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Cicer arietinum - Importance, Distribution, Use and Breeding Guidelines

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ABSTRACT

The chickpea (*Cicer arietinum* L.), a plant species of the genus Cicereae, is a member of the Fabaceae family subfamily Papilionaceae. It is grown in more than 55 countries, primarily in regions with dry soil and climate. Today, chickpeas are grown throughout the Americas, the Middle East, Australia, South Asia, North Africa, and Southern Europe. After the common bean, it is the second most widely grown leguminous crop worldwide. The study briefly reviews the origin, distribution, nutritional value and use of *Cicer arietinum*, as well as its importance under conditions of changing climate, deepening food insecurity and fodder deficit. Its main characteristics as a food and forage crop, and some of its advantages compared to other leguminous crops, are presented. The main methods and guidelines of chickpea breeding, as well as the prospects for its cultivation worldwide and in Bulgaria are also discussed.

Keywords: chickpea, use, distribution, importance, breeding guidelines.

INTRODUCTION

For centuries, legumes have been an integral part of the human diet, but their nutritional potential is underestimated, and consumption still remains low (WHO, 2022). The world today is facing a major challenge of achieving food security and ensuring balanced nutrition for the planet's population. The statistics are discouraging: about 800 million people suffer from chronic hunger, and about two billion from a lack of one or more micronutrients. At the same time, more than half a billion people suffer from obesity. The use of plant genetic resources to develop improved crops and varieties adapted to specific conditions of concrete agro-ecosystems is of key importance to ensure food security and sustainable agricultural production. Common beans, peas, chickpeas, and lentils represent a huge potential for a food program implementation. They are characterized by a high content of protein, fiber, vitamins, minerals, and amino acids, and also a high energy value (Shikhalieva et al., 2016). Chickpea (*Cicer arietinum* L.) is a plant species of the genus Cicereae, belonging to the subfamily Papilionaceae, within the family Fabaceae. Vavilov and Posypanov (1983) indicate two centers of its origin: the Hindustan and the Mediterranean. *Cicer arietinum* L. is grown as a cultural species and is divided into four subspecies: Eastern, Asian, Eurasian, and Mediterranean. Each subspecies, in turn, is divided into varieties. The most important is the Eurasian subspecies. This subspecies can be divided into three groups: South European, Central European, and Anatolian. Chickpea varieties are characterized by high genetic diversity and have great potential to adapt to climate changes (Jukanti et al., 2012). Moreno and Cubero (1978) distinguish two main types of cultivated chickpeas: desi and kabuli. The desi types have anthocyanin pigmentation on the stem, pink corolla leaves, and colored and thicker seed coats. The kabuli types do not have anthocyanin pigmentation on the stem,

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have white corolla leaves, and white or beige seeds (ram's head shaped) with a thin seed coat. Subsequently, an intermediate type of seeds, which are close in shape to those of peas, was also recognized. The seed weight usually varies from 0.1 to 0.3 g and 0.2 to 0.6 g in desi and kabuli species, respectively. The desi types represent for about 80-85% of the total chickpea area and are mainly grown in Asia and Africa. The kabuli types are mainly grown in Western Asia, North Africa, North America and Europe. The aim of our study was to present chickpea production during a multi-year study and to highlight methods and guidelines for chickpea breeding in order to improve yields.

MATERIAL AND METHODS

This study analyses the chickpea production parameters in the world during the period from 2001 to 2019. The research is based on the available data already existing in related statistical publications. Data from Faostat 2022 were used (http://faostat.fao.org/). For the calculation of the yield and the size of the area, we used a basic statistical method. All data are presented in tabular and graphical form.

RESULTS AND DISCUSSION

Chickpea production

Chickpea is currently cultivated in South Asia, North Africa, Southern Europe, the Middle East, Australia and the Americas (Jukanti et al., 2012) (Figure 1). It is cultivated in more than 55 countries, mostly with drier soil and climate conditions. Statistics show that it is the second most cultivated leguminous crop in the world after the common bean, and in the last decade, world chickpea production has increased by 44%. The total world area of legumes is 95.76 million hectares, of which 17.19 million are with chickpeas. Thus, of the total production of leguminous crops, chickpea accounts for 18.63% (Faostat, 2022).

