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Heterosis Manifestations and Degrees of Dominance of Main Traits in Chickepea Hybrids (*Cicer arietinum* L.) and Health Benefit

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ABSTRACT

The study was conducted during the period 2023-2024 at the Institute of Forage Crops (Pleven) and aimed to assess the heterosis and degrees of dominance of main traits in F1 chickpea hybrids. Crosses were realized to increase seed productivity through the hybridization of suitable parental forms (Garbanzo 1, Blanco Lechoso, VSP 11, Garbanzo negro, Irenka and Balkan) of the Desi and Kabuli types (Desi × Kabuli and Kabuli × Desi). Hybrids exhibing higher positive heterosis for height/plant, number of pods and seeds/plant, and \ earliness were predominantly of the Desi × Kabuli type. For seed weight and 1000 seed mass the Kabuli × Kabuli type showed superior performance, while for first pod height, Desi × Desi combination were superior. For several key traits, the highest hypothetical and true heterosis was recorded as follows: in Garbanzo negro × Blanco Lechoso for height/plant (140.76%; 133.04%), in Irenka × Blanco Lechoso for number of pods (59.11%; 37.50%) and seeds/plant (77.06%; 42.81%), in Blanco Lechoso × Garbanzo negro for seed weight/plant (131.60%; 129.83%) and 1000 seeds mass (85.45%; 20.88%). The gene actions controlling plant height and first pod height in all hybrids was predominantly of the positive overdominance type. For seed weight, 1000-seed weigh and earliness, negative dominance, and overdominance were observed, whereas for pod and seed numbers, intermediate inheritance predominated in most cases.

Keywords: chickpea, heterosis, productivity, breeding, health benefit.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the second most widely grown legume crop worldwide in terms of cultivated area and ranks third in total production. Today, it is grown in countries in Central Asia, East Africa, Eastern Europe, America, and Australia. Chickpea seeds have diverse applications in agriculture, animal husbandry, and the food industry (Omelyanuk, 2012; Bykova, 2017; Koul et al., 2022; Singh et al., 2022). Increasing chickpea areas is hampered by insufficient knowledge of the biology and genetic potential of the crop. Chickpea yield and productivity are strongly influenced by agronomic practices, including fertilization, weed management, and irrigation regimes, which significantly affect yield components and plant performance. In this regard, a comprehensive study of chickpea collections and identification of appropriate sources of valuable traits is imperative for creating new varieties with increased productive potential (Funga et al., 2016; Bulti et al., 2019; Phiri et al., 2023).

A significant part of the main breeding traits of chickpeas, such as productivity, pods number and seeds number per plant, longevity of growing season, and others, are quantitative. Their manifestation is determined by multiple gene associations (polygenes) with relatively small individual effects, which vary under the influence of environmental conditions (Bykova, 2017; Gupta et al., 2017; Lakmes et al., 2022;

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Khrisanapant et al., 2022). Intraspecific hybridization remains the main breeding method for creating source material for the subsequent selection of elite plants that give beginning new chickpea varieties. Therefore, studying the inheritance patterns of quantitative traits is still relevant today. Knowledge of the patterns acting in decomposing hybrid populations allows a more effective selection of appropriate genotypes. The most important patterns in trait inheritance are manifestations of heterosis, degrees of dominance in the first and second hybrid generations, and degree and frequency of transgression (Pratap and Kumar, 2011; Duc et al., 2015; Berger et al., 2017; Murthy et al., 2017; Qulmamatova et al., 2024). In the past few years, advances in chickpea genomics have provided more opportunities to study its unique biological characteristics, including advances in sequencing its genome (Jain et al., 2013; Varshney et al., 2013). Agro-ecological parameters, regional climate, genotype and mineral nutrition influence the yield of plants (Popović et al., 2013, 2015; Rajičić et al., 2019; Ugrenović et al., 2021). However, conventional breeding methods are still most commonly used to develop new genotypes in this crop.

The aim of the study was to analyze the values of genetic parameters and the variation of a group of traits in F1 chickpea hybrids to support their targeted use in the breeding programs.

MATERIAL AND METHODS

The study was conducted during the period 2023-2024 at the Institute of Forage Crops (Pleven, Bulgaria). Hybridization was carried out between chickpea varieties of "Kabuli" type (Garbanzo 1, Blanco Lechoso) and "Desi" type (VSP 11, Garbanzo Negro, Irenka and the Bulgarian variety Balkan). The parental forms (P1 and P2) and first hybrid generation (F1) were studied in the following combinations: Garbanzo 1 × VSP 11, VSP 11 × Garbanzo 1, Garbanzo Negro × Blanco Lechoso, Balkan × VSP 11, Blanco Lechoso × Garbanzo Negro, Irenka × Blanco Lechoso. Sowing was carried out manually, according to the classical scheme (P1, F1, P2), in optimal terms, according to the crop growing technology, at a sowing distance of 50/20 cm and a depth of 5 cm. Plant material from the aboveground biomass of parental forms and F1-hybrids was analyzed. Biometric measurements included the following traits: height/plant (cm), 1st pod height (cm), pods number/plant, seeds number/plant, seed weight/plant (g), mass of 1000 seeds (g), duration of the germination-flowering period (days).

