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Breeding for Early Heat Stress Tolerance in Wheat

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ABSTRACT

Wheat, a major contributor to global food security, is highly vulnerable to early heat stress, particularly as climate change intensifies. Early sowing practiced to optimize moisture and avoid terminal heat stress, exposes crops to elevated temperatures during critical stages like germination, tillering, and grain filling. As a C_3 plant, wheat thrives at 15-20°C, but early heat disrupts photosynthesis, reduce chlorophyll content, impair carbon partitioning, and negatively affect grain quality and yield. To combat these challenges, wheat exhibits various adaptive mechanisms, including improved membrane stability, enhanced photosynthesis, and activation of heat shock proteins (HSPs) that protect cellular components from heat damage. Breeding strategies should be adopted to mitigate early heat stress to sustain wheat production. Traditional breeding focuses on selecting resilient genotypes, while advanced techniques like genome-wide association studies (GWAS), marker-assisted selection, and CRISPR-Cas9 offer precise genetic improvements. Speed breeding further accelerates development of heat-tolerant varieties. Screening tools like Canopy Temperature Depression (CTD), Heat Susceptibility Index (HSI), and SPAD meter readings for chlorophyll content help identify tolerant genotypes. Integrating genomics, transcriptomics and metabolomics technologies enhances the understanding of heat tolerance mechanisms. Collaborative efforts among breeders, biotechnologists and agronomists are crucial for developing heat-resilient wheat, ensuring global food security amidst climate change.

Keywords: Wheat, early heat stress, heat tolerance, breeding strategies, heat shock proteins, CRISPR-Cas9

Introduction

Out of total world food grain production, wheat shares about 30% contribution. Wheat accounts for about fifty percent contribution in global grain market. Wheat demand is projected to be 840 million tonnes to feed around 10 billion people by 2050 (Sharma et al., 2015). The well-known constraint behind low production in wheat is global warming. Wheat being C_3 plant requires a range of 15-20^{O}C temperature conditions as compared to C_4 crop (Ruan et al., 2012).

With global climate change, heat stress is becoming a more serious limitation on wheat production (Ni et al., 2018). Majorly, abiotic stresses like heat causes more yield loss, compared to biotic factors (Coast et al., 2022). As global temperatures rise, heat stress, a regular risk to wheat in the subtropics, becomes more dangerous in regions that produce wheat (Ding et al., 2021).

Farmers tend to sow wheat in early October to utilize most of the moisture after harvesting of rice. It saves at least one irrigation of the season. Also, along with adoption of good agronomic practices, early sowing keeps terminal heat stress escaped. Wheat due to early sowing, is harvested till end of March to early April. Moreover, most of the present cultivars are not bred for early sowing conditions. That is the main reason why present cultivars in wheat mature early and are poor yielding. Cultivars for farmer's field are not well adapted to early sowing environments. The role of genes behind breeding cultivars of wheat suitable for early as well as mid-season planting conditions is unknown till date (Bhanja et al., 2021).

Characteristics of wheat environment:

Climate factors such as temperature, moisture, CO_2 levels, weather changes, and soil moisture deficiency would have an impact on agricultural productivity, either positively or negatively (Joshi and Kar, 2009). Deryng et al. (2014) elaborated effects of high CO_2 concentration and impact of ever-changing climate on wheat production. The threatening significant effects of climate change on dropping yield potential of wheat was reported by Tripathi et al. (2016). Wheat production is expected to decrease by 6% for every degree increase in temperature. Around 100 million hectares of global area of wheat is heat prone. This area lies in low lying latitude of earth (Braun et al., 2010). Heat stress is also becoming a serious problem in colder northern wheat-growing regions due to rising severity throughout heading to maturity (Liu et al., 2014). Eastern Gangetic plains, peninsular region and central regions are most susceptible heat prone areas in India (Singh et al., 2007, Joshi et al., 2007). Heat stress occurs typically due to rising canopy temperature, which is dependent on air and soil temperature, soil and canopy properties, and soil moisture loss. Joshi et al. (2007) found that reducing the 'cold time' in wheat also reduced yield.

Genetic variability for adaptation and survival under heat stress:

Previous studies have found that high temperatures generate a variety of morphological,physiological, molecular, biochemical and cellular changes in plants (Barnabás et al., 2008; Almeselmani et al., 2012). There is growing evidence that heat stress has a major detrimental influence on yield during the reproductive phases (Farooq et al., 2011; Balla et al., 2012; Semenov and Shewry 2011). Major impacts of elevated temperatures include pollen sterility and abortion, drop in dough quality, hampered grain filling, reduction in seed weight etc. (Hays et al., 2007; Altenbach et al., 2012). In nutshell, yield is compensated on account of reduction in grain number, advanced grain maturity, reduction in tiller number, plant height, etc. (Rahman et al., 2009; Zhang et al., 2010).

Great negative impacts of heat are observed during flowering and reproductive stage, of wheat (Djanaguiraman et al., 2020). It is reported that after anthesis, if temperature rises from normal range (15°C-20°C) to high temperatures (40°C-45°C) yield of wheat gets by reduced to about 23% of normal production (Fleitas et al., 2020). However, reactions are also affected by the duration of heat stress, as well as the pace at which temperature rises. Because of a process known as basal thermotolerance, plants may still grow at temperatures over the ideal range. Pretreatment of wheat genotypes to mild heat develop tolerance in wheat genotypes to high lethal temperatures. Usual practice of exposure to gradual increase in temperatures develops heat tolerance in wheat genotypes (Qin et al., 2008; Mittler et al., 2012).

Most sensitive stages in wheat affected by heat stress includes stages from flowering to grain filling (Farooq et al., 2011). Elevated temperatures degenerate tapetum, interfere meiosis (Sakata et al., 2000, Zinn et al., 2010), and biomass accumulation, which ultimately reduces the grain yield in wheat (Reynolds et al., 2007).

Anatomical/ growth stages and phenophases:

1- Seed germination coupled with Tillering stage:

Various factors influencing seed germination and tillering in wheat are triggered by elevated temperatures during germination stage in wheat. Seed germination and seed vigour are the most significant features for obtaining a better crop stand and greater yield, and seed germination is primarily dependent on temperature, with the temperature range for optimum germination varying depending on the crop species. The normal temperature range favourable for seed germination in wheat is 1-4°C. The percentage of germination goes on decreasing above the optimal range of temperature. Germination percentage increases as the temperature rises from the base to the ideal range, and declines as temperature rises over the optimum range. High temperatures (45°C) induced cell death and embryo damage in *Triticum aestivum* during the early stages of germination. High temperatures are unsuitable for wheat development and the establishment of new seedlings (Akter and Rafiqul, 2017). Essemine et al., (2010) studied that the temperature rise in night conditions drops germination percentage at higher rate as compared to diurnal temperatures.

2- Grain filling duration:

Heat stress, among other abiotic stresses, has a negative impact on plant chlorophyll and grain filling stage. During the mid anthesis phases, excessive temperatures influence fertilisation and seed set, reducing wheat yield (Ferris et al., 1998). High temperatures also causes ultra-structure changes in the aleurone layer, increasing stomatal density, closing stomata, shrinking cell size and a decrease in wheat flour quality (Zahra et al., 2021). High temperatures limit uptake of sucrose which reduces starch synthesis in endosperm. It leads to improper carbon partitioning in the wheat plant (Harris et al., 2023).

3- Flowering and panicle development:

High temperatures have a detrimental effect on wheat, reducing productivity and production. High temperatures reduce the number of grains and reduce the maximum production potential during the floral initiation and spikelet development stages (Janjua et al., 2010). Challenged seedling growth and photosynthesis as a result of decreased activity of photosystem II was observed in elevated temperature conditions by Tewari and Tripathy (1998).

4- Photosynthesis, respiration, and developmental stages:

High temperature affects leaf appearance and elongation and shortens the length of leaf elongation. It also retards root development during the reproductive stage due to reduced carbon partitioning to roots (Batts et al., 1998). High temperatures above 40°C have a negative impact on photosynthesis and reduce the solubility of O_2 and CO_2. As a result, the rate of photosynthesis is reduced, the rate of respiration is increased, and the level of CO_2 is higher than the level of O_2 (Wingler et al., 2000). High temperatures directly affects the activity of ribulose-1, 5-bisphosphate carboxylase/oxygenase, Rubisco binding protein and Rubisco activase in wheat leaves (Prasad et al., 2008). Mitochondrial respiration is extremely temperature sensitive. When the temperature rises beyond 50°C, the rate of respiration drops, resulting in the damage of the respiratory mechanism. Short-term drought conditions also reduce root and leaf respiration. Increased inflow of assimilates ensures higher respiration rate of seed, and ultimately reduces yield due to improper assimilate partitioning in elevated temperature conditions (Wardlaw et al., 1980). According to Rehman et al. (2009), productivity in wheat gets reduced per degree rise in temperature in tropical, subtropical, desert and arid regions. Viable leaf area is reduced which in turn affects photosynthetic rate as well as water use efficiency of wheat under high temperature stress conditions (Castro et al., 2007). Schuster et al. (1990) discovered that the source and sink relationship is disturbed in this regard. Figure 1 shows the effect of temperature on various physiological processes and growth rate of plants (Fitter and Hay 2012).

5- Final yield:

High temperatures have an impact on both the supply and sink of assimilates, reducing crop output. Under high temperatures, leaf area and photosynthesis, as well as shoot and grain biomass, rapidly reduced (Shah and Paulsen, 2003). While, temperature elevating from 27-32°C at night, grain production decreases by 90% (Jalil et al., 2020). As cultivated under high night temperatures, wheat plants lose 20% of their grain weight as compared to normal temperatures, while, decreasing trend in seed setting of wheat was observed in high temperature conditions during anthesis in wheat (Sun et al., 2018). The reduction in grain yield up to 39%, fifty percent reduction in number of grains per spike, twenty four percent reduction in harvest index was observed in one report by Pradhan et al. (2015). A typical trend of reduction in number of days to booting, flowering, maturity and harvesting is main effect of heat on wheat. Due to late sown conditions grain filling duration window in wheat gets significantly decreased and affects yield greatly.

Wheat plants often face heat and drought stress simultaneously, especially in regions with arid or semi-arid climates. The combined effect can be more detrimental than either stress alone, as both impact water-use efficiency, photosynthesis, and grain development. Breeding and management practices focus on developing wheat varieties with combined heat and drought tolerance for sustainable productivity. Table 1 summarizes the key differences between heat stress and drought stress.

Germplasm screening for heat tolerance

Evaluation of indigenous and foreign germplasm for heat tolerance is crucial since genetic heterogeneity for heat tolerance may exist within wheat genotypes.

Various screening methods at seedling stage are found effective while selecting germplasm for heat tolerance viz. carbon discrimination method, screening by dry weight, screening through canopy temperature depression method, screening by observing chlorophyll content of leaf, chlorophyll fluorescence of wheat etc.

Leaf senescence, CTD, CT, MTS, grain filling duration are some important screening methodologies for tolerant germplasm in wheat at later stages (Driedonks et al., 2016; Narayanan 2018).

Relation between physiological parameters and heat stress

1- SPAD:

The chlorophyll meter, commonly referred to as a SPAD meter, is a compact and portable tool designed for measuring leaf greenness, which corresponds to the relative chlorophyll concentration in leaves. Unlike traditional destructive methods, this diagnostic tool offers significant savings in terms of time, space, and resources.

The SPAD meter operates by measuring the light transmittance through leaves at two distinct wavelengths: 650 nm and 940 nm. These wavelengths are selectively absorbed by chlorophyll, allowing the device to estimate the chlorophyll content in the leaf. Additionally, the SPAD meter provides insights into leaf nitrogen content, as chlorophyll concentration is closely related to the nitrogen status of plants. This nondestructive approach has become a valuable resource in agricultural and environmental studies (Netto et al., 2005).

2- Canopy temperature:

Canopy and organs temperature (flag leaf, peduncle and spike) can be recorded instantaneously with a hand-held infrared thermometer. A study was conducted which showed high CTD (Canopy Temperature Depression) values in Stay Green genotypes under heat stress conditions which concluded that Stay Green is highly associated with CTD (Dolferus et al., 2011). A positive correlation of canopy temperature depression was found with stomatal conductance and grain yield (Bonari et al., 2020).

3- NDVI:

It is a type of optical sensor unit. It is measured generally in two stages. Firstly, after one month of sowing and secondly, one fortnight after anthesis. Figure 2 shows NDVI values at different stages in wheat crop (Aranguren et al. 2020).

4- Heat susceptibility index (HSI):

HSI of individual genotypes can be calculated by the method suggested by Fischer and Maurer (1978). The genotypes that have high positive HSI values are susceptible to higher temperature and vice versa. If HSI value is < 0.5, then the genotype is highly stress tolerant, if HSI > 0.5 < 1.0, it is moderately stress tolerant, and if HSI > 1.0, it is susceptible to heat stress.

5- Heat response index (HRI):

It is a formula/index based on the genotypic response to heat. This formula was first used by Bidinger et al. (1987). Based on genotypic response the germplasm under screening is categorized under groups comprising of genotypes which escape heat, genotypes which resist heat and genotypes having mechanism of tolerance to heat (Munjal and Dhanda, 2016).

6- Stress tolerance (TOL):

TOL was computed using the formula given by Hossain et al. (1990). The genotypes having high values of TOL show higher yield reduction.

According to study conducted by Shehrawat et al. (2020), for a heat tolerant genotype, heat susceptibility index and stress tolerance parameters should be on the lower side, as these parameters are negatively correlated with grain yield. While, the parameters like heat response index, heat tolerance index etc. are positively correlated with grain yield. Therefore, the values of HTI, HRI should be on higher side.

Breeding methods adopted in heat stress

Basically, three types of strategy are adapted by plants to combat heat stress

1- Escape mechanism: Plants undergo physiological, morphological, biochemical and biological modifications in their genotypes and escape heat stress duration. Plant completes its life cycle before detrimental effects of heat and escape.

2- Defense mechanism: Various heat shock proteins, reactive oxygen species gets activated and increase in their levels in plant to combat heat stress. Plants produce ROS in response to heat stress. Also, the heat shock proteins respond rapidly to heat stress.

3- Tolerance: It refers to morphological, biological, phenological, biochemical as well as physiological modifications in plant to tolerate detrimental effects of heat and to maintain cell turgor so as to maintain its production levels (Soni et al., 2023)

To prevent denaturation of proteins due to heat stress, protein folding is favoured through chaperones. Plant start producing more heat shock proteins and activity based on HSP's gets enhanced. All the above-mentioned activities are significantly enhanced with seed priming in nutrient rich media (Chakraborty and Dwivedi 2021). The mechanism of photosystem II is prevented from damage due to special types of heat shock protein i.e sHSP's. It prevents protein damage and ensure high photosynthetic rate of the plants by regularizing electron transport chain. It also ensures proper ATP synthesis and plants grow normally (Haslbeck and Vierling, 2015).

Morphological adaptations

- good seed potential
- proper vegetative growth
- leaf rolling
- inhibited early leaf senescence
- better biomass accumulation

Physiological alteration

- better tillering habit
- increase membrane thermostability
- better photo assimilate translocation
- active photosynthetic metabolism

Biochemical alteration

- sustaining high chlorophyll content
- enhanced activity of soluble starch synthase enzyme
- ROS scavenging and detoxication

Molecular alteration

- activation of stress responsive proteins
- protein folding and regeneration, denaturation of abnormal protein
- inhibition of apoptosis
- protection of cytoskeleton

Conventional breeding:

Breeding programmes are typically carried out in an area that is comparable to the crop's growing region. Accordingly, breeding lines should be chosen for heat tolerance while the weather is hot (Mickelbart et al., 2015).

To select superior genetic stock against heat stress, stable performance of plant in terms of yield in heat stress conditions is a conventional approach to focus upon (Mishra et al., 2014). Masthigowda et al. (2022) proposed that pollen viability is a crucial characteristic for screening wheat genotypes' tolerance to withstand heat stress. According to another study conducted by Ul Hassan et al. (2021), high potential grain weight under heat stress may potentially be a more important criterion in selecting cultivars for heat tolerance and resilience to changing future climate conditions. It is necessary to identify donor genotypes for heat tolerance through genetic resource screening. Establishing heat stress tolerant genotypes by examining regional genotypes of wheat that are highly adapted to heat stress is the first stage in developing a wheat breeding programme for heat stress (Bita and Gerats 2013).

Advanced breeding:

To create heat-stress-tolerant cultivars, advanced breeding techniques includes GWAS and marker-assisted backcrossing. Genome diversity among species yielded in genes/QTL's responsible for heat tolerance in wheat (Wahid et al., 2007). SSR and AFLP markers were used in various studies to map these QTL's (Lu et al., 2020). Advance markers such as, DArT (Diversity Arrays Technology markers), SNP's (Single Nucleotide Polymorphism), NGS (Next Generation Sequencing), etc. are found promising in breeding heat tolerant genotypes in recent years in wheat crop (Cabral et al., 2018; Sonah et al., 2012). Genomic selection may be coupled with GWAS or QTL studies to better incorporate trait of heat tolerance in novel genotypes. These methods can be found effective for pyramiding genes from diverse genome size (Bassi et al., 2016).

With the complexity of the underlying heat tolerance mechanisms, genome wide analysis has proven to be a valuable method for identifying heat stress responsive genes (Wang et et al., 2015). Research is also oriented towards functional analysis of genes for heat tolerance in background of transgenics (Clavijo et al., 2017). Study of overexpression of gene related to heat tolerance and genes contributing sense and response to heat are also revolutionary and trending areas of research now a days (Zang et al., 2017).

Deep insights to understand mechanism of heat tolerance at transcriptomic, metabolomic and genomic levels is need of the hour. It will better respond to ongoing efforts to combat heat (Bhardwaj et al., 2021). All chemical strategies linked to heat stress tolerance in wheat plants start at a few heat stress tolerance genes that contain genomic DNA (Deshmukh et al., 2014). Genes contributing heat tolerance in wheat has been determined through studies of genome expression and genomic screen (Yeh et al., 2012). Heat tolerance genes' mRNAs (transcript products) are translated into functional proteins, which in turn produce proteomes (proteomics), which are responsible for the tolerance to heat stress. Plants use small non-protein coding RNAs, or microRNAs, to show some post transcriptional gene expression. Understanding the mechanisms underlying wheat's heat tolerance is improved by research on microRNAs and micromics (Chinnusamy et al., 2007). According to Abdulrahman et al. (2020), metabolomics is an additional omics technique that can be applied to the phenotyping the traits contributing to heat tolerance in genetically modified plants. To elucidate the response pattern of plants against abiotic as well as biotic stress and to determine the function of genes contributing to trait of concern, metabolomics is the better possible way out.

Traditional breeding procedures, which might take more than ten years to generate high- performing cultivars with targeted features, are proving to be ineffective and become a barrier in developing heat-tolerant wheat varieties. However, a new breeding method known as 'speed breeding' has been developed to shorten the generation time, accelerate the development, marketing, and commercialization of improved plant varieties (Imam et al., 2024). It manipulates temperature, light duration, and intensity to accelerate the crop development. Every year, this speed breeding method can produce up to six generations of bread wheat (*Triticum aestivum*) and durum wheat (*Triticum durum*) (Watson et al., 2018). Recently, genome editing tools and resources such as CRISPR-Cas9, TILLING, and others have been used to improve wheat heat tolerance (Liang et al., 2017). As a result, the combination of these advanced tools and speed breeding may provide scientists with an effective inducement to conduct heat tolerance research in wheat.

Transgenic Approach:

In comparison to traditional breeding and marker-assisted selection programmes, genetic engineering's direct introduction of a limited number of genes looks to be a more desirable and quick way to improve stress tolerance. Current engineering procedures rely on the transfer of one or more genes encoding biochemical pathways or signaling pathway endpoints that are regulated by a constitutively active promoter. These gene products offer protection against environmental challenges, either directly or indirectly. Transgenic technology has developed as an effective technique for enhancing crop genetics in order to enhance survival, growth, and yield (Sun et al., 2022). However, little progress has been made towards developing heat-tolerant transgenic wheat plants.

