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GENETIC RESOURCES OF CHICKPEA AND THE EFFECTIVENESS OF THEIR USE IN BREEDING

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ABSTRACT

The article summarizes the characteristics of economically valuable features of a large set of chickpea samples in arid conditions of the steppe of Ukraine. The data on the spread of culture on our planet shows the positive impact of food made from its seeds on human health. A number of genotypes have been identified and described, which combine a significant number of important agronomic traits that are of significant value for breeding. Special attention in the research was paid to the identification of genotypes tolerant to elevated air temperatures and insufficient moisture in the soil. A brief description of the varieties created with the participation of exotic genetic plasma is given. As a result of many years of study of accessions of chickpea, sources of increased seed productivity, large seeds, high protein content, tolerance against pathogens, improved technological qualities of seeds have been identified. Individual genotypes have been identified in which several economically valuable indicators have been improved. It is shown that the combination of traits of samples of different ecological and geographical origin in one genotype has a high probability of obtaining valuable recombinant forms by accumulating positive adaptive genes. A particularly wide variation of breeding material is needed to prevent disease outbreaks and the widespread of pests, the danger of which increases significantly with the homogeneity of the gene pool.

Keywords: chickpea, collection samples, vegetation duration, drought tolerance, protein content, seed size.

INTRODUCTION

Chickpea is one of the most common legumes on our planet. In terms of crop area, it ranks third, conceding only to soybean and bean. Particularly intensive growth of its crops takes place in the XXI century. If in 2000 it was grown on an area of 10,2 million hectares, in 2016 they reached 12,6 million hectares, and in 2018 – 17,8 million hectares. Thus, the annual average growth of crop today is 422 thousand hectares. At the same time an increase in its yield observed. In 2000, it was 790 kg/ha, in 2016 – 890, and in 2018 – 960 kg/ha. This increase in the production of commercial seeds is due to a number of positive factors of this crop. First, it is an extremely valuable food for humans. Its seeds contain 24–32% protein and 5–6% oil. The biological value of protein is 52–78%, the digestion coefficient is 80–83%. It is important to emphasize that the amino acid composition of chickpea protein is close to the ideal FAO standard. In addition, the seeds of this crop contain a rich complex of vitamins, minerals and other biologically active substances. Therefore, chickpea is a high-quality baby food. Its seeds do not contain anti-nutrients, so there is no need to heat it when used for food or feed needs.

Chickpea seeds contain large amounts of potassium and calcium, as well as selenium. And these elements are known to be directly related to hemopoiesis, prevent the development of many diseases, including cancer. Therefore, the use of chickpea in the diet helps to treat endocrine disorders, cardiac arrhythmias, nervous diseases, the dissolution of unwanted formations in the gallbladder and bladder, normalize blood pressure, strengthen the heart muscle, increase vascular elasticity.

The World Health Organization (WHO) recommends eating 80 grams of legumes daily and the Indian Medical Research Committee (ICMR) consuming at least 47 grams/day of these components of the diet. But today the share of these products in India is only 30–35 g/day/person, due to their high prices. The main legume in this country is chickpea, whose gross output is 40% of the total balance of legumes. Approximately the same situation has developed in countries such as Pakistan and Bangladesh. In India and the surrounding countries, chickpea are usually consumed in the form of whole seeds, peeled, halves, which are called dhal, or as a flour called besan. Mixing the besan product with wheat flour gives such by-products as roti or chapatti, which are used to make confectionery and various snacks. During the growing season, chickpea, its leaves and fully formed green beans are used as vegetables. Dhal halves (dhal, dal) are used to make mixtures with vegetables, meat and sauces, which are the main food for the population of these countries. In European and North American countries, chickpea are used as whole seeds.

Thus, legume foods are used without any processing or after shelling, in the form of flour, in most cases in a mixture with cereals. They are easy to pack, freeze, preserve. In the holy month of Ramadan for Muslims, the first evening dish is harara or cherba – a soup of chickpea, lentil and pea. Today, about 140 countries use chickpea for food.

Chickpea belong to the group of legumes, the feature of which is the ability to bind nitrogen from the air and thus form their seeds, as well as to leave a certain amount of this element in the soil, which is absorbed by subsequent crop rotations. The process of nitrogen assimilation takes place in special organs – nodules, which are formed on the roots of legumes. Nitrogen fixation is due to the activity of symbiotic bacteria that are in the soil, then bind to the root hairs, penetrate them, intensively divide and absorb molecular nitrogen. Its amount depends on the type of plants and environmental conditions. In most cases, legumes such as soybean, pea, chickpea, lentil, bean bind from 70–80 to 120–150 kg/ha of nitrogen in the active substance during the growing season. It is important to note that the nodules that form at the root are the center to which other types of beneficial microorganisms join. Due to active symbiotic nitrogen fixation, the needs of plants in nitrogen are almost completely met, good conditions for photosynthesis are created and on this basis a high seed yield is formed. Symbiotic nitrogen acts much better on plants than mineral, because it goes mainly to the formation of seeds, and most of the latter enters the vegetative organs, which often leads to excessive growth of aboveground mass. Estimates show that in modern conditions with intensive farming about 25% of the costs are nitrogen fertilizers. Therefore, the use of legumes in crop rotation with effective biological nitrogen fixation makes it possible to significantly save money and energy.

Experts from the US Department of Agriculture believe that the problems of nitrogen fixation by plants, photosynthesis, genetic engineering are the highest priority in modern conditions.

Given the positive effect of chickpea plants on the soil, it is a fairly good as previous crop for a number of crops in plant rotation. Studies in Australia have shown that the placement of wheat in crop rotation after legumes allows you to get an additional 1000–1200 kg/ha of grain (Angus J. F. et al., 2015). Approximately the same results were obtained in Ukraine.

Analysis of literature sources, problem statement. Chickpea (Cicer arietinum L.) belongs to the tribe Cicereae, family Fabaceae, subfamily Papilianaceae. Both chickpea cultivars and the main wild species have 8 pairs of chromosomes in their cells (2n=16). As we noted earlier, the crops are constantly expanding, it is introduced into production by a number of countries, including Ukraine. But the yield of chickpea is still low. One of the reasons for this condition is that, as a rule, it is cultivated in regions with rather unfavorable weather conditions, where other crops are not able to give economically grounded yield. Another factor that significantly affects the level of yield is the presence of well-adapted to specific conditions varieties. Despite the rather intensive activities of such world-famous research centers as the International Research Institute of the Semi-Dry Tropics (ICRISAT, India, Patancheru) and the International Center for Agricultural Research in Dry Areas (ICARDA, Syria, Aleppo) in the field of genetics and chickpea breeding still needs a solution. First of all, this applies to resistance to diseases and pests, as well as to the creation of drought-resistant varieties (Gaur P. M. et al., 2012). One of the reasons for this condition is the relatively narrow genetic variability of economically valuable traits of crop (Lin R. et al., 2008; Saced A. et al., 2011). This feature is due to the formation of a number of "bottlenecks" in the process of domestication of chickpea, namely the limited area of distribution of the wild ancestor C. reticulatum, which is currently found only in the southern part of Turkey. Another factor is its monophyletic origin, which has led to a great loss of genetic variability, which in the foreign scientific literature is referred to as the "sinking effect (foundereffect)" (Abbo S. et al., 2003). In most crops that evolved in parallel with chickpea, such as wheat, this property was much lower due to recurrent hybridization with related species. There was also a significant decrease in variability due to the transition from autumn to spring sowing at the beginning of the Bronze Age, which was associated with severe damage to the causative agent of Ascochita. Finally, the fourth factor that is common to all crops is the replacement of local breeds with newly created varieties, which are usually linear.

