

Conference Paper

Heritability of Productivity Elements of Chickpeas and its Importance for Practical Breeding

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ORCID:Svetlana Kuzmina: <http://orcid.org/0000-0002-2256-0434>**Abstract**

This study examined the genetics of the variability in quantitative traits and showed the possibility of selecting hybrids with a new, more favorable combination of traits, which is of practical interest for breeding. The main goal of our research was to determine the coefficients of heritability by the mass of seeds and the number of beans per plant in hybrid combinations of chickpeas, which allowed establishing the potential of parental varieties in the transfer of valuable genes responsible for plant productivity to offspring and expanding the spectrum of plant genetic diversity. The experiments were conducted in the fields of the educational and experimental farm of the Omsk State Agrarian University in the southern forest-steppe of the Omsk region in 2016-2018. The research included 6 chickpea samples with a complex of valuable traits from the Federal Research Center of the All-Russian Institute of Plant Genetic Resources named after N.I. Vavilov (VIR, St. Petersburg) and 8 hybrid combinations obtained on their basis. It was found that the mass of seeds per plant was characterized by low heritability ($H^2 = 22.8\%$) and the number of beans per plant was high ($H^2 = 54.0\%$). The variability of the mass of seeds per plant was largely paratypical and was influenced by environmental conditions; the variability in the number of beans per plant was due to genetic factors and indicated a high genetic diversity in the studied splitting chickpea populations. Selection based on the number of beans per plant was highly effective even in early generations of the hybrids. Selection by the mass of seeds from the plant was ineffective; it should be carried out in later hybrid generations under favorable growing conditions. The selection of valuable genotypes was most successful in hybrid chickpea populations by seed weight per plant: C-35 x ILC-2394, C-80 x ILC-2394, C-27 x ILC-2394, and by the number of beans per plant: C-27 x ILC-2394, C-27 x ILC-2402

Keywords: chickpeas, heritability, selection, genetics, productivity

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1. Introduction

The interest of agricultural enterprises and peasant farms in chickpeas in the West Siberian region is growing every year. Chickpea is a leguminous crop with high drought

and cold resistance, adaptability for harvesting, high nutritional value and multiple uses for food purposes [1–3]. However, the zoned varieties of chickpea under the conditions of the Omsk region do not meet the requirements of modern agriculture in terms of ripening and productivity [4, 5]. A collection of chickpea samples from different ecological and climatic zones can be the starting material for creating new varieties [6, 7].

In solving the problem of accelerating the creation of new varieties of this crop for the West Siberian region [8–10]. It is of great importance to use genetic and statistical methods of assessment, in particular, to determine the heritability of valuable traits in order to obtain practical recommendations for the selection of unique genotypes in splitting hybrid populations [11–13].

The phenotypic manifestation of selectively valuable traits in chickpea is formed as a result of the interaction of the genotype and environmental conditions [14–16]. Heritability characterizes the genetic condition of a trait. To select genotypes with the desired traits, it is necessary to focus on traits with high heritability [17–19]. The higher the heritability coefficient, the wider the genetic diversity, the greater the proportion of phenotypic diversity due to genotypic variability. The lower the heritability coefficient, the more significant is the influence of environmental conditions (modification variability) for the formation of the trait, and the genetic diversity is not great [20–22]. At high values of the coefficient of heritability, mass selection will be effective, and individual selection at its low values.

The main goal of our research was to determine the coefficients of heritability by the mass of seeds and the number of beans per plant in hybrid populations of chickpea, which makes it possible to establish the potential of parental forms in the transfer of valuable genes responsible for plant productivity, offspring and expansion of the spectrum of plant genetic diversity.

2. Methods and Equipment

The experimental part of the work was carried out in the educational and experimental farm of the Omsk State Agrarian University together with the Center for Collective Use “Selection and seed production of field crops” in the southern forest-steppe of the Omsk region (2016-2018). The object of research was the collection samples obtained from the Federal Research Center of the All-Russian Institute of Plant Genetic Resources named after N.I. Vavilov (VIR, St. Petersburg) with a complex of valuable features: ILC-2394

(Turkey), ILC-2402 (Bulgaria), C-27 (Uzbekistan), C-35 (Krasnodar), C-82 (Uzbekistan), C-80 (Azerbaijan) and 8 hybrid populations of the second generation obtained with their participation. Sowing was carried out in the 2nd decade of May at a depth of 5 cm. The repetition was four-fold. The number of seeds in each repetition in parental forms was 20 pcs., in F2 that was 60 pcs. Plant nutrition area was 10 x 60 cm². The counts and observations were carried out in accordance with the “Methodological instructions for the study of the collection of grain legumes” (1975). Statistical processing was carried out according to the methodology described in the manual by B.A. Dospekhov. The heritability coefficients in a broad sense were determined by the formula of [23].