Conclusions

Breeding for heat stress in field crops is a major challenge at global level. The heat stress effect are usually confounded with water stress. Heat stress impairers photosynthesis, carbohydrates, proteins, lipid metabolism and cell membrane functions that lead to decline in plant growth and consequently grain yield. To maintain high yields with better response to heat stress in crops is best possible through various metabolic, metabolomic, transcriptomic, biochemical and molecular responsive mechanisms. In order to infuse tolerance against heat stress in wheat genotype, assembly of gene constellations determining heat shock responses, membrane thermal stability and vernalization responses should be accommodated in agronomic elite wheat genotypes. Different agronomic options, as well as biochemical and molecular approaches, must be combined to investigate the realistic response of plants against heat stress at the field level. Collaborative team efforts from plant breeders, biotechnologists, molecular biologists and physiologists would aid in the developing novel thermo-tolerant genotypes in wheat to combat heat stress globally.

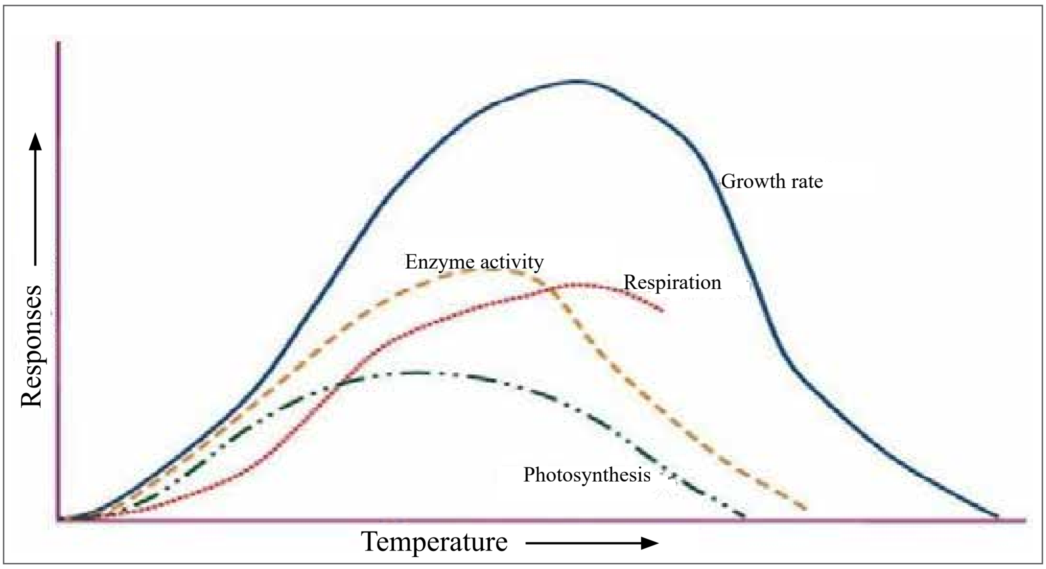

Figure 1. Effect of temperature on various physiological processes and growth rate of plants (Fitter and Hay, 2012).

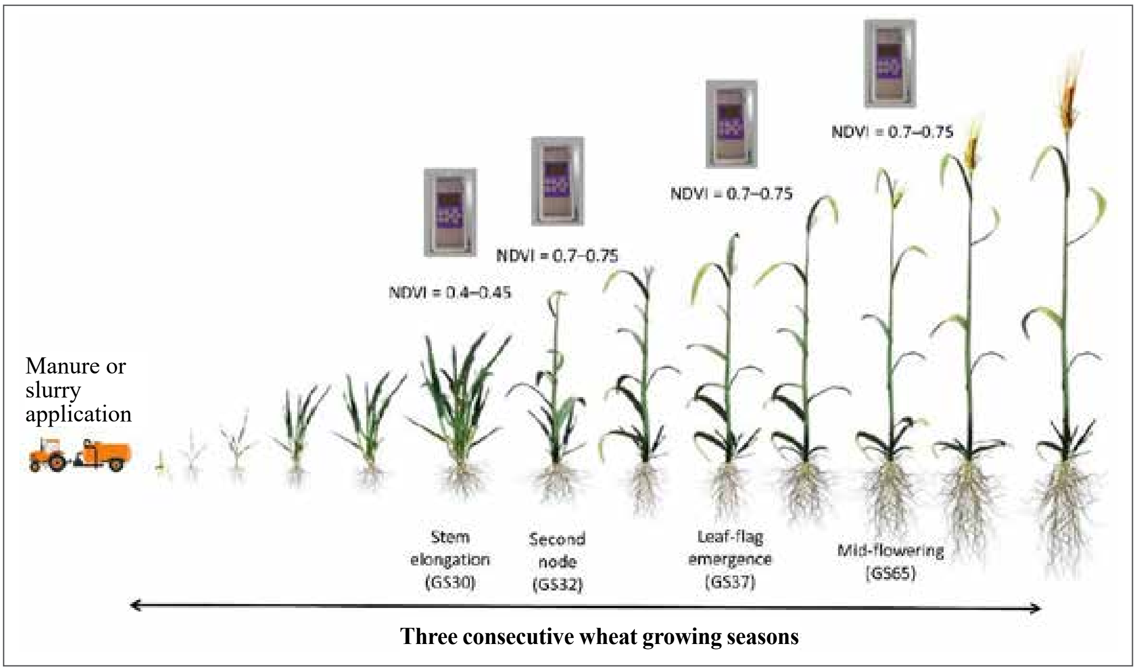

Figure 2. NDVI values at different stages in wheat crop (Aranguren et al., 2020).

Table 1. The key differences between heat stress and drought stress.

Aspect	Heat Stress	Drought Stress
Primary Cause	High temperatures	Low water availability
Impact on Physiology	Disruption of enzymatic and metabolic processes	Disruption of water uptake and retention
Key Mechanism	Production of heat shock proteins and antioxidant activity	Root architecture and osmotic adjustment
Critical Stage	Flowering and grain filling	Any growth stage, but often during flowering or grain filling
Visible Symptoms	Leaf scorching, reduced grain size	Leaf wilting, rolling, yellowing

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Research on Yield and Quality Values of Some Chickpea (*Cicer arietinum* L.) Genotypes in Winter Sowing

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ABSTRACT

This research is a regional yield trial study within the scope of the national project carried out as a part of breeding studies. In this study, advanced chickpea genotypes and registered varieties are tested at different locations and the results of Adana location are discussed in this study. The experiment was conducted in 2023 to determine yield, morphological characteristics and quality values in winter sowing under Eastern Mediterranean ecological conditions. The experiment was set up in a randomized block design with four replications. In the study, plant height, flowering time, grain yield, hundred grain weight and quality parameters of the varieties were analyzed. According to the results, plant height of the varieties varied between 46,5-59,8 cm; Urfa GAP-3 genotype was the shortest and Adana-5 genotype was the tallest. Flowering time varied between 68,3-77,3 days; Aksu chickpea variety was the earliest and Diyarbakır-2 genotype was the latest. Hundred grain weight values varied between 38,8-49,3 g (Hasanbey-Adana-1 genotypes, respectively). Grain yield ranged between 129,5-316,0 kg/da from Adana-1 genotype and Hasanbey chickpea varieties, respectively. According to the data obtained at the end of the research, Hasanbey, Ubet, UrfaGAP-1, Aksu, and UrfaGAP-1 genotypes, which have the highest values in terms of grain yield, can be recommended for the region. However, in order to make a better decision, it should be supported by more long-term and detailed agronomic studies.

Keywords: Chickpea, winter sowing, yield and quality

Introduction

Chickpea belongs to the group of self-fertilizing plants with diploid chromosome number (2n=16) (Cobas et al., 2007 and chickpea is classified under the Fabaceae family. In Türkiye, chickpea is widely cultivated throughout the country and especially in Central Anatolia and serves as a multipurpose crop. First, it fixes atmospheric nitrogen in the soil, increasing soil fertility and reducing the need for fertilizer in subsequent crops. Legumes play an important role in promoting sustainable agriculture by maintaining soil fertility through biological nitrogen fixation together with symbiotic *rhizobium* present in root nodules (Negi et al., 2004). Secondly, chickpea can be grown in arid regions due to its taproot; it encourages more intensive and productive use of land, especially in areas where land is limited, as it plays an active role in removing or reducing fallow areas by making maximum use of soil moisture and ensuring crops every year (Yeşilgün, 2006). According to Gil et al., (1996) chickpeas are very important as an affordable source of protein. This suggests that the inclusion of chickpeas in a person's regular diet can reduce malnutrition and improve health, especially for poor people who cannot afford to buy cattle products.

The data for chickpea in Türkiye for the year 2022 show a cultivation area of 456,480 ha, a production of 580,000 tons, and a grain yield of 127,00 kg/da (FAO, 2024). Although the importance of chickpea plant is known, the average productivity is low throughout the country and production is realized far below its potential due to various reasons. The main factors limiting chickpea production are difficulty in accessing certified seeds, difficulty in accessing improved varieties, constraints of biotic and abiotic stress factors Singh et al., (2016). Sharma et al., (2013). In addition to these, global climate change is another issue affecting agricultural production all over the world. Global climate change affects the growth and development of plants with decreasing precipitation, changing seasonal distribution of precipitation, increasing temperature and CO_2 concentration, changes in diseases, pests and weeds, and affects yield positively or negatively for different plant groups (Naumann et al., 2018; Zhu et al., (2016).

The aim of this study is to achieve the deserved yield and quality in chickpea production, which is intensively cultivated for sustainable agriculture in Türkiye. For this purpose, registration of chickpea varieties with high adaptation to regions, resistant/tolerant to biotic and abiotic stress factors and providing certified seeds to the service of farmers.

Materials and Methods

This research was conducted in the experimental field of the Institute at Adana location in the Eastern Mediterranean region in the 2023 growing year. The research experiment was established according to the randomized block design with four replications. Plots of 9 m^2 were planned as 4 rows (5mX4 rowsX0,45m) with 45 cm between rows and 8 cm above rows, and fertilizer was applied at 3 kg/da N and 6 kg/da P_2O_5 with planting. After the plants emerged from winter, weeds were controlled mechanically by hoeing when the plant height was about 10-15 cm and before flowering. The traits examined in the field studies were analysed in the JUMP statistical analysis programme using a random blocks experimental design.

Doğankent location, where the trials were planted in this study, is located at (37°00´ N, 35°20´ E) latitude and longitude coordinates and has alluvial soils in terms of soil structure. Çukurova region is a delta plain formed by the alluvium carried by Seyhan, Ceyhan and Tarsus rivers. The soils in the test area are loamy and have a slightly alkaline reaction. It is medium in organic matter, poor in nitrogen and phosphorus, but rich in potassium. Eastern Mediterranean Agricultural Research Institute Experimental Area Soil Analysis Report (Table 1.)

The experimental area is under Mediterranean climatic conditions and meteorological data are given in Table 2. When the temperature averages of the year in which the experiment was carried out are examined, it is observed that the temperature values are close to the long-term average in terms of temperature, but the temperature values in July showed values above the long-term average. In recent years, due to global warming, there have been irregularities in the distribution of precipitation and intensities in the amount of precipitation from time to time. In some years, heavy rainfall can damage plants by promoting root diseases. Stresses experienced in plants (drought, drying out, rotting due to excessive rainfall, or root diseases, etc.) cause yield and quality losses. In the 2023 growing year, it is observed that rainfall amounts are low compared to long years and their distribution is irregular. Relative humidity rates showed values parallel to long years (Table 2).

Results and Discussion

This research was carried out in the experimental field of Adana-Doğankent Institute in the 2023 growing year by sowing in December during the winter sowing period.

The lowest and highest plant height values of chickpea genotypes were obtained from Gap-3 chickpea genotype with 46,5 cm and Adana-5 genotype with 59,8 cm, respectively. The overall average plant height of the genotypes was 53,6 cm (Table 3). Plant height and first pod height are very important agronomic parameters in chickpea farming and they indicate whether the plants are suitable for machine harvesting or not. The height of the plant height of chickpea plants determines the suitability for machine harvesting Mart et al., (2017). It was found that plant height of chickpea genotypes varied between 39,0-60,2 cm in Konya conditions Ceyhan et al. (2013). The plant height values obtained by the researcher and the values determined in this study were similar. Chickpea sowing time has an effect on plant height values. Plant height values are higher in winter sowing than in summer sowing. Bakoğlu and Memiş, (2002), Since varieties with short plant height may cause significant grain losses in machine harvesting, it is of great importance to prefer tall varieties. Long plant height reduces grain loss in machine harvesting.

Plant Height (cm), Days of Flowering (days) and Anthracnose Disease Observations Values of Chickpea Genotypes are given in Table 3.

In terms of days to flowering, the lowest and highest values of days to flowering were obtained from Aksu chickpea variety with 68,3 days and Diyarbakır-2 genotype with 77,3 days, respectively. The average number of days to flowering of the genotypes was 72,6 days (Table 3). In chickpea farming, days to flowering values and days to pod pod podding represent the most important parameters indicating whether chickpea varieties are early or late Mart et al., (2017). In the studies conducted with the days to flowering values of chickpea plants in terms of agronomic characteristics, Aydoğan (2012) found that the number of days to 50% flowering varied between 59,0-67,3 days, Karakan (2014) 57,0-62,3 days, Uzun et al., (2012) 57,5- 65,5 days, Bayrak et al., (2015) 56,5 days.

In the current study, varieties were tested for Ascochyta blight disease in disease gardens under artificial epidemic conditions in Ankara and Eskişehir locations. Under artificial epidemic conditions, Diyarbakır-2 genotype and Hasanbey and Ubet chickpea varieties were sensitive with a score reading of 7 in the Ankara disease garden,

In Eskişehir disease garden, varieties and genotypes were found to be tolerant genotypes with a score reading of 4-5 (Table 3). Ascochyta blight disease has a negative effect on chickpea hundred grain weight, average grain size values and yields, causing yield losses and decreasing hundred grain weight. Chickpea varieties to be planted for winter should have high tolerance/resistance to winter and Ascochyta blight disease.

Grain Yield (kg/da) and 100 Grain Weight (g) Values of Chickpea Genotypes are given in Table 4.

In this study, the statistical difference between genotypes in terms of yield was not found to besignificant. The lowest grain yield of chickpea genotypes was obtained from Adana-1 genotype with 1295 kg/ha, while the highest grain yield was obtained from Hasanbey chickpea variety with 3160 kg/ha. The general yield average of the genotypes was 2065 kg/ha. However, in terms of grain yield, Ubet with 2648 kg/ha, Urfagap-1 genotype with 2595 kg/ha, Aksu variety with 2581 kg/ha and Urfagap-2 genotypes with 2436 kg/ha were found suitable for evaluation (Table 4). Mishra et al. (2002) reported that the number of pods in a plant was the character with the highest positive effect on seed yield. Grain yield may vary depending on factors such as cultivation technique, climate and soil conditions and genetic structure of chickpea.

In this study, statistical differences among the genotypes in terms of 100 grain weight were significant; in terms of the values obtained, the largest grain variety was Adana-1 genotype with 49,3 g, the smallest grain varieties were Urfagap-3 genotype with 38,5 g and Hasanbey variety with 38,8 g. The general average of 100 grain weight of chickpea genotypes was 43,7 g. However, Adana-5 genotype with 47,9 g, Ubet variety with 47,1 g, Adana-3 genotype with 46,7 g and Urfagap-1 genotypes stood out as coarse grain (Table 4). The most important factor in price formation in the markets is the cleanliness and grain size of the product.

Generally, chickpeas with large grains are sold at higher prices. Another important issue in variety breeding is that grain size should be as homogeneous and stable as possible. In chickpea, hundred grain weight varies according to the environment in which the plant is grown, sowing time and norm and is known to directly affect grain yield. In the previous studies, it was reported that facial grain weight varied between 29,87-39,90 g by Yaşar (2010), between 30,6 and 47,6 g by Erdin and Kulaz (2014), between 32,2-41,4 g by Kaya et al., (2016), between 41,2-41,3 g by Yalçın et al., (2018). Facial grain weight is similar to previous studies. The reasons for the difference are thought to be affected by the genotypes used and environmental conditions.

The results of quality analysis of chickpea genotypes in Adana location are given in Table 5.

In Adana location, the average hundred grain weight values obtained from chickpea varieties in winter sowing were 40,5 g; water absorption capacity 0,460 g/grain; swelling index 2,23%; cooking time 49 min; %protein ratio 25,7%; and sieve values 8,3 mm. The lowest average crude protein values of the genotypes were determined from Ubet variety with 23,6% and the highest average crude protein values were determined from Diyarbakır-3 genotypes with 27,3% (Table 5). Although there is a wide variation in the chemical structure and composition of the grain among chickpea varieties, it has been reported that climate, soil structure, soil nutrient content, agronomic practices, living and non-living stress factors and heredity are effective on the chemical composition of the grain Güngör et al. (2018), Adak, (2021); Erol et al. (2023).

Conclusions

In terms of suitability of chickpea genotypes used in this study for the ecology of the region, some varieties were found to be prominent. The general yield average of the genotypes was determined as 206,5 kg/da. However, in terms of grain yield, Ubet with 264,8 kg/da, Urfagap-1 genotype with 259,5 kg/da, Aksu variety with 258,1 kg/da and Urfagap-2 genotypes with 243,6 kg/da were found suitable for evaluation.

Table 1. Some physical and chemical properties of trial area soils.

Soil Structure							
Distribution							
Sand (%)	**Silt (%)**	**Clay (%)**	**pH (1:1)**	**Lime (%)**	**Org. Matter (%)**	**Total salt (%)**	**P_2O_5 (kg/da)**
32.0	37.7	30.3	7.43	12.0	1.3	0.2	4.1

(Trial Area altitude 23m)

Table 2. Adana province climate values for 2022-23 and long years.

Months	Average Temperature (°C)		Rainfall (mm)		Relative humidity (%)	
	Long Years (1982-2021)	2022-23	Long Years (1982-2021)	2022-23	Long Years (1982-2021)	2022-23
December	10,43	11,2	121,48	24,7	68,67	68,53
January	9,05	9,9	109,01	16,0	67,69	63,65
February	10,15	8,62	81,87	61,1	65,68	58,89
March	13,14	14,86	63,08	81,4	66,74	67,09
April	17,27	17,14	49,67	47,5	68,02	66,08
May	21,40	21,55	42,15	42,2	68,03	61,27
June	25,17	23,72	13,97	0,0	69,01	67,50
July	27,08	36,32	7,46	2,00	69,94	62,15
Total			488,69	274,9		

Table 3. Plant height (cm), days of flowering (days) and anthracnose disease observations in chickpea genotypes.

Variety	Varieties /Line	Plant Height (cm)	Flowering (days)	Ascochyta Blight [*Ascochyta rabiei* (Pass. Labr.)] artificial epidemic	
				Ankara	Eskişehir
1	DİYARBAKIR-1	50,8	72,3	4	5
2	DİYARBAKIR-2	48,5	77,3	7	5
3	DİYARBAKIR-3	55,5	70,8	4	5
4	GAP-1	49,3	72,8	6	5
5	GAP-2	52,5	70,0	6	5
6	GAP-3	46,5	69,5	6	5
7	ADANA-1 (FLIP97-74C / FLIP97-125C // FLIP-98-31C)	56,0	72,3	6	5
8	ADANA-2 (FLIP98-177C /CIYT SP-90/ FLIP85 -75C -5/3/ FLIP-09-21C)	55,0	74,0	4	5
9	ADANA-3 (FLIP98-177C /CIYT SP-90// FLIP85 -75C -5/3/ FLIP-97-32C)	54,0	74,8	4	4
10	ADANA-4 (ER/IŞIK-05-11E/ÇAGATAY)	48,3	72,8	5	5
11	ADANA-5 (MEKSİKA NOHUTU/ CIYT SP-90/ FLIP85 -75C -5E/3/ FLIP-97-90C)	59,8	74,8	5	5
12	HASANBEY	57,8	71,8	7	5
13	ARDA	54,0	74,0	4	5
14	AKSU	56,0	68,3	6	5
15	AZKAN	57,0	74,3	6	5
16	UBET	57,5	71,8	7	5
Average		53,6	72,6	-	-
Minimum		46,5	68,3	4	4
Maximum		59,8	77,3	7	5

Table 4. Grain yield (kg/ha) and 100 grain weight (g) values of chickpea genotypes.

