KAPITEL 7 / *CHAPTER 7* [7]

CULTURE OF CHICKPEA: ELEMENTS OF CULTIVATION UNDER IRRIGATION CONDITIONS OF THE SOUTHERN STEPPE OF UKRAINE

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Introduction.

In modern world agriculture it is difficult to overestimate the role of legumes. Their nitrogen-fixing capacity makes it possible to replenish soil reserves with free symbiotic nitrogen, which allows farmers to reduce the use of mineral fertilizers. Vegetable protein from pulses is the cheapest. The lack of adequate vegetable protein leads to a deterioration in the food supply of the population, excessive feed consumption and higher costs of livestock products. The main source of vegetable protein is legumes, which provide 2-3 times more protein per unit area than cereals and help preserve soil fertility, reduce the use of nitrogen fertilizers, and produce environmentally friendly products. In order to produce the planned volumes of high-protein grain in each region, it is necessary to select a group of legumes that best utilizes their biological potential. In the Southern Steppe of Ukraine, the trend toward climate aridization makes such a crop as chickpea promising [1-3]. Possessing high drought resistance, heat tolerance, and harvesting technology, chickpea can stabilize the production of high-protein grain and increase the sustainability of the entire agroecosystem. In this regard, improving the methods of growing it on irrigated land is important.

To increase the productivity of chickpea, methods aimed at improving the supply of moisture to plants and optimizing the phytosanitary condition of crops are of great importance. First of all, it is the selection of rational methods of sowing plants, as well as the regulation of weeds through the use of modern herbicides. Optimization of these processes will allow the most efficient use of agrobiological resources in the process of realizing the potential productivity of modern chickpea varieties. All of the above became the basis for choosing the direction of our research.

Chickpea plays an important role in solving the problem of vegetable protein, as this crop is characterized by high yields and the grain is rich in nutrients. It contains 18-30% protein, 48% fat, 48-56% nitrogen-free extractives (starch, sugar, etc.), 3.5-

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5% fiber, 2.8-3.7% ash, and vitamins [4-10]. Although chickpea lags behind soybeans or beans in terms of protein content, it is the leader among all legumes in terms of nutrition. In terms of fat content, chickpea grain is second only to soybeans [11-14].

Chickpea protein is rich in essential amino acids - methionine and tryptophan. The trace element composition of the grain is rich in phosphorus, magnesium and potassium. It is also a good source of lecithin, vitamin B2, vitamin B1, nicotinic and pantothenic acids, and choline. The amount of vitamin C in chickpea seeds is not very high, but it increases significantly when the seeds germinate. Chickpea greens contain oxalic, citric and malic acids [11-13].

According to academician O. Babych, with a chickpea grain yield of 25 c/ha, the protein yield is 675 kg/ha and fat 112.5 kg/ha, which is 12 and 53.5 kg/ha more than peas with a yield of 30 c/ha, respectively [4].

By the end of the XX century, chickpea became the world's third most important legume crop after soybeans and peas. According to the FAO, chickpea crops account for 15% of the world's pulses, producing about 13% of the world's pulses. The leaders in its consumption are the peoples of India, Pakistan and Bangladesh. In recent years, the world's chickpea crops have occupied about 7 million hectares, with an annual increase in its area of about 1% [10, 11, 13].

About 95% of all chickpea production for food purposes is concentrated in developing countries. Of these, about 75% of the total volume grown is in South Asia. The main chickpea producers in the Southwest region are India, Pakistan, and Turkey. In India, chickpeas account for more than 40% of total pulse production. In India, chickpeas are the main source of protein in vegetarian cooking. The plant is used in medical practice in Asia and Europe. Products made from chickpeas are included in the mandatory assortment of European supermarkets, given their compliance with the requirements for a balanced diet [15]. It has been established that chickpeas have a positive effect on the human brain due to the content of tryptophan, which forms one of the most important hormones and neurotransmitters of the human central nervous system - serotonin [1, 2].

Turkey is a major exporter of chickpeas in Asia, accounting for 30% of global chickpea exports at the end of the 20th century. Latin American countries grow about 3% of chickpeas. Among African countries, chickpeas are grown in Ethiopia, Morocco and Tanzania. More recently, Australia has started commercial production of chickpeas. Since there is practically no domestic demand in this country, the products are grown for export to the markets of Asian countries - India, Pakistan and

Bangladesh. Mexico is another major exporter of chickpeas, accounting for 17% of total exports, mainly to the United States [4].

In Ukraine, demand is growing and the area under chickpeas is expanding. In recent years, chickpea crops have begun to spread rapidly, first in the South and then in the Forest-Steppe region. In 2016, the largest planted areas were in Donetsk (29.6%), Odesa (28.2%) and Kharkiv (19.7%) regions. In Ukraine, its production area is growing every year and already in 2005 amounted to 33 thousand hectares [16]. Over the past 10 years, the area under chickpea has increased and amounts to about 60-70 thousand hectares. It is also important that the demand (and hence the price) for chickpeas is higher than for soybeans or peas, for example [17]. In 2014-2015, chickpea grain exports reached 20 thousand tons.

