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THE ROLE OF CHICKPEA GENETICS IN IMPROVING YIELD RESILIENCE UNDER ABIOTIC AND BIOTIC STRESS CONDITIONS.

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Abstract. Chickpea (*Cicer arietinum* L.) is one of the world's most important grain legumes, contributing significantly to food security, soil fertility, and sustainable agricultural production. However, its productivity is severely affected by abiotic stresses such as drought, heat, and salinity, as well as biotic stresses including *Ascochyta* blight. This review aims to examine recent advances in chickpea genetics and breeding strategies for improving yield resilience under adverse environmental conditions, with particular emphasis on their relevance to Uzbekistan. The study was conducted using a comprehensive review of scientific literature published between 2014 and 2025. Recent findings indicate that conventional breeding, marker-assisted selection, genomic technologies, and CRISPR/Cas9 gene editing have substantially enhanced the development of stress-tolerant chickpea varieties. These approaches improve drought tolerance, disease resistance, and adaptation to multiple environmental stresses while supporting sustainable agricultural production. The review concludes that integrating modern genetic technologies with appropriate agronomic management can significantly improve chickpea productivity and resilience. Continued research, investment in breeding programs, and the responsible application of advanced biotechnology are essential for ensuring long-term food security and climate-resilient agriculture in Uzbekistan.

Keywords: Chickpea, *Cicer arietinum*, genetics, plant breeding, drought tolerance, disease resistance, CRISPR/Cas9, yield resilience, climate change, Uzbekistan.

Annotatsiya. No'xat (*Cicer arietinum* L.) dunyodagi eng muhim dukkakli ekinlardan biri bo'lib, oziq-ovqat xavfsizligi, tuproq unumdorligini saqlash hamda barqaror qishloq xo'jaligini rivojlantirishda muhim o'rin tutadi. Biroq uning hosildorligi qurg'oqchilik, yuqori harorat va sho'rlanish kabi abiotik omillar hamda askoxitoz kasalligi kabi biotik omillar ta'sirida sezilarli darajada kamayadi. Mazkur maqolaning maqsadi no'xatning hosildorlik barqarorligini oshirishda genetika va seleksiya sohasidagi zamonaviy yutuqlarni tahlil qilish hamda ularning O'zbekiston sharoitidagi ahamiyatini baholashdan iborat. Tadqiqot 2014–2025-yillarda chop etilgan ilmiy adabiyotlarni tizimli tahlil qilish asosida amalga oshirildi. Tahlil



natijalari shuni ko'rsatdiki, an'anaviy seleksiya, markerlarga asoslangan seleksiya, genom texnologiyalari va CRISPR/Cas9 gen tahrirlash usullari stress omillariga chidamli no'xat navlarini yaratishda muhim natijalar bermoqda. Ushbu yondashuvlar qurg'oqchilikka chidamlilikni, kasalliklarga qarshilikni va turli noqulay ekologik sharoitlarga moslashuvchanlikni oshirish orqali barqaror hosildorlikni ta'minlashga xizmat qiladi. Xulosa qilib aytganda, zamonaviy genetik texnologiyalarni samarali agrotexnik tadbirlar bilan uyg'unlashtirish no'xat yetishtirish samaradorligini sezilarli darajada oshirishi mumkin. Shuningdek, seleksiya dasturlarini rivojlantirish, ilmiy tadqiqotlarni qo'llab-quvvatlash va ilg'or biotexnologiyalarni mas'uliyat bilan joriy etish O'zbekistonda oziq-ovqat xavfsizligini mustahkamlash hamda iqlim o'zgarishiga moslashgan qishloq xo'jaligini rivojlantirish uchun muhim ahamiyat kasb etadi.

Kalit so'zlar: No'xat, Cicer arietinum, genetika, seleksiya, qurg'oqchilikka chidamlilik, kasalliklarga chidamlilik, CRISPR/Cas9, hosildorlik barqarorligi, iqlim o'zgarishi, O'zbekiston.