Variety	Varieties	Yield (kg/ha)	100 Grain Weight (g)
1	DİYARBAKIR-1	1715	44,5 c-e
2	DİYARBAKIR-2	1604	40,1 fg
3	DİYARBAKIR-3	2106	40,9 fg
4	URFAGAP-1	2595	46,7 a-c
5	URFAGAP-2	2436	41,2 e-g
6	URFAGAP-3	1899	38,5 g
7	ADANA-1 (FLIP97-74C / FLIP97-125C // FLIP-98-31C)	1295	49,3 a
8	ADANA-2 (FLIP98-177C /CIYT SP-90/ FLIP85 -75C -5/3/ FLIP-09-21C)	2428	45,7 b-d
9	ADANA-3 (FLIP98-177C /CIYT SP-90// FLIP85 -75C -5/3/ FLIP-97-32C)	1963	46,7 a-c
10	ADANA-4 (ER/IŞIK-05-11E/ÇAGATAY)	1828	42,4 d-f
11	ADANA-5 (MEKSİKA NOHUTU/ CIYT SP-90/ FLIP85 -75C -5E/3/ FLIP-97-90C)	1421	47,9 ab
12	HASANBEY	3160	38,8 g
13	ARDA	1926	39,8 fg
14	AKSU	2581	44,6 b-d
15	AZKAN	1428	44,7 b-d
16	UBET	2648	47,1 a-c
Average		2065	43,7
CV (%)		340	5,3
F		not significant	**
Minimum Significant Difference		-	3,3

CV: Variation of Coefficient * : 5% Significant level ** : 1% Significant level

Table 5. Quality analysis results of chickpea genotypes in Adana location.

Variety	Varieties	Dry Weight (100 grain) (g)	Water Intake Capacity (g/grain	Water Intake Index (%)	Cooking Time (minutes)	Protein (%)	Sieve Value (mm)
1	DİYARBAKIR-1	40,1	0,471	2,42	50	27,2	8,2
2	DİYARBAKIR-2	34,8	0,426	2,23	57	25,1	7,7
3	DİYARBAKIR-3	37,4	0,419	2,19	42	27,3	8,1
4	GAP-1	42,9	0,520	2,35	46	25,8	8,5
5	GAP-2	40,9	0,461	2,26	40	26,0	8,4
6	GAP-3	35,3	0,412	2,19	49	26,5	7,9
7	ADANA-1	44,8	0,520	2,26	56	26,6	8,7
8	ADANA-2	40,6	0,443	2,17	52	25,0	8,4
9	ADANA-3	42,1	0,486	2,19	50	24,6	8,7
10	ADANA-4	46,2	0,503	2,20	54	25,1	8,4
11	ADANA-5	46,5	0,499	2,12	50	25,1	8,6
12	HASANBEY	33,9	0,372	2,17	60	25,0	7,7
13	ARDA	37,8	0,431	2,21	46	25,8	8,1
14	AKSU	40,4	0,470	2,26	44	26,1	8,2
15	AZKAN	40,8	0,451	2,20	45	26,8	8,1
16	UBET	42,7	0,476	2,25	49	23,6	8,3
Average		**40,5**	**0,460**	**2,23**	**49**	**25,7**	**8,3**

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Bread Wheat Variety "PARLA"

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ABSTRACT

The aim of this study is to present the yield and winter hardiness characteristics of PARLA variety developed by crossing method to the scientific world. PARLA is bread wheat "SABALAN" as the male parent and "PALANDÖKEN 97" as the female parent. It was registered under the name PARLA at the Field Crops Registration Committee meeting in March 2024 on behalf of the East Anatolia Agricultural Research Institute. This variety has white spikes with awns and red grain color. In yield trials conducted in different regions of East Anatolia of Türkiye, it gave an average grain yield of 7466.2 kg ha^{-1}. The average heading date of the PARLA variety is 10-15 June, plant height is 105-110 cm. 1000 kernel weight is 34 g, and hectoliter weight is 78 kg/hl. The average protein content was measured as 15.6%, flour yield as 62,3 %, Zeleny sedimentation as 59 ml, alveograph energy as 400 joule, gluten index as 93%. PARLA variety has 26.4% higher yield than the mean of yield (5907 kg ha^{-1}).

Keywords: Bread wheat, breeding, quality and yield

Introduction

Among cultivated plants, wheat has a cultivation area of 242.7 million/ha in the world. Total wheat production is 946 million tons and average yield is 3.4 ton ha^{-1}. Türkiye ranks 10th in the list of countries with 6.6 million hectares of wheat cultivation area (Anonymous, 2022a). Wheat, which is the main source of nutrition in human nutrition, has the largest cultivation area in our country as well as in all countries. Türkiye's total wheat production is 20.6 million tons and ranks 9th in the world in terms of production. However, the yield per hectare is considerably lower than many countries. Türkiye's yield average is 2.7 tons ha^{-1} and ranks 16th among the world countries. Grains constitute 73% of the arable land in the Eastern Anatolia Region. The total cereal cultivation area in the region is 1.2 million hectares and wheat is grown in approximately 701 thousand hectares of this (Anonymous, 2022b). Abiotic stress factors are the most important factors affecting yield. Many researchers are trying to develop varieties resistant to drought and cold. For this purpose, Cold and Drought Hardiness Centers have been established in Türkiye and resistance breeding studies have been focused on. It has been emphasized by Sharma and Thakur (2004) that the traits to be used in selection should be evaluated together with grain yield. Winter wheat and other cereal species must be tolerant to winter. Climate data and winter damage findings were compared in many locations in Finland and climate data were related to winter damage levels and that there was a significant connection between winter damage and yield (Peltonen et al., 2011). In the study conducted by Küçüközdemir et al. (2009), 45 genotypes were exposed to different temperatures with different cold acclimation periods, the tolerance of the genotypes were determined and as a result of the study, a winter-hardy variety named Ayyıldız was developed.

Increasing wheat yield in our region and our country will be possible by developing and producing varieties resistant to stress factors. The aim of this study is to introduce the PARLA bread wheat variety, which ranks first in terms of yield and quality to the scientific world.

Materials and Methods

Materials

Our new variety PARLA was compared with 3 advanced breeding lines and Ayyıldız (AYZ), Alturna (ALT), Alparslan (ALP), Palandöken 97 (P-97), Doğu 88 (D-88) varieties. Phenological characteristics of the genotypes are given in Figure 1. According to the Go CHORD graph, the genotypes shown in the red area have red spike color, while the genotypes that are not red have white spike color. The grain color of the genotypes shown in the blue area is red, while the grain color of the ones that are not blue is white. In addition, the genotypes shown in the green area have awned spikes, while the genotypes that are not green have awnless spike structure. Accordingly, it is seen that the Parla variety has white, awned spike and red spike color (Figure 1).

Method

PARLA bread wheat variety was developed by Eastern Anatolia Agricultural Research Institute by hybridization method. The female of PARLA variety is Palandöken 97 variety registered by Eastern Anatolia Agricultural Research Institute in 1997, and its male is Iranian local variety called Sabalan. Hybridization study was carried out in 2005-2006 wheat growing season in Erzurum Central location. It was purified by using modified bulk selection method during it's breeding. Bulk method was made selection from F_1 population to F_5 population. 20 spikes were selected by pedigree (single spike) method in F_5, selected sister lines were planted separately as pure line in F_6. 3 of the lines which were purified in F_6 were selected and taken to the observation nursery and their seeds were multiplied. Selections were made from lines that were prominent in terms of agro-morphological characteristics, resistance to winter and diseases. After obtaining sufficient seeds from the selected lines, standard varieties and many advanced breeding lines were taken to one year preliminary yield and two years yield trials and the trials were established in dry conditions in the Erzurum-Aziziye location. While yield trials were ongoing, all lines in these trials were tested to winter hardiness under controlled conditions at the Cold Hardiness Test Center of the Eastern Anatolian Agricultural Research Institute to determine how many degrees they could be tolerance in without snow environment (Küçüközdemir, 2016). In the winter hardiness tests conducted, it was determined that PARLA showed resistance to -19°C under controlled conditions in without snow environment. From the three sister lines in the yield trials, the best line (PARLA) in terms of yield, yield components, quality, disease and winter resistance was selected and transferred to the regional yield trials together with standard varieties and advanced breeding lines.

Regional yield trials were established in Aziziye, Pasinler, Erzincan and Muş locations for 3 years to determine the yield, yield components and quality characteristics in the region. Trials sowing were made between September 1 and October 1, the most suitable date for winter in Erzurum (Akkaya and Akten 1989; Özcan and Acar 1990). The sowing of trials was completed in mid-October in Muş and Erzincan. Cultural procedures (fertilization, herbicide etc.) were carried out on time. İt was sown 500 seeds/m^2, plots size were 7.2 m^2 in sowing, were reduced to 6 m^2 in harvest. Harvests were done in Muş and Erzincan in July, and in Aziziye and Pasinler in August with a plot harvester (Hege®). Seeds from all plots coming from the locations were cleaned by using plot threshing machines, weighed, yields were calculated as kg/ha, and necessary samples were taken for quality analyses. Quality samples of standard varieties and the candidate (PARLA) were sent to Ankara Field Crops Central Research Institute Plant Food Research Center. Their quality analyses were carried out by the Center. The registration application of Parla, which had high yield in all locations in regional yield trials and whose quality characteristics (Table 1) were at the desired values, was made with the Erzurum B1 code in 2021.

Results and Discussion

In hybridization studies, it is very important to select the selected parents from genotypes with high adaptation to regional conditions. The fact that the parents of the PARLA variety are high yielding and resistant to abiotic and biotic stress factors has caused it to have high yield and adaptation ability. Tan et al. (2005) emphasized that the resources to be used in plant breeding studies should be selected consciously in order to use plant resources more quickly and effectively in plant breeding studies. Özgen (2005) stated that plant breeding studies have an important role in the increase in product in the last 50 years; thanks to classical plant breeding methods, especially cross varieties, significant increases have been achieved in the amount and quality of the product obtained. The data obtained from the Muş location, where the regional yield trials were established, were excluded from the statistical evaluation because they were not in accordance with normality. While no statistical difference was found between years in the Pasinler location, it was determined that there were very significant ($p < 0.01$)

differences between years in the Aziziye and Erzincan locations; between locations in the average of years; and between years in the average of locations. Since rainfall was sufficient and temperatures were at optimum levels in both years in the Erzincan location, yields were also high. Winter drought was experienced in Erzurum in the 2021-2022 and 2022-23 growing seasons, but since air temperatures were above the long-term average, winter damage wasn't occurred. In September, October and November 2021, there was sufficient rainfall in the Aziziye location and the plants emerged, but in the Pasinler location, since the lack of rainfall in September delayed field preparation and therefore planting, the plants did not germinate well and entered the winter very weakly. In years when winter drought occurs, since there is not enough snow cover, there is significant winter damage and therefore plant deaths in varieties sensitive to winter and cold. Therefore, the development and production of winter-resistant varieties is very important. Battenfield et al. (2013) stated that in recent years, the private and public sectors have made major investments in wheat breeding studies, and despite the negative impact that climate change will have on wheat yield in the large plains, genetic progress can minimize this effect and probably balance some of it. Toklu et al. (2001) reported that there has been progress in the potential yields of the selected genotypes in recent years and that this potential can be increased even further.

In 2021-22, a total of 426.5 mm of precipitation occurred in Aziziye and 310.5 mm in Pasinler; and in 2022-23, a total of 449.6 mm of precipitation occurred in Aziziye and 423.7 mm in Pasinler. Although there was not much difference in total precipitation in Aziziye in both years, in the second year, the fact that precipitation was more in the beneficial period for plants (April-June) doubled the yields. The average yield in the first year was around 2500 kg ha^{-1}, but Parla, which stands out with its earliness, had a yield of 30-40% more than other varieties with 4208.3 kg ha^{-1}. Our other early variety, Alparslan, followed with 3458.3 kg ha^{-1}. In the second year, all genotypes gave yields close to each other. Demir and Turgut (1999) stated that breeding provided a 30-50% increase in yield and that these varieties obtained were suitable for the region, resistant to drought, cold, pests, early maturity, disease and high yield. Also, the situation is similar for the Parla variety in the Pasinler location. 310.5 mm of rainfall occurred in the first year in the Pasinler location. The Parla variety was not affected by the winter and early spring drought experienced this year, and the average yield of the trial was 5246 kg ha^{-1}, while the Parla variety had a yield of 9103 kg ha^{-1}, which was approximately twice the yield of the other genotypes. The highest yield in all locations was obtained from the Parla variety in the year averages, and 9483.3 kg ha^{-1} was obtained in Erzincan, 7251.4 kg ha^{-1} in Pasinler and 5663.9 kg ha^{-1} in Aziziye. Again, when the data of three locations and two years were evaluated together, the highest yield belonged to the PARLA variety with 7466.2 kg ha^{-1}. Similarly breeding research work was also carried by Panwar et al. (2013) and developed a new high yielding bread wheat variety WH 1105, it was also good in quality parameters and resistant to stress.

According to the Heatmapper graph (Figure 2), as the color goes from red to green, while the yield values of the genotypes in the relevant location increase, the black color represents the average. Accordingly, it was seen that the Palandöken 97, Doğu 88, Line-2, Ayyıldız and Line-3 genotypes had average and below average yield values. However, it was determined that the Line-1, Alturna, Alparslan and PARLA genotypes had high yield values. In addition, the fact that the color tone of the PARLA variety had a lighter green color compared to the Line-1, Alturna and Alparslan genotypes showed that it had the highest value in the trials.

According to the PCA graph (Figure 3), it was seen that the genotypes were divided into 3 different groups. While the first group included Ayyıldız, Alparslan, Line-2, Line-1 and Alturna genotypes, the second group included D-88, Line-3 and Palandöken-97 genotypes. The PARLA variety was separated from the other genotypes in terms of yield value alone and was included in the 3th group.

In the Venn graph, the intersection cluster of locations and location averages is generally seen. According to this graph, the PARLA variety stands out as the genotype with the highest yield value in all locations and location averages. While Alturna and LINE-1 genotypes were the genotypes with the highest yield after Parla in all 3 locations, the Ayyıldız variety was the prominent variety in the Erzincan location, and the Alparslan variety was the prominent variety in the Aziziye and Erzincan locations (Figure 4).

When examined in terms of quality characteristics, it is seen that PARLA's 1000 grain weight is 34 g, hectolitre weight is 78 kg/hl, protein ratio is 15.6%, Zeleny sedimentation is 59 ml, waiting sedimentation is 61 ml, alveograph energy value is 400 W, gluten index is 93%, and flour yield is 62.3% (Table 2). Ayrancı et al. (2004) reported that the aim of breeding is to develop stable varieties in terms of yield and quality and that promising genotypes can be tested in different places and years and the superior ones can be used as variety candidates.

Wheat has strategic importance in Türkiye and the world. Many crises that have occurred in the world have shown the importance of countries being self-sufficient in terms of food. Although Türkiye is a self-sufficient country in terms of wheat production, exports need to be increased in terms of the country's economy. Global climate changes necessitate the development of high-yielding, high-quality varieties that are highly adaptable, resistant to abiotic and biotic stress factors.

Conclusions

In winter wheat breeding studies, productivity and quality, as well as resistance to winter, cold and drought, are the most important selection criteria. The PARLA bread wheat variety stands out in many ways. The PARLA is a variety that tolerant to winter, drought and rust diseases. İt has high-yielding and high-quality parameters. An application has been made for the variety to be taken under protection and production has started as of 2024. The elite seed of the variety will be produced by the Eastern Anatolia Agricultural Research Institute. It will contribute to the country's economy by benefiting Turkish agriculture.

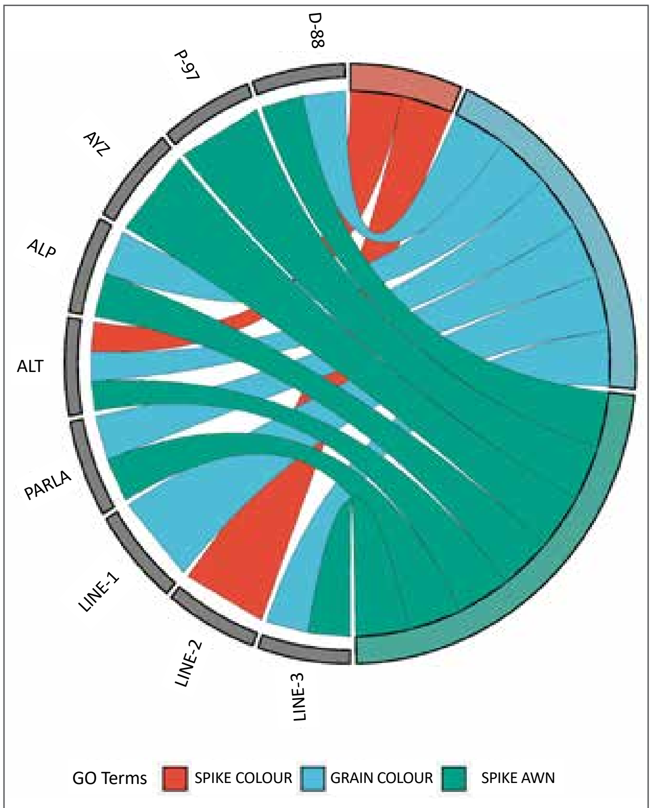

Figure 1. Go CHORD graph (Morphological characteristics of the genotypes in the trials).

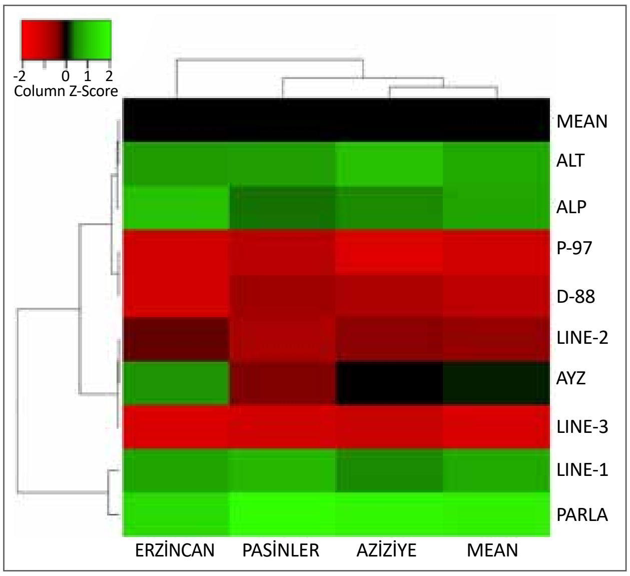

Figure 2. Heatmapper graph (Status of genotypes based on locations).

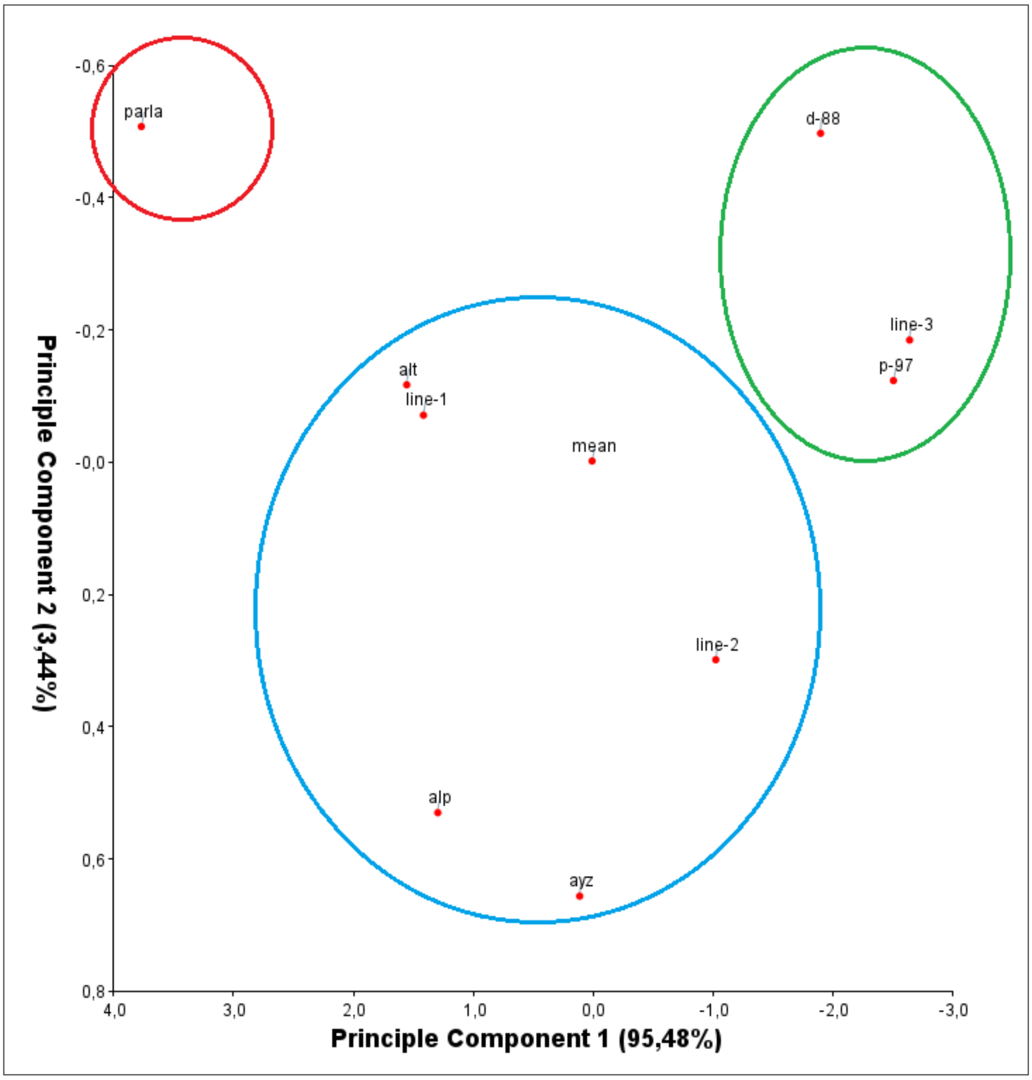

Figure 3. PCA graph (Grouping of genotypes).

