bean primarily depend on environmental factors, including soil composition, day length, temperature patterns, and the availability of moisture. Temperature is a crucial factor for biological processes and, therefore, for plant growth and development. A specific amount of heat is required for the transition from one growth stage to another, for example, from sowing to emergence. The amount and distribution of precipitation are the second critical condition for successfully growing the lablab bean.

The research showed that for successful cultivation of lablab bean to achieve a marketable yield (1.5-2.1 t/ha) of green pods in the Right-Bank Forest-Steppe region of Ukraine, specific agrometeorological conditions are necessary: a total of active temperatures above 10°C should be between 1,177.3°C and 1,387.1°C during the sowing-to-harvest period, combined with precipitation levels ranging from 268.9 to 341.2 mm. The graphs (Figs. 5 and 6) clearly illustrate the direct relationship between lablab bean yield and the total active temperatures above 10°C, as well as the amount of precipitation. Correlation coefficients of 0.72 and 0.74 respectively confirm the statistical significance of this link. Using the calculated regression equations, it is possible to predict lablab bean yield based on the total air temperatures above 10°C and the amount of precipitation during the growing season. The results of this study indicate that an increase in the total air temperatures above 10°C during the sowing-to-harvest period leads to an increase in the green pod yield of 20.2 kg/ha. At the same time, an increase in precipitation of 10 mm results in a yield increase of 59.1 kg/ha.

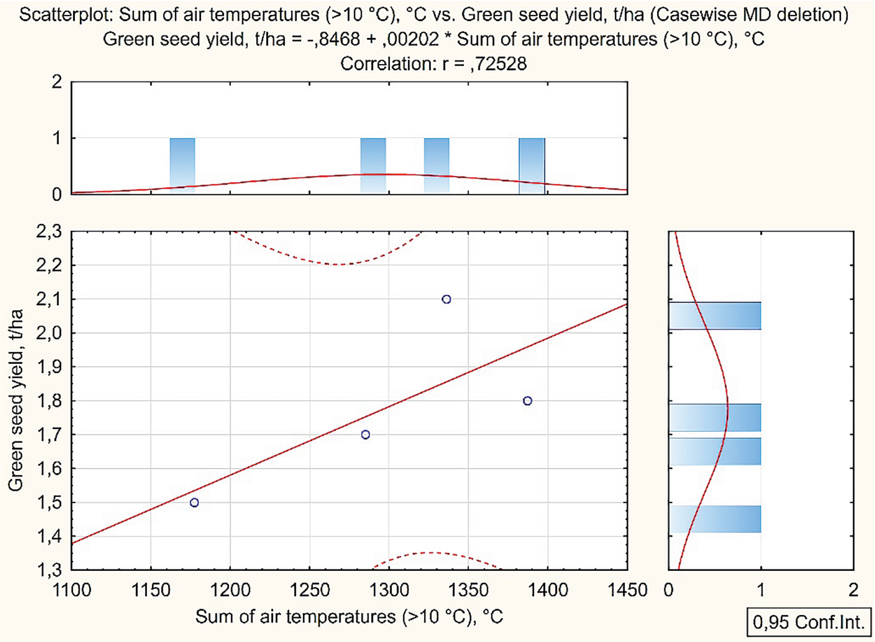

***Figure 5**. Relationship between green pods of lablab bean yield and the sum of temperatures above 10°C during the period from sowing to harvest (average for 2016-2018)*
***Source:** developed by the authors based on the conducted research*