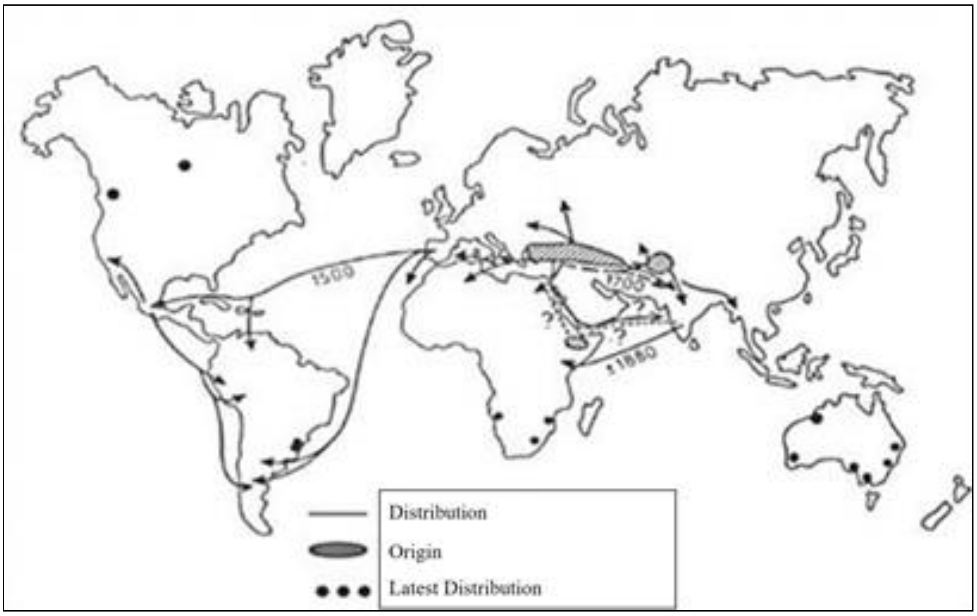


Figure 1. Origin and distribution of chickpea over the past 500 years

Figures 2 and 3 reflects trends in chickpea production from 2001 to 2019. A sustained area increase was found from 7,030,615 ha in 2001 to 14,220,390 ha in 2019. Other major producers are the USA, Canada, Mexico, Iran, Ethiopia, Pakistan, Turkey, Australia and Myanmar (Camiletti and Nelson, 2023). India is the country with the largest chickpea production in the world (followed by Australia and Turkey) with a share of about 66.19% (Figure 3).

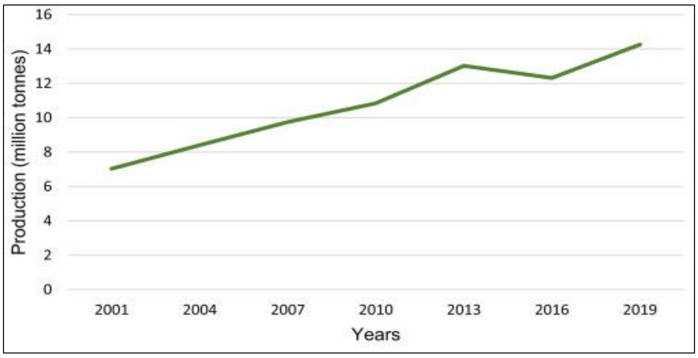


Figure 2. World chickpea production (t), 2001-2019

According to Singh et al. (2021), India is the largest producer and consumer of chickpea, while Australia is the major exporter. According to the latest data, harvested areas worldwide are 14.8 mil. ha, production is 18.1 mil. t, and the average yield is 122.18 kg/ha (Faostat, 2022). In conditions of global climate change, chickpea cultivation is an alternative in areas with insufficient rainfall and pronounced water deficit. The high drought resistance, comparative tolerance to diseases and pests, and suitability for fully mechanized harvesting define it as a very attractive crop in such areas (Novikov, 2020). It is not demanding on the soil and can be grown on lighter, poor and saline soils. It is a warm climate plant, but it tolerates both high and low temperatures well (Angelova and Stoilova, 2009). Thanks to its symbiosis with nodule bacteria, it is also considered one of the best predecessors in crop rotations. Novikov (2020) points out five main areas in which the crop has a useful contribution: food security, complete nutrition, maintaining a healthy human status, increasing soil fertility, and combating climate change. It is used as a raw material for the food and canning industry, in forage production, and the pharmaceutical industry due to the wide range of macro and microelements and biologically active substances it contains (Fedotov et al., 2004).