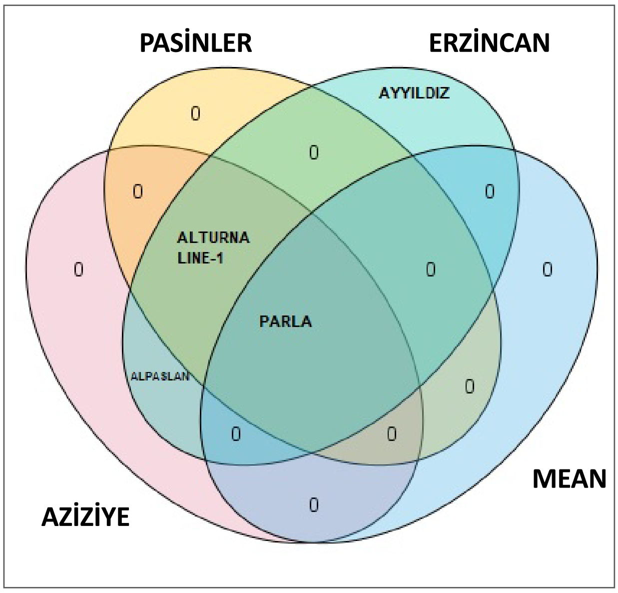

Figure 4. Venn graph (Prominent genotypes in locations).

Table 1. Yields of the genotypes based on locations in 2022 and 2023 (kg ha^{-1}).

GENOTİP	Yield (kg ha^{-1})											
	Aziziye			Pasinler			Erzincan			2022	2023	Mean
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean			
PARLA	4208.3 a	7119.4 AB	5663.9 A	9102.8 A	5400.0 CD	7251.4 A	1131.39 A	7652.8 B	9483.3 A	8203.3 A	6724.1 B	7466.2 A
ALTURNA	2713.8 bc	7522.2 A	5118.1 AB	5297.2 BC	6527.8 A	5912.5 B	9450.0 A-C	7666.7 B	8558.3 AB	5820.4 BC	7238.9 A	6529.6 B
LİNE-1	2925.0 a-c	6588.8 BC	4756.9 BC	6569.4 B	5716.7 BC	6143.1 B	8958.3 BC	8380.6 A	8669.4 AB	6150.9 B	6895.4 B	6523.1 B
ALPARSLAN	3458.3 ab	6055.6 CD	4756.9 BC	6013.9 B	5294.4 DE	5654.2 B	10450.0 AB	7655.6 B	9052.8 AB	6640.7 B	6335.2 C	6487.9 B
AYYILDIZ	2555.5 bc	6452.8 C	4504.2 B-D	3966.7 D	5941.7 B	4954.2 C	9052.8 BC	7900.0 B	8476.4 BC	5191.7 CD	6764.8 B	5978.2 C
LİNE-2	2902.7 a-c	5580.6 DE	4241.7 C-E	4100.0 CD	5144.4 DE	4622.2 CD	7961.1 CD	7166.7 C	7563.9 C	4988.0 CD	5963.9 D	5475.9 D
DOĞU 88	2366.7 bc	5727.8 DE	4047.2 C-E	4322.2 CD	5088.9 DE	4705.6 CD	6230.6 DE	6680.6 D	6455.6 D	4306.5 DE	5832.4 D	5069.4 DE
PALANDÖKEN 97	1933.3 c	5305.6 E	3619.4 E	4447.2 CD	4433.3 F	4440.3 CD	6575.0 DE	6500.0 D	6537.5 D	4318.5 DE	5413.0 E	4865.7 E
LİNE-3	1508.3 c	6158.3 CD	3833.3 DE	3394.4 D	4938.9 E	4166.7 D	5869.4 E	6730.6 D	6300.0 D	3590.7 E	5942.6 D	4766.6 E
Average	**2730.2 B**	**6279.0 A**	**4504.6 C**	**5246.0 ns**	**5387.3 ns**	**5316.7 B**	**8429.0 A**	**7370.4 B**	**7899.7 A**	**5468.4 B**	**6345.6 A**	**5907.0**
LSD (P=0.05)	1463.7*	558.9**		1296.1**	383.9**		1886.2**	298.7**				
CV (%)	13	5	14	14	4	11	14	2	10	17	4	15
LSD (P=0.05)		Year: 486.1** Genotype: 757.4** Year x Genotype: 1071.2*			Year: 382.0 Genotype: 660.4** Year x Genotype: 933.8**			Year: 291.8** Genotype: 967.8** Year x Genotype: 1368.7**		Location: 461.9** Genotype: 890.2** LocxGen: 1541.9**	Location: 168.1** Genotype: 235.8** LocxGen: 408.4**	Year: 213.8** Genotype: 453.6** YearxGenotype: 641.5** LocxYear: 542.3** Genx Lok(Year):1111.1**

ns: non significant; **: significant at 0.01; *: significant at 0.05

Table 2. Quality values of varieties included in the trials.

Varieties	Grain color	SKCS (%)	1000 kernel weight (g)	Hectolitre weight (kg/hl)	Protein ratio (%)	Zeleny sedim. (ml)	Waiting sedim. (ml)	Water Absorb. (%)	Alveograph Energy (W)	Gluten (%)	Gluten index (%)	Flour yield (%)
Doğu 88	Red	60,11	34	78,8	13,94	48	48	62,9	219	33,5	26,5	61,0
Palandöken 97	White	13,44	39	77,2	13,86	36	34	54,0	158	31,4	43,8	57,3
Ayyıldız	White	77,6	35	76,8	14,97	41	61	62,9	422	23,8	97,9	57,0
Alparslan	Red	64,14	29	77,2	15,18	70	72	63,0	403	37,6	87,0	56,8
Alturna	Red	70,15	38	78,4	13,80	61	73	63,5	429	29,8	93,3	65,2
Erzurum B1 (PARLA)	Red	63,41	34	78,0	15,6	59	61	63,0	400	42,3	93,0	62,3

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Advances in Breeding Techniques for Genetic Improvement in Ashwagandha [*Withania somnifera* (L.) Dunal]

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ABSTRACT
Ashwagandha (*Withania somnifera* (L.) is a medicinal plant, also known as winter cherry or gooseberry. The Indian subcontinent, North-Western and Central parts of Africa, and the Mediterranean region are the native palaces of ashwagandha. The dry and subtropical climate is best suited for its growth and development. Its roots are mainly consumed as a health tonic for fitness, longevity and vitality. It is an important stimulant of the human immune system cells, phagocytes, and lymphocytes: and it is also able to relieve the effects of stress and improve health. It is also utilized to treat COVID-19, flu, insomnia, asthma, bronchitis, emaciation, dementia, inflammation, neurological disorders, and Parkinson's disease. It has 12 types of withanolides, five unknown alkaloids, several free amino acids, glycosides, tannins, chlorogenic acid, glucose, and several flavonoids in the leaves. The availability of Ashwagandha as a natural vegetation is reduced drastically due to its constant uprooting for utilization. Therefore, it is an insistent need to evolve the high yielding varieties of ashwagandha. Even today its cultivation relies on wild, semi-wild plants or primitive cultivars, which have not acquired genes for high productivity. There is enormous scope to improve its yield and quality. Ashwagandha is generally grown under harsh climatic conditions; therefore, identification of the superior genotypes for drought and high-temperature tolerance is essential for genetic manipulation through breeding techniques. Nowadays, plant phenomics is a good technique for analyzing plant biomass, development and growth rate, as well as leaf chlorophyll, carbohydrates, protein, and water content. The male and female parts are present in the same flower and pistil is surrounded by anthers and both mature at same time, which favors self- pollination. But natural out-crossing is also observed in some conditions, thus hybridization is a possible way to utilize heterosis through transgressive segregants. Therefore, any breeding methods may be applied as per suitability and availability of plant genetic resources. In addition, molecular breeding is an excellent way to enhance the specific biomolecules through marker assisted technique, suitable for any kind of genetic improvement related to biotic and abiotic resistance.

Keywords: *Withania somnifera*, Ashwagandha, breeding aspects, root yield, biomolecules

Introduction

Ashwagandha belongs to the family "Solanaceae" and genus "*Withania*" and its botanical name is *Withania somnifera* (L.) Dunal. It is a self-pollinated crop having the chromosome number 2n=48. It is known by several other names viz., winter cherry, Indian ginseng, Asgandh and poison gooseberry. The ashwagandha plants, berries, seeds and roots are presented for identification in Fig. 1. It is a perennial plant species with immense therapeutic uses in traditional as well as modern medicine systems (Datta et al., 2010). Ashwagandha is a "royal herb" because of its potent rejuvenating and life-prolonging effects on the human body (Sharma et al., 2011). This herb has antioxidant, anxiolytic, adaptogens, anticancer, anti-parkinsonian, anti-venom, and anti-inflammatory properties (Gupta and Rana, 2007). It also acts on various systems of human body including neurologic immune, energy-production, endocrine and on the reproductive system. It has regenerative properties, and thus, useful to treat nervous fatigue, insomnia, potency issues, tiredness, skin issues, coughing, liver tonic, anti-arthritic, resolving reproductive system issues, and other ailments (Arya et al., 2021).

In the Indian ayurvedic medicinal system, it is popularly known as rasayana, or a tonic for fertility and longevity (Singh et al., 2010). Its root contains flavonoids, alkaloids, steroids, and many active functional ingredients (Kumar et al., 2015). It is used for headache treatment, development of the nervous system, heart problems, anesthesia, blood pressure and reduced cholesterol level (Kirti and Arya, 2019). Aslo is utilized in a wide range of clinical activities such as immunomodulation, memory sharpener, stress elevator, anti-epileptic, anti-ageing and antioxidant (Arya et al., 2022a). Besides, it is also effective to cure hypoglycemic, cardiorespiratory and hypocholesterolemia problems (Tiwari et al., 2014). Generally, its roots extracts and powders are available in markets for use as prescribed doses with water, milk, ghee, or honey (Gupta et al., 2006).

Origin and distribution

Range of distribution of ashwagandha includes the Canary Islands and the Mediterranean region, as well as Africa, the Middle East, India, Afghanistan, Pakistan Sri Lanka, and China (Fig. 2). It originated from north-western and central India as well as the Mediterranean region of Africa (Kumar et al., 2020). It is a xerophytic plant and found widely adapted to diverse climatic conditions. However, it thrives best under arid and semi-arid climatic conditions which is characterized by sandy loam soil with adequate drainage and warm environment with sufficient rainfall around 400mm (Jana and Charan, 2018). In India, for commercial cultivation it is grown in several provinces and its roots are exported in the international market. In All India coordinated trials the maximum root yield of 1.0-1.1 tons/ha was observed.

Genetic variability and related species

Genetic improvement of any crop depends on the available genetic variability for yield and its contributing traits as well as quality parameters. A number of researchers reported sufficient genetic variability and genetic divergence in the ashwagandha using conventional methods (Kumar et al., 2007; Yadav et al., 2008; Kumar et al., 2012; Joshi et al., 2015; Sukh et al., 2015; Patel and Desai, 2017; Srivastawa et al., 2018; Ekka et al., 2021; Venugopal et al., 2021) and modern molecular techniques (Chaurasiya et al., 2009; Arif et al., 2010; Parita et al., 2018; Koli 2022). When sufficient genetic variability or a particular gene of interest is not found within the species, it may be transferred from the related species. In the case of ashwagandha, there are about 61 related species have been reported throughout the world; these belong to the genus *Withania*. Out of these, the most important are *Withanis somnifera* (L.) Dunal, *W. coagulans* (Stocks) Dunal, *W. ashwagandha*, *Withania frutescens* (L.) Pauguy, and *W. begonifolia* (Roxb.) Hunz (Srivastava et al., 2020).

Bioactive compounds

Bioactive compounds of ashwagandha such as Withaferin-A, Withanone, Withanoside IV, Withanolide-A, and Sitoindosides VII-X play an important role alone or in combination as potential therapeutic agents (Kaur et al., 2017). Twelve withanolides, five unidentified alkaloids, several free amino acids, chlorogenic acid, glycosides, glucose, condensed tannins, and flavonoids are the bioactive compounds found in the plant (Indian chemotype) (Khare, 2007). Proteins like glycoprotein and withania lectin protein have medicinal properties. The main alkaloids belonging to ashwagandha are withanolide, somniferine, somniferinine, somine, withanine, pseudowithanolides, withanonine and withasomine (Covello and Ciampa, 1960) and (Patel and Desai, 2017). Like ginseng, ashwagandha was also found to be effective against COVID-19. Young (2022) revealed the potential preventive and therapeutic roles of ginseng in COVID-19 based on its regulatory role in inflammasome initiation.

Ashwagandha plants are also well known to trigger the immune system cells, namely, lymphocytes and phagocytes, which also assist in controlling the effects of stress and promote general wellness and other problems (Singh et al., 2001). Phyto-chemicals and root extracts have antiviral activity and may be efficient in controlling viral infections (Balkrishna et al., 2020). Now-a-days, an immunity boosting plant, is playing a very vital role to fight against coronavirus (Koli et al., 2021) Hoffmann et al. (2020) observed that Withanone and Withaferin-A interact with transmembrane protease serine 2 (TMPRSS2) and block entry of SARS-CoV2 into cells. Kumar et al. (2020a) also reported inhibitory potential of three natural compounds, Wi-A, Wi-N and CAPE for TMPRSS2 besides its known inhibitor Camostat mesylate. Sangwan and Sangwan (2013) studied the secondary metabolites and reported that the withanolides are C28 steroidal structures based on an ergostane system having oxidation at C22 and C26 location to form a lactone ring. The tri-terpenoid source pathway is used to construct withanolides.

Sivananthan et al. (2014) explained the biosynthesis of major and minor withanolides in *Withania somnifera* and found that the highest total withanolides detected withanolide A (7606.75 mg), withanolide B (4826.05 mg), withaferin A (3732.81 mg), withanone (6538.65 mg), 12 deoxy withanstramonolide (3176.63 mg), withanoside IV (2623.21 mg), and withanoside V (2861.18 mg)] were obtained in the combined treatment of chitosan (100 mg/l) They reported higher concentrations of total withanolides in shake-flask culture (2.13-fold) and bioreactor culture (2.13-fold) as compared to control temperature (1.66-fold). Generally, the bioactive compound content of ashwagandha increases when plants are in stressful conditions. It is important for plant adaptation and protection against adverse environmental conditions (Ramakrishna and Ravishankar, 2011). Bioactive compounds are formed as a protection mechanism in response to abiotic and biotic stress conditions. Biochemical and morphological variations highly depend on the environment and interaction with the environment (Arya et al., 2022b).

Earlier, the medicinal plants were easily available in forest areas and mountain regions, but due to continuous utilization at large scale reduced their availability. Therefore, it is need of hour to develop the high yielding improved varieties of important medicinal plants to produce the good quality raw drugs to fulfill the local demands of ayurvedic medical practitioners as well as the global demands of drug manufacturing industries (Arya et al., 2022a).

A. *Conventional Methods*

Conventional breeding methods are, although time consuming and labour intensive but still effective and useful to develop new varieties in ashwagandha. Most used conventional methods are discussed here:

Pure line breeding method: Ashwagandha is predominantly a self-pollinated plant species due to self-compatible pollination behavior is mainly accomplished due to proximity of stigma and anthers (Mir et al., 2012). Therefore, a pure line breeding method is used for its quick genetic improvement from the past several decades. In this method, the most desirable plants are selected based on root yield contributing traits and quality parameters (Fig. 3). The efficacy of selection generally depends on the heritable variations available in the base population (Koli et al., 2022). Manivel et al. (2017) studied a set of ashwagandha 328 (DWS1 to DSW327) pure lines derived from JA 134. According to Srivastava (2018) high heritability in conjunction with high genetic advance was observed for fresh root weight, 12 deoxywithastramonolide in roots, and plant height, which indicated that selection could be effective for these traits. Kujur (2021) reported strong heritability and high genetic advance due to additive gene action, and hence selection particularly for yield and quality parameter would be effective.

Pedigree method: In this method, two genetically diverse parents are crossed, and the pedigree record of segregating generation is maintained (Fig. 4). Using this, superior and desirable traits are combined in one parent and sometimes the transgressive segregants to be evolved due to synergistic effect of different gene combinations (Koli and Arya, 2022). Dhuri et al. (2017) reported high heterosis for root yield and other traits. Thus, there is possibility to obtain the desirable transgressive segregants for root yield and its quality parameters. The Bulk method is the modification of Pedigree method, and it is commonly used to evolve the population having resistance or tolerance to biotic and abiotic stress. In this scheme, plants are grown in the field to face all the natural calamities and plants surviving in natural conditions are harvested in bulk up to F_6 generations. Then, individual plants were selected and harvested separately and tested in trials for their performance.

Back cross method: This method is used when a most promising variety becomes susceptible to disease or insect pests and a source of resistance is available (Fig. 5). The procedure of gene transfer will depend on inheritance of genes whether recessive or dominant. In case of recessive gene transfer, one generation selfing is required to identify the high yielding desirable plant with resistance. This may be utilized to improve the quality parameters if high heritability is available. Medicinal plants are generally cultivated under harsh climatic conditions; therefore, identification of the superior genotypes for high temperature tolerance is essential for effective manipulation through breeding techniques (Arya et al., 2022b). Therefore, the newly developed elite genotypes of Ashwagandha to be evaluated for heat stress under semi-arid conditions.

According to Arya et al. (2022b) the breeding among high yielding genotypes (HWS 105 and HWS 1333) and stress tolerant genotypes (JA 134 and RAS-16) may lead to development of transgressive segregants, having the potential of high root yield along with heat tolerant characteristics. Kumar et al. (2012) studied different growth phases and low temperature stress - and concluded that the enhancement of marker secondary metabolites is not a direct consequence of plants' phenology, but low temperature also acts an important factor. Econometrics based on root biomass yield and content of secondary metabolites in various growth phases recommended 180 days after plantation to be the most suitable time for root harvesting.

B. *Modern Techniques*

The development of useful and cost-effective modern techniques is needed in the present era, for rapid development of new high yielding and quality cultivars of ashwagandha. Therefore, these would be utilized in the ashwagandha breeding programs. The plant phenomics, speed breeding, double haploids and molecular markers once identified and established could offer consistent and remunerative results as described below:

***Plant phenomics*:** It is a good technique to analyze plant features such as plant biomass, its development & growth rate, leaf pigments (chlorophyll and anthocyanin), and deposits of lignin, carbohydrates, starch, and protein content in the plant and water content. It empowers the plant breeders to quickly assess ashwagandha plants for drought tolerance, salt tolerance, heat tolerance, nutrient use efficiency and improvement in herbage and root yield and its quality parameters (Fig. 6). Drought is a most severe and unpredictable abiotic stress, faced at any stage of growth and affecting crop yields. Therefore, it is necessary to develop drought tolerant cultivars to ensure sustainable yield production in an ever-changing climate (Joshi et al., 2021). Now-a-days, to overcome the issues of global warming, the climate resilient varieties are in more demand. With the help of plant phenomics techniques, climate resilient varieties could be developed for its commercial cultivation. In ashwagandha, erect plant with 1-3 main branches having single prominent tap root supported with minor secondary roots and root hairs seems to be the most desirable phenotype which, can tolerate drought stress and accumulates maximum alkaloids.

