MODERN TRENDS IN THE DEVELOPMENT OF AGRICULTURAL PRODUCTION

PROBLEMS AND PERSPECTIVES

EDITED BY
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The monograph presented for review is a collection of the results of actual achievements of domestic agricultural scientists, obtained directly in real conditions. The authors are recognized experts in their fields, as well as young scientists and postgraduate students of Ukraine. Research is conceptually grouped into 5 sections: modern technologies in crop production and fodder production; economy of the agro-industrial complex; breeding and breeding in the 21th century; protection and quarantine of plants; agrochemistry and soil science. The monograph will be interesting for experts in plant breeding, economics, plant protection, selection, agrochemistry, soil science, scientific workers, teachers, graduate students and students of agricultural specialties of higher education institutions, and for all those who are interested in increasing the quantity and quality of agricultural products.

Keywords: modern technologies, crop production, fodder production, plant protection, quarantine, agrochemistry, soil science, economy of agro-industrial complex.

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CHICKPEA VARIETIES PRODUCTIVITY DEPENDING ON COMBINATION OF DIFFERENT SOWING METHODS AND SOWING RATE IN THE EASTERN FORESTS STEPPE OF UKRAINE

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The article presents the results of four-year studies on the influence of various combinations of the seeding rate and row-spacing width on plants productivity and grain cropping capacity of chickpea varieties in the conditions of Eastern Forest-Steppe of Ukraine. The highest productivity of chickpea plants of Budzhak and Odyssey varieties was formed on variants with the lowest seeding rate in combination with 15 cm row-spacing. In this variant plant nutrition area was close to the square with the sides ratio 1.0:1.1. At the same time, through the smaller number of plants per unit of area, the grain yield in this variant was significantly inferior to the variants with a higher seeding rate. Two better combination of the seeding rate and row-spacing width were distinguished which ensure the formation of the highest cropping capacity of both chickpea varieties. This is combination of 800 thousand pieces/ha seeding rate with 15 cm row-spacing and 700 thousand pieces/ha seeding rate with 30 cm row-spacing. On mentioned variants, the grain yield of Budzhak variety was 2.34 and 2.44 t/ha respectively, and the grain yield of Odyssey variety – 2.61 and 2.51 t/ha.

***Key words**: chickpea, varieties, seeding rate, row-spacing width, sowing method, productivity, cropping capacity, crop structure*

In Ukraine the largest sown areas are occupied by soy beans and peas among legumes (Babich, 2014). Although the recent weather conditions make producers look for more stress resistant crops of this group which can ensure higher and stabler productivity of qualitative seeds under the conditions of moisture shortage. Chickpea is the most drought and heat resistant seed bean crop. It can endure air drought and heat and grow even in the semi-desert regions (Kernasyuk, 2018).

Chickpea is grown in more than 50 countries on the total area amounting to 13,5 mln ha. 90 % of the obtained yield belong to the South and Fore Asia India (72 %), Pakistan (10 %), Iran (5 %) and Turkey (4 %). Beyond this region the largest seed productivity takes place in Australia (3 %) and Ephiopia (2 %) (Jukanti et al., 2012; Supihanov, 2017; Omprakash & Hemant, 2018).

Though in Ukraine chickpea is not widely spread. Only during the last decade rich landowners began to take an interest in this crop because of precipitation shortage and high temperatures at the vegetation period of seed bean crops. Some last years were very favorable to grow chickpea. That is why the areas under this crops increased from 15–20 thousand to almost 100 the thousand pieces/ha (Sichkar, 2019). Soil-climatic conditions in Ukraine are suitable to grow this crop on the area amounting to more than 1 mln. ha (Vozhegova, 2019). So taking into consideration a big demand of the world`s market for chickpea, it can be one of the most profitable crops in Ukraine.

Conditions and research methods

The research program provides for the study of the complex effect of the seeding rates and sowing methods on chickpea grain cropping capacity and the productivity elements that determine it. Multiple-factor experiments were laid by the method of splitted plots in three repetitions according to the generally accepted methods (Rozhkov, Puzik, & Kalenska, 2016). Plots of the first order were Budzhak and Odyssey chickpea varieties (factor *A*), of the second order – three variants of row-spacing width: of 15, 30 and 45 cm (factor *B*), of the third order – five variants of the seeding rates: of 500 thousand pieces/ha, 600, 700, 800 and 900 thousand pieces/ha (factor *C*). The area of the sowing plot was 25 m^2, and the calculation area was 20 m^2. The main elements of cropping capacity structure were determined using the method of State variety testing of agricultural crops (Volkodav, 2000).

Hydrothermal conditions in the years of research differed significantly from long-term indicators, which allowed us to investigate the influence of the studying factors more fully and discover the optimal ratios of their parameters.

The growth and development of chickpea plants in 2016 was taking place at low air temperatures at the initial stages of growth and excessive precipitation throughout the growing season. The amount of precipitation exceeded the index of climate norm by 143 % (Hydrothermal Coefficient – 1.38), which led to a decrease in indicators of plant survival rates, to the forming of bigger number of unproductive beans and to the lengthening of phenological phases passing of chickpea varieties development.

Hydrothermal conditions in 2017, with the exception of April, can be described as arid (rainfall was 59 % below normal, Hydrothermal Coefficient – 0.87). However, despite the low moisture content of crops, the optimum temperature regime provided favorable conditions for the growth and development of chickpea plants.

Weather conditions in 2018 were characterized by deficiency of precipitation, its disproportionate distribution during the growing season, and high temperature indicators. The amount of precipitation during the growing season was 136 mm, which is 63.5 % less than the average multiyear data. The average temperature during this period exceeded the norm by 3.4 °C. It should be mentioned that the weather was excessively dry and warm at the beginning of the growing season. In April, the average temperature was 4.0 °C higher than normal, and precipitation fell almost 2.5 times less. However, during the first decade of May, precipitation twice exceeded the norm at an abnormally high temperature of 23.2 °C, which is almost 10.0 °C higher than the average temperature. There were no rains in the third decade.