Аннотация. Нут (*Cicer arietinum* L.) является одной из важнейших зернобобовых культур в мире, играющей значительную роль в обеспечении продовольственной безопасности, повышении плодородия почв и развитии устойчивого сельского хозяйства. Однако его урожайность существенно снижается под воздействием абиотических факторов, таких как засуха, высокая температура и засоление почв, а также биотических факторов, включая аскохитоз. Цель настоящей статьи заключается в анализе современных достижений генетики и селекции нута, направленных на повышение устойчивости урожайности к неблагоприятным условиям окружающей среды, а также в оценке их значения для сельского хозяйства Узбекистана. Исследование выполнено на основе систематического анализа научных публикаций, опубликованных в период с 2014 по 2025 год. Результаты обзора показывают, что традиционная селекция, маркер-ассоциированная селекция, геномные технологии и редактирование генома с использованием системы CRISPR/Cas9 значительно расширили возможности создания сортов нута, устойчивых к различным стрессовым факторам. Эти подходы способствуют повышению засухоустойчивости, устойчивости к болезням и адаптации растений к неблагоприятным условиям окружающей среды, обеспечивая более стабильную урожайность. Сделан вывод о том, что интеграция современных генетических технологий с эффективными агротехническими мероприятиями способна существенно повысить продуктивность нута. Дальнейшее развитие селекционных программ, поддержка научных исследований и ответственное внедрение современных биотехнологий являются важными условиями обеспечения продовольственной безопасности и развития климатически устойчивого сельского хозяйства в Узбекистане.

Ключевые слова: нут, *Cicer arietinum*, генетика, селекция, засухоустойчивость, устойчивость к болезням, CRISPR/Cas9, устойчивость урожайности, изменение климата, Узбекистан.



INTRODUCTION

Chickpea (*Cicer arietinum* L.) is among the most significant grain legumes in the world and it is increasingly becoming valuable to dryland agricultural systems in the Central Asia including Uzbekistan. Being a source of high-protein crop, an ideal source of dietary fiber and micronutrients, chickpea has a direct role in food and nutritional security. Chickpea also becomes important in crop rotation in farming systems because it contains the capacity to fix nitrogen in the atmosphere and thus enhance soil fertility and save the application of synthetic nitrogen fertilizers (Calia et al., 2024). The growth of grain legumes, including chickpea, has been seen as a promising avenue to the production diversification, a promotion of soil health, and environmental benefits of intensive monocropping systems to Uzbekistan.