The plant phenomics technique constitutes a modern glasshouse with headhouse, laboratory space, growth chambers and a state-of-the-art, automated, high-throughput phenotyping system. The phenotyping system houses have a large pot carriers on a 250 m conveyor belt system for automated watering, weighing and high- throughput digital imaging with the help of two cameras, visible (RGB) and hyperspectral (Surya Kant et al., 2023 personal communication). It is an excellent technique to speed up the assessment of the available germplasm for further utilization in development of new varieties of ashwagandha.

According to Banerjee et al. (2020) the precise, efficient, and timely measurement of traits in crop plants is essential in the evaluation of the breeding lines. in breeding trials, assessment of biomass is difficult, as reproductive and senescence stages do not relate to reflectance spectra, and multiple growth stages occur concurrently in diverse genotypes. Moreover, vegetation indices (Vis) saturate at high canopy coverage, and vertical growth profiles are difficult to capture using Vis. A new program was implemented involving a fusion of complementary spectral and structural information, to calculate intermediate metrics such as crop height model (CHM), crop coverage (CC) and crop volume (CV), which were found useful to calculate dry weight and fresh weight of above-ground plants. As we know, roots are underground plant parts and responsible for absorbing the water and nutrients from the soil. Therefore, identification of important root traits responsible for consumptive use of soil moisture and nutrients particularly under the stress environment is essential. But the roots vary as per the growing conditions, and it becomes tough to record the observations on roots. Therefore, Kennedy et al. (2022) suggested the different growing techniques, imaging cameras and analysis software programs for recording the better observation on important root traits.

Double haploid technique: This is the most successful technique to obtain the 100% homozygous lines in one year in self-fertilized plant species otherwise it takes nearly 6-7 years to get the homozygous lines (Fig. 7). According to Lemos et al. (2022) double haploid lines may be achieved through *in vitro* anther or pollen culture of F_2 plants and followed by chromosome doubling through colchicine application. For the development of double haploids, a standard protocol is required to be developed for ashwagandha. It is already developed in some of the solanaceous plant species i.e. in Datura by Maheshey et al in early 1970s and in tobacco by Kasperbauer and Collins in 1974.

Therefore, by using the available literature for the development of double haploids in datura or tobacco and tissue culture techniques for micropropagation in ashwagandha double haploids could be developed. Generally, double haploid production procedure has five steps as depicted in Fig. 7. Das et al. (2011) reported *in vitro* and seed propagated plants of elite genotypes with high performing recommended varieties Poshita and Jawahar 22 of ashwagandha for cytomorphological parameters and chemical contents. The results demonstrated the reliability of *in vitro* raised plants, highlighting the value of biotechnological approaches in the development of planting materials. This is one of the fastest techniques to breed new genotypes/ varieties. Kaul et al. (2009) described that *in vitro* procedure could be well utilized for rapid amplification of a selected genotype and hybrid line.

Nagella and Murthy (2010) studied cell suspension cultures for the development of withanolide A and reported that 10 g L^{-1} of inoculum on a fresh weight basis, full strength MS medium, 3% (w/v) sucrose, a four-week culture cycle, and an initial medium pH of 5.8 were the best for biomass accumulation. These findings are beneficial in the scaling-up phase. Sivanandhan et al. (2014) studied the impact of seaweed extracts on biomass and withanolides accumulation in shoot suspension culture. Supplementing 40 % G. edulis extract in MS liquid medium for 24 hours resulted in the highest biomass accumulation [62.4 g fresh weight and 17.82 g dry weight (DW)] and withanolide production (withanolide A 0.76 mg/g DW; withaferin A 2.80 mg/g DW; withanolide B 1.66 mg/g DW; and withanone 2.42 mg/g DW) after 35 days of culture. For optimal biomass and withanolide processing, this naturally available G. edulis extract-treated multiple shoot suspension culture protocol was found as a viable alternative to shake-flasks. Recently, Hancock et al. (2015), Ma et al. (2020) and Lemos et al. (2022) used the double haploid production technology successfully in tobacco.

Marker Assisted Selection

The molecular markers are useful to study the genotypes of ashwagandha for the genetic distinctness, uniformity, discrimination, so that the identified desirable genotypes could be utilized in further varietal developmental programs. Molecular markers are more advantageous as they are not influenced by the environment and large samples can be tested quickly and accurately. Several researchers used different molecular markers and some of them are discussed here. In recent years, nucleotide gene sequencing is permitted for simple and fast recognition of any genotypic mutation such as SNP, SSR, and Insertion/Deletion (IN/DEL) in full-length genomes of different genotypes. This technique gives more remuneration at low costs as well as rapid identification of molecular markers. Diverse DNA markers like RFLP, RAPD, STS, SSR, ISSR, ETS, DArT and SNP analyses are being developed for differentiation, identification and selection of promising genotypes.

Restriction fragment length polymorphism (RFLP): It is based on differences in the length of DNA fragments obtained when DNA from different genotypes is digested with restriction enzymes that recognize specific DNA sequences. Although RFLP is an excellent technique for genome mapping and genetic fingerprinting, it requires a large amount of sample DNA and probe labeled DNA sequence that hybridizes with one or more fragments (Jo et al., 2017).

Random Amplified Polymorphic DNA (RAPD): The RAPD markers are comparatively simpler and easier than RFLP and to identify polymorphic DNA fragments. It requires a small quantity of DNA, thus making it a more economical method. However, RAPD is a dominant marker and only useful in advance generations assessments. It is reported that the classification of ashwagandha species by comparing interspecies and intraspecies mutational relations by means of polymorphic bands of RAPD. Based on the genetic diversity, it is possible to do genetic improvement in the cultivars of ashwagandha. Chaurasiya et al. (2009), Arif et al. (2010) and Dharmar and De Britto (2011) studied divergence in ashwagandha through RAPDs, isoenzymes, polypeptide polymorphism, and withanolide profiles. Chauhan et al. (2022) used RAPD and reported its simplicity for the selection of high-yielding bioeconomic varieties that could be utilized to improve ashwagandha breeding programs. RAPD generates nonspecific amplicons depending on experimental and ambient conditions; therefore, it is difficult to ensure reproducibility. To overcome the problem, an analysis of a sequence-characterized amplified region (SCAR) marker was found effective in terms of convenience and reproducibility.

Sequence-tagged site (STS): STS markers involve analysis of a sequence for specific clones followed by construction of diverse primers for genetic analysis. A DNA library requests to be recognized for the construction of specific STS primer sets. Recently, methylation filtering (MF) enables removal of repetitive DNA and is thus useful for creating a library of genetic regions. RAPD and PCR-RFLP markers explain insufficient numbers of suitable loci within the genome and have poor reliability, sensitivity, discriminatory ability, and reproducibility, posing difficulties in differentiation in varieties. In contrast, an STS marker with simplicity allows for easy verification of outcome with high reproducibility and, therefore, useful for analysis of massive genetic resources or varieties.

Simple Sequence Repeats (SSR): It uses the fabrication of primers for repeated onomeric, dimeric, trimeric, and early selective strategies tetrameric DNA sequences. This method is costly and time consuming for construction of a genomic library and for primer invention; however, it is a codominant marker and has very high reproducibility. Paramar et al. (2015) derived SSR markers from cross transferability are less polymorphic than ESTs-SSR, because there is a significant conservation of markers among genera. A total of 13 alleles were detected in 10 loci, with an average of 1.3 per locus. The applicability of cross-genera amplification of solanaceous SSR provides a good opportunity for studying *W. somnifera*. The new set of six polymorphic EST−SSR loci will enable the characterization of population genetic diversity and structure throughout the species in conjunction with cross-transferable SSRs for which till date no information about EST-derived as well as genomic SSR is available. (Paramar et al., 2015). Molecular characterization with the help of SSR markers, the promising genotype HWS 8-18 was also compared with other varieties/genotypes (Table 1).

It was found unique and different from all other genotypes/varieties. The genotype HWS 8-18 is differentiated based on presence of CAMS 34 primer 50 kb band which was absent in HWS-205, HWS-205 and HWS 12-12. In addition to this, it was differentiated from HWS 1203 and JA-20 due to absence of CAMS 34 primer 400kb band, as this was present in HWS 8-18 (Koli and Arya 2022). Parita et al. (2018) studied 36 ashwagandha genotypes using SSR primers. Amplicons' sizes ranged from 130 to 1652 bp, with an overall polymorphism of 94.71 percent. For the polymorphic SSR primers, the PIC value ranged from 0.219 (EMS-5) to 0.865 (EMS-12). Thirteen SSR primers revealed the dissimilarity indices, ranged from 0.069 (between MWS-205-3-2 and MWS-322-1-2) to 0.846 (between RAS23-2-1 and MPAS-15-3-1). A dendrogram was drawn on DARWIN 6.0.15 PC-based software and grouped in three clusters.

Single Nucleotide Polymorphism (SNP): SNPs are used to identify the genetic variations among the genotypes. Each SNP represents a difference in a single DNA building block, known as a nucleotide. Arpan et al. (2014) investigated whether heterotic positive QTL alleles based on hybridization can be introgressed in a fine quality good agronomic genetic base using marker assisted selection. Via RNA sequencing, they developed a wide resource of *Withania* specific genomic microsatellite markers and SNP. The expression of 101245 unigenes in parents was quantified using an RNA-seq technique. Thirty percent of transcripts had different speech levels between parents, with the majority having more than 1.5 fold changes. RNA sequencing was found helpful in marking the Withanolide biosynthesis pathway and identifying SNPs that imparts functional polymorphism in pathway genes, allowing for the guess of heterosis potential.

Inter-Simple Sequence Repeat (ISSR): It showed considerable diversity between the genotypes. The combined unweighted pair group technique with arithmetic mean (UPGMA) dendrogram of morphological, biochemical, and molecular markers grouped all 25 genotypes of ashwagandha into two main clusters at 0.61 coefficient value. In addition to this, secondary metabolite profiling by high-performance liquid chromatography (HPLC), there were high variations for withanolide B (WL-B), withanoside-V (WS-V), wedelolactone (WDL), withanoside-IV (WS-IV), and withaferin A (WF-A) content between different genotypes. For the total alkaloid and withanolide concentration in the roots and leaves, high heritability with an increased genetic gain was observed, indicating that selection based on these traits could be an effective method in breeding programs. Furthermore, the path coefficient analysis showed a direct positive impact of the total root fiber, WL-B (leaves), WF-A (leaves), WS-IV (roots), WDL (roots), and the total alkaloid content on the dry root yield. High content of WDL, a high-quality bioactive withanolide, was also described for the first time in the genotype UWS23. These properties can further be exploited to improve the dry root yield in ashwagandha genotypes. The outcomes of the present study also provide an essential foundation for the selection of high-yielding bioeconomic varieties that could be utilized to improve Ashwagandha breeding programs (Chauhan et al., 2022).

Koo et al., (2022) conducted simultaneous analysis of transcriptomes and metabolomes from adventitious roots of two tetraploid species (*Panax ginseng* and *P. quinquefolius*) and two diploid species (*P. notoginseng* and *P. vietnamensis*) revealed the diversity of their metabolites and related gene expression profiles.

Results

The transcriptome analysis showed that 2,3-OXIDOSQUALENE CYCLASEs (OSCs) involved in phytosterol biosynthesis are upregulated in the diploid species, while the expression of OSCs contributing to ginsenoside biosynthesis is higher in the tetraploid species. In agreement with these results, the contents of dammarenediol-type ginsenosides were higher in the tetraploid species relative to the diploid species. They indicated that the accumulation pattern of ginsenosides correlates with the expression level of various OSC genes and with polyploidy level in *Panax* species, suggesting that dammarane-type and oleanane-type ginsenoside biosynthesis pathways are upregulated in tetraploid *Panax* species, likely due to the genome duplication event.

CRISPR Technology: This technology is the latest one used for genetic improvement in crop plants. It may be utilized in ashwagandha, as it is already used by Choi et al. (2022) in ginseng. They designed two sgRNAs (single guide RNAs) for target mutations in the exon sequences of the two PPT synthase genes (both PPTa and PPTg sequences) with the CRISPR/Cas9 system. Transgenic ginseng roots were generated through Agrobacterium-mediated transformation. The mutant lines were screened by ginsenoside analysis and DNA sequencing. Result: Ginsenoside analysis revealed the complete depletion of PPT-type ginsenosides in three putative mutant lines (Cr4, Cr7, and Cr14). The reduction of PPT-type ginsenosides in mutant lines led to increased accumulation of PPD-type ginsenosides. The gene editing in the selected mutant lines was confirmed by targeted deep sequencing. They have established the genome editing protocol by CRISPR/Cas9 system in *P. ginseng* and demonstrated the mutated roots producing only PPD-type ginsenosides by depleting PPT-type ginsenosides. Because the pharmacological activity of PPD-group ginsenosides is significantly different from that of PPT-group ginsenosides, the new type of ginseng mutant producing only PPD-group ginsenosides may have new pharmacological characteristics compared to wild-type ginseng. This is the first report to generate target-induced mutations for the modification of saponin biosynthesis in *Panax* species using CRISPReCas9 system.

Multi Location evaluation

Once the promising genotypes are developed and identified as promising at one location, they are further evaluated along with checks for its yield performance over multiple locations for three years to judge for consistency in yield as well as for quality parameters (Arya et al., 2022). Stability is one of the most important requirements of any breeding program for yield and quality traits in targeted locations. The variations in genotypes mainly depend on the locations and interaction of genotypes with locations. Explaining such variations is biased upward by the fact that all genotypes generally don't react in the same way as change in circles and the two locations do not have exactly the same environmental conditions. Therefore, combined analysis of any variance is calculated that can measure GxE interaction and identify prime components, though it is not sufficient to declare the G x E interaction effectiveness. In Ashwagandha, AMMI1 biplots and simultaneous selection index statistics identified SKA-11 as the most desirable genotype for root branches and length while SKA-26 and SKA-27 for root diameter (Kumar et al., 2020b).

Conclusions

The information on conventional as well as modern breeding methods in ashwagandha will be able to stimulate the medicinal plant breeders to develop new high root yielding varieties with high root quality for the utilization for domestic use as well as for commercial marketing. A breeder can choose any of the above-described methods for varietal development in ashwagandha.

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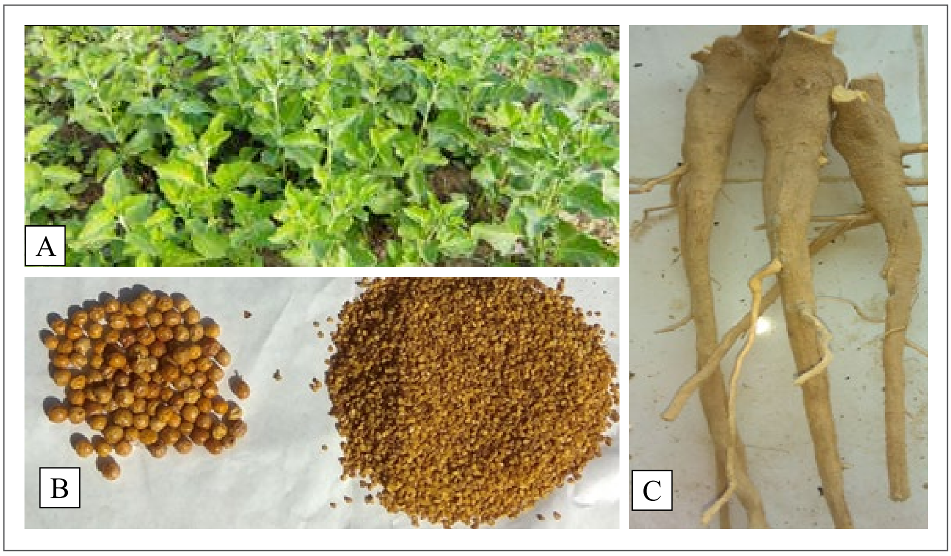

Figure 1. A. Ashwagandha plants, B. Ashwagandha Berries and Seeds, and C. Ashwagandha Roots. (Original)

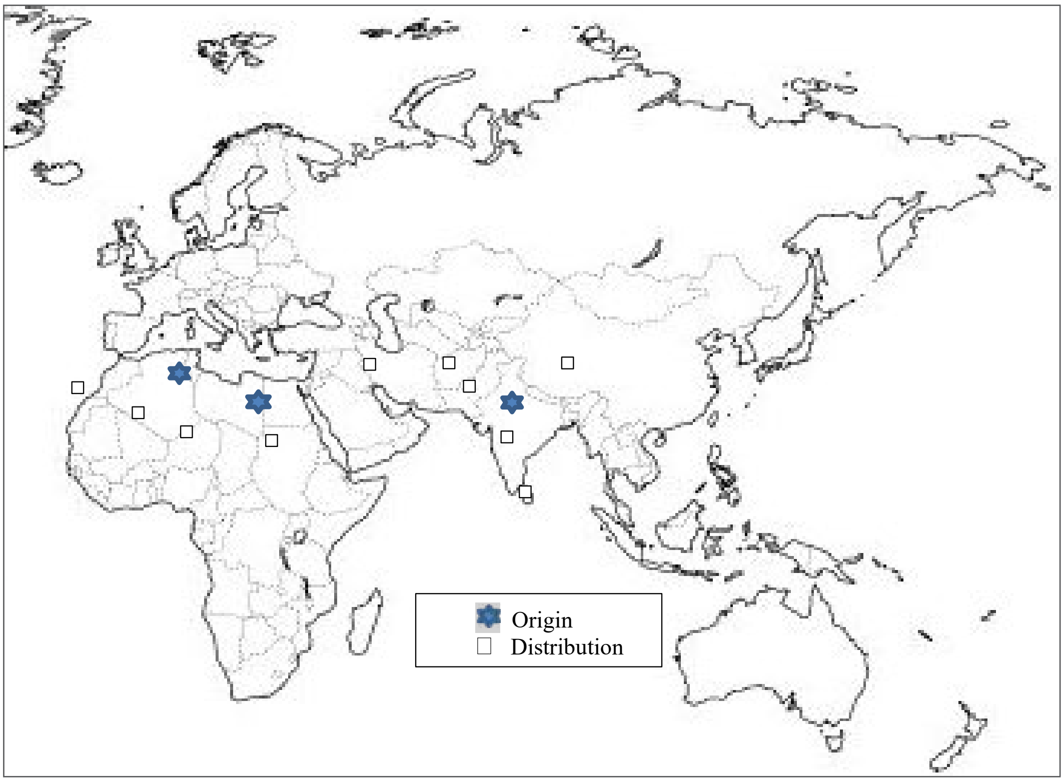

Figure 2. Origin and distribution of ashwagandha.

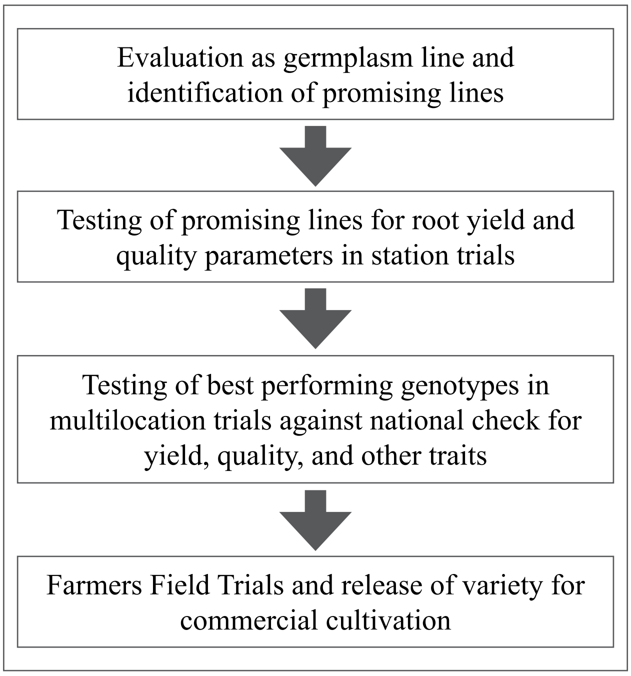

Figure 3. Schematic diagram of Pure line breeding method.