3. Results

The weather conditions during the years of the experiments were different: in 2016 and 2018 it was slightly arid (GTC = 1.01 and 1.1, respectively), in 2017 it was arid (GTC 0.72).

Of great importance in the selection of chickpeas for yield is the mass of seeds and the number of beans per plant. During our research, the weight of seeds per plant in chickpea varied from 4.6 to 26.3 g and varied significantly depending on the weather conditions.

The most favorable conditions for the growth and development of chickpea plants were the conditions of 2016. The aridity of the second half of the growing season contributed to a more friendly and faster maturation of plants and high productivity. The weight of seeds per plant of hybrids varied from 17.1 to 26.3 g and averaged 22.4 g, in maternal forms it varied from 12.2 to 20.1 g (average 15.8 g), in testers it ranged from 21.7 to 28.6 g (the average weight was 25.2 g) (Table 1). There were significant differences both between parental forms and between hybrids. Plants from hybrid combinations had the maximum seed productivity: C-35 x ILC-2394 (26.3 g), C-25 x ILC-2402 (25.8 g), C-27 x ILC-2394 (25.2 g).

Year 2017 was characterized by excessive soil and air moisture in July and September, which negatively affected the formation of crop yields. The mass of seeds per plant decreased by 16.0 g and averaged 6.4 g (5.2-7.8 g), in maternal forms it decreased by 8.5 g (7.3 g on average), in testers it reduced by 17 g (8.1 g on average). The largest mass of seeds per plant was in hybrid combinations: C-80 x ILC-2394 (7.8 g), C-35 x ILC-2402 (7.1 g).

The conditions in 2018 turned out to be extremely unfavorable for chickpea plants. For instance, torrential rains against the background of low air temperatures in late July-August led to prolonged flowering, damage to plants by fusarium and a significant

decrease in productivity and its elements. Compared to the most favorable 2016, the productivity of hybrid plants decreased by 17.2 g and averaged 5.2 g, in maternal forms it decreased by 9.9 g (5.9 g on average), in testers it reduced by 17.7 g (7.4 g on average). The most productive under stress conditions were the hybrid combinations C-27 x ILC-2402 (5.8 g), C-35 x ILC-2394 (5.7 g).

The coefficient of heritability, the mass of seeds per plant in different hybrid populations of chickpea over the years of testing varied from 14.6 to 31.6% and on average had a low value ($H^2 = 22.8\%$). The low heritability of seed productivity in chickpea is probably due to a significant proportion of paratypical variability of the trait. Only 22.8% of the variability of the trait under study is due to genetic factors and mainly depends on environmental conditions. The low heritability ratio may also indicate a reduced genetic diversity in the studied chickpea populations. Thus, selection on this basis will be ineffective. In order to exclude the loss of valuable forms of highly productive plants, it is advisable to carry out individual selection in later hybrid generations.

TABLE 1: Seed weight per plant in hybrid combinations of chickpea, g

Sample, hybrid combination	2016	2017	2018	Mean
Parent forms				
C-27	18.2	8.8	6.9	11.3
C-35	20.1	6.3	5.4	10.6
C-82	12.2	8.6	6.2	9.0
C-80	12.8	5.6	5.1	7.8
ILC-2394	21.7	7.4	5.6	11.6
ILC-2402	28.6	8.8	9.2	15.5
Lim min÷max	12.2-28.6	5.6-8.8	5.1-9.2	7.8-15.5
Mean	18.9	7.6	6.4	10.9
LSD ₀₅	2.84	1.14	0.96	1.64
Hybrid combinations F ₂				
C-27 x ILC-2394	25.2	6.4	5.2	12.3
C-27 x ILC-2402	22.6	6.4	5.8	11.6
C-35 x ILC-2394	26.3	5.7	5.7	12.6
C-35 x ILC-2402	25.8	7.1	5.1	12.7
C-82 x ILC-2394	17.1	5.2	4.6	9.0
C-82 x ILC-2402	24.2	6.5	4.5	11.7
C-80 x ILC-2394	18.6	7.8	5.1	10.5
C-80 x ILC-2402	19.2	6.3	5.4	10.3
Lim min÷max	17.1-26.3	5.2-7.8	4.5-5.8	9.0-12.7
Mean	22.4	6.4	5.2	11.3
LSD ₀₅	3.36	0.96	0.78	1.70

TABLE 2: Heritability of seed mass per chickpea plant, %

Hybrid combination	2016	2017	2018	Mean
C-27 x ILC-2394	31.6	19.8	20.8	24.0
C-27 x ILC-2402	24.1	18.2	18.0	20.1
C-35 x ILC-2394	31.5	20.8	25.9	26.1
C-35 x ILC-2402	26.5	23.5	17.5	22.5
C-82 x ILC-2394	25.2	16.3	19.5	20.3
C-82 x ILC-2402	29.7	18.7	14.6	21.0
C-80 x ILC-2394	27.0	30.0	23.8	26.9
C-80 x ILC-2402	23.2	21.9	18.9	21.3
Lim min÷max	23.2-31.6	16.3-30	14.6-25.9	20.1-26.9
Mean	27.3	21.1	19.9	22.8