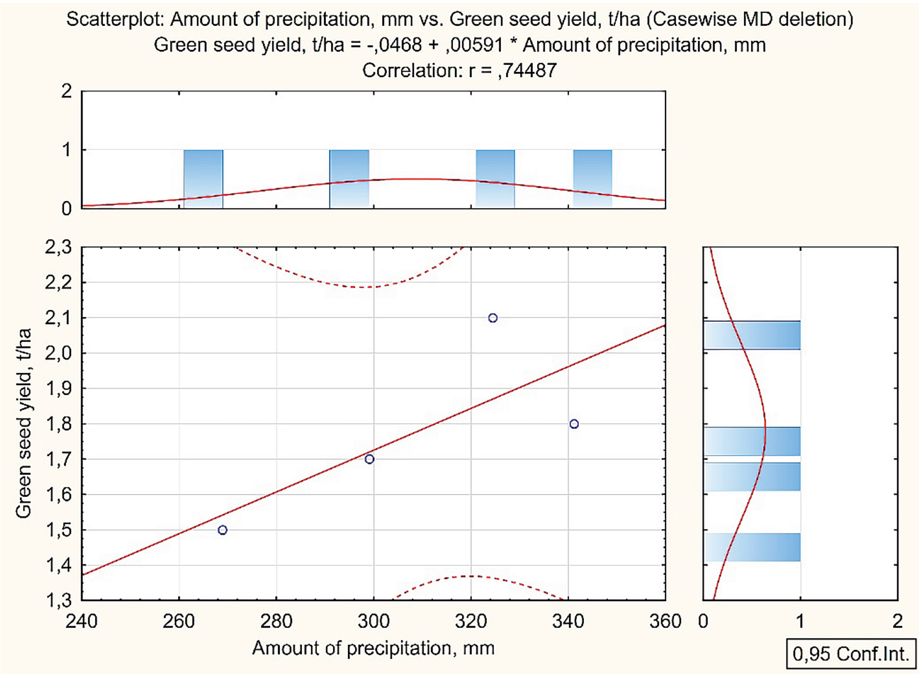

***Figure 6**. Relationship between green pods of lablab bean yield and the level of precipitation during the period from sowing to harvest (average for 2016-2018)*
***Source:** developed by the authors based on the conducted research*

According to Table 1, F = 10.76 and F crit = 9.55, meaning F > F crit. Therefore, the effect of the studied factor on the resulting characteristic can be considered statistically significant, which is also confirmed by the significance level (p-value = 4.78E-05), which is less than 0.05. At the same time, the proportion of influence of sowing dates on the yield of green pods was 50.2%.

***Table 1**. Results of variance analysis*

Source of variation	SS	df	MS	F_{05}	p-value	F crit
Between groups	1.6875	3	0.5625	10.76215	4,78E-05	2.90112
Within groups	1.672528	32	0.052267			
Total	3.360028	35				

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

To assess the consistency of the studied sample, the coefficient of variation was used, which estimates the relative deviation of the observed values from the arithmetic mean. As shown by the analysis of the coefficients of variation for lablab bean green pods yield, sowing from the third tenday period of April (control) to the first ten-day period of June resulted in moderate variability, as the coefficient of variation in these cases ranged from 11.11% to 17.64% (Table 2). To determine the adaptive capabilities of the lablab bean, the authors considered two indicators: general adaptability, which characterised the ability of plants to achieve stable yields across a wide range of growing conditions, and specific adaptability, which was determined by resistance to specific stress factors (cold, drought, pests, etc.). According to the analysis of the general adaptive capacity of the lablab bean plants, the highest values for this indicator were observed when sown in the first tenday period of May (GAC = 0.325). The lowest values for this indicator were found in plants sown in the first ten-day period of June (GAC = -0.275). Regarding specific adaptability capacity, plants sown from the first ten-day period of May to the first ten-day period of June showed equally good adaptation to the specific growing conditions (SAC = 0.06)

***Table 2**. Parameters of the adaptive capacity and stability of the lablab bean at different sowing dates (2016-2018)*