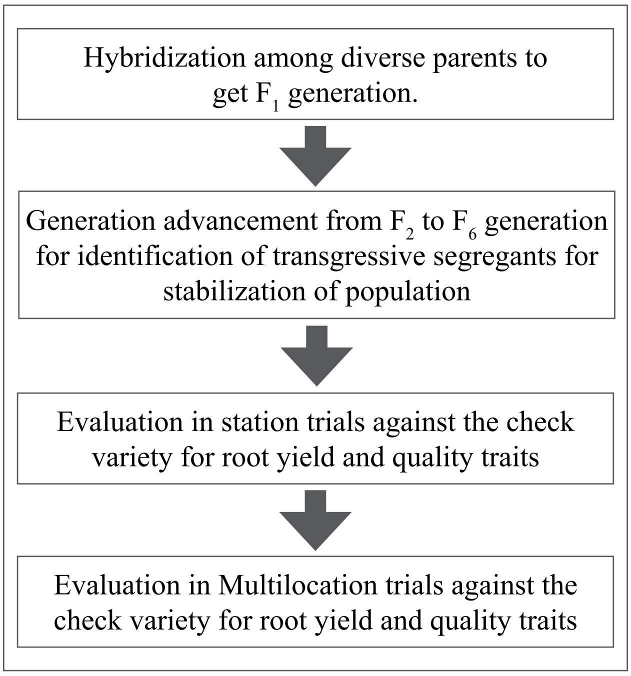

Figure 4. Schematic procedure of Pedigree method in Ashwagandha.

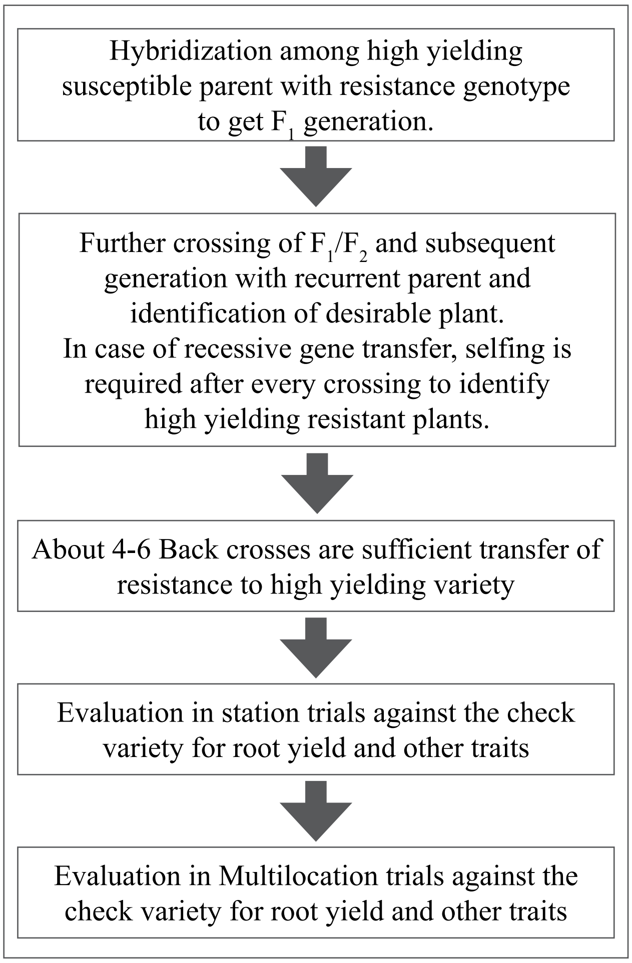

Figure 5. Schematic procedure of Backcross method in Ashwagandha.

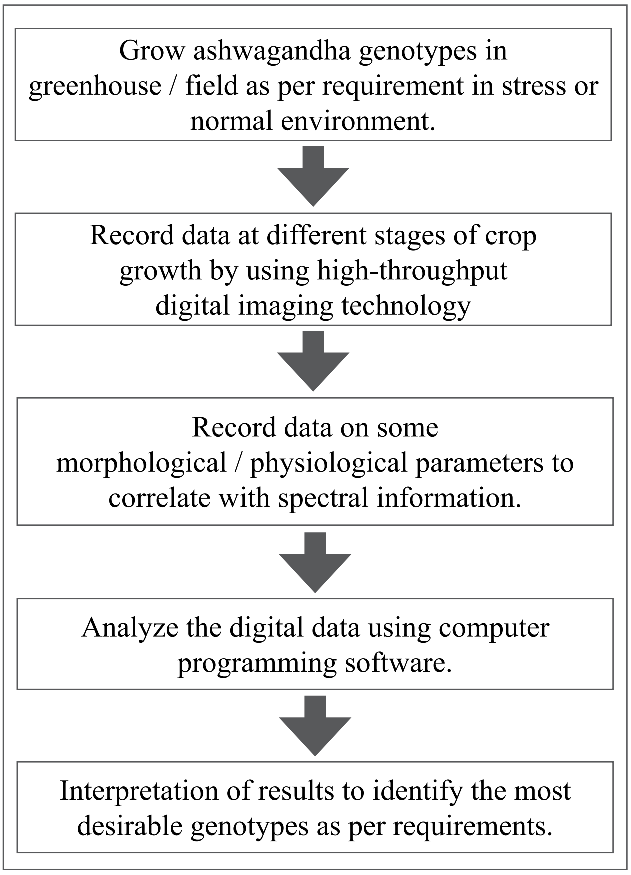

Figure 6. Schematic diagram of Pure line breeding method.

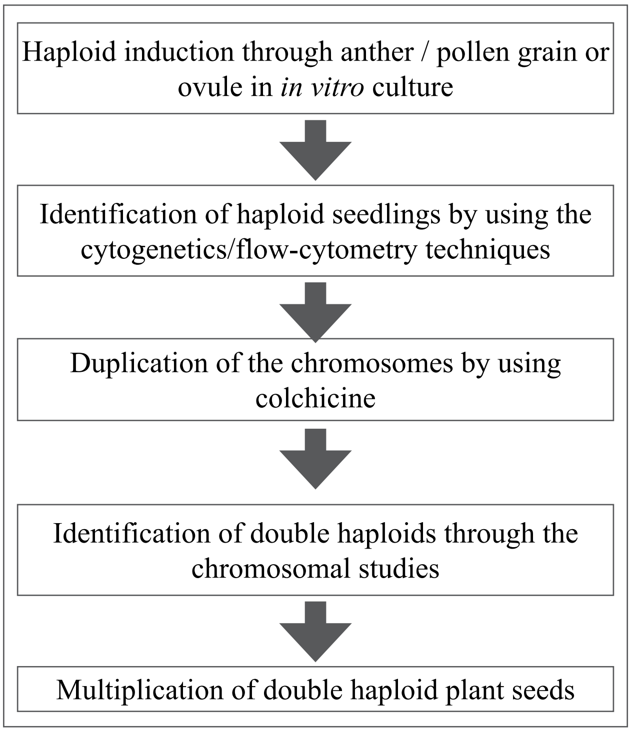

Figure 7. Schematic diagram of Pure line breeding method.

Table 1. Ashwagandha SSR Markers profile of some important genotypes and varieties.

S N	**Marker**	**CAMS 34**			**CAMS 351**			**CAMS 376**			
		Allele Size									
	Genotype	50 kb	200 kb	400 kb	50 kb	130 kb	420 kb	130 kb	170 kb	200 kb	350 kb
1	HAG-1	-	+	+	-	-	+	-	+	+	+
2	HWS 1203	+	-	-	-	-	-	+	-	-	-
3	HWS 8-18	+	+	+	-	-	+	-	-	-	-
4	HWS-205	-	+	+	-	-	+	-	+	-	-
5	HWS-222	-	+	+	-	-	+	-	+	-	-
6	JA - 20	+	-	-	+	+	-	-	+	+	+

Source: Koli and Arya, 2022

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Determination of the Problems Seen in Chickpea Production Areas in the Central Black Sea Region in Türkiye

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ABSTRACT

The aim of this study is to determine some crucial issues in chickpea farming and some characteristics of chickpea producing agricultural enterprises in Samsun, Amasya, and Tokat provinces in the Middle of Black Sea Region in Türkiye. For this purpose, 3 districts where chickpea production is made in these provinces were selected and a survey study was conducted according to the sampling system. Frequency analyzes were made according to simple statistical methods in Microsoft_Excel and the problems encountered were evaluated according to weighted rating. Thus, it has been tried to determine the problems encountered in chickpea production in the region and according to separate provinces. The survey was revealed that the major issues are 45% disease (chickpea blight), 21.47% vertebrate (pig) damage, 8.59% effect of marketing, 7.09% weed infestation, and 6.66% in the ecological conditon, according to the weighted grading. Expensive input was one of the most important problems affecting chickpea production intensively. The 70% of landowners has 0.8-10 ha small-size farm and the farms consisted of multi-part structures. The result of the survey study was illustrated that major problems are small size farm plots, elder farmers which the average age of the over 50 years old, and the unsuitable mechanization due to slopping land in chickpea farms.

Keywords: Chickpea, survey, chickpea producer problems

Introduction

Chickpea is located in the Eastern Mediterranean region, where Türkiye is the gene center, and it is one of the first cultivated plants (Akçin, 1988). Dry seeds contain a high percentage of protein (15-32%) and carbohydrates (50-74%), as well as minerals such as phosphorus, calcium and iron, and their richness in vitamins A, B and Niacin make them an important place in people's diets (Smithson et al., 1985). Despite their high protein content, legumes have very low cholesterol levels. In Türkiye, people obtain 80% of their daily protein needs from plantal products and 20% from animal products. Legumes such as beans, chickpeas, and lentils are the most important plantal protein sources (Onder, 2015).

Chickpea is very content in terms of soil demand and stands out among the legumes with its resistance to lime and salinity. Although chickpeas grow well in light, calcareous sandy soils, the ideal growing soil is sandy-loam soils. It does not like very acidic soils (Onder, 2015). In addition to having small green parts, it is also drought resistant thanks to its taproot system. In addition to the nitrogen binding of the *Rhizobium* bacteria in its roots to the soil, it gains importance in terms of development time and productivity (Eker,2019). In Türkiye, edible legumes were planted in a total area of 871.134 hectares in 2020. As of the same year, the total cultivation area of chickpeas in the country is 511.561 ha and the production is 630.000 tons. With these values, chickpea has become the most planted and produced edible legume in Türkiye (TUIK, 2021).

In spite of the fact that the Black Sea Region provides 9% of Türkiye's production in terms of chickpea production (Anonymous 2007), this value has decreased to 5% (Burucu 2020). A total 98% of production is provided by the Central Black Sea Region, which is enclosed by Samsun, Amasya, Corum and Tokat. Continuous cultivation of grain on the same land such as monoculture, especially wheat, causes deterioration of soil structure. Therefore, legumes should be grown in rotation with grains. In order for the crop rotation system to be successful in cereals, suitable annual legumes are needed. Chickpea is one of the main crops grown alternately with cereals in dry agricultural areas in order to meet marginal land use, reduction of fallow lands, its place in crop rotation and farmers' own needs.

There are various natural, economic or socio-economic factors that restrict chickpea production in Türkiye and all over the world. For example, anthracnose disease [*Ascochyta rabiei* (Pass) Labr.], which is a biological factor, has a direct effect on the cultivation area and especially the production amount. Although there is product loss at varying rates depending on the severity of the disease, product loss can reach 100% in some years (Düzdemir et al., 2008). In the research carried out to determine the mechanization problems in chickpea farming in Erzurum region, the problems in chickpea farming; it has been emphasized that it will be possible to solve it with complementary approaches that include breeding, agronomy, climate and soil conditions, appropriate planting, maintenance techniques and the socioeconomic structure of the farmers (Guler, 2011). The problems of dry bean production were determined in Konya conditions, it was determined that the farmers were insufficient in planting frequency, fertilization, irrigation, disease and pest control practices (Önder et al., 2012). It has been stated that in order to produce a quality bean in the region, the deficiencies determined in the knowledge level of the farmers in terms of cultivation techniques should be eliminated (Önder et al., 2012). Future projections were developed for the sales markets of chickpeas, lentils and dry beans grown in Türkiye, it was determined that between 2017-2021, the cultivation areas of chickpeas, red lentils and dry beans in Türkiye, the production amount and exports will decrease, consumption amount, import and producer prices will increase (Doğan et al., 019). The supply-demand balance will shift to the supply side, this shift will result from the increase in imports, not from the increase in production, and that foreign dependency in legumes will increase (Bolat et al., 2017). Ozturk (2019) reported that the investigating the economic status of chickpea cultivation in the Seydisehir district of Konya province; it has been determined that the enterprises producing chickpeas have an average of 5.68 ha farm land. The same researcher also stated that in these enterprises, producers must produce consciously and in accordance with the technique in order to make a profitable production.

In this study, it is aimed to determine the problems encountered in chickpea production and some characteristics of chickpea producing agricultural enterprises in Samsun, Amasya, and Tokat provinces located in the Central Black Sea Region.

Materials and Methods

This study was carried out in Samsun, Tokat, and Amasya between 2014 and 2016. The survey study in the study was carried out according to random sampling. The survey study was carried out according to random sampling. The survey studies of this research were carried out in 72 randomly selected agricultural enterprises producing chickpea in 10 districts of Samsun, Tokat, and Amasya provinces (Table 1).

In order to determine the problems related to chickpea farming in the region on the basis of "volunteering", questionnaires prepared from questions containing some demographic and business information of the producer and basic chickpea farming information were used.

In the study, the questions asked to business owners in the survey are presented in Table 2 below. In Microsoft_Excel, frequency analyses were performed according to simple statistical methods and the problems encountered were evaluated according to the weighted rating.

Results and Discussion

Number of Individuals in the Business:

It has been determined that the number of individuals in the surveyed businesses ranked between 5 and 18 people. When the distribution of the number of individuals to the enterprises is examined, the number of individuals varies between 5-6 people in 38.0% of the enterprises. This was followed by families of 3-4 with 19.1% and families with 1-2 persons with 17.5%. Businesses with 11-12 and 13-14 individuals gave the lowest frequency value with 1.6% (Figure 1).

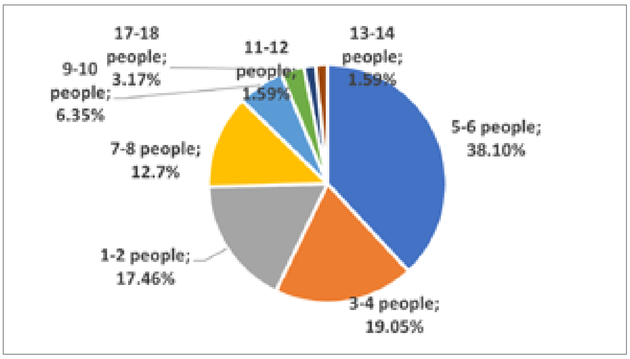

Figure 1. Frequency values of the number of family members of businesses

Education Levels of Farmers:

Considering the education levels of the individuals working in the farms, it is seen that all of the household heads are literate, 75% are secondary school graduates, 7.1% of the spouses are illiterate and 82% are secondary school graduates. When the education levels of the children in the enterprises were examined, it was determined that approximately 5.3% of them were illiterate. However, it is possible that these children are at pre-school age (0-6 years old), 81% of them are secondary school graduates. Considering the level of consciousness, it was striking that the ratio of household heads (5%) and children (1.79%) who received university education was very low (Figure 2).

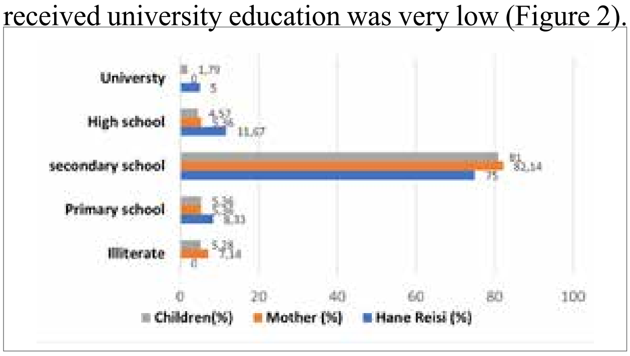

Figure 2. Frequency values of educational status of families in the farms studied.

Occupational Status of the Individuals on the Farm:

While 93% of the surveyed producers are only farming based on crop production as a profession, the others are engaged in civil servants, tradesmen and animal husbandry as an additional job besides farming. When the spouses of the producers were examined, it was seen that 62% of them carried out farming and animal husbandry together. While 7.1% of the rest of the spouses contribute to the economic situation by working in the civil servants, tradesmen and private sector, 33.3% are housewives who do not belong to any occupational group. While 12.9% of the children contribute only through farming, the remaining part is in an effort to take part in different sectors (Figure 3).

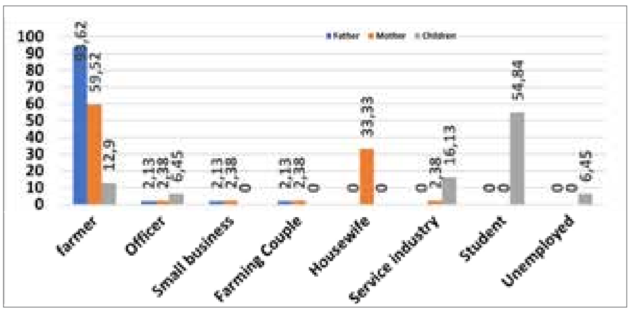

Figure 3. Occupational status frequency values of individuals in enterprises.

Chickpea farming majority is family farms in Türkiye. In particular, the level of education is very important for producers to be open to innovations, to adopt chickpea cultivation techniques and to put them into practice. A total 75% of the producers and 82% of their spouses in the research area are secondary school graduates. 93% of the surveyed producers are only farming based on crop production as a profession. While 62% of the wives of the producers are engaged in farming and animal husbandry together, almost 1/3 of the wives (33.33%) are housewives who do not directly contribute to production. A significant part of the children of producers are trying to take place in areas other than the agricultural sector.

Karabak and Cevher (2002) stated in their study in Central Anatolian conditions that the producers of chickpeas and lentils concentrated in the 36-55 age group and that the producers reduced the production of chickpeas and lentils at advanced ages. The researchers determined that 68.9% of the subjects were primary school graduates, 14.4% were secondary school graduates, and 4.4% were graduates of college or university. They also determined that chickpea and lentil cultivation decreased as the education level of the producer increased in the region. 82% of the producers in the region are only farming, 18% are self-employed and civil servants besides farming.

In a study conducted in Konya-Seydişehir, it was determined that 48.8% of chickpea producers were primary school graduates, 7.6% secondary school, 30.2% high school, 13.4% college or faculty graduates (Oztürk, 2019).

The human resources of the enterprises in the research area; Similar to the results of previous research, it consists of people who do not have higher education, most of whom are only farming as a profession. It was previously emphasized in Düzdemir et al. (2008) that the knowledge and economic levels of chickpea growers with low education levels are not sufficient to make decisions in production, therefore they mostly use traditional chickpea growing methods.

Agricultural Land Assets of Farms (Da):

While 42% of the examined enterprises have 0.9-5 ha land assets, 21% have 5-10 ha, 8.7% 10-15 ha, 14.0% 15-20 hectares and 1.8% of them have 60 hectares of land (Figure 4).

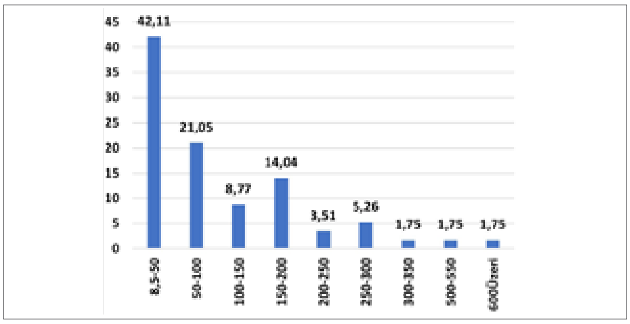

Figure 4. Size (Decare) of land in surveyed farms.

The existence of land is important in terms of operating agricultural parcels, using an efficient agricultural mechanization, highly competitive production in small farms and increasing the cost of activities such as irrigation investments (Eren, 2021). Ozkaya (1996) emphasized that the criterion in determining the development of small enterprises is the width of the soil used by the enterprises, but there may be different classifications according to whether this land is wet or dry. According to 2017 Farmer Registration System data, the average land assets of agricultural enterprises in Türkiye is 70 decares (Anonymous, 2019). Of the enterprises in the research area, 24.5% proportionally have land assets above the average of Türkiye. The vast majority of the remainder operate on farmland equal to or less than this average. It is not possible to realize a modern and efficient agricultural production in these farms.