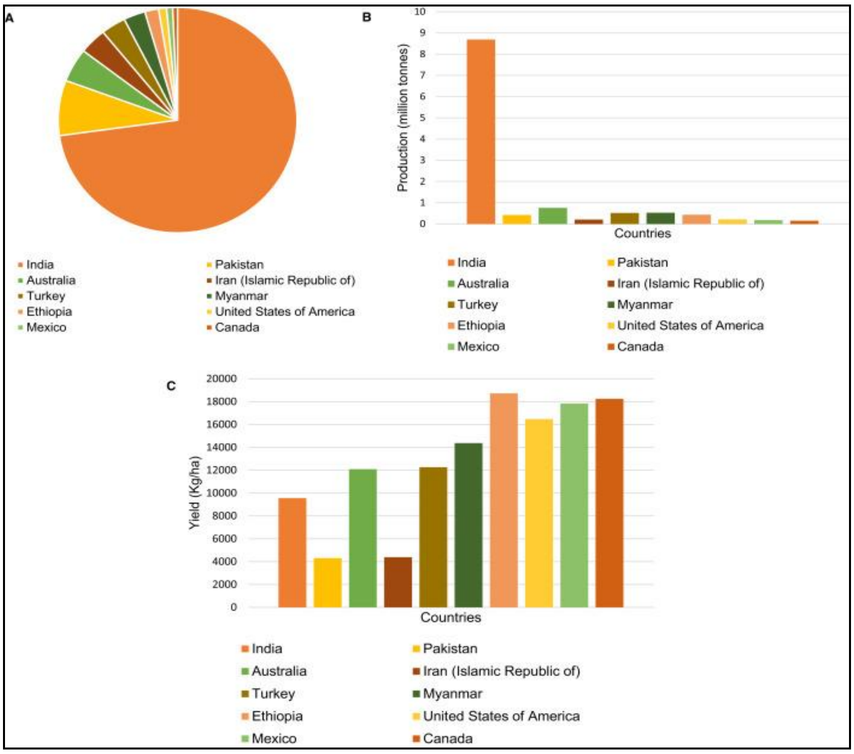


Figure 3. A - Harvested areas (ha), B - production (tonnes) and C - average yields (kg/ha) in chickpea

Nutritional value

In terms of nutritional value, chickpea is not inferior to pea, lentil, and common bean, and in terms of fat content, it is superior to many legumes (except soybeans). Bampidis and Christodoulou (2011) defined it as a high energy and protein source in animal nutrition. Depending on the variety, cultivation technology, and climatic conditions, the seeds contain from 13 to 31% protein, from 4 to 7% fat, from 45 to 60% nitrogen-free extractive substances, and from 2.5 to 5.0% ash (Mordvintsev et al., 2013). For country conditions, Petrova et al. (2017) indicated the following contents of crude protein, crude fiber and raw ash: 19.3-23.3% (average 21.4%); 2.1-7.3 (average 3.5%); 2.3-2.9% (average 2.6%). Jukanti et al. (2012) found higher values for in vitro protein digestibility (65.3-79.4%) compared to those of other legumes: *Cajanus cajan* (60.4-074.4%), *Vigna radiata* (67.2-72.2%), *Vigna mungo* (55.7-63.3%) and *Glycine max* (62.7-71.6%).

Regarding biological completeness and digestibility, the proteins in seed composition are close to those of animals. In terms of nutritional value, chickpea protein is comparable to casein. It contains all the essential amino acids (except sulfur-containing amino acids), in an optimal ratio, while at the same time surpassing soybeans regarding lysine, arginine, valine, leucine and isoleucine. The digestibility of nutrients in seeds is high - 78-97% (Pavlovskaya, 2004). Starch is the major storage carbohydrate, followed by dietary fiber, oligosaccharides, and simple sugars such as glucose and sucrose. Although lipids are present in small amounts, chickpea is rich in nutritionally important unsaturated fatty acids such as linoleic and oleic acids. b-Sitosterol, campesterol and stigmasterol are important sterols present in chickpea oil (Jukanti et al., 2012). The average content of macro and microelements is as follows: K - 968-975, Ca - 190-192, Mg - 126-130, B - 198-200, P - 445, Fe - 957-960 mg. The seeds contain a number of valuable vitamins and trace elements necessary for the human and animal organism. 100 g of seeds contain the following vitamins: A - 0.17-0.21; B1 - 0.26-0.29; B3 - 0.48-0.55; C - 3.56-3.90; PP - 2.21-2.36 mg, as well as pyridoxine, pantothenic acid, and choline. In terms of selenium content, chickpea takes first place among legumes (Suyundukov and Mirkin, 2009). Like other annual legumes, chickpea seeds also contain antinutrients, but the antinutrient content is 21.1 times lower than in soybean seeds, and 2.5 times lower than in pea seeds.

Chickpea as a food crop

Riped chickpea seeds are consumed as cooked, and unriped seeds as a vegetable. Adding chickpea flour (10-20%) to wheat flour when baking bread and confectionery increases the nutritional value and taste of the products. It has been established the possibility of using this flour in the production of semi-finished products from minced meat to balance the meat product in terms of biochemical composition. It should be noted that chickpea is an affordable alternative to more expensive animal protein, which makes it very suitable for improving the diet. Protein coming from milk, for example, is five times more expensive than protein that can be obtained from chickpea. The protein content of the crop's seeds is twice that of wheat and three times that of rice. Chickpea has a low content of fat and a high content of soluble fiber, which helps lower cholesterol and improves digestion. The high content of iron and zinc makes it a suitable agent for anemia control (Ying et al., 2007). According to various researchers (Jukanti et al., 2012), it is an important part of a healthy diet and reduces the risk of various diseases (chronic, cardiac, oncological, etc.). Milner (2000) define it as a "functional food", i.e. a food that provides health benefits beyond main nutrition.