Indicator	Sowing date			
	Third ten-day period of April (control)	The first ten-day period of May	The third ten-day period of May	The first ten-day period of June
Green pod yield (Mean), t/ha	1.8 ± 0.061 [a]	2.1 ± 0.084 [ab]	1.7 ± 0.079 [b]	1.5 ± 0.078 [c]
Coefficient of variation (V), %	11.11	12.60	15.56	17.64
General adaptive capacity (GAC)	0.025	0.325	-0.075	-0.275
Specific adaptability capacity (SAC)	0.03	0.06	0.06	0.06
Relative stability (Sgi), %	1.45	2.67	3.30	3.74
Plasticity (bi)	1.68	1.79	2.32	-1.79
Homeostasis (Hom)	0.16	0.17	0.11	0.09
Breeding value of the genotype (BVG_i)	1.33	1.09	0.69	0.49

***Note:** different letters (a, b, c, d) indicate values that were significantly different from each other within the same row of the table, according to comparisons using Tukey's test with Bonferroni correction*
***Source:** developed by the authors based on the conducted research*

The concept of relative genotype stability is crucial for making comparative analyses easier across experiments involving different crops, genetic types, environments, and traits being studied. The relative stability of a genotype is similar to the coefficient of variation when examined across various environments. Therefore, under different growing conditions, all the studied treatments showed a high degree of stability in green pod yield (Sgi ranging from 1.45% to 3.75%), as the deviation in this indicator did not exceed 25%. The reaction of a genotype to improvements in environmental conditions can be assessed using the regression coefficient. If the value of this coefficient is greater than one (bi > 1), it indicates a high sensitivity of the species or variety to changes in growing conditions. Under optimal growing conditions, such a variety is capable of producing a significantly higher yield. Conversely, if the coefficient is less than one (bi < 1), it is less sensitive to changes in conditions and, consequently, responds less to improvements in cultivation techniques. In cases where the regression coefficient equals one (bi = 1), changes in the variety's yield are fully correlated with changes in growing conditions.

Further analysis of the data showed that the lowest level of sensitivity to improved growing conditions was demonstrated by the lablab bean sown in the first ten-day period of June. Therefore, for every 1 t/ha increase in average yield, the yield of this treatment only increased by 1.79 t/ha. Out of all the sowing dates studied, the third ten-day period of May proved to be the most sensitive to changes in yield levels under the test conditions (with a 1 t/ha increase in average yield, it increased by 2.32). The next most sensitive were the treatments sown in the first ten-day period of May (bi = 1.76) and the third ten-day period of April (control) (bi = 1.68). Regarding homeostasis, which describes the ability of plants to develop normally under unfavourable environmental conditions, the treatments sown in the first ten-day period of May (Hom = 0.17) and the third ten-day period of April (control) (Hom = 0.16) stood out. The lowest homeostatic value (Hom = 0.09) was observed for the treatment sown in the first ten-day period of June.

It is generally accepted that species (or varieties) that only produce high yields under optimal conditions pose a risk to production, as they may not be able to maintain such yield levels with inadequate care or unfavourable weather. Therefore, to assess the overall characteristics of the lablab bean, considering both their potential yield and their ability to maintain it under different conditions, the breeding value of the genotype was used. High breeding values of the genotype were characteristic of the sowing dates in the third ten-day period of April (control) and the first ten-day period of May, with values of 1.33 and 1.09, respectively. This indicates that these sowing times provided an optimal combination of high yield and stability, which is particularly important in the context of unfavourable growing conditions. The yield of lablab bean green pods showed a strong positive correlation (r = 0.71-0.99) with general adaptability, plasticity, homeostasis, and breeding value of the genotype. In contrast, yield showed a strong negative correlation with the coefficient of variation (r = -0.75) and a moderate negative correlation with relative stability (r = -0.50). The analysis suggests that the yield of lablab bean green pods is closely linked to its adaptive characteristics (Fig. 7).