In 2019, there was also a significant shortage of moisture at temperature indicators at the level of the climate norm. From February to July, only 111 mm of precipitation fell (63 % of the average multiyear indicators). Bigger part of them – 100 mm fell in the second half of April and in the first decades of May and July. During the second and third decades of May and the whole June, there was no productive precipitation.

Thus, weather conditions in the years of the research significantly differed from the average multiyear indicators by the temperature regime, the amount and distribution of precipitation. However, taking into account the global climate warming in recent years, it can be noted that they were typical for the area. In general, weather conditions during the growing season of 2017 and 2019 corresponded to the biological requirements of chickpea cropping more.

Discussion of research results

The effectiveness of different seeding rate combinations and variants of row-spacing width were studied in the conducted research, so it is important to analyze the cropping capacity of sowings simultaneously with plant productivity, since there is reverse link between them, namely: with increase in plants density up to a certain limit their yield increases at the same time the productivity of one plant is reduced. Therefore, it is important to determine the level of plant productivity at which the highest crop yield is formed. At the same time it should be taken into account the parameters of plants nutrition area, which are determined by the sowing method and the seeding rate, setting the best their combination to improve the realization of potential of chickpea varieties yield.

It is quite logical that variability in the number of chickpea plants per unit area before harvesting was largely caused by the influence of the seeding rate in the studying diapason. In particular, the maximum difference in the number of chickpea plants before harvesting at the influence of the principal effect of this factor was 18.2 pieces/m^2 (40.7 pieces/m^2 at the seeding rate of 500 thousand pieces/ha and 58.9 pieces/m^2 at the seeding rate of 900 thousand pieces/ha), whereas at the influence of the studying variants of row-spacing width – only 4.3 pieces/m^2 (48.2 pieces/м^2 on the variants with row-spacing of 45 cm and 52.5 pieces/m^2 with row-spacing of 15 cm) (table 1).

In the experiments it is noted a natural tendency to reduce the difference in the number of plants at a gradual stable increase in the seeding rate per 100 thousand/ha. So, on average by variants of row-spacing width and varieties with the increase of the seeding rate of 500 to 600 thousand pieces/ha the number of plants before harvesting rose by 5.9 pieces/m^2 (14.5 %), from 600 to 700 thousand pieces/ha – by 4,7 pieces/m^2 (10.3 %), from 700 to 800 thousand pieces/ha – by 4.1 pieces/m^2 (8,2 %) and from 800 to 900 thousand pieces/ha – by 3.1 pieces/m^2 (5.9 %). At the same time, the seeding rate by the variants of the experiment increased by 20.0 %, 16.7, 14.3 and 12.5 %, respectively.

It was determined that higher indicators of plants quantity before harvesting provided the variants of drill sowing with 15 cm row-spacing, which is quite natural, since competition between plants in the rows at the same seeding rate was signi-ficantly less than with row-spacing of 30 and all the more of 45 cm. In particular, on the variants with 15 cm row-spacing, with increasing the seeding rate of 500 to 900 thousand pieces/ha (80 %) plants survival rate increased by 21.6 pieces/m^2 (52.7 %), and on the variants with 45 cm row-spacing – only by 15.8 pieces/m^2 (40.1%).

For more complete understanding of the effect of the studying seeding rate and row-spacing width combinations, it is advisable to determine the parameters of the nutrition area that they form. They were determined by the actual seeding rate, not by the density of the plants before harvesting

At the seeding rate of 500 thousand pieces/ha, on variants with row-spacing width of 15, 30 and 45 cm, on one linear metre of a row on average 7.5, 15.0 and 22.5 plants will be located, respectively. At the seeding rate of 600 thousand pieces/ha, there will be 9.0, 18.0 and 27.0 pieces, of 700 thousand pieces/ha – 10.5, 21.0 and 31.5 pieces, of 800 thousand pieces/ha – 12.0, 24.0 and 36.0 pieces and of 900 thousand pieces/ha – 13.5, 27.0 and 40.5 pieces of them, respectively.

Table 1

Number of chickpea plants before harvesting depending on row-spacing width and norms of the seeding rate, pieces/m^2 (average during 2016-2019)

Variety (factor *A*)	Seeding rate, thousand pieces/ha (factor *C*)	Row-spacing width, cm (factor *B*)			Average
		15	30	45	
Budzhak	500	41.7	41.8	39.5	41.0
	600	48.6	47.4	45.4	47.1
	700	51.2	51.7	50.3	51.1
	800	56.1	54.0	52.9	54.3
	900	60.0	57.3	55.1	57.5
Odyssey	500	39.8	40.6	38.7	39.7
	600	47.1	45.9	43.4	45.5
	700	52.9	51.7	47.8	50.8
	800	58.1	57.1	52.2	55.8
	900	62.6	59.6	54.7	59.0
Average by factor A	Budzhak	51.5	50.4	48.6	50.2
	Odyssey	52.1	51.0	47.4	50.2
Average by factor *C*	500	40.8	41.2	39.1	40.4
	600	47.9	46.7	44.4	46.3
	700	52.1	51.7	49.1	51.0
	800	57.1	55.6	52.6	55.1
	900	61.3	58.5	54.9	58.2
Average by factor *B*		51.8	50.7	48.0	50.2

Based on these calculations, the average distance between plants in a row with 15 cm row-spacing at the seeding rates of 500, 600, 700, 800 and 900 thousand pieces/ha is 13.3 cm, 11.1, 9.5, 8.3 and 7.4 cm, respectively. On variants with 30 cm row-spacing, the interval between plants in a row at these seeding rates is 6.7 cm, 5.6, 4.8, 4.2 and 3.7 cm, and with 45 cm row spacing – 4.4 cm, 3.7, 3.2, 2.8 and 2.5 cm, respectively.