It should be noted that the value of the heritability coefficient in different years was influenced by the conditions of plant growth. Thus, under more favorable conditions, heritability increased due to an increase in genetic diversity in the splitting hybrid populations of chickpea; therefore, phenotypic variability was largely due to the genotype. For instance, in favorable conditions of 2016, the heritability coefficient averaged 27.3%, and in extreme conditions for chickpea in 2018, it decreased to 19.9%. Selection on this basis is recommended to be carried out in more favorable growing conditions for the culture.

The level of phenotypic manifestation of the number of beans per plant also depended on hydrothermal conditions. The studied indicator during the research in different hybrid combinations varied from 22.4 to 102.2 pcs. (58.7 pcs. on average).

In 2016, the number of beans per plant in hybrids varied from 72 to 102.2. (an average of 91.9 pcs.), in maternal forms it ranged from 48.6 to 87.2 pcs. (62.8 pieces on average), in testers it varied from 93.3 to 105.7 pieces. (99.5 pcs. on average) (Table 3). Maternal forms and hybrids significantly differed among themselves in the number of beans. The maximum number of beans was in hybrid populations with the participation of the tester C-35 x ILC-2394 (102 pcs.) and C-27 x ILC-2394 (98 pcs.).

In 2017, the number of beans in chickpea hybrids decreased by 39.1 pieces. and amounted to an average of 52.8 pcs. (from 46.6 to 68.2 pcs.), in maternal forms decreased by 3.8 pcs. (59.8 pcs. on average), for testers it reduced by 59.2 pcs. (40.3 pcs. on average). The largest number of beans per plant was observed in hybrid combinations: C-80 x ILC-2394 (68.2 pcs.) and C-27 x ILC-2394 (57.1 pcs.).

In 2018, compared with the most favorable 2016, the number of beans in chickpea hybrids decreased by 60.6 pcs. and amounted to an average of 31.3 pcs (from 22.4 to

TABLE 3: Number of beans per plant in hybrid combinations of chickpeas, pcs.

Sample, hybrid combination	2016	2017	2018	Mean
Parent forms				
C-27	54.2	48.6	26.8	43.2
C-35	87.2	60.1	24.3	57.2
C-82	48.6	55.9	36.2	46.9
C-80	61.1	71.0	29.2	53.7
ILC-2394	105.7	48.3	36.1	63.3
ILC-2402	93.3	32.3	28.0	51.1
Lim min÷max	48.6-105.7	32.3-71.0	24.3-36.2	43.2-63.3
Mean	75.0	52.6	30.1	52.6
LSD ₀₅	11.3	7.9	4.5	7.8
Hybrid combinations F ₂				
C-27 x ILC-2394	98	57.1	38.3	64.5
C-27 x ILC-2402	96	48.6	28.8	57.8
C-35 x ILC-2394	102.2	51.2	38.6	63.9
C-35 x ILC-2402	94	54.1	22.4	56.8
C-82 x ILC-2394	88	49.6	32.4	56.7
C-82 x ILC-2402	72	47.1	28.2	49.1
C-80 x ILC-2394	94	68.2	25.1	62.4
C-80 x ILC-2402	91	46.6	36.8	58.1
Lim min÷max	72-102.2	46.6-68.2	22.4-38.6	49.1-64.5
Mean	91.9	52.8	31.3	58.7
LSD ₀₅	13.78	7.92	4.70	8.80

38.6 pcs.), in maternal forms it decreased by 33.6 pcs. (29.1 pcs. on average), in testers it reduced by 67.4 pcs. (32.1 pcs. on average). Hybrid combinations C-27 x ILC-2394 (38.3 pcs.) and C-35 x ILC-2394 (38.6 pcs.) had the largest number of beans under stress conditions.

The heritability coefficient of the number of beans per plant in different hybrid populations of chickpea ranged from 38.6 to 65.1% and averaged 54.0%, which indicates the possibility of breeding improvement of these traits by direct selection of valuable genotypes by phenotype already in early generations hybrids. Most of the phenotypic variability of the trait is due to genetic factors and indicates a high genetic diversity in the studied chickpea populations. Thus, selection on this basis will be highly effective.

The heritability of the studied trait changed slightly depending on the growing conditions: under favorable growing conditions, it averaged 56.8%, in extreme conditions, it averaged 51.5%, which confirms the genetic conditionality of this trait. Successful selection for this trait is possible regardless of growing conditions.