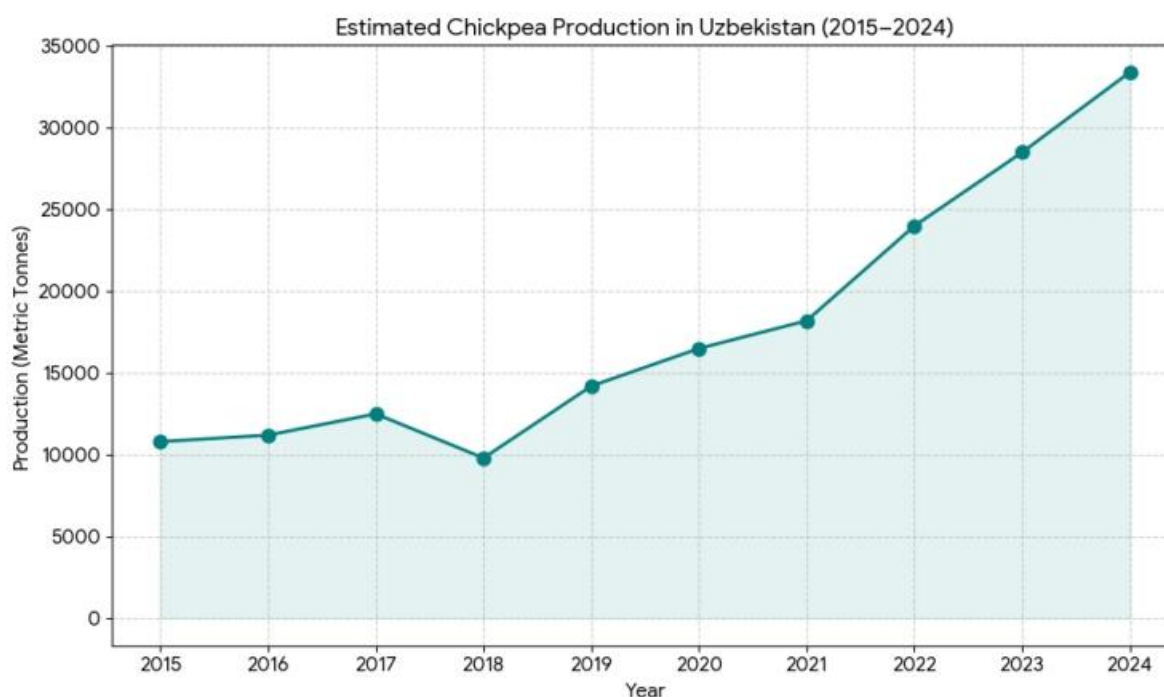


Figure 1 chickpea production in Uzbekistan

Retreated from: National Statistics Agency of Uzbekistan

Although chickpea has agronomic and nutritional advantages, several abiotic and biotic stresses limit its production. Drought is commonly known as the most pressing negative constraint, because the crop is commonly cultivated on left-over soil moisture and very little or no irrigation applied to it, subjecting it to terminal water shortage during flower formation and grain filling. Salinity in the soil and heat also lead to stability of yield in most environments and large-scale diseases like *Ascochyta* blight (*Ascochyta rabiei*) and other foliar and root pathogens may result in devastating losses in vulnerable genotypes. Such limitations are worrying especially in times of climate change that is expected to increase drought and heat spells in semi-arid areas. The objective of the report thus is to provide viable growing guidelines to chickpea depending on agro-textures of ecological situations in Uzbekistan; to address the role of the modern genetic and geneformaed technologies that have been employed in improving chickpea; and to comment on the ethical challenges and issues surrounding



the application of contemporary genetic and gene form technologies in chickpea enhancement.

LITERATURE REVIEW

Drought stress has been identified as the main production issue with chickpea that perennial reduces its production in rainfed, as well as drylands. As demonstrated by several studies, terminal drought is common when chickpea is in flowering and grain filling phase and it has made significant decreases to yield in both desi and kabuli varieties. Genetic studies have revealed that the physiological characteristics that regulate drought resilience in chickpea include a deep root system, osmotic prognosis, and high water efficiency (Varshney et al., 2014). Genotype screening studies also substantiate the fact that the genotypes vary widely in terms of tolerance to moisture stress with some genotypes performing better relative to others according to the drought selection indices (Farshadfar and Javadinia, 2011). These findings point at the necessity of implementing drought resistant genotypes in production systems.



Figure 2. Difference of desi and kabuli varieties

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In addition to drought, there are also other signs that indicate that chickpea is subjected to cross genus stresses that are caused by heat and salinity, and these still aggravate crop losses in arid zones. Multi-stress response studies reveal that certain genotypes of chickpea have the ability to manifest drought, heat, and salinity tolerance simultaneously (Pushpavalli et al., 2020). Nevertheless, the other research establishes that chickpea itself is susceptible to soil salinity and large penalties of yields have been identified even at an intermediate level of salt concentration (Flowers et al., 2010). This difference between genotypes can be used to promote the fact that varieties that are resilient and adapted to respective environmental limitations need to be selected and subsequently rolled out.

Regarding disease pressures, the findings indicate that Ascochyta blight continues to be among the most destructive biotic stresses in the production of chickpeas. Recent research states that genetic resistance is accessible but differs across lines, and that breeding has to persist to keep up with the evolution of pathogens (Sharma & Ghosh, 2016). Disease resistance breeding is demonstrating significant



advancements using both traditional and molecular methods, with overall consistency in field performance that continues to differ (Li et al., 2015; Choudhary et al., 2023). Multiple genotypes resistant to *Ascochyta rabiei* are also identified as a result of screening of different germplasm, further indicating the importance of purposeful breeding (Du et al., 2012).