Chickpea is the most drought-resistant crop, with a transpiration coefficient of 350, but it decreases to 290 when fertilized, while chickpea has a 400, and pea has a 500. In addition, plants have a high osmotic pressure of cell sap - 17 atmospheres, while peas have 7 atmospheres less, which contributes to the development of the root system and the transportation of water from great depths [3, 15]. Also, chickpea cells contain less free and more bound water, which results in lower evaporation than other legumes [3, 14, 15, 16].

Using this feature is the basis for increasing the yield of chickpea grain in areas with a moisture deficit of up to 20%, so it is sown mainly on non-irrigated lands, and rarely on irrigation [17-21]. However, the efficiency and payback of irrigation water for chickpea cultivation is very high, and yields can increase dramatically up to 45%, especially when irrigated during the phase from flowering to bean formation [22-27].

Experimentally, it was found that under irrigation conditions in southern Ukraine, chickpea grain yield increased by 0.84-0.96 t/ha compared to non-irrigated areas [22, 23, 28, 29, 30]. However, with excessive moisture, the number of ovaries sharply decreases, the beans grow, but seeds are not formed in them [2, 22].

Therefore, it is important for the crop to have a scientific basis for the irrigation regime. Chickpea requires a lot of water during swelling, as seeds absorb about 121% of water relative to their weight [3, 23, 28, 29, 31, 32].

According to other data, on average, chickpea requires 106% of moisture by weight of seeds. During the branching phase, the optimal moisture content is 70-80% of HB, but its greatest need for water is noted during budding. Excessive precipitation in any phase can contribute to ascochitosis [3].

Chickpea plants are characterized by high water retention capacity. Thus, according to experimental data, plants lost only 9% of moisture in 4 hours, compared to 26-33% in peas during the flowering phase, where the moisture content is 40.4% [9, 22]. Chickpea is under severe stress from a lack of moisture in the period from flowering to the beginning of grain filling [23]. The lack of moisture at this time leads to a 67% yield loss (from 2766 kg/ha with irrigation to 909 kg/ha without it). Even under conditions of limited (economical) irrigation, the yield of chickpea in semi-desert climatic conditions is higher than under conditions without irrigation. The economical irrigation regime provides for 1 watering at the beginning of grain filling or additionally during the flowering phase. Water-saving irrigation allows to obtain a chickpea yield only at the level of 60-90% of the value of full irrigation, but at the same time increases the efficiency of water use by 28-52% [22, 28, 29].

A similar opinion is expressed by other scientists, who note that a lack of moisture during the filling phase of chickpea grain leads to a significant decrease in yield. But a high level of moisture availability during the ripeness phase restores the secondary growth of the crop, which greatly delays and complicates harvesting [11, 12, 32].

In the semi-desert climate of Jordan, chickpea plants under natural moisture conditions reached their maximum dry weight earlier and 33 acquired optimal harvesting moisture faster than under irrigation (weekly irrigation at a rate of 7 mm/ha). This is due to a shorter growing season due to the reproductive phase of growth and accelerated ripening under non-irrigated conditions. Reduction of chickpea yield by varieties: Flip 93-255, Jubeiha 3 and genotypes: DZ 10-11, DZ 10-92 without irrigation was 49-54% compared to irrigation [26].

According to the studies conducted in the fields in Policoro (Southern Italy), irrigation had a positive effect on the productivity of chickpea plants of only three varieties (Pa1, Pa3 and Kairo). They increased dry matter content from 17 to 24%, grain yield from 13 to 24%, number of beans from 15 to 32%, and number of seeds per bean from 14 to 27%. On all other varieties, irrigation led to a decrease in productivity from 10 to 21% or did not give any positive results [27].

Despite its drought tolerance, when forming highly productive agrocenoses in the rice checks of Kalmykia, chickpea culture consumes up to 3010-4060 m3/ha of water during the growing season. The main source of moisture, up to 47% of total water consumption, is soil moisture reserves. Soil moisture is the main prerequisite for high and sustainable grain yields. It is necessary for the start of growth processes, is the main solvent of nutrients and determines the conditions of growth and development during ontogeny [14, 22, 23, 30, 32].

Studies with different conditions of irrigation cessation (no irrigation; irrigation before flowering (85 days after sowing); irrigation after the beginning of grain formation (129 days after sowing); irrigation for the entire period) show that non-irrigated plants had low leaf water potential, evapotranspiration, photosynthetic activity, low dry matter and yield. Cessation of irrigation before flowering led to a decrease in photosynthetic activity and yield by 33% due to a decrease in the number of beans. Irrigation after the beginning of grain formation caused a slight increase in yield due to the formation of additional beans with small grains. Water stress had the greatest effect on the number of beans formed on the plant and almost no effect on the number of grains per bean [22, 23].

When placing chickpea on irrigation, irrigation should be carried out at a rate of 250-300 m3/ha in the flowering and flowering phases - the beginning of bean formation. This will almost double the yield. However, in wet years or at high irrigation rates, there is a risk of fungal diseases [5, 21, 22, 23].