Rotation Planning in Farms:

The enterprises in the research area consider various reasons when determining their planting systems. If Figure 5 is examined, it will be seen that the surveyed enterprises place chickpeas in single, double, and triple rotation systems. While chickpea is mostly included in rotations created with wheat, it can also alternate with irrigated plants such as sugar beet and vegetables. Chickpea is mostly grown in arid and marginal areas in Türkiye. In the areas where the research was carried out, the dominant plant of the arid areas is wheat. Rotations with wheat are mostly done in arid areas. Wheat-sunflower-chickpea, wheat-onion-chickpea, wheat-sugar beet-chickpea, wheat-bean-chickpea and wheat-poppy-chickpea rotations are also applied in the enterprises.

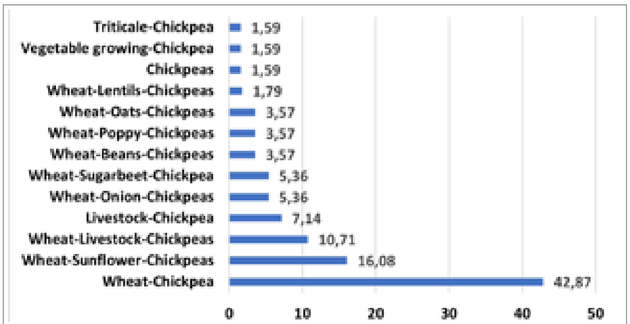

Figure 5. Frequency values of the plant groups entering the crop rotation with the chickpea plant.

Karabak and Cevher (2002), in their study in Central Anatolian conditions; that the producers in the region mostly use wheat/legume (chickpea-lentil) double rotation; however, they emphasized that the triple systems of wheat/legume/fallow and wheat/chickpea/forage crops are also common in the Central Anatolia Region. In the area where we conducted our research, the producer mostly preferred the rotation with wheat. However, it is used in different triple systems according to the irrigation possibilities in the region.

The Most Preferred Pre-plant in Chickpea Agriculture

When the products grown in the farms were listed during the study period, wheat was the most commonly grown crop. Since wheat is mostly grown in arid areas, chickpea comes in second place because it is the plant that has the most alternation with wheat in the crop rotation system. These plants are followed by vetch, barley and sunflower, respectively (Figure 6).

The presence of water is also effective in the selection of other plants preferred for production besides chickpeas. Karabak and Cevher (2002) found that wheat, barley, green lentils, and red lentils are the most grown products in these areas, along with chickpeas, in their study in Central Anatolian conditions dominated by dry agricultural areas.

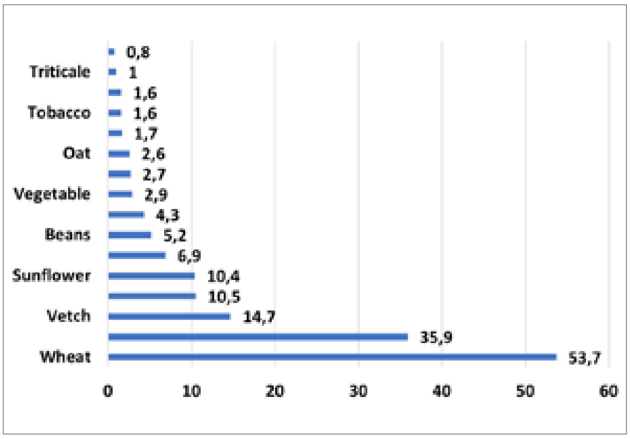

Figure 6. Frequency value of the most preferred products in farms together with chickpeas.

The 20 most preferred products in the enterprises examined in the research conducted by the Credit Bureau of Türkiye (2019) at the level of Türkiye, Wheat, Barley, Corn, Tomato, Alfalfa, Oats, Pepper, Potato, Sugar Beet, Sunflower, Watermelon, Bean, Cotton, Olive, Melon, Chickpea, Vetch, Onion, Grape, Cucumber. The finding we obtained in our research area is compatible with both literature reports.

However, since the region we are researching is between the transitional climate and the Black Sea climate, and receives higher amounts of precipitation than the Central Anatolian conditions, it shows more similarity with the results of the Credit Records Bureau research.

The most important factor in the emergence of this situation is undoubtedly the availability of water and irrigation facilities in the region.

Total Cultivation Areas in Farms by Plant Types (da):

When products are listed according to planting areas in farms, wheat takes the first place. It was followed by sunflower, vetch and barley. Chickpea, which was in the second place in the list of the most preferred products, fell to the fifth place in the total cultivation area. It can be said that the main reason for this decline in chickpeas is that sunflower, vetch and barley are preferred more than chickpeas in alternation with wheat in enterprises with large land assets. Chickpea cultivation is carried out in smaller farms and in arid areas (Figure 7).

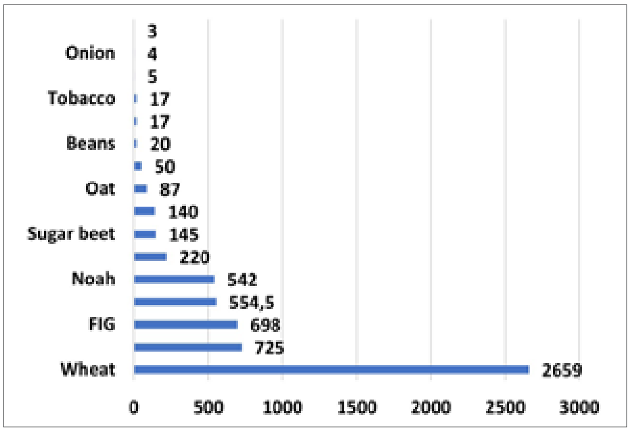

Figure 7. Cultivation area (da) by plant species in farm

Karabak and Cevher (2002) focused on their study on Central Anatolian chickpea and lentil production, found that the common plant in the total cultivation areas in the study area is wheat (50.0 %), followed by barley (18.0% and chickpea (12.0 %). In the research conducted by the Public Credit Bureau (2019), at the level of Türkiye, Wheat ranked first with an average cultivation area of 11.5 hectare, while chickpeas ranked second with an average cultivation area of 10.6 hectare.

In the same study, chickpea was ranked 15th with 5.6% among the 20 most cultivated products, while it was the second product with the highest average area in terms of average cultivation area. In our research, chickpea came after wheat, sunflower, vetch and barley with 542 decares in the researched enterprises. Although chickpea cultivation requires intensive labor, it has become one of the important crops that are in rotation with wheat in dry areas, especially due to the fact that mechanization has begun to be used in harvest and the use of herbicides in weed control has become widespread. For this reason, chickpea is one of the prominent plants in terms of cultivation area in regions where dry agricultural areas are common. Our findings support the literature.

Type of Seed Used by Chickpea Producers

While 35.21% of chickpea producing enterprises preferred Spanish grain type chickpeas, 25.35% preferred domestic types. Although 34% of the enterprises obtained the seeds from previous years, they used the seeds of the registered varieties (Figure 8).

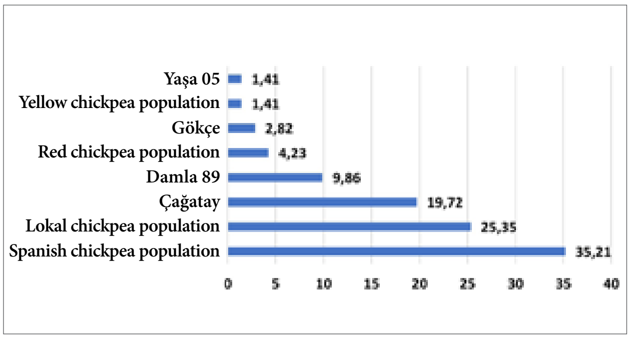

Figure 8. Frequency values of varieties used by chickpea producers.

When we look at the varieties used by the chickpea production enterprises in the survey area, it is seen that the mostly Spanish seeds and village populations are used. It is followed by a local variety, “Yerli” and a registered variety “Çağatay”. In addition to the Spanish, Native, Red and Native Yellow Chickpeas, which are popular in the region, the registered varieties of Çağatay, Damla-89, Gökçe and Yaşa 05 were also preferred seeds. The prevalence of local populations in the region also affects the yield; plays an important role in the producer’s overall low yield. This is a common situation in chickpea cultivation in the country. For example, in a study carried out in Central Anatolian conditions, it was seen that breeders preferred local populations called Spanish and Native in addition to registered varieties. Producers also used Damla-89 and Gokce registered varieties (Karabak and Cevher, 2002). In our study, it will be easily seen that the cultivar preferences of the breeders are very similar to the breeders’ preferences in previous years. Karabak and Cevher (2002) stated that 85% of the producers in their study do not use certified seeds in chickpeas and lentils, due to the fact that certified seeds are expensive (69.9%), not available (18.8%) and lack of knowledge about seeds (8.3%) tied. Ozturk (2019) stated that the businesses in the Seydisehir region do not demand the certified seed too much, that the producers mostly prefer Gökce and very few of them prefer Aksu varieties.

Seed Supply Places of Chickpea Producing Farms

A total 59.7% of chickpea producing farms in the region separate their seeds from the previous product. 19.0% of the enterprises obtained their seeds from trader and 10.5% from other producers. The remaining

21.2% of producers also stated the seeds they obtained from companies selling registered varieties as seeds (Figure 9). Most of the producers in the survey area (89.2%) use seeds whose quality is not fully known and which have begun to lose their certified characteristics. Serious yield losses occur because they cannot show resistance to various biotic and abiotic stress factors.

Karabak and Cevher (2002) stated that 43.2% of the seeds used by the producers in the working areas were supplied from their own enterprises, 13.4% from the neighbours and 11.0% from the provincial and district directorates of agriculture. The producers in Seydişehir obtain the seeds from private companies, cooperatives and other farmers (Oztürk, 2019).

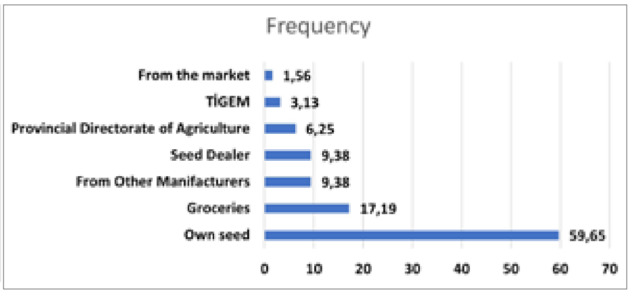

Figure 9. Frequency values of the places where chickpea producing farms supply seeds.

Situation of Soil Analysis of Farms Producing Chickpea

Most of the farms producing chickpea in the region (91.0%) do not have soil analysis before production. However, businesses still use various chemical fertilizers while growing chickpeas. Fertilization without such technical knowledge and findings causes significant environmental and economic damage. Considering that the active ingredients of chemical fertilizers, such as groundwater and soil pollution, are imported, the economic cost of misuse and misuse will also emerge as an important problem. Düzdemir et al. (2008), in their study in the Tokat region, determined that most of the producers did not have soil and leaf analyses done because they did not consider it important or because they did not trust the results. However, it is very important to determine the level of fertilizer use in agricultural production, the factors affecting it and its efficiency (Karkacıer et al., 1999). Oztürk (2019) stated that in order to increase the declining yield in the Seydisehir region, the farmers should improve themselves in plant nutrition and provide sufficient micronutrients by having an analysis on the unproductive soils.

Types of Fertilizers Used by the Farms in Chickpea Cultivation

The types of fertilizers used by the farms in chickpea production are given in Figure 10. According to this graph, producers mostly preferred chemical fertilizers. 45.5% of the producers used DAP (Diammonium Phosphate), 18.2% CAN (Calcium Ammonium Nitrate) and 15.3% compound fertilizer 20-20-Zn. DAP is the fertilizer that meets the nitrogen and phosphorus needs of chickpeas in the best combination in terms of quantity. This may have played an important role in their preference.

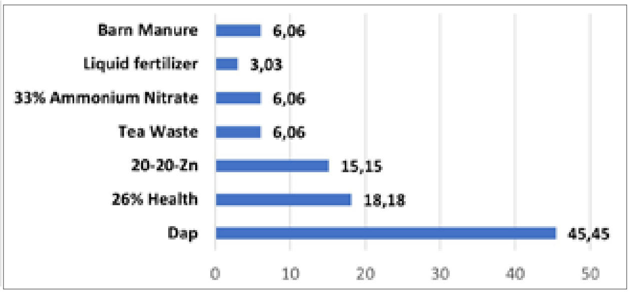

Figure 10. Frequency values of fertilizer forms used in farms.

Farmers think that using fertilizers in agricultural production generally has positive effects (Esengün et al., 1995). However, it is also very important to have sufficient technical knowledge in the use of fertilizers. Düzdemir et al. (2008), in their study with chickpea producers in the Tokat region, determined that approximately 60% of the farmers used fertilizer (incomplete or excessive amount) to grow chickpeas, and they mostly decided on the amount and type of fertilizer, taking into account the economic conditions. In the survey study conducted in 4 provinces in Central Anatolia (Ankara, Yozgat, Çorum, and Konya), it was determined that 20% of the chickpea producing farms use base fertilizer and 8.8% use top fertilizer. That was determined that producers generally prefer Diammonium phosphate (DAP, 10-20 kg/da) as base fertilizer and Ammonium Nitrate (5-13 kg/da), and Urea (10-25 kg/da) as uppermost fertilizer. In the research, it was determined that the use of fertilizer in chickpeas and lentils is less than other products. The reasons for this were explained as high fertilizer prices (61%), lack of knowledge of the producers about the cultivation technique (18%) and the lack of the habit of using fertilizers (8%).

Chickpea Harvest Times in Farms

As can be seen from Figure 11, 82% of the farms are harvested between the end of August and the beginning of September. Chickpea is a long day plant. It is planted as a summer cottage in almost all regions of Türkiye to avoid disease and weed damage (Sepetoglu, 1994). However, in this case, drought and high temperatures, especially during flowering, cause yield losses as well as variability in harvest times. Chickpeas are harvested between July and September in Ankara, Çorum, and Yozgat provinces and between June and August in Konya (Karabak and Cevher, 2002).

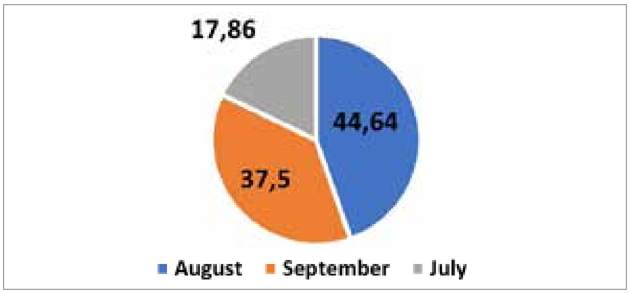

Figure 11. Frequency of harvest periods on farms.

Harvesting Method of Chickpeas on Farms

A total 93% of the farms harvest by hand and thresh the threshing process (Figure 12). Today, when migration from the village to the city is intense, the lack of sufficient workforce threatens the chickpea agriculture seriously. This problem occurs during the harvest and threshing period. Although manual harvesting is a process that requires sufficient labour and intensive labour, the lack of sufficient labour is becoming an important problem day by day and may affect the producer's view of chickpea agriculture.

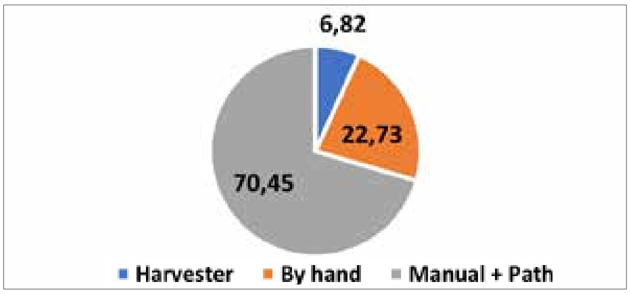

Figure 12. Frequency values of chickpea harvest patterns in farms.

Karabak and Cevher (2002); They reported that in Central Anatolian conditions, chickpeas were mostly harvested by hand and blended with batter. In Güler (2011); He said that in Erzurum conditions, chickpeas are generally harvested by plucking by hand and then threshed with a mulcher machine. The researcher emphasizes that the use of combine harvesters in the chickpea harvest is increasing day by day in Erzurum conditions. Yılmaz and Yıldırım (2016); They stated that the most harvested products by combine harvester in Central Anatolian conditions were barley and wheat, followed by maize, oats and chickpeas. They stated that the reason for the limited use of combine harvesters in chickpea harvest is the low cultivation area of chickpeas.

When the harvest and threshing methods of chickpeas are examined in the enterprises included in our research, it will be clearly seen that they are similar to the literature reports. In the majority of enterprises, chickpeas are plucked by hand and blended with batter. However, minimizing grain losses, especially at harvest, is a very important issue in grain products such as chickpeas. In this, the use of certified, improved seeds should be expanded in all chickpea cultivation areas, especially in the research region, with an upright structure adapted to local conditions, resistant to diseases and pests, suitable for machine harvesting. In addition, machine settings should be paid attention to in harvesting operations with a combine (Güler, 2011).

Problems Limiting Chickpea Cultivation

In the survey study, chickpea growers were asked to list the main problems they encountered in chickpea farming. Producers listed the three most important problems limiting chickpea agriculture in the region as disease (Chickpea blight) (45.2%), vertebrate (Pig) damage (21.5%) and marketing (8.6%), respectively (Figure 13). Again, factors such as weed invasion, drought and high temperature may come to the fore from time to time.

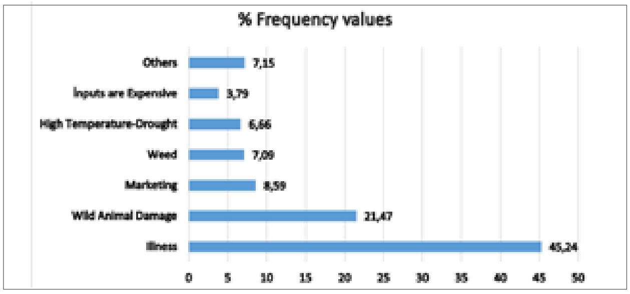

Figure 13. Problems limiting chickpea cultivation and frequency values.

It was stated that the cultivation areas, production amount and export of chickpea, red lentil and dry bean products could be decrease, consumption amount, import and producer prices could be increase in Türkiye. In the study, it is stated that the balance in the supply-demand balance will shift to the supply side, this shift will result from the increase in imports, not from the increase in production, and that foreign dependency in legumes will increase (Bolat et al., 2017).

It was understood that the most important problems of chickpea producers in Central Anatolian conditions are low product prices and instability. It is seen that economic problems were also on the basis of the social factors that limit production. In addition, anthracnose disease appeared as a limiting factor in chickpeas (Karabak and Cevher, 2002). Öztürk (2019) determined that among the problems of the farmers producing chickpeas, there are some problems arising from the lack of market alternatives, market uncertainty, financing difficulties and production problems. In the study commissioned by the Credit Registration Bureau (2019), on the problems encountered in plant production in general; the problems faced by farmers during production are respectively "input cost" (83%), "fighting diseases/pests" (36%), worker problems (33%), "irrigation" (2%-7%) and "climatic problems" (2%) are listed. It was determined that the most important problem of the farmers after the production, namely in the marketing phase, is the low selling price (78%). In addition, it was stated that in order to produce a quality bean in Konya conditions, it was stated that the deficiencies determined in the knowledge level of the farmers in terms of cultivation techniques should be eliminated (Önder et al., 2012). There is a great similarity between our findings and the literature.

Conclusions

The results of the survey to determine the problems encountered in chickpea production in the provinces of Samsun, Amasya, and Tokat located in the Central Black Sea Region and to determine some characteristics of the agricultural enterprises producing chickpea can be briefly summarized as follows.

- In the examination of the basic human resources characteristics of the enterprises; the number of individuals in the enterprises varied between 5-18 people, and it was determined that they mostly consisted of 5-6 (38.0%) people. In the enterprise, 75% of the household heads and 82% of the head spouses are secondary school graduates. In the enterprises, 93% of the household heads carry out farming based on only herbal production as a profession, and 62% of the spouses carry out farming and animal husbandry together. A total 12.9% of children contribute only by farming.