For each hybrid combination, arithmetic means (x), standard errors (Se), coefficient of variation (VC, %), degree of dominance (d/a), hypothetical and true heterosis were calculated. True heterosis represents the superiority of the hybrid in a given trait over the better parent (HP), while hypothetical heterosis refers to superiority over the average value for both parents (MP) (Omarov, 1975). The type of inheritance of traits in F1 hybrids was determined by the ratio of dominant to additive parameter (d/a) (Mather and Jinks, 1971). The cytoplasmic effect (R) was determined using Reinhold's method (2002). A positive value of R (R>0) means that paternal hereditary factors have a greater influence on the manifestation of a given trait, and a negative value (R<0) indicates a stronger impact of maternal cytoplasmic heredity.

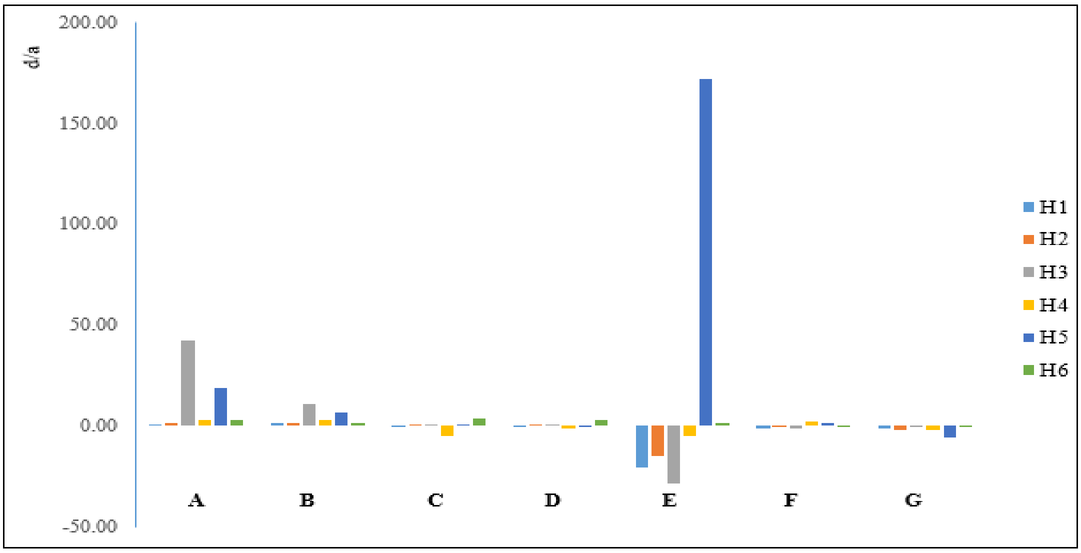
The date of the flower beginning was adopted as a criterion for assessing the degree of early maturity, and the early-ripening coefficient was used for a quantitative assessment (Kuzmova, 2002). For ultra-early varieties, the value of this coefficient ranged from 1.00 to 1.17; for early varieties, from 1.17 to 1.33; for medium-early varieties, from 1.4 to 1.66, and for late varieties, it was >1.66. Statistical analysis was performed using Microsoft Excel 2016.

RESULTS AND DISCUSSION

The effect of heterosis, characteristic of first-generation hybrids (F_1), has been used in a number of studies in legume crops. In some plant species, a number of difficulties have been identified, such as a low percentage of hybrid seeds obtained, and artificial pollination in self-pollinating crops, which prevent the use of heterosis on a scale exceeding the experimental level (Talebi et al., 2008; Bushulyan and Sichkar, 2009). When working with hybrid populations in the early generations, sufficiently complete information on the expression of traits in the progeny is essential. Such information is provided by the indicators of heterosis and degree of dominance, which allow for a better understanding of inheritance patterns and facilitate the selection of superior genotypes. Under the conditions of the present study, almost all hybrids (except Garbanzo 1 × VSP 11) exhibited higher plant height compared to the parental forms (Table 1).

The hybrid combination Garbanzo Negro × Blanco Lechoso considerably exceeded the taller parent (138.89 cm). A very high positive (both hypothetical and true) heterosis was observed in it. In the reciprocal cross, an excess of the hybrid over the parents was also observed but less pronounced. When combining the varieties Garbanzo 1 and VSP 11, hybrids with slightly expressed positive hypothetical heterosis were obtained. The true heterosis was negative (-4.50) only in Garbanzo 1 × VSP 11. The inheritance of height/plant (Figure 1) in the studied hybrid combinations ranged from positive dominant (Garbanzo 1 × VSP 11) to over dominant in all others. The direction of inheritance was towards the parent with higher values, which is favorable.