Given the intense climate change that we have seen in recent decades, the main task of breeding is to create resistant to biotic and abiotic factors of chickpea varieties. And among abiotic factors, the most important is resistance to elevated temperatures and insufficient moisture in the soil. These indicators are the main barrier to high yields in most countries (Magbool M. A. et al., 2017; Darai R. et al., 2016; Choudhary A. K. et al, 2018; Kaloki P. et al., 2019).

The effectiveness of breeding work largely depends on the correct selection of parental components of crosses, the volume of hybrid populations of early generations, the availability of experience in the selection of elite plants. The generalization of the results of breeding in different countries and for a large set of crops shows that the use for hybridization of genotypes originating from different zones provides an increased likelihood of obtaining a valuable breeding material. In this case, the greatest success can be achieved if the hybridization involves the original forms from the centers of origin of certain crops.

Isolation of reliable sources and donors of economically valuable traits contributes to the expansion of genetic diversity of chickpeas and increase the efficiency of its breeding. By crossing geographically distant forms in hybrid populations successful combinations of economically valuable traits are obtained, new transgressive forms are distinguished, ecological plasticity and resistance to biotic and abiotic environmental factors are expanded. In the process of further selection, unwanted symptoms are eliminated. Quite often, in such crosses, the so-called zones of chromosomes are involved in recombination, which are "silent", multiple exchanges and the nature of their distribution on separate sections of chromosomes are intensified.

In order to preserve and maintain large sets of genotypes in the world, collection centers have been established, the purpose of which is to constantly replenish new forms and study and generalize economically valuable traits, acquaint breeders with them by publishing catalogs and publications, supplying seeds according to applications.

Chickpea are known to have more than 80,000 specimens of local races, bred varieties and wild forms, which are stored in more than 30 genetic banks. The largest collections of chickpea genotypes are maintained and studied at the International Research Institute of the Semi-Dry Tropics (India, Patancheru, ICRISAT) and at the International Center for Agricultural Research in Dry Areas (Syria, Aleppo). Unfortunately, due to internal reasons, this research facility has been relocated to Lebanon since 2012. ICRISAT was established in 1972 with headquarters in India (Patancheru). Today, it includes regional centers in Mali (Bamako) and Kenya (Nairobi), as well as research stations in Niger (Niamey), Nigeria (Kano), Malawi (Lilongwe), Ethiopia (Addis Ababa), Zimbabwe (Bulawayo). It is funded by the Ford Rockefeller Foundation, its charter is signed by FAO, the institute is part of the UN Development Program. ICRISAT works closely with the International Agricultural Research Advisory Group (CGTAR), which coordinates research on food security, human health, and land use. It should be noted that the area of semi-arid tropics is characterized by very changeable weather conditions, insufficient rainfall, very poor soils. The main crops with which this institution works are chickpea, cowpea, peanut, various types of millet, sorghum. Its basic genetic bank is 119,700 samples collected from 144 countries. The collection of chickpea has more than 20 thousand samples of cultural and 308 forms of 18 wild species (Ahmad F. et al., 2005; Singh M. et al., 2016; Archak S. et al., 2016). The varieties of chickpea created in this institute are well adapted to the conditions of India, for their cultivation they get a good net profit. The strategic plan outlines the solution of four main tasks: development of a flexible system of management under changing and arid conditions; introduction of market-oriented agricultural production; intensive development of legumes production, which will significantly improve the health and adaptive properties of people; increasing the yield of grain crops in dry conditions in order to avoid hunger (ICRISAT, 2010). It should be borne in mind that the territory of the semi-arid tropics is 6.5 million square kilometers, it includes 55 countries with a population of over 2 billion people. As a result, 280 million people live on one dollar a day, and more than 700 million on two dollars.

Due to the lack of quality food, especially with a high content of protein and essential amino acids, the strategic plan is to introduce new varieties of legumes, the main feature of which is resistance to abiotic and biotic factors. In addition, they must be characterized by an increased level of nitrogen binding to the air, their seeds must have good culinary characteristics. Modern genetic-molecular methods and modern modeling are now intensively used for their creation. Important attention is paid to the development of seed production of this group of crops.

The Genetic Bank of Syria includes more than 12,000 genotypes of C. arietinum and 260 samples of 8 wild species. By 2005, these two research institutions had sent more than 135,000 seed samples to various countries around the world. It should also be noted that they carry out a lot of scientific work on genetics and chickpea breeding. ICARDA provides support to research institutions and individual farms in Jordan, Morocco, Ethiopia, Egypt, Tunisia, Turkey, Afghanistan, India, Iran, Oman, Pakistan, Sudan, Uzbekistan, the UAE and Yemen. This scientific institution was organized in 1977 with its center in Aleppo. Its main purpose is to conduct research for the agricultural sector in the Middle East and North Africa, where there are extremely arid conditions. Emphasis is placed on the creation and implementation of drought-resistant varieties, efficient use of water resources, diversification of production systems, integrated farming. One of the main tasks is to expand and preserve bioresources, as well as increase the efficiency of their use in breeding work. Scientific work is carried out with such crops as durum and soft wheat, barley, chickpea, lentil, field bean and a number of other crops. After decentralization in 2012, in addition to Lebanon (Beirut), 4 research centers with more specific tasks were established. In Egypt, the emphasis is on the efficient use of irrigated systems, especially in wheat fields. For Turkey, Central Asia and Iran, systems are being developed for growing winter wheat and winter barley in the highlands, where severe winters occur. A third program has also been established in Turkey (Izmir) to study wheat rust. Sudan is conducting research on the heat resistance of wheat and the production of food from legumes.

In addition to these institutions, there are a large number of genetic banks in the world, where chickpea are grown in large quantities. Among them it is necessary to note Australia, where the gene pool of chickpea is 8414 samples, among which 241 forms belong to wild species (Singh M. et al., 2016). It should be noted that in India, in addition to ICRISAT, there is another research institution that deals with genetics and chickpea breeding, the National Bureau of Plant Genetic Resources (NBPGR, New Delhi). It also maintains a large collection of culture, numbering 14,651 accessions, which includes 241 forms of wild species. Scientists of this institution evaluated the gene pool of chickpea in the amount of 14,651 samples, on the basis of which a working collection (coreset) was selected for its use for breeding purposes (Archak S. et al., 2016). As a result of intensive scientific work, sources of specific economic characteristics were identified here, including those resistant to soil salinity IC 296691 (№ 98008); resistant to Ascochita IC 296738 (№ 13008), GL 84100 and IGL 87045; tall with a compact bush IS 296887 (№ 02003); erectile low-growing type IC 296886 (№ 96088); fast-growing, with rapid flowering and maturation form IS 296430 (№ 03031); fasciated with a thick stem IC 395465 (№ 03061) and others. A significant number of collection forms are studied in Iran (5700), Pakistan (2122), Russia (2091), Turkey (2054) and the USA (6561). It should be noted that our domestic collection, which is stored in the National Center for Genetic Resources of Plants of Ukraine (Kharkov), is well described and intensively used in breeding work. It has 820 accessions from 54 countries (Kobyzeva L. N., 2011). Wild species of chickpea are an important source of economically valuable traits, especially in relation to resistance to abiotic and biotic factors (Bains N. S. et al., 2012). Evaluation of 88 wild genotypes in northwestern India revealed a wide range of variability in such important morphological features as plant pigmentation, leaf shape and size, pubescence density, seed shape and size (Singh M. et al., 2014). Of particular value are wild species of C. echinospermum, C. reticulatum, C. bijugum, C. pinnatifidum and C. judaicum, which are characterized by a significant level of resistance to cold stress (Singh K. B. et al., 1990, 1993; Toker C., 2005; Berger J. D. et al., 2005) and C. anatolicum, C. reticulatum, C. microphyllum, C. oxydon, C. montbrettii, C. pinnatifidium, C. songaticum and C. echinospermum, which are drought-resistant (Toker C. et al., 2007; Canci H. et al., 2009; Chandora R. et al., 2020). Berger and colleagues (Berger J. et al., 2002) believe that wild forms of chickpea in genetic banks represent only a small fraction of the wider variability that exists in the general population of wild species. Although in recent years, genetic and molecular studies of the variability of basic morphological, physiological and biochemical traits, genetic structure and adhesion groups have begun (Saxena M. S. et al., 2014; Das S. et al., 2015). Based on crosses of cultivated chickpea C. arietinum with its wild species, genetic maps with clear identification of genes encoding valuable economic traits were constructed with the help of markers. The use of wild-type genes in breeding will significantly expand the range of variability of chickpea, attract new alleles to hybridization, through which it is possible to overcome some barriers, especially those related to resistance to pathogens. Thus, wild species and local races are a significant reserve of a fundamentally new source material. Using collection samples, including from remote crosses, ICRISAT has created more than 50 varieties of chickpea, which are recommended for cultivation in India, Australia, Bangladesh, Algeria, Ethiopia, Italy, Myanmar, Nepal, Oman, Syria, Sudan, Turkey, USA and Cyprus (Singh M. et al., 2016). The most common varieties are Chaffa, Dohad yellow, BDN 9-3, Annegeri-1, JG 74, Pragati and BG 287. In addition, of the 126 varieties of chickpea that was bred in India, the most common parental forms were PB 7, IP 58, F 8, S 26 and Raba (Upadhyaya H. D. et al., 2018). Variety RV 7 is included, as the parent form, in the pedigree of 41% of varieties. Despite the large amount of research on chickpea in India, the increase in its yield was very slow, and in lentil and local legumes, it did not change at all (Kumar S. et al., 2004). These results indicate the need to expand the genetic base of this group of crops.