The size of chickpea grain is quite an attractive feature for agricultural producers, because the price of commercial grain largely depends on the weight of 1000 seeds. In this regard, a new variety was created that was not inferior to the best varieties in terms of productivity and, based on the results of state variety testing, was included in the Register of Plant Varieties of Ukraine in 2003 under the name Antei [18]. Unfortunately, its disadvantage is its susceptibility to disease, which leads to significant annual losses in quality and yield in general. In addition, the sprawling shape of the bush, even with a slight thinning of the crop, leads to the breakage of 2nd order branches and direct yield losses. Nevertheless, Antaeus did its job and gave impetus to further breeding work towards the creation of varieties with large grains. In 2005 and 2008, Triumph and Budzhak, which form larger grains than the previous variety, were included in the Register of Plant Varieties of Ukraine [7, 8, 19].

Triumph, Budzhak, Odyssey and Skarb produce large light seeds that are in high demand on the Ukrainian and international markets. The yield of these varieties averages 22-26 c/ha and depends largely on the cultivation technology and weather conditions of the year [8, 22, 23].

An analysis of the achievements of breeders in most crops has shown that following a certain model improves breeding work and leads to accelerated development of new varieties. According to the leading breeders V. I. Sichkar and O. V. Bushulian [6, 18], chickpea varieties with a weight of 1000 seeds of 320-350 and 400-420 g and a growing season of 90-120 days should be developed for the South of

Ukraine. The germination-flowering period should last 20-25 days, and the flowering and flowering-ripening periods should last 35-45 days. The optimum plant height for this region is 50-60 cm, the height of the lower bean attachment is 15-17 cm, and the best bush shape is compressed upright with 2-3 branches of the 1st order and 4-6 - of the 2nd. To increase the number of beans per plant, a two-legume gene should be introduced, and plants should be resistant to major diseases, as epiphytoties will be observed with the expansion of chickpea acreage in the South of Ukraine. Collection varieties accumulate from 18 to 32% of complete protein in their seeds. But experience shows that targeted breeding to increase protein content is a very complex and expensive process. Therefore, it is more expedient to create more productive varieties while maintaining the protein content at an average level.

In modern conditions, varieties and hybrids are independent factors of agricultural intensification. The varietal composition of chickpea has expanded in recent years, which provides a wide range of choices for their introduction into production. For the rainfed conditions of the Southern Steppe of Ukraine, it is necessary to study chickpea varieties with high adaptive properties to local conditions.

The peculiarity of the development of modern crop cultivation technologies is that they are increasingly focused on specific varieties, and this is the logical conclusion of the breeding process. This requires the development and improvement of cultivation techniques for each variety in order to use soil and climatic resources more efficiently. For example, in order to obtain high sustainable yields of chickpea grain, it is essential to determine the optimal sowing method for its cultivation, taking into account the biological characteristics of individual varieties.

7.1. Research conditions and methodology.

The research was conducted under drip irrigation conditions on the experimental field of the Mykolaiv State Agricultural Research Station of the Institute of Irrigated Agriculture of the National Agrarian Academy of Sciences of Ukraine.

The soil of the experimental field is southern chernozem, residually slightly saline, heavy loamy with a humus content of 2.9%. Nutrient availability of the topsoil (mg/100 g of absolutely dry soil): nitrate nitrogen - 2.8; mobile phosphorus - 5.3; exchangeable potassium - 13.7. The acidity of the soil is close to neutral (pH 7.1). The lowest moisture capacity of the soil layer is 0-30 cm - 24.8%; 0-100 cm - 24.7%, wilting moisture - 11.7% of the soil mass in dry state, bulk density - 1.35-1.38 g/cm^3.

Field experiments and laboratory studies were conducted according to the following methods:

1. Methodical recommendations for conducting field experiments under irrigation conditions of the Ukrainian SSR. Dnipropetrovs'k; UkrNIOSH, 1985. part 1. 114 c.

2. Methodical recommendations on evaluation of field experiments, production testing of new varieties, agrotechnological methods and technologies under irrigation conditions of the Ukrainian SSR. Dnipropetrovs'k; UkrNIOSH, 1985. part 2. 127 c.

3. Ushkarenko V.O. Analysis of variance and correlation in agriculture and crop production: a textbook / [Ushkarenko V.O., Nikishenko V.L., Holoborodko S.P., Kokovikhin S.V.]. Kherson: Ailant, 2008. 272 c.

Chickpea cultivation is generally accepted, except for the technological methods that were taken for study. Sowing of chickpea was carried out in a wide-row method with a row spacing of 45 cm, and in a conventional row method with a row spacing of 15 cm, in the fields of irrigated crop rotation of the experimental base of the Mykolaiv State Research Institute of Plant Industry of NAAS. Predecessors - black fallow. The standard in the experiment was the Triumph chickpea variety. The seeding rate was 0.6 million germinating seeds per 1 ha for continuous crops, and 0.4 million germinating seeds per 1 ha for wide-row crops. Mineral fertilizers were applied for pre-sowing cultivation with harrowing, at the rate of $N_{32}P_{32}K_{32}$. The form of fertilizer was nitroammophoska (16:16:16). Soil moisture was maintained within 80-70-70 % HB, soil moisture control was determined by the instrumental (thermostat-weight) method or by a tensiometer. The area of the accounting plot was 25 m2. Replication was three times. The following factors were included in the experimental design:

- Chickpea varieties (factor A): Triumph (control), Budzhak, Memory;
- sowing methods (factor B): row - with a row spacing of 15 cm (control); wide-row - with a row spacing of 45 cm
- herbicide background (factor C) - Pulsar® 40, CP (1 l/ha); Bazagran®, BP (2 l/ha); Pivot® 10, v.r.k. (0.8 l/ha).