The area of nutrition of a single plant on all studying variants of row-spacing width at the seeding rates of 500 thousand pieces/ha, 600, 700, 800 and 900 thousand pieces/ha, under conditions of their distribution at an equal distance from each other in a row makes 200 cm^2, 167, 143, 125 and 111 cm^2, respectively. At the same time, the shape of the nutrition area at the same seeding rate on the studying variants of row-spacing width differs noticeably. So, at the seeding rate of 500 thousand pieces/ha on variants with 15 cm row-spacing, it is closer to a square with the ratio of sides 1.1:1.0, with 30 cm row-spacing, it has the shape of a rectangle with the sides ratio 4.4:1.0 and on variants with 45 cm row-spacing – an elongated rectangle with the ratio of sides – 10.2:1.0.

In the range of the seeding rate of 600 to 800 thousand pieces/ha on the sowing variants with row-spacing of 15 and 30 cm nutrition area has the ratio of sides 10:1, while at 45 cm row-spacing width it has the shape of an elongated rectangle in a ratio of sides more than 10:1. In particular, for the seeding rates of 600, 700, 800 and 900 thousand pieces/ha, this ratio is 12.2:1.0; 14.1:1.0, 16.1:1.0 and 18.0:1.0, respectively.

Based on the given data, wide-row sowing at 45 cm provides significantly worse conditions for plants growth and development, since even at the smallest seeding rate, the shape of the area is strongly narrowed with a ratio 10.2:1.0. The shape that is closer to the optimal area of plant nutrition is formed on variants with 15 cm row-spacing, since even at the maximum seeding rate of 900 thousand/ha the ratio of sides of the rectangle was 2.0:1.0. On the variants with 30 cm row-spacing, taking into account admissible indices of distance between plants in the row below which they begin to reduce productivity dramatically (Fartukov et al., 2018; Petrova, et al., 2018), the seeding rate of 500 to 800 thousand pieces/ha provided better conditions for plants development. At the maximum seeding rate of 900 thousand pieces/ha on the variants with row-spacing width of 30 cm, distance between plants in the row was less than 4.0 cm, and the shape of the nutrition area was closer to the elongated, that leads to an abrupt worsening of conditions formation of productive agrocenosis.

It is quite naturally that bigger number of plants before harvesting at a similar seeding rate was marked on the variants of drill sowing method with 15 cm row-spacing. To a greater extent this tendency evinced at higher seeding rate, in other words, at a bigger competition between plants in the row. For example, on average during the years, the difference between the number of plants on variants with row-spacing of 15 and 45 cm at the seeding rate of 500, 600, 700, 800 and 900 thousand pieces/ha made 1.6 pieces/m^2, 3.8, 3.4, 5.3 and 7.4 pieces/m^2, respectively. The difference by this indicator between the variants with row-spacing of 15 and 30 cm was much smaller – 0.7 pieces/m^2, 1.5, 0.1, 1.8 and 3.6 pieces/m^2, respectively.

Research results show that the difference by the number of plants before harvesting on variants with row-spacing of 15 and 30 cm became apparent by increasing the seeding rate over 800 thousand pieces/ha. It proves that in the range of 500 to 800 thousand pieces/ha competition between chickpea plants by row-spacing width of 15 and 30 cm was virtually equivalent. On variants with 45 cm row-spacing, the number of plants before harvesting in comparison with 15 cm row-spacing was less by all seeding rates, which says about worse conditions for the resource potential expression of plant productivity and, as a result, a decrease in cropping capacity.

Analysis of crop structure elements has shown that plants productivity depended on the number and mass of grain from one plant, and in combination with the indicators of plants number before harvesting, the level of chickpea varieties yield was determined.

Similar to the indicators of plants number per unit of area, the number of seeds per plant also to a greater extent depends on the seeding rate. By its gradual rise on step of gradation, more noticeable decrease in the number of seeds on one plant was noticed. So, on average by varieties and sowing methods, with increasing the seeding rate of 500 to 600 thousand pieces/ha and of 600 to 700 thousand pieces/ha the number of seeds on one plant decreased by 0.5 pieces, of 700 to 800 thousand pieces/ha – by 0.7 pieces and of 800 to 900 thousand units/ha by 1.1 pieces (table 2).

It should be noted that with an increase in the seeding rate, the number of seeds per plant decreased in Odyssey variety more, although this index at all seeding rates was higher than in Budzhak variety. On the one hand, this indicates higher genetic potential of Odyssey variety, on the other – a narrower range of optimal plant density for this variety. Thus, the highest difference by number of seeds per plant, depending on the seeding rate, on average by the variants of row-spacing width in Budzhak variety was 2.5 pieces, and in Odyssey variety – 3.0 pieces.