In order to solve this problem, it is widely practiced to cross an adapted genotype with a accessions that carries a valuable gene. If necessary, re-saturate with this sample, i e backcross. Thus create a breeding material, which is distinguished by a broad hereditary basis, the so-called pre-breeding. In further breeding work, recombinant self-pollinating lines are formed from it, which serve as valuable parental forms in the process of further hybridization. As we noted earlier, another method of extending genetic variability is interspecific hybridization. Wild ancestors have undergone a long period of evolution during fairly changing environmental conditions and today grow, as a rule, on uncultivated and poor soils (Yadav S. S. et al., 2019; Maxted N. et al., 2015). For example, in Australia with mild winters, winter chickpea crops are often exposed to low temperatures during the flowering period, resulting in delayed bean formation for more than a month. Studies show that among cultigens, no forms resistant to this factor have been found, while among wild species they exist (Berger J. D., 2007; Berger J. D. et al., 2012). In this country, the species C. echinospermum is intensively used in the selection of chickpea as a source of resistance to root rot pathogens. Based on introgressions, a number of lines resistant to this pathogen have already been derived (Knights E. J. et al., 2008). A number of authors note that the recently collected wild species is characterized by a high level of resistance to biotic factors, such as Ascochita, Phytophthora, root rot nematode (Reen R. A. et al., 2019). They have significant variability in terms of flowering, which can be used in breeding programs (Kozlov K. et al., 2019).

Recently, breeders are paying more and more attention to collecting and maintaining the global gene pool of cultivated plants in order to find genetic donors of traits, especially those that were lost in the early stages of species cultivation. This problem can be solved with the help of wild relatives introduced into the culture of agricultural plants. With purposeful introgression of foreign genetic material, the possibilities of the selection process will increase significantly. The creation of new combinations of genes and the formation of their co-adapted blocks will increase variability, especially quantitative traits, which is extremely important for more efficient breeding work.

There are about 1,800 plant genetic banks in the world, which support more than 2 million genotypes. The largest of them belongs to the United States, where more than 500,000 samples are stored. Then comes China with 400 thousand, India (370 thousand), Russia (330 thousand), Japan (240 thousand). In the Ukrainian Bank the number of accessions exceeds 140 thousand (Engejs J. M. M. et al., 2012; Weise S. et al., 2016). Genotypic diversity of crops is usually preserved in their natural community (in situ) or maintained outside their natural habitat (ex situ). Vavilov’s theory of centers of origin of cultivated plants, his law of homologous series of hereditary variability, as well as fundamental works on geographical patterns of gene distribution have gained international recognition and formed the scientific basis for the collection, mobilization, storage and use of global plant bioresources. The most extensive collections contain the powerful potential of valuable genes to create varieties and hybrids of crops on a broad genetic basis, which allows synthetic breeding to create varieties with high productivity and quality, resistance to pathogens, pests and abiotic stressors. Today, about 75% of the world's diversity of cultivated plants on our planet is lost and in the future the world community must do everything possible both to preserve ex situ existing collections and to replenish them with new samples. On our planet, about 1,800 genetic banks are stored and maintained in the gene pool of cultivated and wild plants, of which 625 are located in Europe, the total volume of collection forms of which reaches 2 million genotypes (Engejs J. M. M. et al., 2012; Weise S. et al., 2016). The European Plant Genetic Resources Information Catalog (EURISCO) was established in 2001–2013 under the European Plant Genetic Resources Information Infrastructure (EPGRIS) program, funded by the European Union. The latter is coordinated by the Center for Genetic Resources (CGN) in the Netherlands. The Czech Republic, France, Germany, Portugal, the International Institute of Plant Genetic Resources (IPGRI) and the Nordic Gene Bank (NGB) participate in the above-mentioned Center. Since 2014, the responsibility for the European catalog EURISCO has been accepted by the Leibniz Institute of Plant Genetics and Crop Plant Research (Gattersleben, Germany). Individual collections are maintained ex situ in different countries, the data obtained are sent to EURISCO, standardized and summarized. In order to make effective use of the existing gene pool, there is an on-line catalog, which is adjusted by ECPGR – (http://eurisco.ecpgr.org/). As of 2007, the gene pool of wild species numbered 58,193 samples, which were stored in 24 European countries.

To focus on genetic resources for food and agricultural use, in 2003 the ECPGR created A European Genebank Integrated System for Plant Genetic Resources for Food and Agriculture (AEGIS), a pan-European integrated system of plant genetic resources that includes more than 500 European plant collections. The main goal of this organization is to preserve and maintain genetically unique for Europe accessions and make them available to breeders and scientists. Such plant material is reliably stored under conditions that make it possible to prevent their genetic erosion for a long period. Thus, AEGIS maintains genetic plasma, mainly ex situ, in the field of delivery of new samples, their storage, quality assessment, regeneration, description and characteristics, documentation and supply in accordance with the requests of interested scientists and scientific institutions. An international research program has recently been developed to make intensive use of the genetic variability of wild species. In accordance with it, introgressive lines of chickpea F4 – F6 have already been created, derived with the participation of C. reticulatum, C. echinospermum (Shin M. G. et al., 2019; Wettberg E. J. B. et al., 2018; Rani A. et al., 2020). In Turkey, Iran, Afghanistan, the Indian subcontinent, there are a large number of local races that have a number of economically valuable traits that need to be involved in breeding work (Farahani S. et al., 2019). Thus, the maximum level of antioxidant activity was found in local samples from different geographical areas: Azerbaijan, Ukraine, Georgia (Vus N. O., 2018). Deeper changes in yield levels can be achieved by using complex crosses by obtaining so-called MAGIC – hybrid combinations (multi-parent advance degeneration inter-cross). This method of obtaining the source material is important for the construction of genetic maps. On the other hand, inbred lines derived in this way are of great value for breeding because they have a broad genetic basis. For the correct selection of samples for such crosses it is necessary to know well the world's genetic resources and features of inheritance of economically valuable traits. In recent years, methods of genetic markers have been used in parallel with morphological indicators to study the genetic polymorphism of traits of cultivated and wild chickpea (Farahani S. et al., 2019; Gaur P. M. et al., 2014). The results of sequencing the genomes of cultivated and wild chickpeas and lentil revealed that the type of kabul i originates from desi and is relatively young and is characterized by narrow variability (Bajaj D. et al., 2015; Varshney R. K. et al., 2019; Parween S. et al.,2015; Gupta D. S. et al., 2016).