Herbicides were applied using a Stihl SG 20 hand sprayer. The working fluid consumption was 250-260 l/ha. Spraying was always carried out in dry, sunny weather at an air temperature of 19-23°C and relative humidity of 57-78%.

The research was accompanied by the analysis of soil and plant samples, observations of the dynamics of plant growth and development. All observations were made in two non-contiguous replications.

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Soil samples were taken in layers, every 10 cm in quadruplicate.

Soil moisture was determined by the thermostat-weight method, when dried at a temperature of 1050 C for 8 hours to a constant weight.

The total water consumption during the growing season and for individual interphase periods was determined by the water balance method according to the formula:

$$E = M + O + \left(W_h - W_K\right),$$

where E is the total water consumption for the calculation period, m^3/ha;

M - irrigation rate for the period, m^3/ha;

O - precipitation for the period, m^3/ha;

Wh is the moisture reserve in the active soil layer at the beginning of the growing season (calculation period), m^3/ha;

Wk - moisture reserve in the active soil layer at the end of the growing season, m^3/ha.

The water consumption coefficient was determined by the formula:

$$K_E = \frac{E}{У},$$

where KE is the coefficient for the growing season, m3/ha;

Y is the yield of rapeseed seeds, m3/t;

E - total water consumption, t/ha.

The weediness of chickpea crops was determined by the number of weeds, which were counted on 1 m^2 diagonally at ten points at the beginning of the growing season and before harvesting with the determination of the species composition and weight of weeds.

Phenological observations were carried out on fixed plots in two non-contiguous replications. During the phenological observations, 50 typical plants were selected on the plots, on which the onset of the stages of chickpea development was noted: germination, branching, budding, flowering, and full grain ripeness. The beginning of the phase was taken as the time of its onset in 10% of plants, and the full phase was taken as its onset in 75% of plants.

The density of chickpea plants was determined during the period of full germination and before harvesting by continuously counting plants along fixed plots (trial plots method).

The structure of the crop was studied in sheaf samples, which were taken at full maturity, on 0.25 m^2 plots, in four replications. The sheaf weight, number of plants, branches, beans on the main and lateral branches, seeds per bean, number and weight of seeds per plant, and weight of 1000 seeds were determined. Harvesting and accounting of the crop was performed at the stage of full grain ripeness, by weighing. The yield data were adjusted to a standard seed moisture content of 14%. The results of crop accounting were subjected to analysis of variance.

The statistical and mathematical processing of digital data was performed by analysis of variance.

7.2. Results of the research with chickpea crop.

In general, the weather conditions in 2022 were not favorable enough for the growth and development of chickpea. During the growing season, 80 mm of precipitation fell, which is 43% of the norm, but thanks to irrigation, chickpea formed a fairly good seed yield. The main climatic indicators for the study year in comparison with the average long-term indicators are shown in Tables 1-2.

Table 1 - Total precipitation in 2022 for the growing season of chickpea compared to the average long-term data, mm

Month	monthly average	amount long-term average	± to the average long-term
April	18	32	-14
May	29	44	-15
June	30	54	-24
July	3	58	-55

Snow accumulation during the winter of 2021-2022 was inactive, with alternating periods of snow cover formation and thaws. All decades of the winter period were characterized by higher temperatures and lower precipitation compared to long-term data. The spring of 2022 was characterized as dry. According to the first determination of soil moisture reserves, which was carried out on March 28, 2022, the reserves of productive moisture in both the tilth and meter layers of soil were satisfactory. Namely, they amounted to 18-29 mm in the tilth layer and 74-115 mm in the meter layer, depending on the predecessor. At the beginning of the first decade of April, chickpeas

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were sown (5-6.04). During April, dry and cool weather was observed (no effective precipitation). Subsequently, insufficient moisture of the upper soil layers, lack of precipitation and dry winds did not contribute to the good growth and rooting of chickpea plants. Herbicides Pulsar® 40, CP (1 l/ha); Bazagran®, BP (2 l/ha); Pivot® 10, v.r.k. (0.8 l/ha) were applied in the phase of 2-5 true leaves of the crop with a hand sprayer at a rate of 200 l/ha.

Due to the precipitation deficit in May (29 mm or 66% of the norm), the soil moisture supply was poor, and dry conditions negatively affected the further growth of plants, which were already in budding at that time, so the crops were irrigated.