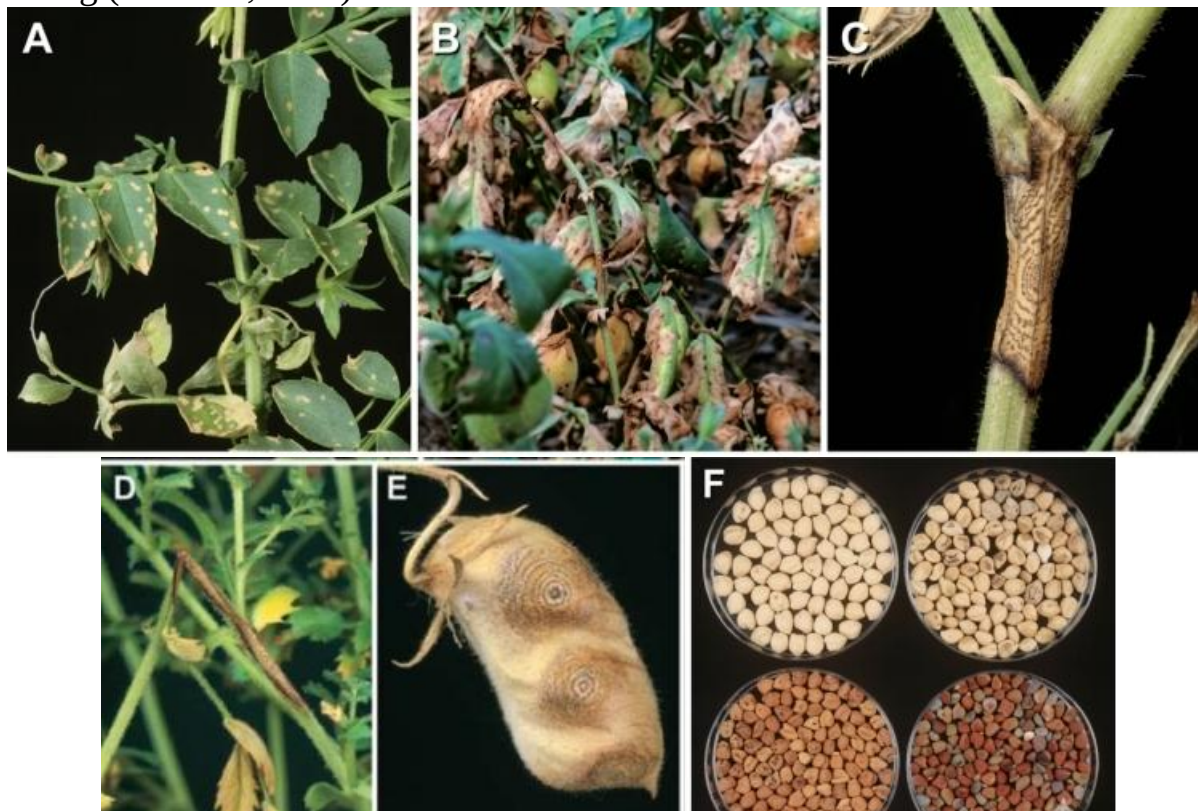


Figure 3. Fig. 1. Symptoms of ascochyta blight [*Ascochyta rabiei*] in chickpea. (A) Small lesions on foliage. (B) Severe foliar symptoms. (C) Stem lesion with pycnidia. (D) Stem breakage due to girdling. (E) Lesions with concentric rings of pycnidia on pods. (F) Healthy and infested seeds (left and right panels, respectively); kabuli and desi types (top and bottom panels, respectively).

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The collective outcomes of these studies suggest that genetic enhancement is the most promising long-lasting remedy to the augmentation of the resiliency of yield in chickpea. Responses of breeding programs have increased the genetics of chickpea by enhancing the resistance to droughts and diseases in the desi and kabuli lineages (Thudi et al., 2016). Genomics and studies have developed research that attests that a significant pool of genetic resources can be tapped to improve future products, and this provides an opportunity to combat existing and future production challenges (Shahnaz et al., 2025). Moreover, the recent studies on gene editing, such as CRISPR Jacques Cas9 use on stress tolerance and virus resistance, propose some innovative means of developing durable varieties quickly (Razzaq et al., 2022; Malik et al., 2023; Singh et al., 2023).

RESEARCH METHODOLOGY

This study employed a qualitative literature review methodology to examine recent developments in chickpea genetics and their role in improving yield resilience under biotic and abiotic stress conditions. Relevant scientific publications were



collected from internationally recognized databases, including Google Scholar, Scopus, Web of Science, SpringerLink, and ScienceDirect. The review primarily focused on peer-reviewed journal articles published between 2014 and 2025, while a limited number of earlier studies were included because of their significant contributions to chickpea genetics and breeding research.

The selected literature addressed key topics such as drought tolerance, heat and salinity resistance, disease resistance, conventional breeding, molecular breeding, quantitative trait loci (QTL), genomic selection, and CRISPR/Cas9 gene-editing technologies. After screening the literature for relevance and scientific quality, the findings were analyzed using comparative and descriptive methods. Similarities and differences among research findings were identified, and recent advances in breeding technologies were evaluated to determine their potential contribution to sustainable chickpea production, particularly under the environmental conditions of Uzbekistan.

ANALYSIS AND RESULTS

It has been revealed through genetic research on chickpea that resilience to stress in terms of yields is closely intertwined with definite physiological and morphological characters under quantitative genetic regulation. Varshney et al. (2014) had to slice up drought tolerance in a large multi-environment analysis based on phenotypic data of many drought hexa positional traits and genetic mapping on multiple populations, finding a number of clusters of quantitative trait loci (QTL). A key QTL cluster on the linkage group CaLG04 was demonstrated with having a significant breeding potential to improve drought tolerance in breeding programs in explaining a large percentage of the variation in key drought determinative phenotypes. These results suggest that resilience does not depend on any one factor but rather the concerted action of many loci that regulate features of root architecture, water decisiveness efficiency, and phenology.