The purpose and objectives of the study. The purpose of the study is to summarize the results of testing a large volume of collection samples of chickpea in the steppes of Ukraine and to identify genotypes with a valuable set of agronomic traits. The donor properties of a number of domestic and introduced forms that were involved in the hybridization program were also analyzed.

MATERIALS AND METHODS

The research was performed during 1995–2020 in the research fields of the Plant Breeding and Genetics Institute – National Center of Seed and Cultivar investigation and the Odessa State Agricultural Research Station of NAAS of Ukraine. The soils of the zone are medium humus chernozems, the thickness of the humus layer reaches 40–50 cm, the reaction is neutral or slightly alkaline (pH 6.0–7.2). The average air temperature is + 9.6°C, the amount of precipitation during the growing season of chickpea – 130-150 mm. The temperature regime is favorable for growing the crop, but arid conditions during the growing season, as a rule, inhibit plant growth and reduce their productivity. Therefore, the main factor that limits the yield of chickpea is insufficient rainfall. The hydrothermal coefficient is often reduced to 0.4–0.5.

The source material was collection samples, which were systematically obtained from the National Center for Plant Genetics Resources of Ukraine (Kharkiv) and directly from the International Research Institute of the Semi-Dry Tropics (ICRISAT, Patancheru, India). According to our applications, during 1997-2000, 1,500 accessions from different countries of the world were attracted from this scientific institution. In the following years, we constantly supplemented our collection with new batches. Thus, in 2007 we obtained 200 resistants against Ascochyta blight, Colletotrichum blight, Botrytis gray forms and 198 genotypes that combine a set of economically valuable traits with seed size. In recent years, our gene pool has been replenished with samples that, according to the latest data from Indian scientists obtained by genetic markers, carry QTL loci that determine the level of drought resistance and are resistant to the imidazolinone group of herbicides.

The predecessor in the experiments was winter wheat or spring barley. Soil preparation technology is generally accepted. Accessions were sown according to the type of breeding nursery in two-meter rows with a row spacing of 45 cm. The standard variety was placed every 20 rows. During the growing season, the main phenological dates were recorded, the necessary measurements and the overall score were performed. The basic elements of productivity and other economically valuable traits were determined in the best samples in the laboratory. The coefficients of variation (V, %) and correlation (r) were calculated on the basis of the obtained data. The description of morphological, qualitative and biological features was carried out in accordance with the methodological recommendations of the Institute of Plant Production n. a. V. Ya. Yuriev (Kyrychenko V. V. et al., 2009; Kobyzeva L. N. et al., 2016). The protein content in the seeds was determined by Kjeldahl, fat – by the method of Rushkovsky. Seed hardness analysis after blanching was performed on a type 2 finometer (Hungary), which is used to assess this indicator in young green pea seeds.

Resistance to fusarium wilt was determined on the established infectious background in the laboratory. Liquid glucose-malt medium was used for culturing of the pathogen (Babayants O. V. et al., 2014; Gontarenko O. V., 1993). The level of resistance was determined on the basis of germination energy, germination and growth intensity of seedlings. Inoculation of chickpea seeds was performed in rolls according to the method of Novikova NE and co-authors (Novikova N. E. et al., 1995). In the field, inoculated seeds were sown in 4 replications, phenological observations were performed during the growing season, and after harvesting, the influence of the infectious background on economically valuable traits was determined (Sichkar V. I. et al., 2018).

RESULTS

Discussion of results

At the initial stage of studying the gene pool of chickpea, considerable attention was paid to the duration of the growing season and its individual phases. Among the studied set of samples, the smallest group consisted of very early maturing forms, the vegetation duration of which was less than 75 days. The most numerous were genotypes with a vegetation period of 81–100 days. But in each group of maturity observed significant variability in the duration of the phases "seedlings – flowering" and "flowering – maturation". Despite this, the largest number of early flowering forms (phase "seedlings – flowering" 30–39 days) took place in a very early and early groups. Among the genotypes with a medium duration of vegetation, early-flowering forms were very rare, and in the late they were completely absent. According to the duration of the period "flowering – maturing", we artificially divided the whole set of varieties into fast-maturing (30–40 days) and slow-maturing (more than 40 days) (Table 1).

Table 1. Distribution of chickpea accessions by phases of development

Maturity group	Number of studied samples	The number of genotypes, %			
		early flowering	late flowering	fast-maturing	slowly maturing
Very early	4	75,0	25,0	50,0	50,0
Early	178	70,8	29,2	51,1	48,9
Average	334	18,0	82,0	46,7	53,3
Late	33	0	100	27,3	72,7

As can be seen from Table 1, the first three groups differed little in the number of fast-maturing and slow-maturing forms. It should be noted that the duration of both these phases was significantly affected by weather conditions (Table 2).

Table 2. The duration of the main phases of development of the best productivity forms of chickpea, days

Variety, collectible sample	Origin	1997		1998	
		Seedlings-flowering	Flowering-maturing	Seedlings-flowering	Flowering-maturing
Krasnokutsky 123, St.	Russia	45	86	36	84
Krasnogradsky 213, St.	Ukraine	45	101	34	85
Dniprovsky 1	-//-	43	92	36	87
Rosanna	-//-	45	95	33	87
Alexandrite	-//-	44	93	36	90
Donia	Hungary	47	99	34	90
Krasnokutsky 195	Russia	50	98	39	85
no title	Mexico	30	80	24	72
Pryvoznyy	Ukraine	45	93	34	86
Flip 85-13c	Syria	44	96	36	89
ILC-6215	-//-	46	100	37	91
LR 56	-//-	37	87	31	82
NEC-2616	Afghanistan	48	95	40	91
NEC-2630	-//-	28	97	24	92
NEC-2638	-//-	42	98	31	92

NEC-2622	-//-	39	88	30	80
NEC-2587	-//-	39	93	31	86
L-532	India	44	88	38	82
NEC-2149	Iran	38	89	31	81
NEC-2152	-//-	38	90	30	86
NEC-2173	-//-	38	84	30	80
NEC-2220	-//-	42	89	39	83
NEC-2228	-//-	42	88	34	86
NEC-2234	-//-	40	86	35	83

Our observations did not show a clear relationship between productivity and the duration of individual phases, although the most productive forms are distinguished by a prolonged period of "flowering – maturing". Short vegetation period is characterized by such forms as the sample from Mexico, NEC-2149 (Iran), NEC-2630 and NEC-2587 (Afghanistan), the average duration of the vegetation period of which is 80-96 days for 94–98 days in the standard. Significant variability in the duration of the growing season and both phases was also found by NI Germantseva in the central zone of the Saratov region (Germantzeva N. I., 2001). She noted that this trait varies especially depending on the amount of precipitation. A number of genotypes from a number of countries of the world were distinguished by the highest productivity at the initial stage of breeding work with chickpea (1995–2001) (Table 3).