The first pod height in F1 hybrids ranged from 31.78 cm (Garbanzo 1 × VSP 11) to 41.00 cm (Balkan × VSP 11). Considerable differences were not found in the crosses and reciprocal combinations. Compared to the parents, all hybrids showed a higher setting of 1st pod. Based on the results of the heterosis calculation, it can be noted that it is positive for all hybrids. The strongest heterosis effects were found in Balkan × VSP 11 (72.275; 39.93). The hypothetical and real heterosis effects were the weakest (8.425; 2.91) in Irenka × Blanco Lechoso. Similarly to the previous trait, in Garbanzo Negro x Blanco Lechoso, a high value (10.90) of the parameter for predominant gene actions regarding the 1st pod height was calculated. The relatively high values in the other hybrids also indicate that the trait inheritance is of positive overdominance type. In the hybrid combinations Blanco Lechoso × Garbanzo Negro and Garbanzo 1 × VSP 11, an influence (although not as strongly expressed) of the maternal cytoplasm on the trait inheritance was found (Figure 2).



A - height/plant; B -first pod height; C - pods number/plant; D - seeds number/plant;
E - seed weight/plant; F - 1000 seeds mass; G - days to flowering
H1 - Garbanzo 1 × VSP 11; H2 -VSP 11 × Garbanzo 1; H3 - Garbanzo Negro × Blanco Lechoso;
H4 - Balkan × VSP 11; H5 - Blanco Lechoso × Garbanzo Negro; H6 - Irenka × Blanco Lechoso

Figure 1. Degree of dominance of main traits in F1 chickpea hybrids

Table 1. Characteristics of parent forms and their F1 hybrids

Hybrids	P1*	P2	F1	Hypothetical heterosis	True heterosis
	Height/plant				
Garbanzo 1 × VSP 11	58.11±2.51	66.90±2.81	63.89±2.26	2.21	-4.50
VSP 11 × Garbanzo 1	66.90±2.81	58.11±2.51	67.89±0.96	8.61	1.48
Garbanzo Negro × Blanco Lechoso	59.60±0.97	55.78±2.66	138.89±2.11	140.76	133.04
Balkan × VSP 11	59.20±1.72	66.90±2.81	75.00±0.57	18.95	12.11
Blanco Lechoso × Garbanzo negro	55.78±2.66	59.60±0.97	94.00±1.75	62.94	57.72
Irenka × Blanco Lechoso	71.90±2.34	55.78±2.66	86.17±3.06	34.99	19.85
	1st pod height				
Garbanzo 1 × VSP 11	29.89±0.27	18.30±1.32	31.78±0.64	31.89	6.32
VSP 11 × Garbanzo 1	18.30±1.32	29.89±0.27	32.67±0.68	35.58	9.29
Garbanzo Negro × Blanco Lechoso	27.70±0.55	29.38±1.03	37.67±1.15	31.99	28.23
Balkan × VSP 11	29.30±0.96	18.30±1.32	41.00±1.88	72.27	39.93
Blanco Lechoso × Garbanzo negro	29.38±1.03	27.70±0.55	34.00±3.73	19.14	15.74
Irenka × Blanco Lechoso	32.70±1.22	29.38±1.03	33.65±1.06	8.42	2.91
	Pods number/plant				
Garbanzo 1 × VSP 11	44.89± 4.39	117.6±19.73	68.00±13.49	-16.30	-42.18
VSP 11 × Garbanzo 1	117.60±19.73	44.89±4.39	82.33±11.27	1.34	-29.99
Garbanzo Negro × Blanco Lechoso	116.90±14.55	41.44±7.32	93.56±13.52	18.17	-19.97
Balkan × VSP 11	156.30±15.94	117.6±19.73	35.00±5.77	-74.44	-77.61
Blanco Lechoso × Garbanzo negro	41.44±7.32	116.9±14.55	80.00±7.5	1.05	-31.57
Irenka × Blanco Lechoso	56.90±11.43	41.44±7.32	78.24±11.44	59.11	37.50
	Seeds number/plant				
Garbanzo 1 × VSP 11	52.56±4.84	142.1±20.45	90.78±21.08	-6.73	-36.12
VSP 11 × Garbanzo 1	142.10±20.45	52.56±4.84	106.56±15.9	9.48	-25.01
Garbanzo Negro × Blanco Lechoso	138.90±16.87	41.44±7.41	124.8±19.43	38.38	-10.17
Balkan × VSP 11	70.30±14.37	142.1±20.45	48.00±5.77	-54.80	-66.22
Blanco Lechoso × Garbanzo negro	41.44±7.41	138.9±16.87	81.00±5.37	-10.17	-41.68
Irenka × Blanco Lechoso	67.60±15.00	41.44±7.41	96.54±11.98	77.06	42.81
	Seed weight/plant				
Garbanzo 1 × VSP 11	22.76±2.46	22.03±4.31	14.72±3.24	-34.24	-35.29
VSP 11 × Garbanzo 1	22.03±4.31	22.76±2.46	16.81±2.31	-24.92	-26.13
Garbanzo Negro × Blanco Lechoso	25.95±3.42	25.55±2.74	20.13±3.1	-21.81	-22.40
Balkan × VSP 11	21.33±4.68	22.76±4.31	18.49±5.35	-16.11	-18.75
Blanco Lechoso × Garbanzo negro	25.55±2.74	25.95±3.42	59.63±4.15	131.60	129.83
Irenka × Blanco Lechoso	11.78±2.62	25.55±2.74	27.51±4.17	47.43	7.69
	1000 seeds mass				
Garbanzo 1 × VSP 11	412.10±12.49	153.94±9.76	151.5±0.54	-46.49	-63.25
VSP 11 × Garbanzo 1	153.94±9.76	412.1±12.49	159.7±0.31	-43.57	-61.25
Garbanzo Negro × Blanco Lechoso	184.95±4.82	609.0±20.06	162.2±0.33	-59.14	-73.37
Balkan × VSP 11	299.66±10.37	153.94±9.76	385.2±0.54	69.85	28.55
Blanco Lechoso × Garbanzo negro	609.00±20.06	184.95±4.82	736.2±0.88	85.45	20.88
Irenka × Blanco Lechoso	169.73±7.48	609.0±20.06	328.5±2.12	-15.63	-46.06
	Days to maturity				
Garbanzo 1 × VSP 11	40.00	31.00	41.00	15.49	32.26
VSP 11 × Garbanzo 1	31.00	40.00	46.00	29.58	48.39
Garbanzo Negro × Blanco Lechoso	48.00	40.00	46.00	4.55	15.00
Balkan × VSP 11	53.00	31.00	61.00	45.24	96.77
Blanco Lechoso × Garbanzo negro	40.00	48.00	67.00	52.27	67.50
Irenka × Blanco Lechoso	56.00	40.00	49.00	2.08	22.50