Chickpea as a fodder crop

Growing chickpeas for forage is considered as an energy-protein alternative to cereals due to the higher content of metabolizable energy at almost double content of protein. Chickpea is defined as a high-protein concentrated feed. It improves the quality of concentrated feeds and nutritional supplements (Pimonov and Kozlov, 2012). The addition of chickpea grain to the ration of pigs promotes growth, in cows and sheep - improves milk yield, in hens - increases egg production (Chabaev et al., 2007). Raw chickpea can be used in ruminant diets at inclusion levels up to 300 g/kg, as the secondary compounds in chickpea are inactivated by fermentation in the rumen. In non-ruminant diets, it can be included up to 200 g/kg to support growth and productivity (Garsen et al., 2007). A higher level of inclusion in the diet of pigs, poultry and fish can be applied after the removal of secondary compounds by heat treatment. During heat treatment, most secondary compounds are destroyed, thus improving the utilization of carbohydrates, fats and proteins. The limited use of chickpea in feeding ruminants until now is due to the large proportion of degradable protein in the rumen, which, if it exceeds the amount necessary for the bacteria development in the rumen, increases the loss of nitrogen and can worsen the feeding efficiency (Serrapica et al., 2021). Chickpea straw can also be used to feed ruminants as it has a relatively high nutritional value The mineral composition includes: calcium - 1.69 g/kg DM, phosphorus - 3.42 g/kg DM, magnesium - 1.78 g/kg DM, potassium - 11.13 g/kg DM, sodium - 0.77 g/kg kg DM, copper - 10.65 mg/kg DM, iron - 90 mg/kg DM, manganese - 22.43 mg/kg DM, zinc - 42.2 mg/kg DM (Bampidis and Christodoulou, 2011). According to Fikadu et al. (2010) dry biomass contained as follows: crude protein (6.19-6.36%), neutral-detergent fiber (55.1-57.5%), acid-detergent fiber (40.5-41.4%) and acid-detergent lignin (8.04-8.52%). Minerals are very important for the growth, reproduction and lactation of animals.

Genotypic basic of chickpea breeding

The genome is an integral index of the genetic information carried by the cell nucleus. In practice, it is the totality of all chromosomes that are combined into one whole. It includes their number, shape, and size, which provide information about the development and growth of living organisms. The number of somatic chromosomes in most wild chickpea species is 2n=16. The species *C. reticulatum* L. has 2 pairs of chromosomes with satellites, while the others differ in only one such pair. Also, a difference in the ratio of the lengths of the chromosome arms (r-index) is found in the different species. *C. judaicum* Boiss is characterized by the most asymmetric karyotype. The species *C. arietinum* is characterized by insignificant variability of the r-index. Based on these studies, it should be concluded that the most likely precursor of the cultivated chickpea is *C. reticulatum*. On the other hand, based on the amount of DNA in the cell, chickpea species can be divided into 3 groups. The first group includes C. judaicum, the second - *C. cuneatum*, *C. bijugum*, *C. pinnatifidum*, *C. reticulatum* and *C. echinospermum*, the third - *C. arietinum* (Rasheed et al., 2024).

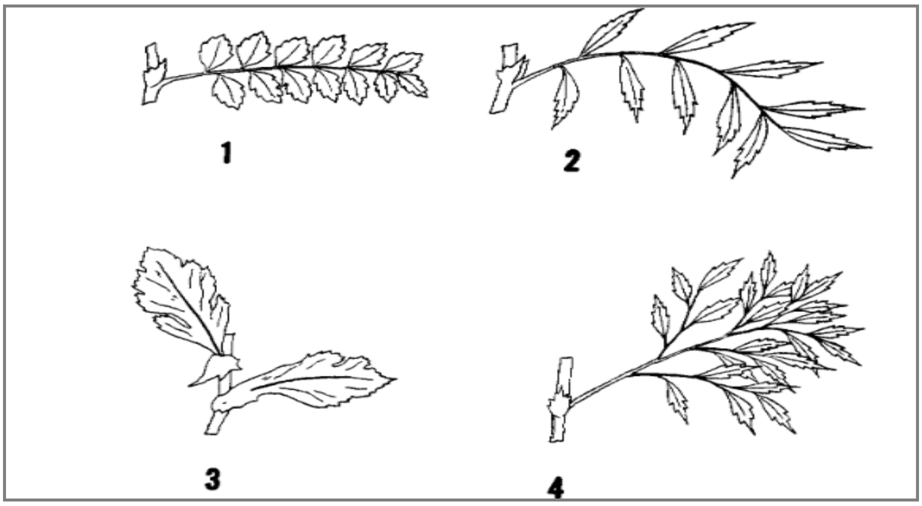
In the past few years, progress in chickpea genomics has provided greater opportunities to study the genomic characteristics of crop and assessment of their biological significance, including advances in genome design and transcriptome sequencing. The intensive development of molecular biology and genetics led to the development of new methods for DNA polymorphism analysis. Among them, the study of polymorphism in the length of restriction fragments deserves special attention. Another technique used is the polymerase chain reaction, which allows many copies of certain pieces of DNA to be received in a relatively short period. To identify primary DNA sections, primers are used, which are oligonucleotides with a length of 10-30 residues. Due to their interaction with DNA, there is a rapid increase in the number of certain fragments of the molecule with a known nucleotide sequence (Talebi et al., 2008). Despite the new approaches mentioned above, traditional breeding methods are still used to develop new genotypes.

Intraspecific hybridization remains the main method for development of starting material for the subsequent breeding of elite plants, giving the outset of new chickpea varieties. The study of the mode of inheritance of quantitative traits is still relevant today. Knowing the patterns acting in disintegrating hybrid populations leads to more efficient breeding and reduces the cost of creating a variety. The most important regularities in the inheritance of traits are the following: heterosis effect, level of inheritance, which is characterized by the degree of dominance and the nature of the genotype-environment interaction, and manifestations of transgression (Ahmed et al., 2007).