Table 3. Average productivity of the best collection forms of chickpea by years, g of seeds/plant

Variety, accessions	Origin	1996	1997	1998
		$\bar{X}$±S$\bar{x}$	$\bar{X}$±S$\bar{x}$	$\bar{X}$±S$\bar{x}$
Krasnokutsky 123, St.	Russia	12,0±2,3	13,3±0,7	12,3±0,8
Krasnogradsky 213, St.	Ukraine	8,6±2,1	---	9,3±0,9
Dniprovsky 1	-//-	15,0±1,3	13,0±1,7	14,3±2,3
Rosanna	-//-	14,6±2,3	14,2±1,9	15,4±2,4
Alexandrite	-//-	14,2±2,1	14,4±0,9	14,6±0,9
Donia	Hungary	17,6±2,0	13,0±1,9	16,2±2,1
Krasnokutsky 195	Russia	16,0±3,1	15,2±1,3	15,1±3,1
no title	Mexico	19,4±2,1	10,2±2,1	16,7±1,2
Pryvoznyy	Ukraine	17,6±1,8	18,6±1,2	16,2±2,1
LR 56	-//-		9,7±0,9	8,9±1,9
NEC-2616	Afghanistan		10,0±0,9	9,8±1,9
NEC-2630	-//-		12,7±1,2	12,6±2,0
NEC-2638	-//-		16,7±1,4	15,2±2,1
NEC-2622	-//-		11,7±2,1	12,3±3,2
NEC-2587	-//-		11,2±1,7	10,0±0,7
L-532	India		11,4±0,9	14,2±1,9
NEC-2149	Iran		12,0±1,2	11,4±2,1
NEC-2152	-//-		10,5±1,3	10,0±2,0
NEC-2173	-//-		10,1±1,3	9,4±1,7
NEC-2220	-//-		10,5±2,4	9,8±1,4
NEC-2228	-//-		13,6±2,3	13,0±2,1
NEC-2234	-//-		18,6±1,2	16,2±2,1

These genotypes have optimized the main elements of productivity, they are well adapted to the arid conditions of the southern part of Ukraine. As can be seen from Table 3, each plant, as a rule, formed more than 10 g of seeds, which provides a yield of 3 t/ha. In addition, identified sources of individual economically valuable traits that are valuable for synthetic breeding work. Increased number of beans on the plant was observed in genotypes Donia (45,6), Dnieper 1 (39,2), Rosanna (38,4), Krasnokutsky 195 (45,6), Mexico (40,1), Pryvoznyy (40,6), NEC-2616

(37,1), NEC-2630 (39,7), NEC-2622 (39,1), NEC-2152 (40,1). Alexandrite (1,5), Flip 85–13c (1,5) and LR (1,5) were the best in terms of the number of seeds in bean. During this period, 4 forms were found from the collection material obtained from India, in which two beans were formed in a node. Artificial removal of one of them led to a decrease in plant productivity by 15–20%, which indicates a positive effect of this trait on yield. All these forms – RSWS, YG-60, SEL-544 and F 404 – belong to the group of desi, ie have small brown seeds. Studies have shown that this trait is recessive and is controlled by one pair of genes (Bushulyan O. V. et al., 2003). Based on the identified genotypes, we have already obtained recombinant lines by hybridization with varieties adapted to the conditions of the Steppe, in which a significant number of nodes with double beans are formed.

A detailed study of the economically valuable features of the basic collection of chickpeas Vus NO allowed to identify the two most valuable samples of a set of useful traits (Vus N. O., 2018). This is a variety of Odessa breeding Rosanna and collection form UD0500196 from Azerbaijan. They belong to the type of Kabuli and combine 7 important characteristics. Rosanna variety is distinguished by resistance to drought and is weakly affected by the causative agent of Ascochyta, increased plant productivity and seed size, protein content, good digestibility of seeds, a positive reaction to nodulation. The local form from Azerbaijan is characterized by resistance to drought and the causative agent of Ascochyta, plant productivity and seed size, good digestibility of seeds.

The modern market of chickpea seeds needs large seeds the kabuli type. The price for large chickpeas (weight of 1000 seeds more than 400 g) is twice higher in comparison with average weight (240–270 g). As sources of large seeds in the initial stages of breeding, we recommended samples from Mexico, the local form Pryvoznyy, NEC-2638 from Afghanistan, the weight of 1000 seeds of which reaches 420–450 g.

In 2003, we examined the seed size of 99 specially selected ICRISATs at our request for collection samples. Under our conditions, we obtained a significant differentiation by seed size, which allowed us to select samples with extremely large seeds (Table 4). The weight of 1000 seeds of some of them reached 600 g and more. This is almost twice the standard Rosanna variety.

Table 4. Characteristics of large-seeded chickpea genotypes, 2003

Sample name	ICRISAT sample number	Trait		
		Weight of 1000 seeds, g	Plant height, cm	Duration of vegetation, days
Rosanna, St.	---	310	45	96
NEC 102	ICC 6233	576	40	88
NEC 50	ICC 6183	550	30,2	96
NEC 101	ICC 6232	570	45	92
NEC 60	ICC 6192	561	35,4	90
NEC 48	ICC 6181	570	35,1	91
P 9623	ICC 4854	630	22,8	88
INIA 103	ICC 11815	600	30,3	600
INIA 110	ICC 11821	600	40	600
INIA 20	ICC 11742	630	30,6	93
INIA 24	ICC 11745	630	40	104
№ 1-1	ICC 11291	558	34,8	88
№ 3	ICC 11294	588	50	88
№ 6	ICC11296	563	50,2	91
NEC 56	ICC 7713	550	40,4	99
Culiacancito (860)	ICC 7346	600	30,1	96
PI 110408	ICC 14926	619	39,7	93
PI 111935	ICC 14929	583	35,1	95
Rar	ICC 14193	620	30,2	96
650 A PerdoSevillano	ICC 14207	630	35	95
698-49	ICC 14209	560	29,8	92
BG 1-046	ICC 13778	640	30	102
BG 1-392	ICC 13787	600	34,8	98

Among the samples with extra-large seeds described in Table 4, such a feature was noted in ICC 13787 and ICC 14926 also by Indian and Syrian scientists (Upadhyaya H. D. et al., 2006), and in ICC 11742 – in India (Gaur P. M. et al., 2006). In this regard, our further research was aimed at identifying large-seeded forms among the world's collection material with a set of other positive features. In the period 2013–2015, 349 samples obtained from the Plant Production Institute and ICRISAT were studied on this basis. The most valuable in terms of productivity and seed size forms are shown in table 5.

Table 5. Productivity and seed size of chickpea collection samples

Sample	Origin	Productivity, g / m^2			Weight of 1000 seeds, g		
		2013	2014	2015	2013	2014	2015
		$\bar{X}\pm S_{\bar{x}}$	$\bar{X}\pm S_{\bar{x}}$	$\bar{X}\pm S_{\bar{x}}$	$\bar{X}\pm S_{\bar{x}}$	$\bar{X}\pm S_{\bar{x}}$	$\bar{X}\pm S_{\bar{x}}$
Budjak, St	Ukraine	88,7±5,8	160,8±3,4	253,2±7,4	387,0±4,8	378,5±6,3	388,5±3,1
P 2 774HR (ICRISAT)	India	186,9±6,8	113,0±4,6	202,8±3,9	434,5±6,1	428,0±5,5	464,0±7,4
QW-5/7	-//-	78,8±1,9	140,6±2,3	191,0±2,1	360,5±11,2	387,0±14,2	430,0±10,1
Efal Bold YN 34009	-//-	121,0±4,9	122,9±5,3	230,0±5,1	440,0±6,0	402,0±15,8	464,0±10,7
NEC 1051	Iran	59,4±0,9	115,5±2,1	259,3±8,7	400,5±9,5	429,5±5,7	465,5±5,6
P-2080	-//-	101,8±4,1	81,2±3,6	143,0±3,6	361,5±6,1	329,0±4,3	364,0±5,5
P 9623	USA	102,0±3,8	78,8±2,8	111,9±4,7	343,5±6,9	383,0±10,8	471,5±5,2
P 9624	-//-	148,5±4,9	136,1±5,5	286,7±10,8	433,5±5,9	412,0±9,8	463,0±4,3
NEC 2559	Afghanistan	152,2±5,0	139,6±3,2	134,6±4,1	253,5±7,8	281,5±9,7	350,5±6,9
Koloryt	Ukraine	65,2±2,3	171,4±3,8	183,6±5,0	317,0±6,7	300,5±7,2	317,0±10,3
P9809	Turkey	120,0±3,9	115,4±2,2	148,2±3,4	316,0±5,9	290,5±8,1	376,5±4,5
NEC 2434	-//-	134,8±2,1	61,5±0,6	135,3±4,3	401,5±7,4	401,5±8,9	454,0±4,8
NEC 2425	-//-	94,7±4,1	94,7±1,8	100,1±7,8	303,5±6,1	302,0±7,2	393,5±5,4
Belaya nobul-23	-//-	110,3±3,2	115,1±2,5	217,0±3,8	400,0±5,3	401,5±4,8	421,0±10,1
CV,%		25,6	31,3	28,1	18,6	19,1	20,0