Table 2 - Average monthly wind temperature during the growing season of sunflower compared to the long-term average, °C

Month	monthly average	average long-term	± to the average long-term
April	9,4	10,5	-1,1
May	16,3	15,5	+0,8
June	22,3	20,5	+1,8
July	24,5	21,2	+3,3

In early June, mass flowering was observed in chickpea crops, but weather conditions remained difficult due to the lack of effective precipitation. Even for drought-tolerant chickpea, the rains that occurred during the second and third decade (33 mm) were not enough for grain formation, filling and ripening, but irrigation offset the negative effects of the drought.

As of July 08, the plant density was 31-46 pcs/m^2. Plant height: Triumph variety - 49-58 cm, Budzhak - 55-59 cm, Pamyat - 45-53 cm, depending on the sowing method and herbicide background. Differentiation of chickpea development was observed depending on varietal characteristics, sowing methods and herbicide background.

Plant care included loosening row spacing and weed control. Weed infestation was low. In general, the overall growth and development of chickpea was satisfactory for the current period. Chickpeas were in the ripening phase, harvested in the second decade of July.

The peculiarities of the phenological phases and the duration of the main periods of chickpea development from full germination to maturation in all variants of the experiment were subject to the scheme generally accepted for almost all field crops -

with an increase in plant density in crops, the phases came earlier and the duration of the periods decreased (Table 3). Thus, with the row seeding method, where the plants were denser, the duration of the period full germination-budding ranged from 11 to 12 days; budding-flowering - from 13 to 15 days; bean formation-ripening - from 30 to 32 days. Increasing the row spacing improved the conditions for plant development and the duration of all major periods of chickpea development increased by 3-7 days.

Table 3 - Phenology of chickpea crop development (average for 2021-2022)

Sowing method	Chickpea variety	Phases of growth and development				
		seedlings	budding	flowering	bean formation	full maturity
In-line	Triumph	22.04.	2.05.	15.05.	10.06.	8.07.
	Memory	22.04.	3.05.	17.05.	12.06.	10.07.
	Budzhak	22.04.	2.05.	15.05.	10.06.	8.07.
Wide row sowing	Triumph	22.04.	5.05.	21.05.	14.06.	10.07.
	Memory	22.04.	7.05.	24.05.	16.06.	15.07.
	Budzhak	22.04.	5.05.	21.05.	14.06.	10.07.

The studied chickpea varieties proved to be mid-season (95-100 days) in the Southern Steppe, the difference between varieties in terms of the length of the growing season was insignificant, except for the Pamyat variety [28, 30]. Thus, the shortest duration of the growing season in the experiment was observed in Triumph and Budzhak varieties - 93-95 days on average in all variants of the experiment. The Pamyat variety had a longer growing season, which ripened 2-5 days later.

Table 4 shows that the lowest total water consumption of chickpea crops was in the variant of row sowing - 3217 m^3/ha, which is lower than this figure in comparison with wide-row crops by 104-125 m^3/ha (depending on the variety).

The coefficient of total water consumption of chickpea ranged from 1289 to 1474 m^3/t. Sowing with a seeding rate of 0.4 million units/ha with a row spacing of 45 cm was one of the conditions for more rational water use in the chickpea field. For the implementation of this agrotechnological technique under drip irrigation, the water consumption coefficient on average for varieties was 1357, while for row sowing with a sowing rate of 0.6 million units/ha - increased to 1406 m^3/t. In our opinion, this can be explained by the fact that in this variant the placement of plants on the area was more uniform, and in continuous crops less moisture was retained mainly due to the increase in plant density.

Table 4 - Water use efficiency of chickpea varieties under different sowing methods (average for 2021-2022)

Sowing method	Chickpea variety	Total water consumption, m^3/ha	Yield, t/ha	Water consumption coefficient, m^3/ha
In-line	Memory	3196	2,17	1474
	Triumph	3217	2,28	1410
	Budzhak	3238	2,43	1333
Wide row sowing	Memory	3321	2,35	1415
	Triumph	3342	2,45	1367
	Budzhak	3342	2,59	1289

It was also interesting to track the efficiency of moisture consumption by chickpea varieties. Our research has shown that this indicator, depending on the chickpea variety, ranged from 1311-1444 m^3/t (on average by sowing method). Plants of the Pamyat variety consumed 56-133 m^3/t more water per unit yield compared to Triumph and Budzhak varieties, respectively.

Chickpea is a highly cultivated plant, and the presence of weeds in crops leads to severe suppression, especially in the early stages of the growing season. The presence of a large number of vegetative weeds during harvesting can also lead to a deterioration in the quality of chickpea grain. No herbicide approved for use in chickpea crops is currently officially registered in Ukraine. Many farms use agronomic weed control measures. However, many years of experience have been gained in the use of a number of herbicides both in Ukraine and other countries. So, mainly in chickpea crops, such soil preparations as Stomp, 33% e.e., Harness, 90% e.e., Frontier Optima, 72% e.e., as well as post-emergence preparations - Pivot, 10% e.e., Bazagran, 48% e.e., Pulsar, 40% e.e., Aramo, 45% e.e., Harmony, 75% e.e. are used.