The heterosis effect, which is characteristic of first-generation hybrids, has been used in many studies in legumes. There are several difficulties in obtaining hybrid seeds, isolating sterile plants, and pollinating self-pollinated crops, which make it unacceptable to use heterosis on a scale exceeding the experimental level. It is found that the selection of high-yielding plants, as a rule, is more likely under strong manifestations of heterosis in hybrid populations of early generations. The effect of heterosis in chickpea is poorly studied. Various studies have reported both positive and negative heterosis in terms of seed productivity depending on the hybrid combination, and in most cases, it is small (Kumari and Prasad, 2003). For correct work with hybrid populations in the early generations, it is necessary to have sufficiently complete information about the nature of manifestation of the main traits in the offspring, the degree of dominance, and the character of decomposition. The study of the frequency and degree of transgression in selection and genetic work is also necessary to determine the regularities in creating forms with the maximum manifestation of certain valuable traits in the breeding process (Mujjassim et al., 2018).

In a number of studies, when conducting a hybridological analysis of the results of crossing chickpea accessions, it was found that the hybrids in F1 differ in the color of leaves, petals and seed coat. In F2, it was observed a decomposition of the nuance of coloring the leaves in the ratio of 3:1, of the corolla - 9:7 and of the seed coat - 15:1. Based on these data and examination of the progeny in F3, it can be suggested that chickpea leaf color is controlled by two complementary genes, one of which is related to a duplicated gene for seed color. A similar decomposition in seed coat color was obtained in other experimental conditions (Van Rheenen et al., 1994). The traits of prostrate growth, white flowers, strong green leaves, simple leaves and green seed coat are determined by recessive genes. When plants with pink and purple flowers were crossed, a simple inheritance of the trait was observed in the F2 hybrid generation in a ratio of 9 pink, 3 light pink, 3 blue, and 1 light blue, indicating the involvement of two factors for corolla color. It was found that petal morphology and flower color are independently inherited traits. Based on the differentiation of the petiole, the following leaf types can be recognized: uni-imparipinnate (normal), multipinnate and simple (leaf) (Figure 4). It was established the differences in leaf type are determined by two genes (ml, sl) that show additive gene action. A multipinnate leaf is formed when the first gene is dominant (ml+sl/sl). A simple leaf type is expressed when the first gene is recessive and the second gene is in any form (recessive/dominant) (ml/ml.), and a normal leaf is formed when both dominant genes are present (ml+sl+) (Pathak and Sahay, 1964).

Regarding the duration of the germination-flowering period in chickpeas, Kuzmina et al. (2022) found that it has digenic control and is determined by two genes with double recessive epistasis (cryptomery), as late flowering dominates over early flowering. The same authors reported that the genetic control of seed size is also digenic in nature and is under the control of two main genes with an additive type of action (epistasis and complementarity), as small seeds dominate over large seeds. Effective breeding of transgressive forms regarding the traits of seed size and duration of the germination-flowering period is possible in all hybrid combinations. Breeding is recommended to be done in F2 or in subsequent hybrid generations. Worldwide, a collection of nearly 100,000 chickpea accessions has been established, which forms the basis of many breeding programs. Yadav and Chen (2007) indicated some main directions in crop breeding: higher yield, greater adaptability (possibility of growing varieties suitable for winter sowing in the Mediterranean and for double cropping in irrigated areas of the Indian subcontinent), resistance to biotic stress (ascochitosis, root rot, insects, nematodes), resistance to abiotic stress (drought, salinity, low temperatures), etc. According to Lakić et al. (2022), over the past five decades, breeders' efforts to increase crop yield have been relatively unsatisfactory.



1 - normal leaf, 2 - narrow leaflets, 3 - simple leaf, 4 - bipinnate leaf.

Figure 4. Leaf type in chickpea

The main limitations are the slight susceptibility to mechanized harvesting, significant damage from pests and diseases, and high sensitivity to heat stress and salinization. According to other researchers (Saeed et al., 2011), the success of breeders in creating new varieties of chickpea is indisputable, but modern production trends and climate changes set new demands. The authors indicate the following main guidelines: short growing season, high productivity and tolerance to abiotic and biotic stress.

Breeding regarding productivity

Developing a variety with a high productivity index indicates the effectiveness of breeding work in all crops. However, increasing productivity is one of the most difficult tasks, as this trait is quantitative and complex in many respects (Angelova, 2007; Popović et al., 2013; Rakašćan et al., 2021; Popović et al., 2022). Complex stepwise hybridization is the main method of selection for productivity. The main elements related to chickpea productivity are the number of basal branches, productive nodes, seeds per plant, weight of 1000 seeds, weight of seeds per plant, foliage mass, etc. A negative correlation was found between some of the indicated characters, but through hybridization it is possible to change this dependence and obtain more productive transgressive genotypes compared to the parental forms (Zhang et al., 2024). The probability of creating positive transgressions increases when crossing parental forms, selected on the basis of differences in productivity elements, as well as those classified as different types. Each variety has certain manifestations depending on its structural elements and their variability. Forms with a different structure of productivity can provide almost the same yields, and vice versa, similar forms in many elements, but different in at least one of them, can have different productivity. Also, the advantage of one element (trait) can be compensated by the negative influence of another (Stefaniak and McPhee, 2017). One of the ways to increase productivity can be the introgression of adaptive genes from old local varieties, especially from the places of genetic diversity of the species.

