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Productivity of Kabuli chickpeas depending on the weather conditions of the year, varieties and methods of sowing in Ukraine

Tetiana Kachanova*, **Tetiana Manushkina, Mykola Samoilenko, Olena Petrova and Nadiia Koloyanidi**

Mykolayiv National Agrarian University, 54020 Mykolaiv, Ukraine
**Corresponding author:* kachanova0909@gmail.com

Abstract

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The purpose of this study was to study the productivity of chickpea plants depending on the variety, method of sowing and weather conditions of the growing year in the conditions of the Mykolaiv region, southern Ukraine. We used a randomized scheme of blocks with a factorial arrangement of 2x4 with two seeding methods (ordinary, 15 cm with the number of plants 60 PCs/m^2 and wide-row, 45 cm with the number of plants 40 PCs/m^2) and four varieties of Kabuli chickpeas (Rosanna, Pamyat, Triumph, Budzhak) in three-fold repetition. The yield of chickpeas, the protein content in the grain, and the yield of conditional protein per unit area were determined, depending on the factors that were being studied. The data obtained showed that in the conditions of the southern Steppe of Ukraine, weather conditions had the greatest impact on the productivity of chickpea plants (their share of influence reaches 73%), while the grain yield varied from 1.04 to 1.83 t/ha depending on the varieties and methods of sowing. The Rosanna variety was characterized by the lowest variability in grain yield over the years. The Budzhak variety had the highest yield between the two contrasting years of moisture availability as 1.48 t/ha against 1.26-1.43 t/ha or 4-17% more in comparison with other varieties, this characterized its high genetic plasticity and compensatory ability. The highest yield of chickpea grain was formed in wide-row crops, with a yield increase of 0.12 t/ha or 9.6% in comparison with the usual row sowing. The protein content of chickpea grains on average in the experiment was 26.0% with a variation in varieties from 22.1 up to 30.3%. A strong correlation between the protein content of chickpea grains and the air temperature during the growing season was established (r = 0.79-0.84). The highest protein content was observed in the chickpea variety Pamyat, but the maximum collection of conditional protein per unit area was provided by the Budzhak variety due to the formation of the highest grain yield.

Keywords: chickpeas; varieties; seeding methods; yield; protein content; conditional protein yield

Introduction

In the southern part of the Steppe of Ukraine, the frequency of droughts increased in recent years, which affected on the yield of agricultural crops, including legumes, which were the main source of complete plant protein. Therefore, in conditions of insufficient moisture, a very valuable promising legume crop – chickpeas (*Cicer arietinum* L.) became widespread. It is characterized by high drought tolerance, heat tolerance, and it is traditionally grown in the semi-arid tropics (Asia and India), Australia, and the Mediterranean (Knights et al., 2007). Chickpea makes up more than 20% of world pulse production (Tatar et al., 2013). Chickpea grain contains 22 up to 31% protein, 4 up to 7% fat, it surpasses most legumes in protein balance, amino acid composition, vitamins and other biologically valuable substances. This leads to a high demand for chickpea grains, which are used for both food and feed purposes (Miguelez & Valenciano, 2005). Further expansion of chickpea acreage is impossible without increasing the competitiveness of production of this crop, especially grain yield.

Taking into account the current state of agricultural production, its own direction of effective integration is the most important way of its development, which would best suit national interests, available resources, geographical position, and potential of the country (Dovgal et al., 2017). In Ukraine, under favorable weather conditions and proper agrophone, the yield of chickpeas can reach 2.5 up to 4.2 t/ha, under extreme growing conditions (drought) the yield would be reduced to 0.7 up to 1.0 t/ha. In particularly dry years, chickpeas compete in productivity with peas (Hadzalo et al., 2005). Sichkar & Bushulian (2001) argue it is possible to increase the level of realization of the genetic potential of chickpeas productivity by optimizing the technology of its cultivation, in particular, using biopreparations, mineral fertilizers, improved elements of crop farming, and so on. In the complex of measures aimed at increasing the yield of chickpeas, an important place belongs to the use of highly productive varieties adapted to local soil and climate conditions. The Register of plant varieties of Ukraine includes 15 varieties of chickpeas exclusively of Ukrainian selection; these varieties are diverse in morphological characteristics and react differently to the soil and climate conditions of the southern Ukraine zone, which is expressed in the crop yield.