- The majority of the farms (63%) in the survey area have 10 ha or less of operating land. The farms included chickpeas in single, double and triple rotations in their crop rotation systems. During the period of the study, most of the wheat was grown in the farms. It was followed by chickpea, vetch, barley, and sunflower. According to the cultivation areas, wheat took the first place, followed by sunflower, vetch and barley. In the order of total cultivation area of chickpea, it is in the fifth place since large landowners prefer sunflower, vetch and barley in alternation with wheat.

- A total 35.2% of the producers preferred Spanish grain type chickpeas as seeds. Producers have used population Spanish, Native, Red, and Native Yellow Chickpeas as well as Cagatay, Damla-89, Gökçe, and Yaşa 05 registered cultivars as seeds. While 59. 7% of the enterprises obtained their seeds from the previous product, 19.0% from grain and 10.53% from other producers, 21.1% of them bought their seeds from companies selling registered varieties.

- Most of the chickpea producers in the region (91.0%) do not have soil analysis before production. However, farms used DAP (Diammonium Phosphate), (18.18%) CAN (Calcium Ammonium Nitrate) and (15.2%) compound fertilizer 20-20-Zn in chickpea production (45.5%).

- A total 82% of the farms in the survey area harvest chickpeas between the end of August and the beginning of September, 93% of the farms harvested by hand and performed the threshing in the form of forging.

- It has been seen that the main problems limiting chickpea farming in the farms in the survey area are disease (blight disease) (45.2%), vertebrate (Pig) damage (21.5%) and marketing (8.6%). These were followed by other problems such as weed invasion, drought and high temperature.

To put it in conclusion; when the agricultural potential of the region and its plant production capacity and structure are taken into account, it will be seen that chickpea will maintain its place in the future and be an economically profitable agricultural product for the producer. However, for this, some improvements should be made in some areas and the way to a more efficient chickpea production should be opened. In this context; first of all, increasing the education level of chickpea producers, informing the producers about the chemical pesticides (herbicides, insecticides, fungicides, etc.), artificial fertilizers used during cultivation, the selection and use of seeds, and the producers being open to innovations in order to increase the yield that decreases as they prefer traditional cultivation methods. need to be educated and informed about If this is done, a sustainable and high yielding chickpea production will be possible in the region for many years. In addition, it is recommended to give importance to the development of varieties compatible with the region, to solve the problems encountered in the marketing of chickpeas from both the producer and the consumer point of view, and to increase the prefer ability of chickpea production compared to alternative products by providing low-cost production.

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Table 1. Survey areas and the number of surveyed enterprises.

Survey areas	Number of surveyed enterprises
Tokat	
Artova	9
Zile	14
Niksar	11
Total	34
Amasya	
Central District	9
Goynücek	11
Merzifon	6
Total	26
Samsun	
Asarcık	3
Ladik	3
Havza	3
Vezirkoprü	3
Total	12
Total Of Locatıons	72

Table 2. Survey questions asked to chickpea producers in the study.

1.	Number of individuals in the business
2.	Education levels of producers
3.	Occupational status of individuals in the enterprise
4.	Agricultural land existence of enterprises
5.	Crop rotation planning in enterprise
6.	The most preferred pre-plant in chickpea agriculture
7.	Total planting areas according to plant types in farms
8.	Seed variety used by chickpea producing farms
9.	Seed supply places of farms
10.	Soil analysis status of chickpea production farms
11.	Types of fertilizers used by farms in chickpea cultivation
12.	Chickpea harvest times on farms
13.	Harvesting of chickpeas on farms
14.	Problems limiting chickpea farming

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Edible Chickpea (*Cicer arietinum* L.) Variety "ISMETBEY 01"

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ABSTRACT

As a result of the chickpea breeding studies carried out at the Eastern Mediterranean Agricultural Research Institute Directorate, Adana location, the variety was developed and submitted for registration; in the registration trials, yield, anthracnose blight/tolerance, quality values and as a result, it qualified to be a variety and was registered in 2024 with the name "Ismetbey 01".

As a result of chickpea registration yield trials established in different regions of Türkiye, the average yield of Ismetbey 01 variety was 275,1 kg/da, while the highest yield value was 414,7 kg/da grain yield. According to the results of the experiment, flowering period of the varieties was 63-152 days, plant height was 40-70 cm, and hundred grain weight was determined in the range of 30,7-48,6 g. In terms of technological characteristics, protein ratio was determined in the range of 22,3-25,4%.

Gradual seed production of our Ismetbey 01 edible chickpea variety; which was registered in 2024, will be planted as of 2025 and will be offered to our farmers.

Keywords: Edible chickpea, yield, quality

Introduction

Chickpea (*Cicer arietinum* L.), self-fertilized, diploid (2n=2x=16) chromosome, is considered an important protein source and food crop in the world and in Türkiye. Among edible grain legumes, chickpea is the second most resistant to drought and low temperature after lentil. It is not very selective in terms of soil requirements. It is drought resistant thanks to its small vegetative parts, short development period and taproot system. The importance of chickpea plant in crop rotation increases the importance of its ability to utilize the free nitrogen of the air with *Rhizobium* bacteria in its roots. Chickpea plays an important role in promoting sustainable agriculture by maintaining soil fertility through biological nitrogen fixation together with symbiotic *rhizobium* in root nodules. Soil is the foundation of crop production. Without soil, neither food can be produced on a large scale nor livestock can be fed. Because soil is finite, it is a precious resource that requires special care from farmers. Many of today's soil and crop management systems are not sustainable. Sound knowledge of soil health and quality is essential for agricultural sustainability.

The chickpea plant is also indispensable for its contribution to the elimination of nutritional deficiencies, in addition to its protein richness. Chickpea is a very important source of protein. Therefore, in countries where animal protein sources are inadequate and expensive, chickpea is an edible grain legume plant of great importance as a cheap protein source for a healthy and balanced diet. It is inevitable to supply the food deficit in the world and in our country from different sources. Therefore, in countries where animal protein sources are inadequate and expensive, chickpea is an edible grain legume plant of great importance as a cheap protein source for a healthy and balanced diet. It is inevitable to supply the food deficit in the world and in our country from different sources. Chickpea is a protein and vitamin-rich edible grain legume plant that contains 18-31%

vegetable protein in its grain, as well as important essential amino acids such as leucine, alanine, lysine, isoleucine, methionine, tryptophan, valine, which are the basic building blocks of the human body, elements such as K, P, Ca, Mg, S, Fe, Mn and vitamins such as A, B and C.

The data for chickpea in Türkiye for 2022 show a cultivation area of 456.480 ha, a production of 580.000 tons, and a grain yield of 127.00 kg/da per unit area (FAO, 2024). Chickpea is grown as a winter crop in the Mediterranean and Southeastern Anatolia regions. Chickpea plants to be grown as winter crops should be tolerant/resistant to Ascochyta blight disease. The most important biotic factor limiting the winter cultivation and yield of chickpea is *Ascochyta rabiei* (Pass) Labr, which causes anthracnose disease. Anthracnose is a fungal disease. The development and rate of the disease varies according to climatic conditions; it occurs mostly in rainy, hot weather with high relative humidity. Especially rain is an important factor in the spread of the disease. For this reason, it is very important that varieties are tolerant/resistant to diseases and pests in breeding.

Our aim in breeding studies is to determine high-yielding, high market value, good quality, anthracnose tolerant/resistant varieties or variety candidates of chickpea varieties. Our Ismetbey 01 chickpea variety is an edible grain legume chickpea variety registered for this purpose.

Materials and Methods

Our material sources in our edible grain legume breeding studies; We provide our materials from material sharing within the scope of the national project, ICARDA material exchange programs, new variations created from our own hybridization programs or local varieties.

Ismetbey 01 chickpea variety is also a variety developed by selection method. Ismetbey 01 chickpea (*Cicer aritinum* L.) variety was registered by the Eastern Mediterranean Agricultural Research Institute in 2024, suitable for winter cultivation in the Mediterranean, Aegean and Southeastern Regions and summer cultivation in other regions. Ismetbey 01 edible chickpea variety was bred from ICARDA origin (FLIP 09 51C) materials by using Introduction breeding method from breeding methods; in 2021 and was registered with the variety name “Ismetbey 01” in 2024 and offered to the service of farmers.

Results and Discussion

Grain yield is the most important breeding objective in edible grain legumes as in other cultivated plants; in addition, grain size is also a highly demanded trait in chickpea breeding. However, due to the negative correlation between grain yield and grain size and between grain size and Ascochyta blight, the optimum grain size should be determined very carefully according to the regional conditions (Mart et al., 2023).

As a result of the two-year multi-location registration trials carried out, the findings obtained with the “Ismetbey 01” chickpea variety were determined by the Seed Registration Agency. Biological characteristics of Ismetbey 01 chickpea variety vary between 63-152 days for flowering and 119-193 days for physiological maturity. The cultivation method is suitable for winter cultivation. Morphological characteristics; plant height is 40-70 cm, first pod height is 23-38 cm, plant growth form has shown development from semi-erect to upright; it is a variety suitable for machine harvesting. Plant grain characteristics 100 grain weight 30,7-48,6 g, grain color light beige, grain shape angular. Technological characteristics of Ismetbey 01 chickpea variety were determined as water absorption capacity 0,44-0,54 g/grain; swelling capacity 0,42-0,51 ml/grain; water absorption index 1,08-1,33%; swelling index 2,38-2,75%; sieve values 11,0-45,6% for 9 mm sieve; 26,7-47,9% for 8 mm sieve; protein ratio 22,3-25,4% (Mart et al., 2023).

Grain yield value of Ismetbey 01 chickpea variety was 275,1 kg/da on average, the highest yield value was 414,7 kg/da and it was determined that it was tolerant to Anthracnose disease. Cooking time was determined between 40-45 minutes. The registration trial results for 2022 and 2023 (Tables 1-2-3) were taken from the report of 2024 winter sowing chickpea variety registration report of the Variety Registration and Seed Certification Center (Mart et al.,2020; Mart et al., 2020; Mart et al., 2021).

Conclusions

Improving chickpea agriculture in Türkiye through chickpea breeding studies, increasing cultivation areas, narrowing fallow areas by introducing chickpea into fallow areas, supporting sustainable agriculture by introducing it into crop rotation are important for the country’s agriculture future.

The introduction of new registered varieties such as Ismetbey 01 suitable for winter and spring cultivation, high yielding, suitable for machine harvesting, high quality, tolerant/resistant to diseases and pests, with high market value, will carry chickpea agriculture forward.

Figure 1. ISMETBEY 01 Chickpeas (*Cicer arietinum* L.) (Original)

Registration year	2024	
Place and year of breeding	Adana - 2021	
The organization that owns the variety	The Eastern Mediterranean Agricultural Research Institute Directorate– Adana/Türkiye	
Breeding organization	Eastern Mediterranean Agricultural Research Institute Directorate	
Breeding method	induction	
Biological properties	Number of days to flowering Number of days to physiological death	63-152 days 119-193 days
Morphological features	Plant height (cm) First pod height (cm) plant growth form Cultivation method	40-70 23-38 Semi vertical to flat winter sowing
Grain properties	Hundred seed weight(g) grain color grain shape	30.7-48.6 Beige (light) Angular
Technological features	Water absorption capacity (g/grain) Swelling capacity (ml/grain) Water absorption index (%) Swelling index (%) Cooking time (min.) Protein rate (%) Sieve values (%)	0.44-0.54 0.42-0.51 1,08-1.33 2.38-2.75 40-45 22.3-25.4 9 mm---- 11.0-45.6 8 mm-----26,7-47.9
Agricultural properties	In registration trials; Average yield (kg/da) Highest yield (kg/da)	275.1 kg/da 414.7 kg/da
Places where registration trials are carried out	Diyarbakır, Adana, Manisa, Şanlıurfa, Kahramanmaraş	

Table 1. Yield Results of 2022 Winter Sowing Chickpea Agricultural Values Measurement Trials (kg/da).

Varieties	Manisa		K.Maraş		Adana		Şanlıurfa		Diyarbakır		Average	
1- Aksu (st)	199,5	e	118,6	a	367,9	ab	274,0	ab	128,8	c	217,8	bc
2- Arda (st)	303,8	ab	87,6	b	349,7	bc	233,1	bcd	166,8	a	228,2	b
3- Sezgin (st)	217,0	de	55,3	d	324,1	bc	241,5	bcd	134,5	c	194,5	de
4- Hasanbey (st)	219,8	de	57,6	d	289,0	c	217,3	cd	136,3	bc	184,0	e
5- Azkan (st)	260,0	bcd	77,0	bc	299,4	c	188,2	d	127,5	c	190,4	de
6- Şahrud	273,0	abc	65,3	cd	347,2	bc	300,3	a	113,8	c	219,9	bc
7- Frikya	286,5	ab	63,2	cd	299,5	c	238,2	bcd	131,3	c	203,7	cde
8- Adana 1	235,3	cde	52,1	d	351,2	abc	249,6	abc	158,8	ab	209,4	bcd
9- Adana 2	292,0	ab	52,7	d	364,8	ab	257,8	abc	124,5	c	218,4	bc
10- Adana 3	317,5	a	65,7	cd	414,7	a	299,0	a	174,3	a	254,2	a
F	*		**		*		**		**		**	
CV (%)	11,8		16,2		12,9		15,6		11,1		15,9	
LSD	44,6		16,4		64,0		56,5		22,6		21,0	

*= Significant at the 0.05 level, **= Significant at the 0.01 level.

Note 1: Table 1 values are taken from Variety Registration and Seed Certification Center Directorate, 2024 winter sowing chickpea variety registration report (Anonymous, 2024).

Note 2: Adana 3 line was registered as Ismetbey 01 chickpea variety in 2024.

Table 2. Yield Results of 2023 Winter Sowing Chickpea Agricultural Values Measurement Trials (kg/da).

Varieties	Manisa		Adana	Şanlıurfa		Diyarbakır		Average	
1- Aksu (st)	237,4	ab	277,7	249,9	ab	363,9	bcd	282,2	ab
2- Arda (st)	181,7	d	308,9	181,7	e	359,0	cd	257,8	cd
3- Sezgin (st)	222,8	bc	283,2	230,8	bc	343,0	d	270,0	bc
4- Hasanbey (st)	223,3	bc	253,4	233,2	bc	371,5	a-d	270,4	bc
5- Azkan (st)	199,0	cd	219,7	201,2	de	356,3	cd	244,1	d
6- Frikya	235,6	abc	265,7	235,4	bc	386,7	abc	280,8	abc
7- Adana 1	245,8	ab	296,5	246,3	ab	395,2	a	296,0	a
8- Adana 2	232,5	abc	262,7	213,7	cd	362,2	bcd	267,8	bcd
9- Adana 3	261,7	a	292,1	260,4	a	390,4	ab	301,1	a
F	**		NS	**		*		**	
CV (%)	11,5		21,1	7,4		5,7		12,5	
LSD	38,0		84,1	24,6		30,8		24,1	

*= Significant at the 0.05 level, **= Significant at the 0.01 level.

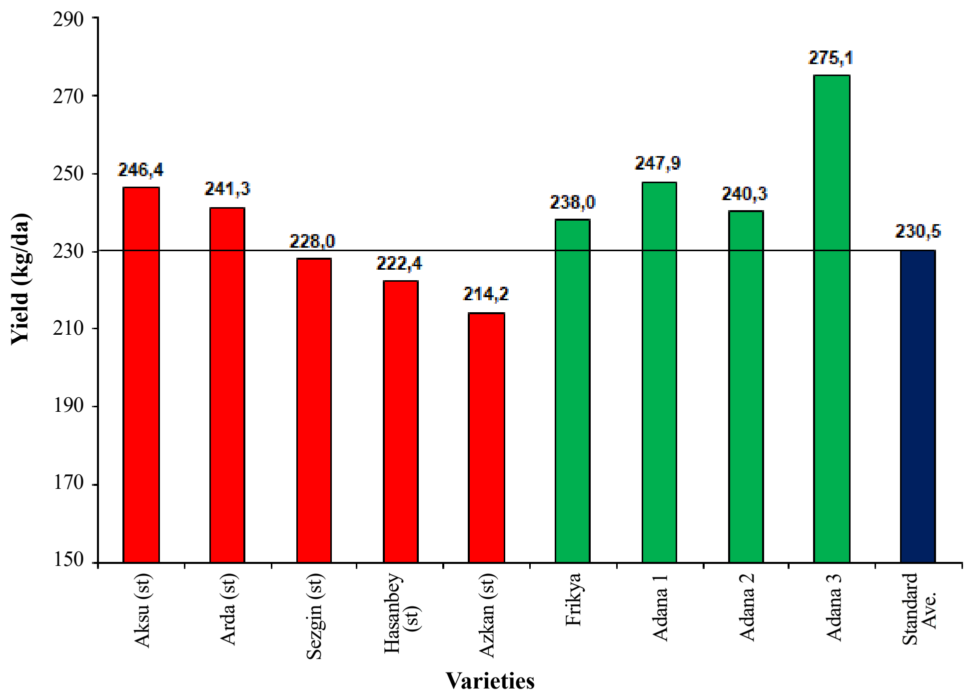
Note 1: Table 2 values are taken from Variety Registration and Seed Certification Center Directorate, 2024 winter sowing chickpea variety registration report (Anonymous, 2024).

Note 2: Adana 3 line was registered as Ismetbey 01 chickpea variety in 2024.

Table 3. Yield Results of 2022-2023 Winter Sowing Chickpea Agricultural Values Measurement Trials (kg/da).

Varieties	Manisa		Adana		Şanlıurfa		Diyarbakır		K.Maraş	General Average	
	2022	2023	2022	2023	2022	2023	2022	2023	2022		
1- Aksu (st)	199,5	237,4	367,9	277,7	274,0	249,9	128,8	363,9	118,6	246,4	b
2- Arda (st)	303,8	181,7	349,7	308,9	233,1	181,7	166,8	359,0	87,6	241,3	bc
3- Sezgin (st)	217,0	222,8	324,1	283,2	241,5	230,8	134,5	343,0	55,3	228,0	cd
4- Hasanbey (st)	219,8	223,3	289,0	253,4	217,3	233,2	136,3	371,5	57,6	222,4	d
5- Azkan (st)	260,0	199,0	299,4	219,7	188,2	201,2	127,5	356,3	77,0	214,2	d
6- Frikya	286,5	235,6	299,5	265,7	238,2	235,4	131,3	386,7	63,2	238,0	bc
7- Adana 1	235,3	245,8	351,2	296,5	249,6	246,3	158,8	395,2	52,1	247,9	b
8- Adana 2	292,0	232,5	364,8	262,7	257,8	213,7	124,5	362,2	52,7	240,3	bc
9- Adana 3	317,5	261,7	414,7	292,1	299,0	260,4	174,3	390,4	65,7	275,1	a
F										**	
CV (%)										13,6	
LSD										15,2	

Note 1: Table 3 values are taken from Variety Registration and Seed Certification Center Directorate, 2024 winter sowing chickpea variety registration report (Anonymous, 2024).
Note 2: Adana 3 line was registered as Ismetbey 01 chickpea variety in 2024.



Note 1: Graph 1 values are taken from the 2024 winter sowing chickpea variety registration report of the Central Directorate of Seed Registration and Certification.

Note 2: Adana 3 line Ismetbey 01 was registered as chickpea variety in 2024.

Graph 1. Yield Graph of 2022-2023 Winter Sowing Chickpea Agricultural Values Measurement Trials.

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In Turkey, wheat was produced 10 million tons in 1923 (Gokgol 1939).

This result was in agreement with result of Sahin and Yildirim (2004).

Similar effect has been widely studied prior to this study (Eser 1991; Bagci et al. 1995; Uzun and Yol 2013).

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Journal article:

Toker C (1998). Adaptation of kabuli chickpeas (*Cicer arietinum* L.) to the low and high lands in the West Mediterranean region of Turkey. Turk J Field Crop 3:10-15.

Toker C and Canci H (2003). Selection of chickpea (*Cicer arietinum* L.) genotypes for resistance to ascochyta blight [*Ascochyta rabie*i (Pass.) Labr.], yield and yield criteria. Turk J Agric For27: 277-283.

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Yasar M, Ceylan FO, Ikten C and Toker C (2013). Comparison of expressivity and penetrance of the double podding trait and yield components based on reciprocal crosses of kabuli and desi chickpeas (*Cicer arietinum* L.). Euphyticadoi:10.1007/s001090000086

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Yasar M (2012). Penetrance and expressivity of double podding characteristic in chickpea (*Cicer arietinum* L.). Dissertation, Akdeniz University, Antalya.

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Abbreviations

Abbreviations should be defined at first mention and used consistently.

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