Breeding regarding duration of vegetation period

The duration of the vegetation period is a decisive indicator of the suitability of a variety for growing in a certain ecological zone. This indicator has an impact on the productivity and quality of the production. Breeding for early maturity is complicated by the fact that the duration of the vegetation period is closely correlated with productivity. Early varieties are often less productive than late varieties. When choosing an early maturing variety, it is necessary to consider not only the duration of the entire growing season but also the interstage periods of sowing-shoot elongation, shoot elongation-flowering, flowering-ripening (Jha, 2018). The growing season of chickpeas is 80-120 days, depending on the variety and environmental conditions. It is a long-day plant by the photoperiodic response; therefore, sowing should not be done later, as this shortens the interstage periods and decreases the yield.

An evaluation of the accessions is carried out at the beginning and the end of the individual stages of phenological development. The beginning of stage is marked when 10-15% of the plants enter it, and the end - at 75%. In breeding in the early maturity direction, varieties with different durations of individual stages should be selected for crossing to obtain an earlier maturing variety. Furthermore, at one parent component, the stages should be short, and at the other, they should be longer (Sadokhin, 2002). By proper selection of parental forms with different durations of individual interstage periods, it is possible to achieve a good combination and create an early maturing variety.

The research indicate that the obtained average values of seed yield in the first year of the research varied from 344.3±10.4 kg ha^{-1} to 576.3±12.7 kg ha^{-1} depending on the influence of all three examined factors. By sowing perennial ryegrass seeds at a greater inter-row distance, the yield of the obtained seeds also increased. By sowing seeds at a distance of 12.5 cm, an average seed yield of 443.2±63.4 kg ha^{-1}, while at the maximum inter-row spacing (50 cm) an average seed yield 485.2±62.8 kg ha^{-1}.

Breeding for increased tolerance to abiotic stress

The seeding rate had a significant statistical effect on the values of the seed yield of perennial ryegrass. In the experimental plots where it was 9 kg ha^{-1} of seed, the yield of 471.0±62.7 kg ha^{-1} is achieved, while the average seed yield of 455.0±63.8 kg ha^{-1} was obtained by sowing 30.0 kg ha^{-1} of seed. Supplementation with nitrogen fertilizers in the first year of the experiment had a statistically significant effect on the seed yield of perennial ryegrass. By using the largest amount of fertilizer (90 kg ha^{-1}), the highest yield has been achieved (541.3±27.6 kg ha^{-1}), while it is in the control variant, on the plots without fertilization (0 kg ha^{-1}), the amount of seed obtained was statistically significantly smaller (377.0±23.2 kg ha^{-1}).

Chickpea is mainly grown in arid and semi-arid regions on poorly fertile soils. In these regions, abiotic stress such as extreme temperatures and drought during the growing season are the main adverse factors that limit its productivity. Globally, drought and extreme temperatures have resulted in 50% and 20% reductions in chickpea seed yield, respectively. The identification and/or development of new high-yielding genotypes with pronounced tolerance to abiotic stress through appropriate selection methods and approaches is sorely necessary. These cultivars should be climate resilient, genetically diverse, efficient and widely adaptable to different environments (Jha et al., 2014). In addition to intraspecific hybridization, interspecific hybridization has also been successfully applied to improve drought tolerance in chickpea (Hajjar and Hodgkin, 2007).

To achieve interspecific hybridization, annual Cicer species are divided into three groups, and hybridization is feasible only within one group. Group-I includes the cultivated species *C. arietinum* (cultivated species), C. *echinospermum* (wild relative) and *C. eticulatum* (wild relative). Group-II includes *C. bijugum*, *C. pinnatifidum* and *C.*

judaicum, and group-III includes only *C. cuneatum*. A high level of cross compatibility was observed in group I, especially in the cross between *C. arietinum* and C. *reticulatum*. Subsequently, complete fertility of F1 hybrids followed by normal segregation of F2 progeny is an indication of successful interspecific crossing of *C. arietinum* and *C. reticulatum*. Interspecific cross between *C. arietinum* and *C. echinospermum* has a high degree of sterility. Differences in pollen fertility were observed in reciprocal crosses of these species, indicating the predominance of maternal effects. Therefore, interspecific hybridization can be used for development of chickpea cultivars with improved drought tolerance, yield and other agronomic characteristics (Pundir and Vandermaesen, 1983).