Research on the influence of genotype, vegetation period, and agricultural technology on chickpea grain yield under rain-fed conditions had been conducted widely (Brown et al., 1989; Horn et al., 1996; Koutroubas et al., 2009). An important element of the growing technology which increases the individual and grain productivity of chickpea plants is the optimal spatial and quantitative placement of plants on the area, which is due to both the method of sowing and the density of plants per unit area. However, the results of research by different scientists are quite contradictory about the optimal number of chickpea plants per unit area, in most cases this is due to different soil and climate conditions for growing the crop. For example, Hernandez & Hill (1983) when growing chickpeas in New Zealand found that the number of plants 33 PCs per 1 m^2 provides the highest grain yield as 2.08 t/ha, and the Desi variety is inferior in productivity to the Kabuli variety, the latter forms a crop of 1.5 t/ha in non-irrigated conditions and up to 2.0 t/ha under irrigation. Saxena et al. (1990) claim that for Northern Syria, the number of chickpea plants Kabuli 19.3 PCs per 1 m^2 provides maximum productivity for irrigation. Indian scientists report that the optimal width for chickpeas is 30 cm and the distance between plants is 10 cm. this creates a plant population of 330 thousand plants per 1 ha. Wide row spacing (45-60 cm) can be used for large-grain chickpea Kabuli plants and for irrigation, because in thickened crops, plants suffer from a lack of light, forming weaker plants and puny grain (Gaur et al., 2010). However, Sichkar & Bushulian (2001) warns that sparse chickpea crops do not fully utilize moisture and nutrients from the soil and are more overgrown with weeds. According to Hermantseva (2001), the level of chickpea yield in broad-row crops in dry years is higher than in low-row crops, and, conversely, with excessive and average moisture availability of plants, the formation of almost the same level of yield is observed in all sowing methods.

According to most scientists, the optimization of chickpea sowing methods should be considered in conjunction with other agrobiological factors as in relation to the sowing period, soil type, moisture reserves, field clogging, level of agricultural equipment, varietal characteristics, etc. Moreover, for this crop in Ukraine there are not enough detailed zonal cultivation technologies, sometimes it is even grown according to the "schemes" recommended for other legumes (soy, peas). Therefore, the purpose of our work was to determine the optimal method of sowing when growing modern domestic varieties of chickpeas in the southern Steppe of Ukraine.

Materials and Methods

The experimental part of the study was conducted in 2008-2010 and in 2017-2019 in the fields of the Mykolaiv region, which were located in the southern Steppe of Ukraine. A feature of the southern Steppe is a sharp continental climate with frequent dry spells in summer. Winter is warm, snowless, and summer is hot. The average annual temperature is 8-10°C, the warmest month of July is 21-23°C, and the coldest January is 3-5°C. The sum of positive temperatures above 10°C reaches 3200-3400°. Spring frosts on average stop in the First decade of April, and the latest ones stop in early May. Autumn frosts occur in the third decade of October. The average long-term duration of the frost-free period is 195-205 days, and the vegetation period is 225 days. The southern Steppe of the Mykolaiv region is a zone of insufficient moisture. The average annual precipitation is 410 mm, including 270 mm during the growing season. Providing plants with moisture in the region is characterized by a hydrothermal coefficient of 0.6-0.7, which indicates an insufficient level of moisture during active vegetation. In the spring, before sowing spring crops, moisture reserves in the soil are not always sufficient. The soil of the experimental field is southern low-humus powdery-heavy loam Chernozem on a carbonate forest.

The object of research was medium-ripened varieties of chickpeas Kabuli: Rosanna, Pamyat, Triumph and Budzhak selection of the Selection and genetic Institute-National center for seed science and variety studies (Odessa). The scheme of the experiment also included methods of seeding such as ordinary (15 cm) and wide-row (45 cm). The sown area of the plot of the first order is 75 m^2; the accounting area is 50 m^2. The frequency is three times, and the placement of sections is randomized. The research used generally accepted methods in crop production.

The chickpea growing technology, with the exception of the elements that were studied, corresponded to the recommended one for the research area. Spring cultivation of the soil began with harrowing, and then continuous cultivation was carried out for 4-6 cm, before which $N_{16}P_{16}K_{16}$ was introduced. Sowing was carried out with a SN-16 seeder with the observance of the width of the rows according to the scheme of the experiment. Seeding rate: for solid crops-0.6 million for wide-row – 0.4 million pieces of germinating seeds per 1 ha. After sowing, the field was rolled up. Weeds were controlled by spraying crops with herbicides in phase 2-5 of the real leaves of the crop. The grain harvest was carried out by direct combining 'Sampo-130', the weight of the grain was recalculated for 100% purity and 14% humidity. The N concentration in chickpea grain samples were determined by modified Kjeldahl method. The air temperature and precipitation were measured at the Nikolaev state agricultural research station.