P1; P2 - first and second parent form.

The results regarding the trait of pod number per plant are presented in Table 1. The parental forms Balkan (156.30), VSP 11 (117.6), and Garbanzo Negro (116.9) were characterized by the highest number of pods. Varieties belonging to the Kabuli type formed a small number of pods (41.44-44.89), while the hybrids had mean values for this trait. Increased number of pods was recorded for Garbanzo Negro × Blanco Lechoso (93.56) and VSP 11 × Garbanzo 1 (82.33). In combinations in which the maternal component is Desi type, the hybrids form a greater number of pods. Heterosis manifestations in hybrids were expressed in a wide range: from strongly negative (-74.44%; -77.61%) in Balkan × VSP 11 to strongly positive (59.11%; 37.50%) in Irenka × Blanco Lechoso. The crosses VSP 11 × Garbanzo 1, Garbanzo Negro × Blanco Lechoso and Blanco Lechoso × Garbanzo Negro were characterized by a weak positive hypothetical and relatively high negative true heterosis. In the hybrid combinations VSP 11 × Garbanzo 1, Garbanzo Negro × Blanco Lechoso and Blanco Lechoso × Garbanzo Negro, intermediate inheritance of the trait with a positive sign was established. With the same degree, but with a negative sign, was the inheritance for the pods number in Garbanzo 1 × VSP 11. In Irenka × Blanco Lechoso, positive overdominance (3.76) was noted, and in Balkan × VSP 11, negative overdominance in the inheritance of this trait (-5.27) was registered.

The parent varieties with more pods/plant logically formed a higher number of seeds/plant. The trait ranged from 41.44 (Blanco Lechoso) to 142 (VSP 11). Similar diversity was obtained in the hybrids. The seeds number reached 124.78 in Garbanzo Negro × Blanco Lechoso, and in Balkan × VSP 11 was only 48. For Garbanzo 1 × VSP 11, Balkan × VSP 11 and Blanco Lechoso × Garbanzo Negro, the heterosis (hypothetical and real) was negative.

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Only Irenka × Blanco Lechoso had high positive values (77.06%; 42.81%) for heterosis manifestations. The trait inheritance ranged from positive overdominant (Irenka × Blanco Lechoso) to negative overdominant (Balkan × VSP 11). For Garbanzo 1 × VSP 11, VSP 11 × Garbanzo 1 and Blanco Lechoso × Garbanzo negro, intermediate inheritance of the trait was characteristic, and for Garbanzo Negro × Blanco Lechoso - positive dominant.

In the present study, the parent forms were contrasting regarding seed weight/plant. Garbanzo Negro (25.95 g) and Blanco Lechoso (25.95 g) were distinguished by high seed productivity. The Balkan variety, although it produced a high number of seeds/plant, had a low weight. It was found that the average values for seed weight/plant were higher than those of the parental varieties in the hybrid combinations Blanco Lechoso × Garbanzo Negro (56.63 g) and Irenka × Blanco Lechoso (27.51 g). Also, it is noteworthy that Garbanzo Negro × Blanco Lechoso (the reciprocal combination) was inferior in productivity compared to both parents. In Garbanzo 1 × VSP 11 and VSP 11 × Garbanzo 1, the direction of crossing did not play an essential role in improving the trait. However, there was a heterosis effect in the inheritance of that trait. Well-expressed positive heterosis manifestations were found in Blanco Lechoso × Garbanzo Negro (131.60%; 129.83%) and Irenka × Blanco Lechoso (47.43%; 7.69%). The heterosis effect in chickpeas (compared to other model plants in breeding) has been less investigated. In previous studies, Mangal and Bahl (1984) reported the presence of positive and negative heterosis in the productivity of 26 chickpea hybrids, which was confirmed in the present experiment.