Table 2

Number of seeds per chickpea plant depending on row-spacing width and the seeding rate, pieces (average for 2016-2019)

Variety (factor *A*)	Seeding rate, thousand pieces/ha (factor *C*)	Row-spacing width, cm (factor *B*)			Average
		15	30	45	
Budzhak	500	12.1	12.0	11.4	11.8
	600	11.7	11.7	11.0	11.5
	700	11.5	11.3	10.1	11.0
	800	11.1	10.6	9.8	10.5
	900	9.9	9.7	8.9	9.5
Odyssey	500	13.2	12.8	12.2	12.7
	600	12.9	12.5	11.5	12.3
	700	12.4	12.0	10.9	11.8
	800	11.6	11.1	10.4	11.0
	900	10.5	10.3	9.2	10.0
Average by factor A	Budzhak	11.3	11.1	10.2	10.9
	Odyssey	12.1	11.7	10.8	11.5
Average by factor *C*	500	12.7	12.4	11.8	12.3
	600	12.3	12.1	11.3	11.9
	700	12.0	11.7	10.5	11.4
	800	11.4	10.9	10.1	10.8
	900	10.2	10.0	9.1	9.8
Average by factor *B*		11.7	11.4	10.6	11.2

To a greater extent the influence of the seeding rate the mutability of grains number per plant became apparent by row-spacing width of 45 cm. So, the maximum discrepancy of seeds number from plants at the influence of this factor on the variants with 15 cm row-spacing was 2.7 pieces (27.0 %), and on the variants with 45 cm row-spacing – 3.0 pieces (34.0 %).

In the studying variants with different row-spacing width, a significant variability in seeds number per plant has also been determined. On average by the years, varieties and sowing rates the highest seeds number per plant was obtained on the variants with 15 cm row-spacing width. By the increase of row-spacing width of 15 to 30 cm seeds number per plant decreased significantly less in comparison with the broadening of row-spacing of 30 to 45 cm. On the variants with density of 500 and 600 thousand pieces/ha there wasn't any difference by seeds number per plant between the variants with row-spacing width of 15 and 30 cm.

At all possible combinations of the seeding rate and row-spacing width, bigger number of seeds from a plant was formed in Odyssey variety. The biggest difference between varieties by this indicator was noted for 15 cm row-spacing width and 500 thousand pieces/ha seeding rate, which says about higher exactingness of Odyssey variety for optimization of plant nutrition area in sowings.

As it was already noted, along with the number of plants per unit of area, the level of plant productivity is determined by the mass of seeds per plant. It is an integral indicator of a number of other crop structure elements. Indeed, by the quantitative parameters of plants (the number of beans and seeds) it is impossible to determine the level of their productivity, since the mass of the seed can vary with a significant range depending on a complex of factors.

For researches that involve studying the influence of different combinations of plant nutrition area and its shape, it is especially important to determine the level of seed productivity of an individual plant, since this indicator has a reverse connection with the number of plants per unit of sown area. Therefore, the task is to determine the optimal combination of plants productivity with their number per unit of area, which ensures the formation of maximum grain yield indicators.

In the conducted studies, with an increase in the seeding rate, the seed productivity of one plant naturally decreased. The maximum mass of grain per plant at the seeding rate of 500 thousand pieces/m^2 was 4.88 g, the minimum at the rate of 900 thousand pieces/ha was 3.57 g (table 3).

We have noted the tendency for increasing the difference between the indices of grain mass from a plant in the variants with a gradual rise in the seeding rate by 100 thousand/ha. So, with its increase from 500 to 600 thousand/ha, grain mass from a plant decreased by 0.32 g, from 600 to 700 thousand pieces/ha – by 0.22 g, from 700 to 800 thousand pieces/ha – by 0.31 g and 800 to 900 thousand pieces/ha – by 0.46 g.

As to the studying variants of row-spacing width, the tendency for reduction the seeds mass of one plant, under conditions of rise in the seeding rate, differed a little. In particular, on the variants of drill sowing method with 15 cm row-spacing, the maximum difference by this indicator was between the variants of the seeding rates of 800 and 900 thousand pieces/ha, and on the variants with 30 cm row-spacing was between the seeding rate of 700 and 800 thousand pieces/ha. On the variants of wide-row sowing method with 45 cm row-spacing grain mass reduction from a plant at rise in the seeding rate had more aligned linear trend. Namely, at reduction of the seeding rate by a constant indicator, the grain mass decreased by the same size and was at the level of the maximum indicators on both variants of drill sowing method. Thus, the range of mutability of grain mass indicators from a plant depending on the seeding rate was bigger by wide-row sowing method with 45 cm row-spacing. On the variants with row-spacing of 15 and 30 cm it was 34.7 and 36.4 % and in case of sowing with row-spacing of 45 cm – 39.4 %.

Table 3

Grain mass from one chickpea plant depending on row-spacing width and the seeding rate, g (average for 2016-2019)

Variety (factor *A*)	Seeding rate, thousand pieces/ha (factor *C*)	Row-spacing width, cm (factor *B*)			Average
		15	30	45	
Budzhak	500	4.70	4.74	4.19	4.54
	600	4.35	4.50	3.87	4.24
	700	4.33	4.31	3.62	4.09
	800	4.16	3.90	3.46	3,84
	900	3.60	3.52	3.14	3.42
Odyssey	500	5.37	5.23	4.82	5.14
	600	5.16	4.94	4.48	4.86
	700	4.88	4.69	4.21	4.59
	800	4.53	4.32	3.91	4.25
	900	4.05	3.92	3.37	3.78
Average by factor A	Budzhak	4.23	4.19	3.66	4.03
	Odyssey	4.80	4.62	4.16	4.53
Average by factor *C*	500	5.03	4.99	4.51	4.84
	600	4.76	4.72	4.18	4.55
	700	4.61	4.50	3.92	4.34
	800	4.35	4.11	3.69	4.05
	900	3.83	3.72	3.26	3.60
Average by factor *B*		4.52	4.41	3.91	4.28

It is logically that with the broadening of row-spacing, grain mass decreased due to the worsening of plant nutrition area. To a greater extent the reduction in grain mass from one plant was observed with the increase in row-spacing width of 30 to 45 cm. On average at the seeding rates and varieties, broadening of row-spacing from 15 to 30 cm reduced the mass of grains from one plant only by 0.11 g, and with row-spacing broadening from 30 to 45 cm – by 0.52 g. Such tendency was observed on the crops of both varieties in all variants with the seeding rates.