In order to analyses meteorological conditions on the years of growing chickpeas, Sielianinov's hydrothermal index (K) was used. K is known as the coefficient of the provision of water in plants. The index was computed as follows:

$$K = P / 0.1 \sum t,$$

where P is sum of monthly mean precipitation in mm, Σt is sum of daily mean air temperatures > 0°C.

Statistical processing of the obtained data was performed by the method of dispersion and correlation analyzes were performed according to Wolf (1966) and Dospekhov (1985) with the help of the programs *Excel* 2010 and *Statistica*, version 6.0.

Results and Discussion

Meteorological conditions in the first half of the growing season in 2008 were quite favorable for chickpea plants (precipitation fell within the norm), but in the third decade of June, the fields were covered by soil drought, at this moment the plants were just in the phase of grain filling, which was critical for the culture. In July, precipitation was recorded twice as much as normal, but they had a stormy character, in addition, the increased air temperature, which remained, accelerated the development of chickpeas, which negatively affected the formation of its crop. In general, the 2008 was a mid-arid year, with chickpea yields averaging 1.51 t/ha for varieties, including Rosanna as 1.39 t/ha, Pamyat as 1.49 t/ha, Triumph as 1.52 t/ha, Budzhak as 1.65 t/ha. The summer dry season was also typical for 2017, when the average yield of chickpeas for varieties was 1.34 t/ha, including Rosanna varieties as 1.32 t/ha, Pamyat as 1.26 t/ha, Triumph as 1.33 t/ha, Budzhak as 1.47 t/ha.

March and April 2009 yr and 2018 yr were characterized by high temperatures and insufficient precipitation, which made it difficult for chickpea seedlings to appear (Figure 1).

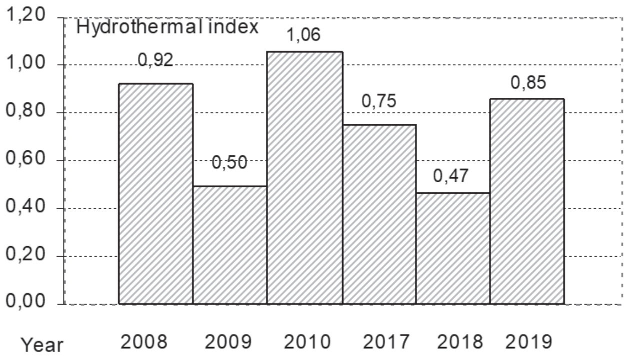

Fig. 1. Hydrometeorological coefficients for years of research

May was also characterized by high temperatures, but sufficient precipitation contributed to the growth and development of crops. In June, dry and hot weather prevailed, which negatively affected the formation, filling and maturation of grain. In July, there was an air drought, which accelerated the maturation of plants and negatively affected the formation of their future crop (Table 1).

So, the average yield of chickpeas in deep-drought 2009 was at the level of 1.10 t/ha, and in the context of varieties: Rosanna as 1.05 t/ha, Pamyat as 1.09 t/ha, Triumph as 1.09 t/ha, Budzhak as 1.17 t/ha. In no less arid 2018 yr, the average yield of chickpeas was 1.19 t/ha, including Rosanna varieties as 1.16 t/ha, Pamyat as 1.16 t/ha, Triumph as 1.19 t/ha, Budzhak as 1.29 t/ha.

In 2010 and 2019, agrometeorological conditions for the formation of the chickpea crop were relatively satisfactory. During the growing season of the crop, precipitation was 1.2-1.5 times higher than the average long-term norm, but it was distributed very unevenly during the period of plant growth and development. So, when the plants had a critical

Table 1. Mean monthly air temperature and total precipitation during vegetation period of chickpea in 2008-2010 and 2017-2019