When conducting research under drip irrigation conditions, the task was set: to develop a technology for protecting chickpea crops with herbicides without the use of mechanical inter-row cultivation. In this regard, in chickpea crops we studied the effectiveness of such post-emergence preparations as Bazagran, 48% a.i., Pulsar, 40% a.i. and Pivot® 10, a.i. Our observations of weed infestation of chickpea crops showed that the number of weeds varied significantly depending on the technology of crop protection (Table 5).

Table 5 - Influence of sowing methods and herbicide background on weed infestation of chickpea crops (average for 2021-2022), pcs/m²

Sowing method	Protection technology (herbicide background)	Annuals		Perennial root sprouts	Total
		cereals	broad-leaved		
Before processing - phase 2-5 chickpea leaves					
In-line	Pulsar (1.0 l/ha)	108	22	4	135
	Bazagran (2.0 l/ha)	102	18	8	129
	Pivot (0.8 l/ha)	105	24	3	132
Wide-row	Pulsar (1.0 l/ha)	118	37	8	163
	Bazagran (2.0 l/ha)	105	36	11	152
	Pivot (0.8 l/ha)	107	39	12	158
2 weeks after treatment					
In-line	Pulsar (1.0 l/ha)	18	3	1	22
	Bazagran (2.0 l/ha)	24	5	1	30
	Pivot (0.8 l/ha)	22	4	2	28
Wide-row	Pulsar (1.0 l/ha)	19	9	3	30
	Bazagran (2.0 l/ha)	26	8	2	36
	Pivot (0.8 l/ha)	23	8	2	33
Before harvesting					
In-line	Pulsar (1.0 l/ha)	20	1	2	23
	Bazagran (2.0 l/ha)	28	2	3	33
	Pivot (0.8 l/ha)	24	2	3	29
Wide-row	Pulsar (1.0 l/ha)	14	3	5	22
	Bazagran (2.0 l/ha)	21	3	6	30
	Pivot (0.8 l/ha)	18	2	6	26

The number of weeds before the treatment of chickpea crops with herbicides was in the range of 129-163 units/m². In the period of 14 days after the application of herbicides, the number of weeds per 1 m² decreased by 100-128 units/m² and reached 28-36 units/m² depending on the herbicide background. Different preparations showed unequal technical efficiency, which in turn caused different degrees of competition for life factors between them and chickpea plants.

Thus, when Pulsar herbicide was applied, weed infestation was reduced by 83%, this herbicide almost completely destroyed bindweed, common ragweed, field bindweed and partially gray mouse and chicken millet. The use of Pivot was highly effective, as weed infestation was reduced by 79%. Some species of chamomile, white

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quinoa and wild violet showed relative resistance to Pivot herbicide. When applying the herbicide Bazagran, it was 77%. It should be noted that the herbicides studied did not inhibit chickpea plants, and no density reduction was observed.

Before harvesting, a slight increase in the number of weeds was observed, but these weeds (mainly field bindweed, ragweed), which sprouted again after irrigation in the second half of the chickpea growing season, did not have a significant impact on the growth and development of the crop. At that time, there was no pronounced effect of sowing methods on weed infestation of chickpea crops.

The objective of our research was to study the formation of yield and quality of chickpea grain depending on the variety, sowing method, and the use of herbicides under drip irrigation. Thus, the studies showed a fairly high efficiency of the above factors in the cultivation of chickpea (Table 6).

Our studies have shown that the methods of sowing chickpea plants significantly affect the level of yield of its seeds. Thus, on average, for all varieties, the maximum grain yield (2.46 t/ha) was obtained in wide-row crops (average for the herbicide background). In this case, the yield increase was 0.17 t/ha or 8% compared to conventional row sowing. The high yield of chickpea in this variant is characterized, first of all, by the optimal spatial and quantitative placement of plants per unit area. The feeding area affects the rate of plant growth and development, as it determines the amount of incoming solar energy, moisture and nutrients. Therefore, by optimizing the sowing method, the yield of chickpea seeds can be regulated.

Table 6 - Influence of sowing methods and herbicide background on the yield of of chickpea varieties (average for 2021-2022), t/ha

Variety (factor A)	Herbicide background (factor C)		
	Pulsar	Bazagran	Pivot
Row sowing method (factor B)			
Memory	2,33	1,98	2,21
Triumph	2,42	2,18	2,25
Budzhak	2,53	2,34	2,43
Wide-row sowing method (factor B)			
Memory	2,42	2,26	2,37
Triumph	2,59	2,28	2,48
Budzhak	2,68	2,43	2,65
SSD_{05}, t/ha	*A – 0,08, B – 0,06, C – 0,08, AB – 0,13, AC – 0,16, BC – 0,11, ABC – 0,24.*		

It is well known that the level of weed infestation of chickpea crops is one of the factors that reduce its productivity. In this regard, research on the effectiveness of herbicides on the formation of chickpea grain yield is quite relevant. Data on the amount of yield reduction are of great importance in the development of an integrated weed control system in chickpea crops, in which the main place is occupied by the definition of such an indicator as the economic threshold for the feasibility of using herbicides.