In these studies, the largest seed formed a sample from India P 2774 HP, the average weight of 1000 seeds which was 442,2 g. It is important to note that this genotype analyzed trait was relatively stable over the years, although during the study the soil moisture level differed significantly. The best conditions were in 2015, despite the fact that the air temperature often exceeded 30^{o}C. Insufficient soil moisture was characterized in 2013 and 2014. In addition, this form was also distinguished by good seed productivity (167,6 g/m^2), which was equal to the standard large-seeded variety Budzhak. The Indian variety Efal Bold – YN 34009, the Iranian NEC 1051 and the American P 9624 favorably combined high productivity and weight of 1000 seeds. We believe that these samples are an important source for the breeding of the most valuable varieties of chickpea.

In 2016, a number of the above samples, as well as a number of new ones, were studied in order to identify such genotypes in which large-seededness is combined with increased productivity (Table 6).

Table 6. Large-seeded samples of chickpea with high productivity

Genotype name	Origin	Weight, g	
		Seeds from the plant	1000 seeds
Budjak, St.	Ukraine	129,4	357,9
Rosanna, St.	-//-	164,2	277
P 2774 HR (ICC 12496)	India	167,1	446
№ 42 (ICC 4976)	-//-	81,7	408,5
P 2984 P (ICC 12434)	-//-	215,2	425
P 9624 (ICC 4855)	USA	201,1	427
P 9623 (ICC 4854)	-//-	120,8	440,5
NEC 1051 (ICC 6856)	Iran	135,4	437
P 1830 (ICC 2285)	-//-	129,3	409
Samplez (ICC 12428)	Turkey	140,8	430
P 9771 (ICC 7627)	-//-	120,8	411
Belaya nobul 23 (10326)	-//-	170.5	411
NEC 2434 (ICC 9510)	-//-	89.3	407.5

P 9741 (ICC 7608)	-//-	163.2	402
Galeleo	-//-	120,3	428
NEC 26422 (ICC 5107)	Israel	162,3	409
1030-91 (ICC 14361)	Mexico	148,7	429
NEC 64 (ICC 6196)	Spain	120,8	405
NEC 115 (ICC 6242)	Tunisia	98,7	428
INIA 50 (ICC 11769)	Chile	115,8	441
493-27	Canada	129,2	424
RBH (ICC 14564)	Bangladesh	174,5	408

Forms P 2774 HR, P 9623, P 9624, NEC 1051, Belaya nobul 23 and NEC 2434 this year confirmed their large seed and good performance. In addition, we were able to further identify a number of genotypes of this type, which we are currently involved in hybridization.

According to its chemical composition, chickpea is a universal crop. Its seeds contain 18,0–30.8% protein, 5,5–7,0% fat, 33–44% starch, 2,8–3,0% ash and 3,0–12,5% fiber. Significant variability in protein content was found in the study of 187 collection forms such as desi and kabul at the International Research Institute of the Semi-Dry Tropics (ICRISAT) in India (Jadhav A. A. et al., 2015). In this study, the magnitude of protein variation was 13,25–26,77%. To determine the genetic control of this trait, the authors used 23 markers, which allowed to test all eight linkage groups of chromosomes. Using this analysis, all studied forms were divided into three subpopulations. Five QTL loci were detected, the two most important being in the LG3 and LG5. The authors claim that the genes that control the protein content of chickpea are mainly concentrated on the LG3 and LG5 chromosomes. It is important to note that by removing the seed skins (peeling) it is possible to significantly increase the protein content of the obtained raw materials (Jukanti A. et al., 2012). Our study in 1996–1999 of 555 collection genotypes by protein content was distributed as follows. In 26.6% of samples seed protein was 18,1–19,0%, in 24,8% – 19,1–20,0%, more than 20,0% of this component was observed in 48,6% of the studied forms. Analysis of protein content over a number of years has shown that this trait is more determined by genetic characteristics than environmental conditions. Samples of Flip 88–13c (23,5%), NEC 25,69 (23,1%), RBH 93 (22,9%), RBH 286 (22,8%) and others (Table 7) stood out with the highest protein content.

Table 7. Protein content and weight of 1000 seeds in chickpea accessions
(average values for 1996–1999)

Sample name	Origin	Average value	
		Protein, %	Weight of 1000 seeds, g
Krasnogradsky 213, St.	Ukraine	19,4	310
Flip 88-35c	Syria	21,9	270
Flip 88-13c	-//-	23,5	280
LR 33-1	-//-	23.4	320
P-9815	Turkey	22,4	270
C-4	India	21,8	200
L-345	-//-	22.1	180
NEC 2157	Iran	22,0	300
NEC 2195	-//-	21.8	230
NEC 2569	Afghanistan	23,1	300
NEC 2573	-//-	23.5	270
NEC 2577	-//-	22.5	275
NEC 2597	-//-	22.3	250
NEC 2616	-//-	23.1	210
NEC 2624	-//-	22.8	320
NEC 2636	-//-	21.9	230
NEC 2637	-//-	21.9	255
RBH 93	Bangladesh	22,9	215
RBH 198	-//-	21,9	240
RBH 256	-//-	22,2	250
RBH 286	-//-	22,8	220
P-3887	Greece	22,1	300

In the eastern zone of the Forest-Steppe of Ukraine the varieties Antey (20,1%), Dniprovsky tall (20,6%), Rosanna (20,7%) and the collection line from India ILC 3248 (20,3%) were distinguished by the level of seed protein and its stability (Vus N. O., 2018). High stability of this trait over the years was found by Krasnokutsky 28, NEC 2556, LEG-CA-14 and Flip 84–158 c. In terms of seed size (more than 400 g), only three forms were distinguished in this group of samples – the local variety Privoznyy, a sample from Mexico and the Afghan instant form NEC 2638, the weight of 1000 seeds of which was 450, 420 and 420 g, respectively. In the following period, we continued to study the protein content in new batches of chickpea samples received from ICRISAT. Among more than 300 genotypes, a number of forms with high protein levels were registered (Table 8).