Under cultivation in abiotic stress conditions, the average seed yield of chickpea is about 1 t/ha, which is far from its productive potential of 6 t/ha under optimal conditions. The combined effects of heat, cold, drought, and salinity have a strong negative impact on crop productivity. In this regard, some physiological, biochemical, and molecular mechanisms are evaluated and analyzed to confer relatively good genotype tolerance to abiotic stress. In parallel, advances in molecular biology and high-performance sequencing have enabled the development of specific molecular markers for the genus Cicer. Marker breeding facilitates and supports the selection of yield components simultaneously with abiotic tolerance.

Advances in molecular biology have enabled the identification of specific genes, proteins and metabolites associated with abiotic stress tolerance in chickpea. As a result of the research done, some promising results have been reported with transgenic plants and using genetic engineering manipulations to obtain drought-tolerant chickpea genotypes (Maphosa et al., 2020). Lakić et al. (2022) recommended further investigation on the basis of the species' high tolerance to drought and using the crop as an elite germplasm resource of traits for adaptation to new climatic conditions in the world's most important crops.

Breeding for increased nodule-forming

Relatively few breeders work in this direction although it is particularly relevant today, in conditions of increasing share of organic production worldwide. The ability of legumes in symbiosis with nodule bacteria to assimilate atmospheric nitrogen provides them ecological advantages in conditions of nitrogen deficiency. The use of this ability in practice allows for a considerable reduction of the use of mineral fertilizers without significant yield reduction while maintaining soil fertility (Solaiman et al., 2011). According to several researchers (Kaur et al., 2015), biological nitrogen fixation can be the basis for solving the plant protein problem. Including air nitrogen in the biological cycle ensures the production of additional protein. The protein productivity of crops that can form nitrogen-fixing nodules under favorable environmental conditions is many times higher than the protein productivity of crops that do not have this characteristic. Varieties with a high level of symbiosis of active nodule bacteria can provide nitrogen to an extent that does not increase the nitrate content in seeds and fresh mass, and is very important for obtaining environmentally friendly products. Considering the importance of this problem in recent years, breeders have tried to identify sources with high nodule-forming ability to be used in breeding to increase the nitrogen fixation intensity (Sahai and Chandra, 2011).

Stages of the breeding process and methods

It usually takes 10-12 or more years to create a new variety. The breeding process consists of three stages: selection of desired parental forms, application of selection in hybrid populations until stabilization of traits, testing the offspring and harvesting them to production level. Initially, it is very important to make a correct choice of parental pairs for combined breeding and subsequently to select hybrid plants. To expand the genetic base or create genetic variation for a desired trait in the next generation, parental components with alternative traits are selected. The work is complicated because of the fact that studying the economically valuable qualities of new forms and their reproduction is a rather long process. Chickpea is primarily a self-pollinating species, but its small and delicate flowers make crossing difficult (Jain et al., 2013). Two main methods of chickpea genetic crossing have been reported: artificial hybridization with and without castration with very low success rates. The success rate of artificial hybridization in the species varies from 10% to 50% due to (as already stated) the technically difficult character of the crossing procedure. Very often, the flowers are damaged during the hybridization itself. Nevertheless, single crosses, multiple crosses and three-way crosses are used for chickpea hybridization (Maqbool et al., 2017).

Field conditions have been found experimentally to be more favorable for outcrossing than greenhouse environments (Tullu and van Rheenen, 1989). Chickpea breeding is done using pedigree, mass selection, backcross, and multiple cross methods. However, in many cases of more complex inheritance, it is necessary to study the decompositing progeny. In this way, however, plant populations become too large and it is rare to obtain a desired combination of two traits in the early generations. In such cases, induced mutagenesis is more appropriate, especially if one of the desired characteristics is present in a well-adapted high-yielding variety. It was found that chickpea is very difficult for genetic improvement, but faster breeding progress could be achieved by applying conventional and more modern methods and breeding approaches (Kalve and Tadege, 2017).

In Bulgaria, chickpea is a well-known crop mainly used for fodder and food provision needs. After 1994 (202,000 ha), interest in this crop grew, which was related to increased consumption and market demand for healthy products. Currently, the areas in our country are limited. In 2022, they are 3529 ha with an average yield of 1534 kg/ha (Agrostatistics, 2022), (Figure 5). According to Petrova and Stamatov (2013), the average yield in experimental conditions is 200 kg/ha, but yields of 300 kg/ha have also been obtained. In Bulgaria, selective-improvement work with chickpeas is carried out at the Dobrudzha Agricultural Institute, Institute of Plant Genetic Resources "Konstantin Malkov" (Kolev and Mihaylov, 2022) and Institute of Forage Crops-Pleven. In the 1990s, Stepnovoi 1, Dobrudzhanski 6, Obraztsov chiflik and Plovdiv 8 varieties were grown in the country. In a study of a source collection of 28 accessions, Petrova et al. (2017) reported positive manifestations of four old Bulgarian varieties (Dreben svirkovski, Dobrudzhanski 6, Obraztsov chiflik 3, Obraztsov chiflik 2). Currently, two varieties are listed in the Official Varietal List of the Republic of Bulgaria: Balkan (Dobrudzha Agricultural Institute) and Kira (Cluser Breeding International GmbH). The main method for achieving the goals of modern breeding chickpea programs is hybridization, with the application of repeated selection - individual and mass, in collections of local and foreign varieties and populations. Experimental mutagenesis as a selection approach in chickpea was applied in Bulgaria after 1970. Since 1997, the method of distant hybridization between annual and perennial species and wild forms of chickpea has also been used. Targeted selection activity has led to the enrichment of the gene pool and the creation of new genetic diversity. The aspiration and efforts of researchers in modern chickpea breeding are aimed at higher productivity combined with a compact upright habit, increased nutritional value of seeds, and a good commercial type, as well as resistance to diseases and pests.