The data obtained in our studies show that the most effective in irrigated conditions of the South of Ukraine is the use of Pulsar or Pivot herbicides in chickpea crops in the phase of 2-5 true leaves of the crop. In particular, in the variant with the use of Pulsar, the highest crop yield was obtained - 2.49 t/ha, which is 0.09-0.25 t/ha higher than its level when using Bazagran and Pivot, respectively (average for varieties and sowing methods).

Thus, the highest yield of chickpea seeds was formed in wide-row crops, with a yield increase of 0.11 t/ha or 7.8% compared to conventional row sowing. The use of Pulsar herbicide in chickpea crops in the phase of 2-5 true leaves increases seed yield by 0.09-0.25 t/ha or 5-9% compared to the use of other chemicals.

Comparative evaluation of chickpea varieties showed that the variety of the Mediterranean subspecies Bujak proved to be the most adapted to the irrigated conditions of the steppe zone of Ukraine, which on average formed the maximum seed yield of 2.51 t/ha, which is 0.14 t/ha higher than the control variety Triumph. Variety Budzhak at wide-row sowing on the background of the use of herbicide Pulsar, 40% a.i., 1 l/ha in the phase of 2-5 true leaves provided the maximum seed yield (2.68 t/ha).

The food and fodder advantages of chickpea are due to the high protein content in the grain (20-32%). Chickpea ranks fourth among pulses in terms of protein after soybeans, beans and peas. Our studies have shown that the protein content of chickpea grain was significantly influenced by the genetic characteristics of the studied varieties (Table 7). Thus, on average, according to the sowing method and herbicide background, the Bujak variety formed the highest amount of crude protein in seeds - 28.9%, which is 2.9% and 1.6% higher than in the Pamyat and Triumph varieties, respectively [22, 23].

The experiment showed a positive effect on the protein content of chickpea seeds caused by herbicide application. Thus, if when spraying crops in the phase of 2-5 true leaves of the culture with Bazagran, the protein content in the grain of varieties ranged from 25.8%, in the variant of Pivot application the protein content increased to 27.6%

(an increase of 1.8% compared to Bazagran), and when using Pulsar - to 28.7% (an increase of 2.9% compared to Bazagran). Thus, in the context of herbicide backgrounds, the amount of protein in the seeds had a small difference, but it was recorded.

Table 7 - Protein content in chickpea seeds depending on the experimental variants (average for 2021-2022)

Variety (factor A)	Herbicide background (factor C)		
	Pulsar	Bazagran	Pivot
Row sowing method (factor B)			
Memory	26,8	22,8	25,4
Triumph	27,8	25,1	25,9
Budzhak	29,1	26,9	27,9
Wide-row sowing method (factor B)			
Memory	27,8	26,0	27,3
Triumph	29,8	26,2	28,5
Budzhak	30,8	27,9	30,5
Standard deviation S	*1,48*	*1,78*	*1,85*
Standard error Sx	*0,60*	*0,72*	*0,75*

In the context of sowing methods, this indicator had the following values: for continuous sowing in the Pamyat variety - 25.0%, Triumph - 26.3% g, Budzhak - 28.0%; for wide-row sowing, protein in the seeds of the Pamyat variety was accumulated at the level of 27.0%, Triumph - 28.2% g, Budzhak - 29.7%. That is, the difference between the sowing methods was also low and amounted to 1.8-2.0% in favor of the wide-row sowing method with 45 cm row spacing.

Chickpea is a valuable food and fodder crop with significant agrotechnical importance. Its production use is especially important in the extremely arid Steppe of Ukraine. The shortage of high-quality commercial chickpeas on the world market creates a unique opportunity for Ukrainian farmers to improve the financial condition of their farms when growing chickpeas. This should be facilitated by the use of new high-tech varieties, which is the cheapest and most effective way to reduce losses from the negative impact of extreme environmental factors and massive epiphytoties of diseases. These current conditions are the basis for the formation of the program and the practical management of chickpea breeding.

Therefore, one of our objectives was to determine the economic efficiency of the studied agrotechnical methods in chickpea cultivation, such as the use of varieties with different sowing methods and the use of herbicides under drip irrigation [33]. The economic efficiency of the studied elements of chickpea cultivation technology was determined by the calculation method based on actual prices in 2022 according to the generally accepted methodology - by costs per 1 ha, profit per 1 ha, cost price and profitability.

The analysis of the data showed that when growing chickpeas with different sowing methods, the best results were obtained in wide-row crops at a seeding rate of 0.4 million germinating seeds/ha (Table 8).