Table 8. Average protein content in seeds of chickpea collection samples, %

Sample	Origin	2013	2014	2015	Average
Budjak, St.	Ukraine	17,3	21,3	17,2	18,6
Flip 85-18c	Syria	20,3	23,1	17,8	20,4
NEC 2561	Afghanistan	17,2	22,1	17,8	19,0
NEC 2633	-//-	17,8	23,4	17,7	19,6
NEC 2554	-//-	19,5	25,7	18,1	21,1
LR 75	India	19,0	21,8	16,6	19,1
Broa CH	-//-	19.9	23.4	15.9	19.7
P 386	-//-	21.3	24.1	16.6	20.7
CP 60	-//-	23.4	22.3	17.7	21.1
NEC 2434	Turkey	18,5	22,0	16,5	19,0
P 2080	Iran	18,2	26,1	16,9	20,6
Super major	Mexico	19,8	21,8	17,4	19,7
NEC 50	Spain	17,7	24,5	14,7	19,0
YM 466	Ethiopia	18,5	24,1	16,8	19,8
Average for the year		18,8	22,8	16,5	19,8

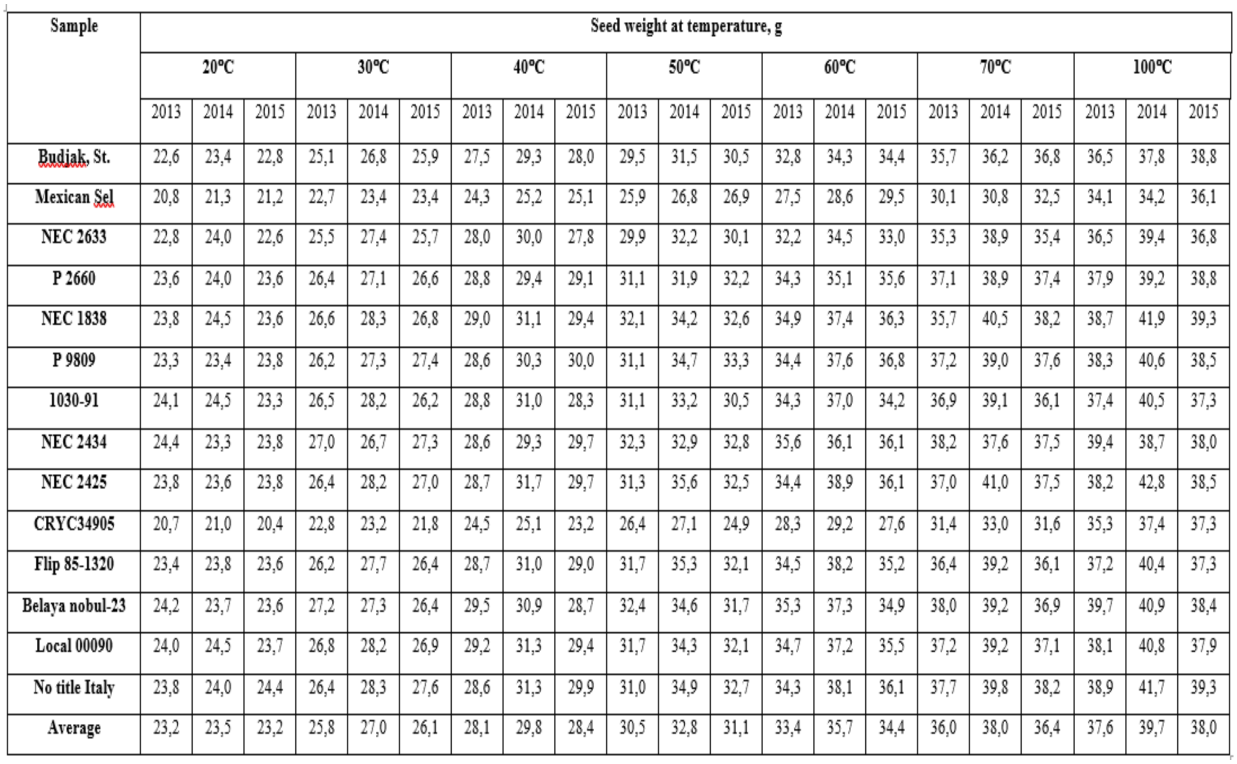
Since chickpea seeds are used mainly for food purposes, so its technological indicators play an important role. In the process of making canned products, the level of swelling and softening of seeds in the process of wet heat treatment is a significant factor. Our studies have clearly shown that when the seeds are soaked at different temperatures, the swelling process is accelerated, albeit at different rates (Table 9).

In the process of temperature growth (40–50°C) NEC 1838, NEC 2434, b/n Italy, were distinguished by increased mass of seeds, the smallest Mexican Sel and CRYC 34905. NEC 1838 NEC 2434, NEC 2425, Belaya nobul-23 and b/n Italy had the highest average weight at maximum temperature (100°C), the smallest – Mexican Sel and CRYC 34905. Analyzing the dynamics of water absorption at different temperatures, it can be concluded that a significant number of easily swellable samples are released when wetting them room temperature. Forms such as NEC 1838, P 9809, NEC 2425, Belaya nobul-23 and b/n Italy had the maximum weight during the whole process at different water temperatures, and the Mexican Sel variety had the minimum. But this trend has not always been observed. Accessions Local 00090 and 1030-91 very quickly increased the mass of seeds at a temperature of 20°C, but at elevated temperatures took an intermediate position. It was found that the highest rate of swelling in three years was observed in samples NEC 1838 (Chile) and b/n (Italy) – 199,8%, and the lowest rate was characterized by Mexican Sel (Iran, desi) – 174,7% (Table 9).

In 2013, such samples as Belaya nobul-23 swelled the fastest – 198,5%, NEC 2434 (Turkey) – 197,0% for 182,5% in the Budjak standard. Slowly absorbed water Mexican Sel (Iran, desi) – 170,5%. In 2014, the maximum growth of this indicator was observed in NEC 1838 (Chile) – 209,5%, b/n (Italy) – 208,5% compared to the standard Budjak – 189,0%. It was the lowest in Mexican Sel (Iran, desi) – 171,0%. Also in 2015, the samples NEC 1838 (Chile) – 196,5% and b/n (Italy) – 196,5% compared to the standard Budjak – 194,0%, the least Mexican Sel (Iran, desi) – 183,0%.

In general, for three years the indicator of "seed swelling" stood out such collection samples as NEC 1838, NEC 2425, Belaya nobul-23 and b/n (Italy), in which its average value varied between 198,3–199,8%. A low level of seed swelling was observed in the sample Mexican Sel (174,7%). It is important to note that this genotype was also distinguished by increased seed hardness after heat treatment (62,3), while the minimum values were in such samples as b/n Italy (44,7), NEC 2425 and Flip 85-1320 (46,0). Of the varieties of our breeding, the highest percentage of swelling at maximum temperature was found in Pamyat (40,8%) and Scarb (39,5%), and the lowest was in the variety Odysseus (38,2%). The seeds of these varieties also had the lowest hardness.