Meteorological elements	Years	April	May	June	July
Mean temperature, °C	2008	11.1	14.9	21.0	23.0
	2009	10.7	16.1	22.3	24.4
	2010	10.9	17.5	22.2	24.6
	2017	10.3	17.2	21.8	23.1
	2018	15.8	21.7	24.3	25.3
	2019	11.9	17.8	23.9	23.4
	$X \pm S_x$	11.8±0.8	17.5±0.9	22.6±0.5	24.0±0.4
	± to long-term average	+1.6	+1.0	+2.2	+1.7
Total precipitation, mm	2008	38	48	25	81
	2009	1	58	33	25
	2010	16	89	75	173
	2017	67	35	8	15
	2018	2	32	22	71
	2019	52	56	63	37
	$X \pm S_x$	29.3±11.2	53.0±8.4	37.7±10.6	67.0±23.7
	± to long-term average	-2.7	+9.0	-16.3	+9.0

period of grain formation, weather conditions were complicated by the lack of effective precipitation and an increase in temperature to 31-34°C. During the period of filling chickpea grain, the heat stopped and there were heavy rainstorms, which significantly improved the condition of crops. The yield of chickpeas in 2010 was 1.63 t/ha, including Rosanna varieties as 1.42 t/ha, Pamyat as 1.58 t/ha, Triumph as 1.73 t/ha, Budzhak as 1.81 t/ha. In 2019, the average yield of chickpeas was 1.41 t/ha, including Rosanna varieties as 1.38 t/ha, Pamyat as 1.37 t/ha, Triumph as 1.40 t/ha, Budzhak as 1.52 t/ha (Table 2).

Thus, the period of research covered various weather conditions throughout the years favorable for the growth and development of chickpea (2010, 2019) to extremely dry (2009, 2018) and typical for the area (2008 and 2017). This allowed us to objectively assess the impact of the studied factors. The highest yield of chickpeas on average for the variants of the experiment was formed in 2010 as 1.63 t/ha, which was by 0.12-0.53 t/ha more than in other years.

The dispersion analysis on Figure 2 shows that the dominant influence on the chickpea crop in the conditions of the Mykolaiv region was weather conditions (73%), the influence of the variety (11%) and methods of sowing chickpea (10%) was also reliable.

Our research showed that the methods of sowing chickpea plants significantly affected the level of grain yield. Thus, on average for all varieties, the maximum grain yield (1.43 t/ha) was obtained in wide-row crops. The increase in

Table 2. Yield of chickpea varieties by different methods of sowing, t/ha

Sowing rate	Variety	Year			Average for 2008-2010	Year			Average for 2017-2019
		2008	2009	2010		2017	2018	2019	
Conventional row (15 cm)	Rosanna	1.31	1.04	1.34	1.19	1.21	1.11	1.27	1.20
	Pamyat	1.45	1.07	1.49	1.13	1.13	1.14	1.30	1.19
	Triumph	1.46	1.06	1.66	1.37	1.23	1.16	1.31	1.23
	Budzhak	1.56	1.13	1.78	1.34	1.43	1.22	1.46	1.31
Wide-row (45 cm)	Rosanna	1.47	1.07	1.49	1.34	1.43	1.15	1.48	1.35
	Pamyat	1.54	1.10	1.67	1.30	1.38	1.18	1.43	1.33
	Triumph	1.58	1.11	1.79	1.40	1.43	1.21	1.49	1.38
	Budzhak	1.75	1.21	1.83	1.42	1.51	1.35	1.57	1.47
S	1.52	1.10	1.63	1.31	1.34	1.19	1.41	1.31	
V, %	8.4	4.9	10.7	7.7	10.1	6.2	7.6	7.4	
$X \pm S_x$	1.52± 0.02	1.10± 0.003	1.63± 0.03	1.31± 0.01	1.34± 0.002	1.19± 0.01	1.41± 0.01	1.31± 0.01	

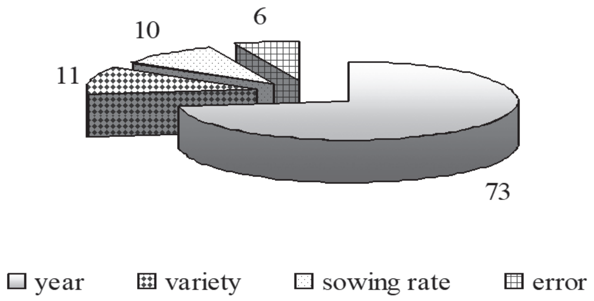

Fig. 2. The influence of factors on the grain yield of chickpea (2008-2010 and 2017-2019), %

yield was 0.12 t/ha or 9% compared to the usual line seeding. High yield of chickpeas in this variant is characterized primarily by optimal spatial and quantitative placement of plants per unit area. The area of nutrition affects the rate of growth and development of plants, because the amount of solar energy, incoming moisture and nutrition elements depends on it. So, by optimizing the sowing method, you can adjust the amount of chickpea grain yield.