The cytoplasmic effect was strongly expressed when crossing Blanco Lechoso with Garbanzo Negro (Figure 2). Therefore, in breeding regarding seed productivity, Blanco Lechoso (Kabuli type) has to be used as a maternal parent component. Garbanzo 1, which is the same type, can be successfully used as a paternal component in hybridization schemes. All other hybrids, due to their weaker productive potential, had negative hypothetical and true heterosis, reflecting the trait inheritance's mode, which is of the negative overdominance type. Bayahi and Rezgui (2018) reported the improvement of some quantitative traits in chickpea by crossing the two main types Desi and Kabuli. Our study partially supports their results, according to which a higher heterosis effect has been obtained in crosses with a paternal form of the Kabuli type. Similar manifestations of cytoplasmic effects were reported by Wafula et al. (2021). A particular effect of maternal influence has been obtained in the hybrid Chaina I × Mwanza 2, which is recommended for creating high-yielding genotypes.

The 1000-seed mass is a characteristic that gives an idea of the seed size. The Kabuli-type varieties were generally large-seeded, with a seed mass ranging from 412.10 g (Garbanzo 1) to 609 g (Blanco Lechoso). Most of the Desi-type varieties were medium-seeded (from 153.94 g to 184.95 g). In this group, Balkan can be defined as a large-seeded variety, with 1000 seeds mass of 299.66 g. Considerable diversity was observed in F1 generation hybrids as the seeds of Garbanzo 1 × VSP 11, VSP 11 × Garbanzo 1, and Garbanzo Negro × Blanco Lechoso were smaller and did not exceed 163 g. Balkan × VSP 11 and Irenka × Blanco Lechoso were determined as large-seeded (385.2 - 328.5 g), and Blanco Lechoso × Garbanzo Negro was distinguished by the heaviest seeds (736.2 g).

When comparing the results obtained for Garbanzo 1 × VSP 11 and Blanco Lechoso × Garbanzo Negro and their reciprocals, it can be noted that the direction of crossing plays an important role in the second hybrid, when Blanco Lechoso is the maternal form. Therefore, this hybrid combination had the highest hypothetical (85.45%) and true heterosis (20.28%). Also, in Garbanzo 1, an extranuclear inheritance was expressed but much weaker. Similar levels of heterosis were also found in Balkan × VSP 11, which is obviously due to the presence of Balkan variety. In the other crosses, the manifestations of heterosis were negative.

The mass of 1000 seeds in chickpea hybrids was inherited mainly from the type of negative overdominance (-1.22 - -5.75) and negative dominance (Garbanzo Negro × Blanco Lechoso; Irenka × Blanco Lechoso), which indicates some advantage of the parents compared to the hybrids. Similar results were obtained by Syed et al. (2012) and Johnson et al. (2019) when studying chickpea hybrids. The authors reported high positive values of heterosis for the traits as period to flowering, vegetation period, pods number and seed weight per plant, and a negative value for 1000-seed weight.

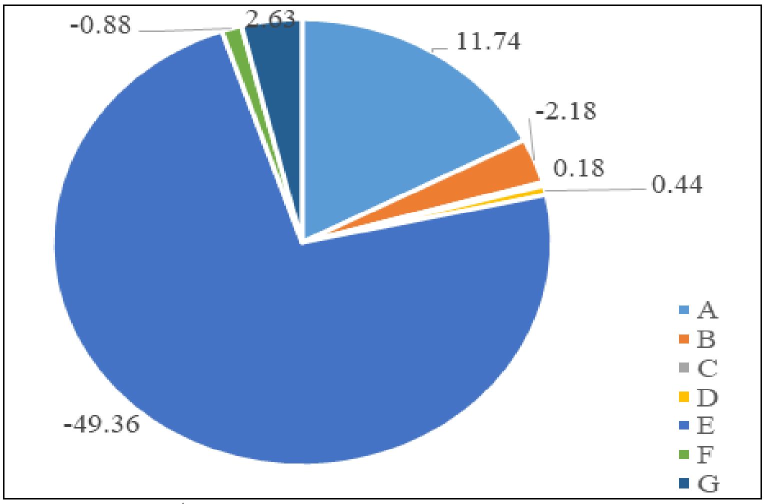
Early maturity is a desired and sought trait in many breeding programs. Chickpea varieties selected in the hybridization scheme differed in their phenological development. The days from germination to flowering varied greatly. VSP 11 was distinguished by the shortest period (31 days), followed by Garbanzo 1 and Blanco Lechoso (40 days). In contrast, Irenka and Balkan were characterized by longer periods until flowering (53 and 56 days). The analysis of data showed that in most cases, the hybrids start flowering later than their parents, or the duration of the period until flowering is closer to that of the later-flowering parent. According to the early-ripening coefficient (Figure 4), varieties and hybrids were divided into the following groups: ultra-early ripening - VSP 11; early ripening - Garbanzo 1, Garbanzo 1 × VSP 11, Blanco Lechoso; medium early ripening - Irenka 4, Balkan, Garbanzo Negro, Irenka × Blanco Lechoso, VSP 11 × Garbanzo 1, Garbanzo negro × Blanco Lechoso; late ripening - Balkan × VSP 11 and Blanco Lechoso × Garbanzo negro. In terms of this trait, the hybrids showed positive hypothetical and true heterosis, which was most pronounced in Balkan × VSP 11 (45.24%; 96.77%) and Blanco Lechoso × Garbanzo Negro 11