Table 8 - Economic indicators of chickpea varieties production depending on sowing methods and herbicide background (average for 2021-2022)

Variety (factor A)	Herbicide background (factor C)	Harvest Yield, t/ha	Protein harvest, kg/ha	Production costs, UAH/ha	Pro forma net profit per 1 hectare, UAH	Profita-bility, %.
Sowing method - row (15 cm)						
Memory	Pulsar	2,33	624	22940	9680	42
	Bazagran	1,98	451	22546	5174	23
	Pivot	2,21	561	22743	8197	36
Triumph	Pulsar	2,42	673	24940	8940	36
	Bazagran	2,18	547	24546	5974	24
	Pivot	2,25	583	24743	6757	27
Budzhak	Pulsar	2,53	736	24940	10480	42
	Bazagran	2,34	629	24546	8214	33
	Pivot	2,43	678	24743	9277	37
Sowing method - wide-row (45 cm)						
Пам'ять	Pulsar	2,42	673	20940	12940	62
	Bazagran	2,26	588	20546	11094	54
	Pivot	2,37	647	20743	12437	60
Тріумф	Pulsar	2,59	772	22780	13480	59
	Bazagran	2,28	597	22386	9534	43
	Pivot	2,48	707	22583	12137	54
Буджак	Pulsar	2,68	825	22780	14740	65
	Bazagran	2,43	678	22386	11634	52
	Pivot	2,65	808	22583	14517	64

With the highest yield for all studied varieties, the cheapest seeds were obtained here (8500-9818 UAH/t). In the case of line sowing, the seeding rate of 0.6 million germinating seeds/ha is considered optimal for the formation of a higher seed yield and economically feasible. However, as a result of lower yields and cost overruns for sowing seeds, this variant results in an increase in cost by 1193-1891 UAH/t and a decrease in profitability by 18-31%.

Among the studied varieties, the highest economic efficiency of grain production was provided by the variety Budzhak. When Pulsar 40 (1 l/ha) was applied, the cultivation of Bujak was the cheapest (the cost of 1 ton was 9858 UAH). Sowing in a wide-row method made it possible to obtain an additional 0.35 tons of grain from 1 hectare, the cost of 1 ton of which, compared to the control (continuous sowing), decreased to 8500 UAH/t, and the profitability was 65%.

In general, for all chickpea varieties, the best results were obtained by applying the herbicide Pulsar and wide-row sowing.

Thus, chickpea cultivation in the irrigated conditions of the Southern Steppe is highly profitable. Depending on the varieties, sowing methods and use of herbicides, production costs per 1 ha are 20546-24940 UAH, the cost of seeds is 8500-11387 UAH/t, and the net profit reaches 5174-14740 UAH/ha at a profitability level of 23 to 65 %.

It was found that the cultivation of the large-grain variety Budzhak provides an advantage in protein collection, in wide-row crops of which, in the best variant of the herbicide Pulsar, the protein collection with the yield reached 825 kg/ha.

Conclusions.

1. The duration of the interphase and vegetation periods of chickpea depended on the variety and sowing methods. The longest vegetation period - 100-105 days - was with the wide-row method of sowing chickpea, and the shortest - with the continuous method of sowing, 93-95 days. The studied chickpea varieties are medium-ripening, the Pamyat variety ripened 2-5 days later, and the difference in the duration of the growing season was insignificant between the other varieties.

2. On average, the total water consumption of chickpea crops from the soil layer of 0-100 cm was 3196-3342 m^3/ha. The lowest coefficient of water consumption was formed at a distance between chickpea rows of 45 cm with a seeding rate of 0.4 million seeds/ha. In the context of varieties, the lowest water consumption for the formation of 1 ton of seeds was in the crops of the large-grain variety Budzhak - 1311 m^3 of water (average for sowing methods).

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3. Due to the slow development in the initial phases, chickpea is largely affected by the negative impact of fast-growing weeds. Therefore, the most effective method of protection is the use of broad-spectrum herbicides on vegetative plants. Thus, against the background of Pulsar 40 (1.0 l/ha) and Pivot (0.8 l/ha), the level of weed infestation of crops was the lowest, and the effectiveness of chemicals reached 79-83%.

4. The highest yield of chickpea seeds was formed in wide-row crops, with a yield increase of 0.11 t/ha or 7.8% compared to conventional row sowing. The use of Pulsar herbicide in chickpea crops increases the seed yield by 0.09-0.25 t/ha or 5-9% compared to the use of other chemicals. Variety Budzhak with wide-row sowing on the background of the use of herbicide Pulsar, 40% a.i., 1 l/ha in the phase of 2-5 true leaves provided the maximum seed yield (2.68 t/ha).

5. Sowing chickpea with a row spacing of 45 cm created the best conditions for the formation of better quality seeds. The protein content under these conditions was the highest and ranged from 27.8 to 30.8% against the background of spraying with Pulsar herbicide. Protein yield by variant varied from 451 to 825 kg/ha.

6. The most economically efficient is the use of a wide-row sowing method, which produces the highest yield for all studied varieties and, accordingly, the cheapest seeds. Wide-row sowing of Budzhak variety for spraying crops with Pulsar herbicide provides a conditional net profit of 14740 UAH/ha and a profitability level of 65%.

For obtaining in the conditions of the South of Ukraine under drip irrigation the yield of chickpea seeds at the level of 2.68 t/ha, conditional protein yield of 825 kg/ha, the lowest water consumption coefficient - 1289 m^3/t, with the highest net profit and profitability level of 65 %, it is recommended to sow the large-seeded variety Budzhak with a row spacing of 45 cm, to control weeds, spray crops in the phase of 2-5 leaves of the crop with the herbicide Pulsar, 40% a.i. (Imazamox, 40 g/l) at 1 liter/ha.

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