Mean	Mean							
V	-0.75	V						
GAC	0.99	-0.75	GAC					
SAC	-0.07	0.71	-0.07	SAC				
Sgi	-0.50	0.95	-0.50	0.90	Sgi			
bi	0.67	-0.68	0.67	-0.24	-0.53	bi		
Hom	0.91	-0.95	0.91	-0.47	-0.81	0.63	Hom	
BVGi	0.71	-0.99	0.71	-0.75	-0.97	0.61	0.93	BVGi

Legend

Pearson correlation coefficients between the studied indicators: green pod yield (Mean), coefficient of variation (V), general adaptability capacity (GAC), specific adaptability capacity (SAC), relative stability (Sgi), plasticity (bi), homeostasis (Hom), breeding value of the genotype (BVGi).

Strength of correlation links:		Direction of correlation:	
(green)	1 – perfect;	$1 \geqslant r > 0$	Positive correlation;
(yellow)	0.66-0.99 – strong;	$-1 \leqslant r < 0$	Negative correlation.
(blue)	0.33-0.66 – moderate;		
(grey)	< 0.33 – weak.		

***Figure 7**. Correlation dependence between the parameters of adaptive capacity and stability of the lablab bean at different sowing times (2016-2018)*

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

The yield of lablab bean green pods showed a strong positive correlation (r = 0.67-0.99) with general adaptability capacity, plasticity, homeostasis, and breeding value of the genotype. At the same time, yield had a strong negative correlation with the coefficient of variation (r = -0.75) and a moderate negative correlation with relative stability (r = -0.50). No statistically significant relationship was observed between yield and specific adaptability capacity (r = -0.07).

DISCUSSION

Overall, the experimental research produced results similar to those obtained in other countries. Studies in India involving 30 genetic types found that the coefficients of variation for the observable characteristics (phenotype) were generally higher than those for the genetic makeup (genotype). This suggests that the influence of the genotype was reduced by environmental factors (Ganapathi & Akshay, 2020). The results of the cluster analysis showed that Cluster 3, which included 12 samples, had the highest yields of green seeds (82.1 kg) and green pods (152.5 kg) (Jahnavi *et al.*, 2023). R. Preetham *et al.* (2020) identified the genetic type IC-427436 among 45 lablab bean genotypes in India, noting its pod weight of 11.0 g and 6.3 seeds per pod, and it demonstrated a significantly higher pod yield of 13.6 t/ha compared to other genotypes. Based on average performance indicators, the genotypes PYR 15-01, Nagavalli local 1, and Nallur local proved to be the best in terms of yield and its components, while the genotype HA 3 was characterised by early maturity and provided an optimal green pod yield of 327 g per plant (Geetha & Divya, 2021).

The formation of agricultural crop yields largely depends on a combination of farming techniques and soil-climate conditions (Litvinova *et al.*, 2023; Syromyatnikov *et al.*, 2023). The authors' research has shown that sowing dates had a significant impact on plant growth and development, determining the optimal phenological stages for achieving maximum productivity. When growing plants in regions where they are newly introduced, the sowing date is a primary factor that needs careful consideration.

Determining the optimal sowing date is based on the characteristics of the variety and the meteorological conditions of the region (Baum *et al.*, 2020; Bobos *et al.*, 2020, 2022). Temperature patterns and soil moisture are the most critical non-living factors influencing seed germination. If these do not match the optimal conditions, it can lead to delayed seedling emergence, disrupted plant development and, consequently, affect the size and quality of the harvest (Suo *et al.,* 2022). In particular, the authors found that for sowing in the third ten-day period of April, the average daily air temperature during the sowing-to-emergence period ranged from 12.2°C to 18.8°C, with an average of 15.5°C. These temperature conditions led to a delay in seedling emergence of 18 days. Conversely, an increase in the average daily temperature to 19.1°C (ranging from 17.9°C to 20.5°C) in the sowing treatment carried out in the first ten-day period of June accelerated germination, thereby reducing the interval between sowing and emergence to 8 days. This is because germination slows down sharply when temperatures fall below the optimum, as low temperatures hinder metabolism and enzyme activity, affecting the entire germination process (Cafaro *et al.*, 2022).