To a greater extent chickpea varieties differed just by the indicators of grain mass from a plant. It was determined a tendency to decrease the difference between grain mass of one plant of both varieties with an increase in the cenotic tension, which indicates the interconnection of a variety with the seeding rate and row-spacing width. Obtained data show less plasticity of Odyssey variety to the mutability of plant nutrition area and its shape. Budzhak variety plants change their productivity in the studying range of the seeding rates and variants of row-spacing width to a lesser extent.

According to the indicators of grain yield of both chickpea varieties, two better combinations of the seeding rate and row-spacing width were identified. This is combination of the seeding rate of 800 thousand/ha with 15 cm row-spacing and the seeding rate of 700 thousand pieces/ha with 30 cm row-spacing. On these indicated variants the grain yield of Budzhak variety made 2.34 and 2.44 t/ha respectively, and on Odyssey variety – 2.61 and 2.51 t/ha (table 4).

Table 4

Grain yield of chickpea varieties depending on row-spacing and the seeding rate, t/ha (average for 2016-2019)

Variety (factor A)	Seeding rate, thousand pieces/ha (factor C)	Row-spacing width, cm (factor *B*)			Average
		15	30	45	
Budzhak	500	1.75	1.99	1.77	1.84
	600	2.02	2.26	1.96	2.08
	700	2.21	2.44	1.96	2.20
	800	2.34	2.26	1.91	2.17
	900	2.21	2.15	1.76	2.04
Odyssey	500	2.02	2.08	2.17	2.09
	600	2.14	2.33	2.16	2.21
	700	2.27	2.51	2.09	2.29
	800	2.61	2.40	2.00	2.34
	900	2.36	2.23	1.87	2.15
Average by factor A	Budzhak	2.11	2.22	1.87	2.07
	Odyssey	2.28	2.31	2.06	2.22
Average by factor *C*	500	1.89	2.04	1.97	1.97
	600	2.08	2.30	2.06	2.15
	700	2.24	2.48	2.03	2.25
	800	2.48	2.33	1.96	2.26
	900	2.29	2.19	1.82	2.10

Noticed combinations of variants provided the formation of the highest grain yield for all years of research (table 5), in addition, the distribution of indicators by variants was also similar, despite a significant discrepancy of cropping capacity level. It indicates the independence of plant nutrition area and its shape from weather conditions of a year, which makes it much easier to choose parameters of plants density and their distribution on the area.

Table 5

Cropping capacity of chickpea grain depending on the combination of row-spacing width and the seeding rate by the years of research, t/ha

Row-spacing width, cm (factor *B*)	Seeding rate, thousand pieces/ha (factor *C*)	Year			
		2016	2017	2018	2019
15	500	0.91/1.63*	2.12/2.31	1.86/2.18	2.11/1.96
	600	1.49/1.50	2.31/2.38	2.02/2.31	2.25/2.36
	700	1.72/1.52	2.54/2.70	1.99/2.22	2.60/2.63
	800	1.73/2.24	2.71/2.86	2.12/2.41	2.81/2.91
	900	1.29/1.43	2.74/2.83	2.03/2.23	2.76/2.94
30	500	1.97/1.86	2.27/2.42	1.90/2.05	1.83/2.00
	600	1.93/2.05	2.72/2.69	2.13/2.24	2.27/2.33
	700	2.12/2.18	2.72/2.87	2.28/2.41	2.64/2.57
	800	1.71/1.77	2.77/2.81	1.87/2.30	2.69/2.70
	900	1.61/1.51	2.68/2.66	1.77/2.13	2.55/2.63
45	500	1.29/2.00	2.13/2.51	1.76/2.15	1.90/2.02
	600	1.40/1.93	2.30/2.39	1.93/2.03	2.21/2.30
	700	1.34/1.71	2.38/2.33	1.84/1.97	2.27/2.33
	800	1.35/1.65	2.36/2.27	1.79/1.88	2.15/2.20
	900	1.17/1.65	2.24/2.13	1.67/1.74	1.94/1.97
Average by the seeding rates	500	1.61	2.29	1.98	1.94
	600	1.72	2.47	2.11	2.29
	700	1.77	2.59	2.12	2.51
	800	1.74	2.63	2.06	2.58
	900	1.45	2.55	1.93	2.47
Average by row-spacing variants	15	1.55	2.55	2.14	2.51
	30	1.87	2.66	2.11	2.42
	45	1.55	2.30	1.88	2.13
Average by	Budzhak	1.54	2.47	1.93	2.32

varieties	Odyssey	1.78	2.54	2.15	2.39
Average by years		1.66	2.51	2.04	2.36
LSD_{05} (of the main effect *A*)		0.06*	0.04*	0.05*	0.06*
LSD_{05} (of the main effect *B*)		0.06*	0.03*	0.05*	0.12*
LSD_{05} (of the main effect *C*)		0.05*	0.03*	0.05*	0.09*
LSD_{05} (of partial comparisons *A*)		0.22*	0.14*	0.19	0.20*
LSD_{05} (of partial comparisons *B*)		0.19*	0.10*	0.16	0.17*
LSD_{05} (of partial comparisons *C*)		0.13*	0.06	0.13*	0.11*

Note: * – the numerator shows indicators for Budzhak chickpea variety, and the denominator is for Odyssey variety.

To a greater extent mutability of chickpea grain yield depended on the influence of weather conditions of the year. It was the highest in 2017 – 2.51 t/ha, the lowest in 2016 – 1.66 t/ha. The maximum range of cropping capacity mutability depending on weather conditions of the growing season was 0.85 t/ha, while at different variants of the seeding rate, row-spacing width and biological peculiarities of the variety – 0.29 t/ha, 0.30 and 0.19 t/ha, respectively.