As noted above, in 2009 and 2018, there were quite difficult agrometeorological conditions, a significant impact on the reduction of chickpea yield was the lack of precipitation and high air temperatures, and the difference between the methods of sowing in the plots of experience was quite small. Thus, chickpea sowing with a row width of 45 cm plants formed a yield on average of 1.12 up to 1.22 t/ha, and sowing with a row width of 15 cm it was less by 0.05-0.07 t/ha or 5-6%. In favorable 2010 and 2019, the difference between conventional row and wide-row crops in yield was 0.13-0.16 t/ha or 8-12 %. The difference in yield between conventional row and wide-row crops in mid-arid 2008 and 2017 was 0.14-0.19 t/ha or 10-15% in favor of wide-row.

Crop losses for the Rosanna variety due to lowercase sowing were slightly higher than for other varieties. Thus, on average for 2008-2010 and 2017-2019, sowing with a row spacing of 15 cm reduced the yield of Rosanna varieties by 0.14 t/ha, Triumph and Pamyat varieties by 0.12 t/ha, and Budzhak varieties by 0.11 t/ha. Thus, the highest crop yield was observed due to the wide-row method of sowing and depended on the variety and weather conditions of a particular year.

According to Bushulian & Sichkar (2009), the smallest difference between the maximum and minimum yield indicates a higher stress tolerance of the variety and its wider adaptive capacity. According to this indicator, preference should be given to the Rosanna variety, whose yield range was the smallest – 0.45 t/ha or 30%, the other varieties for stress resistance were located in this way: Pamyat (0.61 t/ha or 36%); Budzhak (0.70 t/ha or 38%); the lowest stress resistance was the Triumph variety (0.73 t/ha or 41%). The Rosanna variety was also characterized by the lowest yield variability over the years (V = 12%).

Calculations of the average yield of the variety in contrast (stressful and non-stressful) conditions, which characterizes the genetic plasticity of the variety and its compensatory ability, showed that the highest yield during the years of contrasting moisture availability had the Budzhak variety-1.48 t/ha against 1.26-1.43 t/ha or 4-17% more than the Rosanna, Pamyat and Triumph varieties. In some years, Budzhak variety exceeded the yield of other chickpea varieties: in 2008 -by 0.14-0.27 t/ha or 9-15%, in 2009 -by 0.08-0.12 t/ha or 7-9%, in 2010 -by 0.08-0.39 t/ha or 4-21%; in 2017 – by 0.14-0.22 t/ha or 11-17%, in 2018 -by 0.10-0.16 t/ha or 8-14%, in 2019 -by 0.12-0.15 t/ha or 9-11%.

Our research also showed that the protein content of chickpea grains was significantly influenced by the genetic characteristics of the studied varieties (Table 3).

Thus, in the arid conditions of the Southern Steppe of Ukraine, the protein content in grain, in terms of dry matter, in chickpea varieties ranged from 22.1 up to 30.3%. The Pamyat variety formed the maximum protein in the grain – 27.3%, which was higher by 3.1%, 1.1% and 1.3% than the Rosanna, Triumph and Budzhak varieties, respectively. The variability of the protein content in the grain (V) was small and was in the range of 4.6-5.9%.

Our research showed that the protein content in chickpea grains was formed significantly more in dry years of cultivation, when no precipitation fell during the filling and matu-

Table 3. The formation of protein in grain of chickpea in 2008-2010 and 2017-2019

Variety	The protein content in grain, %				
	Average	The scope of variation	The coefficient of variation (V)	The coefficient of correlation «protein content – air temperature» (r)	The coefficient of correlation «protein content – yield» (r)
Rosanna	24.2	22.1-26.6	5.1	0.85	0.04
Pamyat	27.3	24.4-30.3	5.9	0.82	0.03
Triumph	26.6	24.4-29.1	4.6	0.79	0.03
Budzhak	26.0	23.3-28.6	5.0	0.84	0.04

ration of the grain. These were the weather conditions of the summer periods of 2008, 2009, 2017 and 2018. Less protein (by 1.9-3.2%) was contained under sufficiently humid conditions of the specified vegetation period in 2010, 2019. This figure was the highest in the state-arid 2009 year for the Pamyat variety – 30.3%. When considering the relationship of protein content with air temperature, the existence of strong dependencies between these factors was established (r = 0.79-0.84); however, there was no relationship between the yield and protein content in chickpea grains (r = 0.03-0.04).