(57.27%; 67.50%). A weak influence of the maternal cytoplasm was found only when crossing Garbanzo 1 with VSP 11 (Figure 3). In Irenka × Blanco Lechoso and Garbanzo Negro × Blanco Lechoso, the established heterosis effect (compared to the average parental level) was with values of 2.08 to 4.55%, respectively. Compared to the more productive parent, the heterosis effect in them was significantly lower than in other crosses and reached 15.00-22.50%. It can be suggested that in the next generations, earlier-ripening genotypes can be identified from them. The inheritance of early maturity trait was of negative overdominance type, except for crosses Garbanzo Negro × Blanco Lechoso and Irenka × Blanco Lechoso with intermediate inheritance. Previous studies (Parameshwarappa et al., 2012) support the present results. Rathod et al. (2018) reported that a considerable number of F1 chickpea hybrids outperformed their parental forms in terms of duration of emergence-flowering period, height per plant and other main traits, and showed positive heterosis.

The variation coefficient (Figure 5) for height/plant and 1st pod height showed that the hybrids were slightly variable, especially VSP 11 × Garbanzo 1 (4.25%; 6.31%) and Blanco Lechoso × Garbanzo Negro (2.294%; 9.21%). The range of variability for plant height was from 2.94% to 13.92% (Irenka × Blanco Lechoso), and for 1st pod height - from 6.04% (Garbanzo 1 × VSP 11) to 15.96% (Irenka × Blanco Lechoso). Strong variability was found for pod number/plant, reaching 67.78% (Irenka × Blanco Lechoso). In most hybrids, the variability was above 28%, except Blanco Lechoso × Garbanzo Negro, in which variability was at an average level (12.50%).

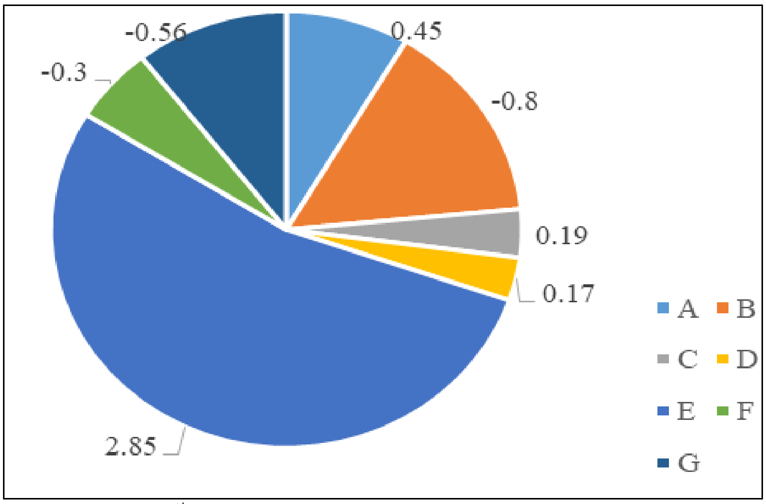
The trait of seeds number/plant was characterized by a wide range of modification variability, most pronounced in Garbanzo 1 × VSP 11 and Irenka × Blanco Lechoso (69.68 - 61.69%). In all hybrids, the number of seeds largely depends on the environmental conditions.

The seed weight per plant follows the variability of the previous two quantitative traits. The variation coefficient values were high in all crosses, especially in Garbanzo 1 × VSP 11 (66.04%) and Irenka × Blanco Lechoso (65.58%). Differences were also reported in reciprocal cross-hybrids. It was found that when the maternal parent is Kabuli type, variability is higher. High variability indicates the possibility of selecting valuable genotypes in the early stages of the breeding process. As the most stable in terms of 1000-seeds mass can be identified VSP 11 × Garbanzo 1 and Garbanzo Negro × Blanco Lechoso, in which the variability was below 7%. Irenka × Blanco Lechoso and Balkan × VSP 11 showed variability ranging from 21.46 to 25.94%, while Blanco Lechoso × Garbanzo Negro was distinguished by the highest instability (31.84%).