This genetic viewpoint is supported by screening various genotypes of chickpea in a water limited environment. Farshadfar and Javadinia (2011) considered genotypes in terms of drought tolerance based on selection indices as a combination of yield and stress responses and found that there was wide genetic variation in genotype tolerance. Genotypes that retain higher yields during drought stress generally have a combination of good qualities observed through QTL studies implying that marker weakens chosen through markers like those described by Varshney et al. (2014) have the ability to hasten the creation of resilient cultivars. These findings combined demonstrate that genetic enhancement is a direct proportional increase in more stable yields in situations where drought is the primary limitation.

In addition to drought itself, resilience in fields of farmers should integrate exposure to heat and salinity. Pushpavalli et al. (2020) discussed cross intolerance in chickpea and demonstrated that some genotypes are able to respond to drought, heat, and salinity stresses in double or triple, instead of single. Such a notion of cross-tolerance is essential as it is the condition in the real field that co-exists multiple stresses. Complementary on this, Flowers et al. (2010) concentrated on the aspect of salt sensitivity in chickpea, and established that the crop is naturally sensitive to salinity, and its yield significantly drops under salty conditions. The resulting evidence suggests



that, to provide true yield resilience in marginal environments, breeding programs need to target multi stress tolerance, rather than single trait drought resistance.

Another significant factor in instability in chickpea yield is Biotic stresses, especially the Ascochyta blight. Progress in identification and deployment of genetic resistance to Ascochyta blight was summarized by Sharma and Ghosh (2016) and demonstrates the existence of resistant lines but requires continued breeding due to the variability of the pathogen. Choudhary et al. (2023) described the traditional and molecular breeding approaches to artificially inducing resistance to diseases in chickpea with emphasis on integration of cross-source resistance genes of chickpea using marker subsection assisted breeding. Similarly, Li et al. (2015) also examined breeding to resist biotic stress and the significance of having a combination of resistance to various pathogens and pests. Du et al. (2012) gave particular evidence of the genotypes that were found to resist *Ascochyta rabiei* and it is an example of how germplasm screening is involved in the process of identifying strong parental lines. These initiatives will decrease the losses caused by disease in the harvest and increase the gains directly related to more dependable production by accumulating resistance alleles and expanding the resistance base.

Genome engineering and gene editing gives further means of enhancing yield resilience. The use of CRISPR-Cas9 to enhance abiotic stress tolerance in chickpea was reported by Razzaq et al. (2022), as one of the reasons is that genome editing is considered a new hope in reducing development time associated with the creation of lines with tolerance to stressors. In CRISPR/Cas9 Gene editing, Malik et al. (2023) provided evidence of the possibility of producing resistance to the chlorotic dwarf virus of chickpea and how disease limitations can be narrowed through precise editing. Singh et al. (2023) assessed the wider applicability of genomics and gene editing to enable chickpea to cope with climate change and feed the population of the world. Though not yet conclusively implemented in agricultural fields, many of these applications still show a very clear roadmap by which specific genetic modifications could result in the enhancement of stress tolerance and, by extension, provide a state of resilience.

CONCLUSION

There are various key constraints influencing the production of chickpea, especially drought, heat, and salinity, as well as diseases like Ascochyta blight. Such stresses always help to lower yield and restrict the performance of crop in a dry land area particularly in the regions such as Uzbekistan where environmental conditions may be quite fluctuating.

The development in breeding and genetics have offered apparent prospects to improve breed tolerance of chickpea to major stresses. Drought resilience, multi-stress tolerance, and disease resistance have been demonstrated to provide a variety beneficial in stabilization of yields under the most adverse conditions. Genetic improvements should be effectively supported by proper agronomic management at production level. Better knowledge of the optimum sowing time, better water and nutrient control, sustainable soil management, and combined pest and disease management contributes to ensuring that benefits of improved cultivars may be fully achieved in the fields of Uzbek farmers.



Based on the reviewed literature, several recommendations can be proposed to improve chickpea production and strengthen yield resilience in Uzbekistan. Expand national chickpea breeding programs by incorporating modern molecular breeding techniques and marker-assisted selection to accelerate the development of stress-tolerant cultivars. Increase investment in research on drought, heat, salinity, and disease resistance to address the growing impacts of climate change on agricultural production. Strengthen collaboration among universities, research institutes, and agricultural extension services to facilitate the transfer of improved technologies to farmers. Evaluate newly developed chickpea genotypes under different agroecological conditions in Uzbekistan to identify varieties with superior adaptability and stable yield performance. Support responsible research and regulatory frameworks for emerging genome-editing technologies, including CRISPR/Cas9, while ensuring transparency, biosafety, and public awareness. Encourage farmers to integrate improved chickpea varieties with sustainable agronomic practices, including appropriate sowing dates, efficient irrigation, soil fertility management, and integrated pest management, to maximize productivity and long-term sustainability.

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