Table 9. Variability of seed mass with increasing water temperature



Sample	**Seed weight at temperature, g**																				
	20°C			**30°C**			**40°C**			**50°C**			**60°C**			**70°C**			**100°C**		
	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015
Budjak, St.	22,6	23,4	22,8	25,1	26,8	25,9	27,5	29,3	28,0	29,5	31,5	30,5	32,8	34,3	34,4	35,7	36,2	36,8	36,5	37,8	38,8
Mexican Sel	20,8	21,3	21,2	22,7	23,4	23,4	24,3	25,2	25,1	25,9	26,8	26,9	27,5	28,6	29,5	30,1	30,8	32,5	34,1	34,2	36,1
NEC 2633	22,8	24,0	22,6	25,5	27,4	25,7	28,0	30,0	27,8	29,9	32,2	30,1	32,2	34,5	33,0	35,3	38,9	35,4	36,5	39,4	36,8
P 2660	23,6	24,0	23,6	26,4	27,1	26,6	28,8	29,4	29,1	31,1	31,9	32,2	34,3	35,1	35,6	37,1	38,9	37,4	37,9	39,2	38,8
NEC 1838	23,8	24,5	23,6	26,6	28,3	26,8	29,0	31,1	29,4	32,1	34,2	32,6	34,9	37,4	36,3	35,7	40,5	38,2	38,7	41,9	39,3
P 9809	23,3	23,4	23,8	26,2	27,3	27,4	28,6	30,3	30,0	31,1	34,7	33,3	34,4	37,6	36,8	37,2	39,0	37,6	38,3	40,6	38,5
1030-91	24,1	24,5	23,3	26,5	28,2	26,2	28,8	31,0	28,3	31,1	33,2	30,5	34,3	37,0	34,2	36,9	39,1	36,1	37,4	40,5	37,3
NEC 2434	24,4	23,3	23,8	27,0	26,7	27,3	28,6	29,3	29,7	32,3	32,9	32,8	35,6	36,1	36,1	38,2	37,6	37,5	39,4	38,7	38,0
NEC 2425	23,8	23,6	23,8	26,4	28,2	27,0	28,7	31,7	29,7	31,3	35,6	32,5	34,4	38,9	36,1	37,0	41,0	37,5	38,2	42,8	38,5
CRYC34905	20,7	21,0	20,4	22,8	23,2	21,8	24,5	25,1	23,2	26,4	27,1	24,9	28,3	29,2	27,6	31,4	33,0	31,6	35,3	37,4	37,3
Flip 85-1320	23,4	23,8	23,6	26,2	27,7	26,4	28,7	31,0	29,0	31,7	35,3	32,1	34,5	38,2	35,2	36,4	39,2	36,1	37,2	40,4	37,3
Belaya nobul-23	24,2	23,7	23,6	27,2	27,3	26,4	29,5	30,9	28,7	32,4	34,6	31,7	35,3	37,3	34,9	38,0	39,2	36,9	39,7	40,9	38,4
Local 00090	24,0	24,5	23,7	26,8	28,2	26,9	29,2	31,3	29,4	31,7	34,3	32,1	34,7	37,2	35,5	37,2	39,2	37,1	38,1	40,8	37,9
No title Italy	23,8	24,0	24,4	26,4	28,3	27,6	28,6	31,3	29,9	31,0	34,9	32,7	34,3	38,1	36,1	37,7	39,8	38,2	38,9	41,7	39,3
Average	23,2	23,5	23,2	25,8	27,0	26,1	28,1	29,8	28,4	30,5	32,8	31,1	33,4	35,7	34,4	36,0	38,0	36,4	37,6	39,7	38,0

One of the "weaknesses" of existing varieties of chickpeas is susceptibility to disease, which leads to a significant reduction in yield and seed quality. With severe epiphytosis, the drop in yield can reach 100% (Halila I. et al., 2010; Soregaon C. D. et al., 2012). Fusarium wilt causes special damage to chickpea plants during seed germination and in the initial stages of growth, as well as Ascochyta at later stages of ontogenesis. Therefore, breeding without taking into account resistance to pathogens of these diseases is almost impossible. As a result of testing various varieties of chickpea on an artificial infectious background in the field, 27 varieties were found that have high resistance to fusarium wilt and have other economically valuable characteristics. The best in terms of stability were desi type forms (with dark seeds NEC 2179, NEC 2212, NEC 2135, NEC 2185, NEC 2201 (from Iran), BEG-482, NO-55, F-370, F-404, NEGRO (from India)), RBH 141, RBH 217, RBH 102 (from Bangladesh) and E 100 (from Greece). Donia (from Hungary), NEC 2183, NEC 2149 (from Iran) NEC 2596 and NEC 2607 (from Afghanistan) and the Rosanna variety were of high stability or tolerance). The NEC 2212 deserves special attention, because in addition to resistance to Fusarium wilt it distinguished by a complex of economically valuable traits. On the basis the experiments carried out by the method of complex crosses, we learned a new valuable initial breeding material which after some time will start varieties resistant to fusarium wilt (Bushulyan O. V. et al., 2012).
In recent years, Ascochyta rabici (Pas. Lab.) has become widespread and increased in our zone. The pathogen develops more intensely in cool and rainy weather. In the period 2010–2011, when such conditions were created in the south of Ukraine, we identified a number of breeding lines that were not affected by this disease. Studies show that, as a rule, increased resistance or tolerance against pathogen show genotypes such as desi. Our research has shown that crosses between desi and kabuli genotypes provide very valuable starting material, as these types carry different gene pools (Sichkar V. I., 2002). In such hybrid combinations recombination processes are intensive, there is a high probability of transgressive forms. Vus NO (Vus N. O., 2018) found two genotypes of chickpea from Russia, Stepnoy 1 and Tall 30, which are characterized by stable resistance to the causative agent of Ascochyta.

In 2019, according to our application, we received from ICRISAT 30 collection samples, which are distinguished by a high level of drought resistance. This feature in India was confirmed by marker analysis. Under our conditions, the above genotypes were distinguished by an extremely short growing season, although they formed a fairly large seed (Fig. 1). Based on the peculiarities of their growth, it can be noted that their drought resistance is due to the evasion of elevated temperatures, and plant productivity is determined by the residual amount of winter and spring precipitation. Their full flowering under our conditions takes place on May 12–15, ripening – in early July. We believe that this material is a valuable source of resistance to adverse drought conditions and it will be used extensively in hybridization in the future.

variety Pam'yat′ ICCW171302 ICCIL06004

Figure 1. General view of chickpea plants grown in arid conditions

This year, we grew 26 samples from this research center to isolate resistant to imidazolinone herbicides accessions. Research in this direction will be continued in the next period.

As a result of intensive study and use in hybridization of local and exotic collection material, we have created 12 varieties of chickpeas, which are listed in the state register of Ukraine (Table 10). Among them, half are distinguished by large seeds, and Rosanna, Alexandrite, Stepovyy velet and Yarina – tolerance against disease.

Table 10. Brief description of chickpea varieties entered in the state register

Variety	Year of entry in the register	Brief description
Rosanna	2000	Arid-resistant, resistant to Ascochyta
Alexandrit	2001	Type of desi, resistant to fusarium wilt
Pam’yat	2002	Resistance to regrowth
Antey	2003	Large-seeded, early-maturity
Triumph	2005	Large-seeded, high-protein
Pegas	2005	Type of desi, resistant to fusarium wilt
Budjak	2008	Large-seeded, arid-resistant
Krasen’	2009	High yield, excellent nutritional qualities
Odysey	2014	Very large seeds (420-430 g)
Skarb	2017	Large-seeded, arid-resistant
Yarina	2019	Large-seeded, disease tolerant
Stepovyy velet	2020	Arid-resistant, disease tolerant

Yield and other economic valuable traits are shown in table 11.

Table 11. Characteristics of chickpea varieties, average data for 2010–2014

Variety	Seed yield, kg/ha		Duration of the growing season, days	Height of attachment of the lower beans, cm	Weight of 1000 seeds, g	Protein content, %
	average	maximum				
Rosanna	1560	2830	92	22	320	27,0
Alexandrit	1780	2910	88	18	275	26,5
Pam'yat	1540	2710	91	21	315	27,1
Antey	1480	2560	88	20	390	28,3
Pegas	1590	2780	85	18	265	27,5
Triumph	1550	2790	93	21	405	28,7
Budjak	1600	2610	91	22	412	27,9
Odysey	1610	2460	91	22	415	28,5
Skarb	1650	2580	94	22	420	26,9

Analysis of the elements of seed productivity has clearly shown that each variety has a certain relationship between them, so to obtain a highly productive genotype due to only one important feature is almost impossible. Despite this statement, it should be noted that the main indicators of high productivity are the number of productive nodes on the plant, the number of seeds in the bean, the increased value of beans in the node.

In the production conditions of our country, the most common varieties are Rosanna, Triumph and Pamyat. In addition, the first two passed the state test and entered in the state register of the Russian Federation.

CONCLUSIONS

As a result of many years of study of accessions of chickpea, sources of increased seed productivity, large seeds, high protein content, tolerance against pathogens, improved technological qualities of seeds have been identified. Individual genotypes have been identified in which several economically valuable indicators have been improved. It is shown that the combination of traits of samples of different ecological and geographical origin in one genotype has a high probability of obtaining valuable recombinant forms by accumulating positive adaptive genes. A particularly wide variation of breeding material is needed to prevent disease outbreaks and the widespread of pests, the danger of which increases significantly with the homogeneity of the gene pool.

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