In terms of seeding methods, this indicator had the following values: for continuous sowing of Rosanna varieties as 23.8%, for Pamyat as 26.9%, for Triumph as 25.7% g, for Budzhak as 25.7%; for wide-row sowing of protein in the grain of Rosanna varieties accumulated at the level of 24.5%, for Pamyat as 27.7%, for Triumph as 26.7% g, for Budzhak as 26.3%. That is, the difference between seeding methods was low and it was 0.1-1.3% in favor of a wide-row seeding method with 45 cm spacing.

An important indicator when evaluating chickpea varieties is the yield of protein per unit area. This indicator is a derivative of the yield and protein content of chickpeas. We found that this indicator depends to the greatest extent on the conditions of the years when the protein was formed in the grain, and less significantly on the biological characteristics of the varieties that were taken for study. Unfavorable meteorological conditions of the growing season of chickpeas contributed to a significant decrease in grain yield, so the protein harvest in unfavorable years for moisture availability was less than in favorable years by 24-182 kg/ha. The maximum protein yield was observed in 2010 (301-488 kg/ha).

Despite the high protein content of the grain of the Pamyat variety, the conditional collection of protein per unit area was determined for the Budzhak variety due to the high level of its yield (Table 4). So, on average, by seeding methods, the conditional protein yield per unit area when growing Budzhak varieties was 361 kg/ha, which is 27 kg/ha or 9 % more than for Rosanna, Pamyat and Triumph varieties (average for 2008-2010 and 2017-2019).

Due to the wide-row method of sowing the crop, the highest protein yield was obtained for all varieties. Further thickening of plants (due to continuous sowing) led to a decline in this indicator due to increased competition between plants for moisture and nutrition elements. Thus, under the influence of the optimal spatial placement of plants on a unit area, this indicator in the Rosanna variety compared with the usual row seeding grew by 46 kg/ha, in the Pamyat variety grew by 52 kg/ha, in the Triumph variety grew by 28 kg/ha, in the Budzhak variety grew by 39 kg/ha.

Conclusions

In the conditions of the southern Steppe of Ukraine, the average yield of chickpea Kabuli grain is formed at the level of 1.31 t/ha with a variation of 1.04 up to 1.83 t/ha depending on the weather conditions of the year, varieties and methods of sowing. Weather conditions have a dominant influence on the chickpea crop (73%). The Rosanna variety is characterized by the least variability in yield over the years. The highest yield between the two contrasting years of moisture availability has a variety Budzhak as 1.48 t/ha against 1.26-1.43 t/ha or 4-17% more in comparison with other varieties, this characterizes its high genetic plasticity and compensatory ability. The highest yield of chickpea grain is formed in wide-row crops, with a yield increase of 0.12 t/ha or 9.6% compared to conventional row sowing. The protein content

Table 4. Yield, protein content and protein harvest on average for 2008-2010 and 2017-2019

Sowing rate	Variety	Yield, t/ha	The protein content in grain, %	Conditional yield of crude protein (CP), kg/ha	Conditional yield of CP (mean value on varieties), kg/ha
Conventional row (15 cm)	Rosanna	1.20	23.8	284	320
	Pamyat	1.16	26.9	312	
	Triumph	1.30	26.4	343	
	Budzhak	1.33	25.7	341	
Wide-row (45 cm)	Rosanna	1.35	24.5	330	361
	Pamyat	1.32	27.7	364	
	Triumph	1.39	26.7	371	
	Budzhak	1.45	26.3	380	
S	1.31	26.0	x	x	
V, %	7.2	5.0	x	x	
$X \pm S_x$	1.31±0.01	26.0±1.66	x	x	

of chickpea grains on average in the experiment was 26.0% with a variation in varieties from 22.1 up to 30.3%. A strong correlation between the protein content of chickpea grains and the air temperature during the growing season was established (r = 0.79-0.84). The highest protein content was noted in the Pamyat variety, but the advantage in protein yield was provided by the Budzhak variety, in broad-row crops of which the protein yield reached 380 kg/ha.

Longer-term experiments are required for monitoring the changes in crop yields and protein content in grain of chickpea. In our region, chickpea types comprising both Desi and Kabuli should separately be investigated in dry and rainy conditions too. This information will be of immense utility for increasing and stabilizing the yield of chickpea in the south of Ukraine.

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