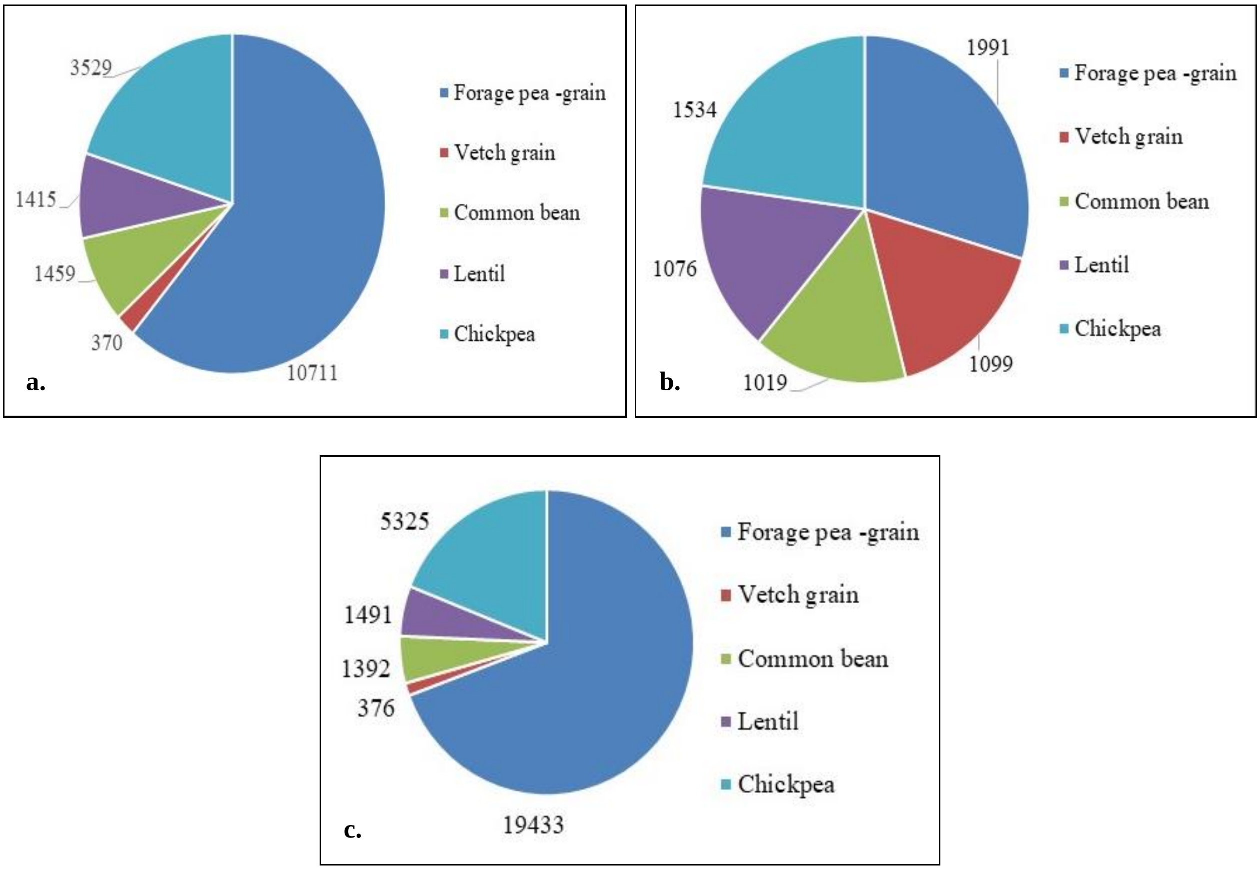


Figure 5. Chickpea area (ha) (a.), yield (kg/ha) (b.), and production (t) (c.) in Bulgaria (2022)

CONCLUSIONS

Based on the review of the scientific literature, it can be concluded that the chickpea remains an underutilized crop with good potential for cultivation under changing climate conditions. This potential is attributed to several valuable characteristics reported by several researchers, including drought resistance, good tolerance to high and low temperatures and soil types, relative tolerance to diseases and pests, favorable biochemical composition and significant benefits for the health status of humans and livestock as both a food and fodder crop. The origin, distribution and use of the species were described, as well as its importance under conditions of deepening food insecurity and fodder deficit.

The main methods and guidelines of chickpea breeding, as well as the prospects for cultivation in the world and Bulgaria were presented and will serve as a valuable reference for researchers engaged in chickpea breeding programs.

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