P. Kimani *et al.* (2022) reported that *Phaseolus vulgaris* L. plants had the highest yields under seasonal temperatures ranging from 11.7°C to 36.7°C, which corresponded to an average temperature of 24.2°C throughout the crop growing season. Furthermore, a maximum temperature of 34°C during the pod formation stage positively influenced the development of pods and seeds, as shown by increased yields in plants exposed to these higher temperatures during this specific growth phase. Research by S. Zeipiņa *et al.* (2022) aimed to optimise vegetable soybean production in the Northern Europe region. Through careful experiments, it was determined that a growing season of 123 to 127 days, a minimum accumulated air temperature above 10°C of 650°C, and a hydrothermal coefficient (HTC) above one produced the most favourable yield results. Presented research also demonstrated that lablab bean plants respond differently to temperature, affecting both the rate of germination and the final yield. For example, the maximum lablab bean yield was obtained when sown in the first ten-day period of May, which coincided with an accumulated air temperature above 10°C of 864°C during the period from emergence to the start of marketable pod maturity, while the minimum yield was noted when sown in the first ten-day period of June – 740°C.

Research by H. Vinay *et al.* (2022) demonstrated that minimum temperature, duration of sunshine, and precipitation amount had a positive correlation with green seed yield. A similar trend was observed in current studies, with a positive correlation between green seed yield and the total accumulated temperature (r = 0.72) and precipitation amount (r = 0.74) during the plant growth and development period. The influence of genotype and sowing date proved to be statistically significant factors affecting the lablab bean green pod yield, as well as the content of crude fibre, crude protein, and total dry matter (Venkatesan *et al.*, 2024). Genotypes with early and mediumearly maturity periods, specifically Phule gauri (145.3 days), AKWAL1816 (146.7 days), and DOL-VARK-18-04 (147.3 days), were found to be the most promising for cultivation (Pachkhande *et al.*, 2022). Simultaneously, the authors of this study determined that the yield of the lablab bean is a result of the interaction between genotype, environmental conditions, and cultivation techniques, and statistical analysis showed that every additional 10 days of the growing season increased yield by 207.3 kg/ha.

Intercropping of agricultural crops is a fundamental and traditional practice among local farmers in Hararghe (Ethiopia), primarily due to the lack of available land. Research findings indicated that growing sorghum together with *Dolichos lablab* at different sowing times affects the grain yield of the sorghum. It is recommended that 4 weeks after sowing sorghum is the optimal time for sowing *Dolichos lablab* in intercropping (Dinkale *et al.,* 2022). Aphid populations are influenced by numerous factors, including environmental conditions, the characteristics of the host plants, and natural predators. Among these factors, weather conditions play a crucial role in shaping aphid populations by affecting their reproduction, development, dispersal, and survival (Sun *et al.*, 2022). A chronological consistency was observed between temperature fluctuations and the initial establishment of aphid colonies, with a peak occurring in mid-June. This aligns with data from M. Almogdad *et al.* (2024) regarding the correlation between rising temperatures and increased aphid activity at this growth stage. Research by C. Mwani *et al.* (2021) found that aphid numbers were low at the seedling stage but gradually increased as the plants developed. Therefore, sowing lablab beans at the optimal times, determined by the specific weather conditions of the year, helped to control and reduce pest damage.

In conclusion, it is clear that selecting the best sowing dates is a key factor that determines the growth and development of lablab bean plants, as well as the yield levels achieved. It was established that the sowing date influenced the balance of temperature and soil moisture, which is critically important for the crop's yield formation. It is recognised that these indicators can vary across different geographical areas depending on the climate and the specific weather conditions of a given year. Presented research suggests that the impact of farming techniques and the region's weather patterns had a decisive influence on the marketable yield of lablab bean green pods.