The experiments showed a tendency to increase the influence of the seeding rate under more favorable weather conditions of the growing season. Thus, the highest discrepancy between yield indicators at different seeding rates in favorable for growing 2017 and 2019 was 0.34 and 0.64 t/ha, respectively, while in less favorable 2016 and 2018 – 0.32 and 0.19 t/ha.

On average, by years, varieties and variants of row-spacing width, the highest grain yield indicators were formed at the seeding rates of 700 and 800 thousand pieces/ha. In particular, for density of 500, 600, 700, 800 and 900 thousand pieces/ha, cropping capacity was 1.97, 2.15, 2.25, 2.26 and 2.10 t/ha, respectively. Mentioned tendency was observed every year. So, in 2016, on the variants of the seeding rate of 500, 600, 700, 800 and 900 thousand pieces/ha, it was 1.60 t/ha, 1.72, 1.77, 1.74 and 1.44 t/ha, respectively, in 2017 – 2.29 t/ha, 2.47, 2.59, 2.63 and 2.55 t/ha, in 2018 – 1.98 t/ha, 2.11, 2.12, 2.06 and 1.93 t/ha and in 2019 – 1.94 t/ha, 2.29, 2.51, 2.58 and 2.47 t/ha, respectively.

The influence of the seeding rates greatly depended on the chosen variant of row-spacing width, so the nature of the trends line of chickpea grain yield at a gradual increase in the seeding rate depending on row-spacing width differs noticeably (Fig. 1).

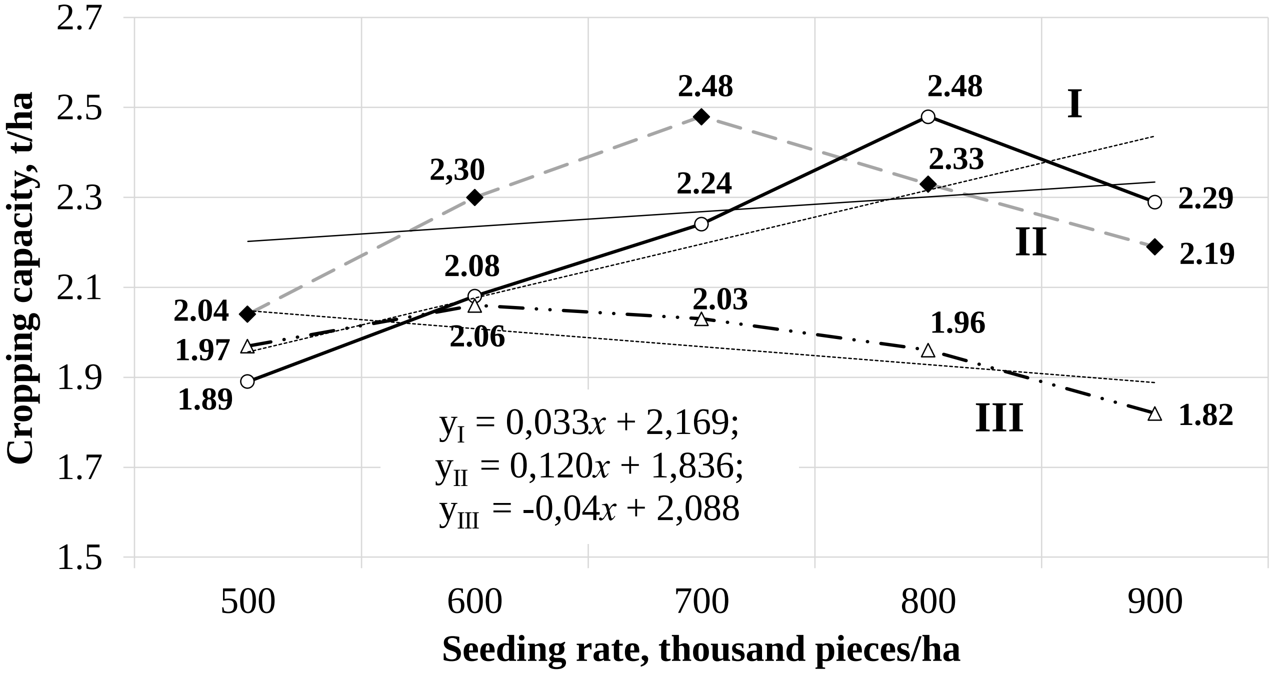

Figure. 1. Cropping capacity of chickpea grain depending on row-spacing width and the seeding rate, t/ha (average by years and varieties).
Row-spacing variants:
– 15 cm; – 30 cm; – 45 cm

Presented regression equations are relevant only within the studying range of the seeding rate. They are not subject to extrapolation, since beyond the limits of the studying range of the seeding rates it is not correct to predict the level of grain yield on the base of these equations.

On variants with 15 cm row-spacing, the highest cropping capacity of chick-pea varieties on average over the years – 2.48 t/ha was obtained at the seeding rate of 800 thousand pieces/hectare. The same grain yield in the variants of 30 cm row-spacing was formed at the seeding rate of 700 thousand pieces/ha. Seeding rate of 600 thousand pieces/ha provided maximum cropping capacity on variants with 45 cm row-spacing – 2.06 t/ha

It was determined that the greatest range of variability of grain yield was provided by variants of row-spacing width. Thus, the discrepancy in grain yield at the influence of this factor was 0.30 t/ha (15.7 %), the seeding rate – 0.20 t/ha (10.2 %), varietal peculiarities – 0.17 t/ha (8.6 %).

Wide-row sowing with 45 cm row-spacing at all variants of the seeding rates provided lower cropping capacity compared to 30 cm row-spacing width. Only on variants of 500 and 600 thousand pieces/ha, wide-row sowing on 45 cm had the advantage over 15 cm row-spacing, however, the level of cropping capacity was significantly lower compared with the highest index in the experiment.