TABLE 4: Heritability of the number of beans per plant in chickpea, %

Hybrid combination	2016	2017	2018	Mean
C-27 x ILC-2394	61.3	58.9	61.0	60.4
C-27 x ILC-2402	65.1	60.3	52.6	59.3
C-35 x ILC-2394	52.9	47.3	64.1	54.7
C-35 x ILC-2402	52.1	58.8	42.9	51.3
C-82 x ILC-2394	57.0	47.6	44.8	49.8
C-82 x ILC-2402	50.7	53.6	43.9	49.4
C-80 x ILC-2394	56.4	57.2	38.6	50.7
C-80 x ILC-2402	58.9	45.2	64.6	56.2
Lim min÷max	50.7-65.1	45.2-60.3	38.6-64.6	49.4-60.4
Mean	56.8	53.6	51.5	54.0

4. Discussion

The coefficient of heritability of the mass of seeds per plant in different hybrid populations of chickpea in our studies had a low value (on average $H^2 = 22.8\%$), which is probably due to a significant proportion of paratypical variability of the trait. The low heritability of seed productivity is confirmed by the studies by Bushulyan O. V., Sichkar V. I. [17]. The strong dependence of this feature on environmental conditions is also noted by a number of scientists [1, 2, 7]. The low proportion of genotypic variability in the mass of seeds per plant indicates the low efficiency of selection of valuable forms in the splitting hybrid populations of chickpea. To eliminate the loss of highly productive plants, it is advisable to carry out individual selection in later hybrid generations.

Hybrid chickpea populations with the highest heritability of seed mass per plant should be considered the most promising in practical and breeding terms: C-35 x ILC-2394 (average $H^2 = 26.1\%$), C-80 x ILC-2394 ($H^2 = 26.9\%$), C-27 x ILC-2394 ($H^2 = 24.0\%$). These populations are characterized by increased genetic diversity, which makes it possible to hope for successful individual selection of productive plants in later hybrid generations under favorable cultivation conditions.

The coefficient of heritability of the number of beans per plant in hybrid populations of chickpea showed a high genetic conditionality of the trait (H^2 on average 54.0%), which is consistent with the results of studies by a number of scientists [2, 4, 7]. The high heritability of the trait under study makes it possible to improve it by direct selection of valuable genotypes by phenotype already in early generations of hybrids. The genetic dependence of this trait is also confirmed by the insignificant variability of the heritability coefficient depending on the growing conditions (from 51.5% - under extreme conditions,

to 56.8% - under favorable conditions), which allows selection for this trait regardless of growing conditions.

Hybrid combinations of chickpeas are of practical interest for breeding as a promising genetic material for increasing the number of beans per plant: C-27 x ILC-2394 (on average $H^2 = 60.4\%$), C-27 x ILC-2402 ($H^2 = 59.3\%$). These populations are characterized by increased genetic diversity, which gives hope for successful selection of chickpea plants with a high number of beans from the next generation (F3).

It should be noted that from the splitting hybrid populations of chickpea C-27 x ILC-2394, C-27 x ILC-2402 and C-80 x ILC-2394, the largest number of lines was selected, characterized by a complex of selectively valuable traits, including those with increased number of beans. This proves the genetic dependence of this trait and indicates the presence of genetic diversity in the studied chickpea combinations. In total, during the study in the field, 87 lines were selected; after rejection, 34 lines continue to be studied. The results obtained are consistent with the calculations of the heritability coefficient and confirm the high efficiency of individual selections for traits with high heritability.

5. Conclusion

1. Economically valuable traits of chickpea in the Omsk region have unequal heritability: the mass of seeds per plant was characterized by low heritability (on average $H^2 = 22.8\%$), the number of beans per plant was high (on average $H^2 = 54.0\%$).

2. The variability in the mass of seeds per plant is largely paratypical and is influenced by environmental conditions, and vice versa, in terms of the number of beans per plant, is determined by genetic factors and indicates a high genetic diversity in the studied chickpea populations.

3. Selection by weight of seeds from a chickpea plant is ineffective; it should be carried out in later hybrid generations, while the selection by the number of beans per plant is highly effective already in the early generations of hybrids.

4. The coefficient of the seed mass heritability per plant is modified by the growing conditions. Under unfavorable environmental conditions, there is an increase in the proportion of paratypical variability of the trait and a decrease in the coefficient of heritability. Selection based on seed productivity is recommended only in favorable growing conditions for the culture.

5. The following hybrid combinations of chickpeas should be considered the most promising in practical and breeding terms:

- by weight of seeds per plant: C-35 x ILC-2394, C-80 x ILC-2394, C-27 x ILC-2394;
- by the number of beans per plant: C-27 x ILC-2394, C-27 x ILC-2402.

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Conflict of Interest

The authors declare no conflicts of interest.

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