CONCLUSIONS

The green pod yield in the study ranged from 1.5 t/ha (first ten-day period of June) to 2.1 t/ha (first ten-day period of May), with an average of 1.8 t/ha. The resulting values for the coefficient of variation in yield (11.1%-17.6%) indicate that the studied sample had a moderate level of variation in this trait. Lablab bean plants sown at the investigated times showed high stability (Sgi < 25) in terms of yield. The assessment of the environmental flexibility of the lablab bean revealed that sowing from the third ten-day period of April (control) to the third ten-day period of May would increase green pod yield due to improved growing conditions. Sowing in the third ten-day period of May provided the highest level of flexibility, characterised by a high positive regression coefficient (bi = 2.32). The weakest response to improved growing conditions, with the lowest green pod yield, was found with sowing in the first ten-day period of June, which had a regression coefficient of bi = -1.79. Among the studied sowing dates for the lablab bean, high levels of consistency across different conditions (Hom = 0.16-0.17) and breeding value of the genotype (BVGi = 1.09-1.33) were obtained with sowing in the third ten-day period of April (control) and the first ten-day period of May. Future research will focus on improving the genetic potential of the lablab bean to enhance yield, nutritional value, and resilience to climate change, which will expand the understanding of the crop's benefits for producing valuable food products.

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CONFLICT OF INTEREST

The authors of this study declare no conflict of interest.

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Вплив термінів сівби на екологічну стабільність, пластичність та адаптивність доліхоса (*Dolichos lablab* L)

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Анотація. Розуміння результатів впливу ґрунтово-кліматичних умов на сільськогосподарські рослини є основою для розробки та впровадження інноваційних технологій та стратегій, які мінімізують негативний вплив на фермерські господарства та сільське господарство в цілому. Мета досліджень – вивчення впливу різних термінів сівби доліхоса для розширення потенційних можливостей вирощування цієї культури в умовах Правобережного Лісостепу України. Для вивчення цієї проблеми використано наступні методи: польовий – для вивчення взаємодії об'єкта дослідження з біотичними та абіотичними факторами та статистичний – для аналізу результатів досліджень з метою визначення параметрів адаптивності доліхоса. Встановлено, що максимальна врожайність зеленого горошку доліхоса (2,1 т/га) досягалася за сівби в І декаді травня, що на 0,3 т/га (16,7 %) перевищувало показник контрольного варіанту (ІІІ декада квітня – 1,8 т/га). Мінімальна врожайність (1,5 т/га) спостерігалася за сівби в І декаді червня. Дослідження також виявило залежність врожайності від тривалості вегетаційного періоду (r = 0,68), суми активних температур (>10 °C) (r = 0,72) та суми опадів (r = 0,74). Встановлено сильну позитивну кореляцію між врожайністю доліхоса та загальною адаптивною здатністю (r = 0,99), пластичністю (r = 0,67), гомеостатичністю (r = 0,91) та селекційною цінністю (r = 0,71). З іншого боку, виявлено негативну кореляцію між врожайністю та коефіцієнтом варіації (r = -0,75) та відносною стабільністю (r = -0,50). Відносна стабільність врожайності (Sgi) варіювалася від 1,45 % до 3,74 %. Коефіцієнт варіації врожайності коливався від 11,11 % до 17,64 % залежно від терміну сівби. В агрокліматичних умовах проведення досліджень високою пластичністю володіли варіанти за сівби доліхоса від ІІІ декади квітня (контроль) до ІІІ декади травня, а низьке значення bi було лише за сівби в І декаді червня, отже, доліхос мав низьку екологічну пластичність. Найвища селекційна цінність генотипу (GBVi = 1,09-1,33) спостерігалася для варіантів за сівби в ІІІ декаді квітня (контроль) та І декаді травня, тоді як найнижча (GBVi = -0,275) – в І декаді червня

Ключові слова: кліматичні фактори; генотип; урожайність; продовольча безпека; бобові