During all years of research at different combinations of the seeding rates and row-spacing width, the highest cropping capacity was provided by Odyssey variety. It is important to note that the advantage of this variety in productivity was higher under condition of plants density optimization. With the thickening of crops and row-spacing broadening, the difference by cropping capacity was gradually levelled, which says about the necessity to choose the optimal density of crops of this variety, in other words, about its greater exactingness for growing conditions.

Over the years of research, the effect of varietal peculiarities also differed. Under more drying conditions, the advantage of Odyssey variety in cropping capacity was less. At the same time, in all years of research the highest seeds yield was provided by this variety. In particular, in 2016, 2017, 2018 and 2019, its cropping capacity on average by the seeding rates and sowing methods was 0.18 t/ha, 0.07, 0.23 and 0.07 t/ha higher than in Budzhak variety.

Among the studying factors, the mutability of grain yield in all years was influenced by sowing methods more. The part of this factor in 2016, 2017, 2018 and 2019 was 23.0 %, 37.2, 30.0 and 29.5 %, respectively (Fig. 2).

The complex contribution of sowing method, taking into account the interaction with other elements, was significantly greater, since the effects of double interaction of this factor with the seeding rates and varieties were an important factor in the total mutability of cropping capacity in the experiments. For example, the part of interaction between the sowing method and the seeding rates and with varieties in changes of grain yield level in 2016 was 9.3 and 23.5 %, respectively. In addition, the part of interaction of all studying factors was 7.9 %. Thereby, variants for row-spacing width in 2016 in interaction with other factors were providing 65.7 % of grain yield changes. In 2017, 2018 and 2019, these indicators were 64.6 %, 53.4 % and 57.4 %, respectively.

The part of the seeding rate in the mutability of chickpea grain yield in 2016, 2017, 2018 and 2019 was 13.9 %, 26.7, 12.0 and 18.3 %, respectively. At the same time, taking into account the interaction with other factors, its contribution was significantly higher.

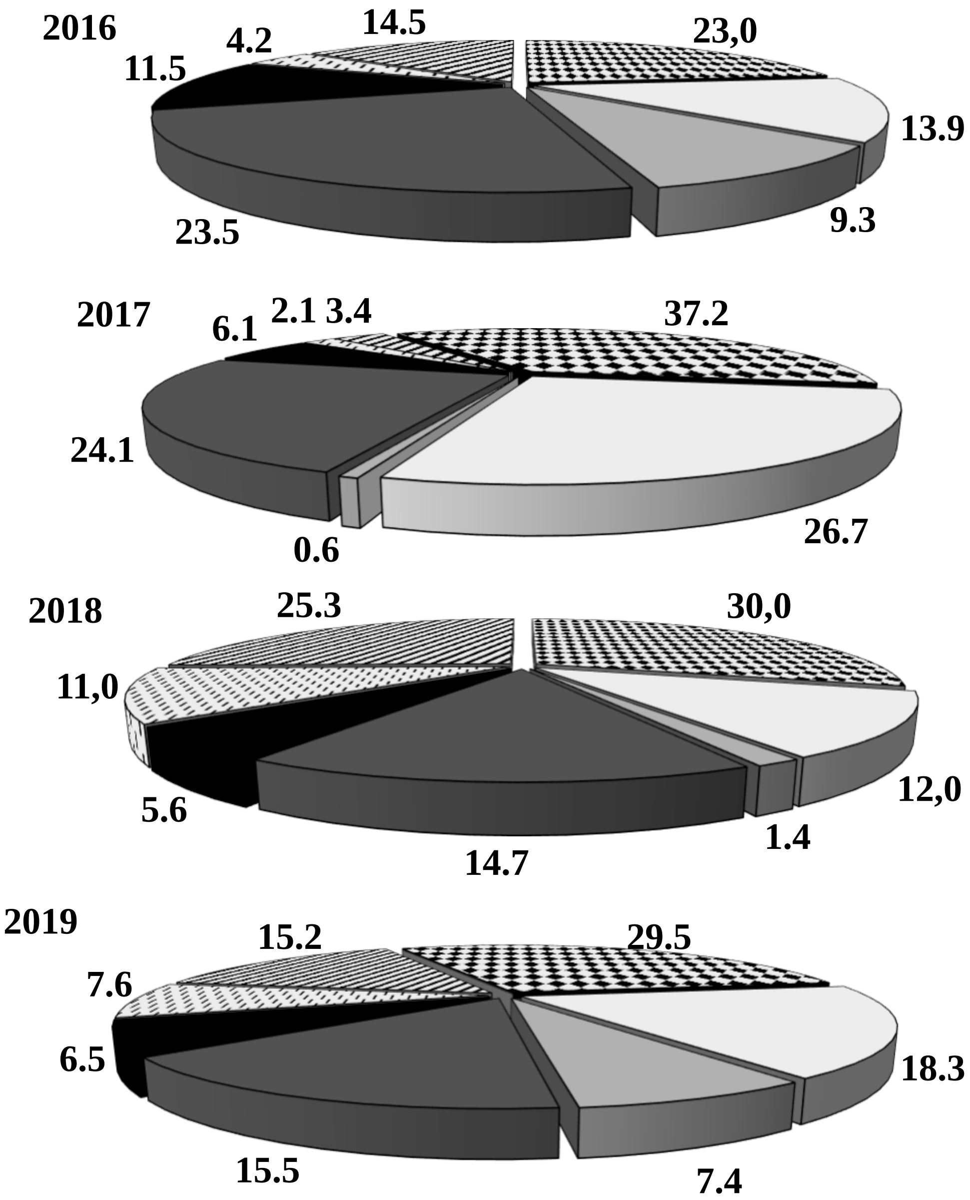

Figure 2. Contributions of the studying factors and combinations of their interaction to the mutabilityof chickpea seed yield by years, %.