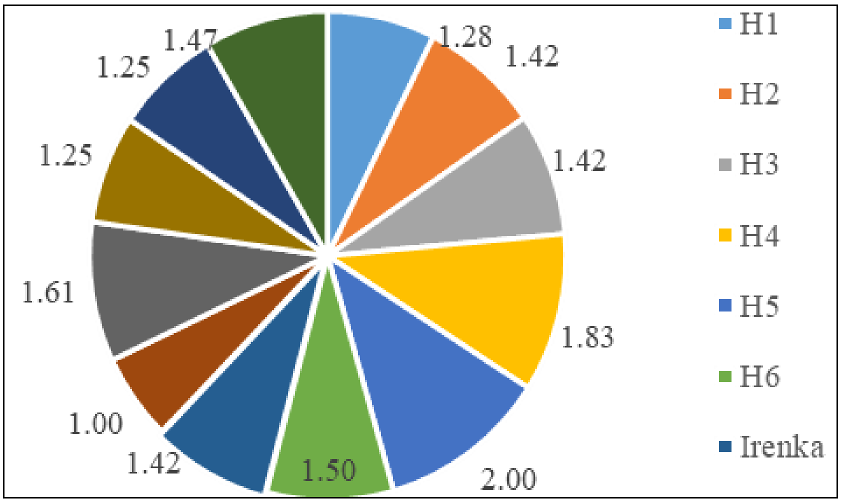
A - height/plant; B - 1st pod height; C - pods number/plant; D - seeds number/plant;
E - seed weight/plant; F - 1000 seeds mass; G - days to flowering.

Figure 2. Cytoplasmic effect (re) in hybrids Blanco Lechoso × Garbanzo Negro and Garbanzo Negro × Blanco Lechoso



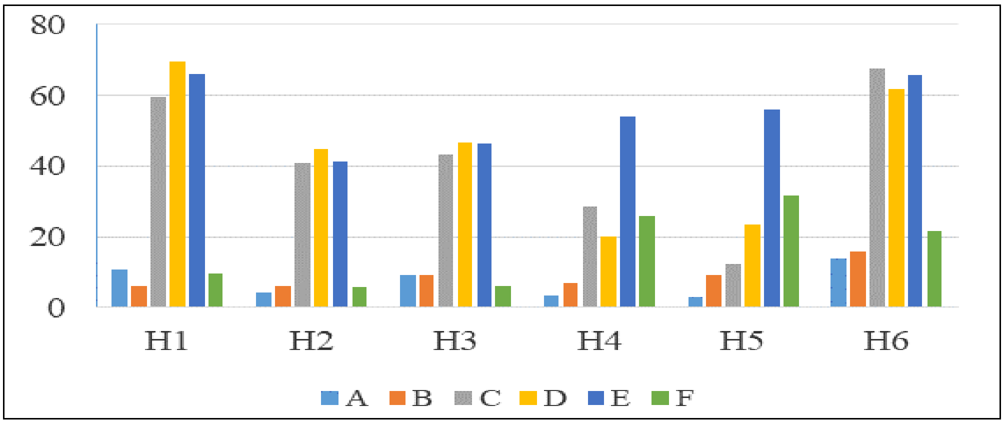
A - height/plant; B - 1st pod height; C - pods number/plant; D - seeds number/plant;
E - seed weight/plant; F - 1000 seeds mass; G - days to flowering.

Figure 3. Cytoplasmic effect (re) in hybrids Garbanzo 1 × VSP and VSP × Garbanzo 1



H1 - Garbanzo 1 × VSP 11; H2 - VSP 11 × Garbanzo 1; H3 - Garbanzo Negro × Blanco Lechoso;
H4 - Balkan × VSP 11; H5 - Blanco Lechoso × Garbanzo Negro; H6 - Irenka × Blanco Lechoso.

Figure 4. Early-ripening coefficient in chickpea hybrids and parent forms



H1 - Garbanzo 1 × VSP 11; H2 - VSP 11 × Garbanzo 1; H3 - Garbanzo negro × Blanco Lechoso;
H4 - Balkan × VSP 11; H5 - Blanco Lechoso × Garbanzo negro; H6 - Irenka × Blanco Lechoso.
A - height/plant; B - 1st pod height; C - pods number/plant; D - seeds number/plant;
E - seed weight/plant; F - 1000 seeds mass.

Figure 5. Coefficient of variation (CV, %) in F1 chickpea hybrids

The analysis of phenotypic (modification) variation indicated thatthe studied traits exhibited substantial variability as a result of the influence of environmental conditions. The present investigation allows us to note the presence of reliable genotypic diversity in chickpea hybrids and gives meaning to further studying the obtained hybrid material. Work in subsequent hybrid populations will allow the selection of promising accessions possessing valuable traits and indicators. Malik et al. (2011) and Shengu et al. (2018) reported lower coefficient of variation for the traits such as plant height, number of pods per plant, and 1000-seed weight in chickpea genotypes. In contrast, seed weight/plant was defined as a variable and unstable trait. According to Zali et al. (2011), chickpea breeding should be oriented towards traits such as seed number/plant and 1000 seed mass, which will contribute to increasing yield. The authors emphasized that chickpea yield could be improved by selecting a genotype with a higher number of pods and seeds per plant, as well as increased 1000 - seed weight.