– factor A (variety);
– factor B (sowing method);
– factor C (the seeding rate);
– AB;
– BC;
– AC + ABC;

Conducted correlation analysis revealed different close links between the grain yield of both varieties and the main elements of the crop structure. Closer direct and reverse links became apparent on variants with Odyssey variety. Grain yield of this variety had a close direct connection with the number of beans on plant before harvesting (r = 0.85), the number of seeds from one plant (r = 0.92), and the mass of grain from one plant (r = 0.91) (Fig. 3). For Budzhak variety, similar connections were significantly smaller – 0.57, 0.63, and 0.68, respectively, and were classified as direct connections of average strength.

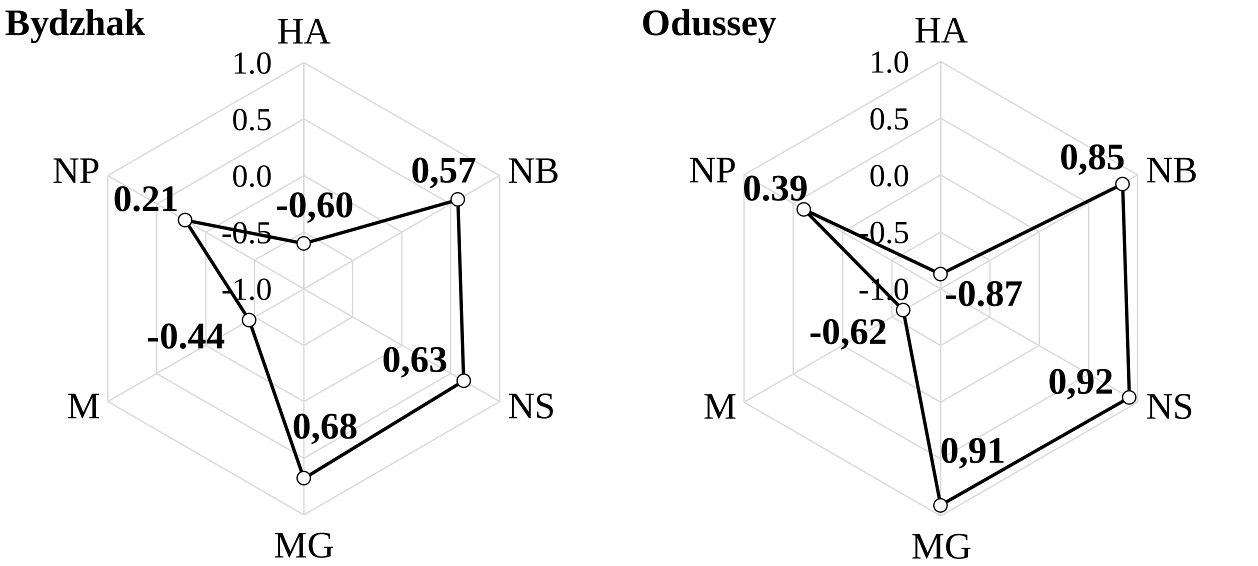

Figure 3. Tightness of correlation links of grain yield with the main elements
of the chickpea crop structure according to four-year data.

Symbols: HA – the height of a lower bean attachment; NB – the number of beans on a plant; NS – the number of seeds on a plant; MG – the mass of grain from one plant; M – the mass of 1000 seeds; NP – the number of plants before harvesting per 1 m^2.

The grain yield had a strong reverse link with the height of a lower bean attachment in Odyssey variety (*r* = –0,87) and a reverse link of an average strength in Budzhak variety (*r* = –0,60). There was an average reverse link between the cropping capacity and the mass of 1000 seeds in both varieties. For Odyssey variety it was *r* = –0,62, for Budzhak variety – *r* = –0,44. Grain yield of Budzhak variety had a weak direct link with the number of plants before harvesting – *r* = 0,21, in Odyssey variety – an average direct link – *r* = 0,39.

Based on conducted analysis, it can be seen that the cropping capacity of seeds depends most on the number and mass of seeds from one plant, and to a lesser extent on the number of plants before harvesting. Rise in seed cropping capacity is accompanied by a decrease in the mass of 1000 seeds and the height of a lower bean attachment. However, these are general tendencies of links that may change under certain circumstances.

Conclusion

1. The highest level of chickpea plant productivity of Budzhak and Odyssey varieties in all years of researches was formed on variants with the lowest seeding rate in combination with 15 cm row-spacing. In this variant,

plant nutrition area was close to a square with ratio of sides 1.0:1.1. At the same time, through the smaller number of plants per unit of area, the grain yield was significantly inferior to the variants with a higher seeding rate.

2. Mentioned tendency of increasing the difference between the mass of grain on the variants of sowing seeds at its gradual rise on the step of gradation – 100 thousand pieces/ha. So, with rise in the seeding rate of 500 to 900 thousand pieces/ha grain mass from a plant decreased by 0.32 g, 0.22, 0.31 and 0.46 g, respectively.

3. By indicators of grain yield of both chickpea varieties, two better combinations of the seeding rate and row-spacing width were distinguished. This is a combination of 800 thousand pieces/ha seeding rate with 15 cm row-spacing and 700 thousand pieces/ha seeding rate with 30 cm row-spacing. On these variants, grain yield of Budzhak variety was 2.34 and 2.44 t/ha respectively, and grain yield of Odyssey variety was 2.61 and 2.51 t/ha.

4. In all years of researches, at different combinations of the seeding rates and row-spacing width, the highest cropping capacity was provided by Odyssey variety. The advantage of this variety was higher under condition of plant density optimization, which indicates about its greater exactingness for growing conditions.

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