The Health Advantages of Chickpeas

Chickpeas are utilised as food in a variety of ways throughout the world. Eighty percent of the dry mass of chickpeas is made up of protein and carbs. Beyond their well-known role in providing protein and fibre, chickpeas have a number of physiological benefits that make them a possible contender for the category of "functional food" (Jukanti et al., 2012) (Figure 6). Amylose and resistant starch are abundant in chickpeas. Amylose offers more resistance to digestion in the small intestine due to its higher degree of polymerisation, which causes a delayed conversion into glucose (Pittaway et al., 2007). Due to the delayed entry of glucose into the bloodstream, less insulin is needed, the glycaemic index (GI) is lowered, and the insulinemic postprandial response is lessened (Osorio-Díaz et al., 2008). Type II diabetes is becoming less common and less severe as a result of these combined effects (Ahmed et al., 2006). The synthesis of prostaglandins, which is essential for controlling blood pressure, depends heavily on linoleic acid (Aurand et al., 1987).

Butyrate has been shown to reduce the risk of colorectal cancer by inhibiting cell growth (Cummings et al., 1981) and inducing apoptosis (Mathers et al., 2002). Previous research suggests that adding β-sitosterol, the main phytosterol found in chickpeas, to a rat's diet can prevent colonic tumours caused by the carcinogen N-methyl-N-nitrosourea (Raicht et al., 1980). Additionally, chickpea seeds' lycopene content may provide defence against prostate cancer (Giovannucci et al., 1995). Another study found that a chickpea isoflavone extract inhibited the formation of epithelial tumours without affecting healthy cells (Julio et al., 2004).

As a low-GI item, chickpeas may be a useful supplement to diet plans. Furthermore, eating chickpeas has been shown to reduce the buildup of fat in obese people. Increased feelings of fullness and satiation result from including chickpeas in the diet (Murty et al., 2010). In comparison to a usual diet, those fed a chickpea diet showed an overall improvement in bowel health in the test by Murty et al. (2010), including higher frequency of defecation, ease of defecation, and softer stool consistency. Bowel function was positively promoted by the Dietary Food - DF (Jukanti et al., 2012).

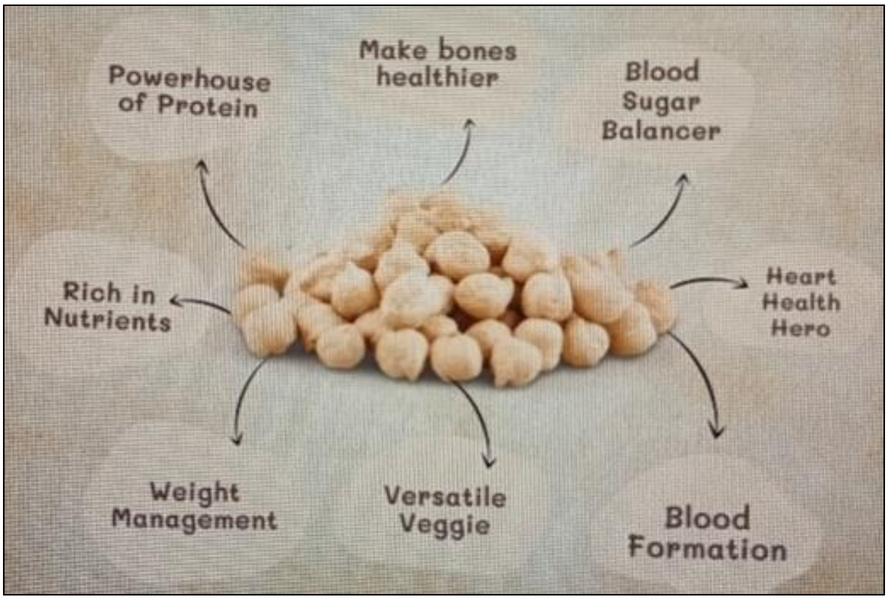


Figure 6. Chickpea health benefit

CONCLUSIONS

The breeding program conducted in chickpea varieties achieved a diversity of agronomic characteristics by hybridization between 6 parental components belonging to the Desi and Kabuli types.

Hybrids with higher positive heterosis for height/plant, number of pods and seeds/plant and degree of earliness were Desi × Kabuli type, for seed weight and mass per 1000 seeds were Kabuli × Kabuli type, and for 1st pod height were Desi × Desi type.

The highest hypothetical and true heterosis regarding some main traits were found as follows: in Garbanzo Negro × Blanco Lechoso for height/plant (140.76%; 133.04%), in Irenka × Blanco Lechoso for number of pods (59.11%; 37.50%) and seeds/plant (77.06%; 42.81%), in Blanco Lechoso × Garbanzo Negro for seed weight/plant (131.60%; 129.83%) and 1000 seeds mass (85.45%; 20.88%).

The gene actions in the manifestation of height/plant and 1st pod height in all hybrids were of positive overdominance type. For seed weight, 1000 seeds mass and degree of early maturity, negative dominance, and overdominance were characteristic, and for pod and seed numbers, in most cases, intermediate inheritance was observed.

Chickpeas are a high-protein, high-fiber food that can be used to prevent or treat Type II diabetes, lower the risk of colorectal cancer by preventing cell growth, protect against prostate cancer, and improve bowel health by increasing the frequency, ease, and consistency of bowel movements.

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