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***Research Article***

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# Analysis of Characters Affecting Yield and Yield in Chickpea

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**HIGHLIGHTS**

- Chickpea is an important legume plant in terms of its protein content.
- Chickpea plants need to be improved in terms of yield and characteristics affecting yield.

**Abstract**

It aimed to reveal some chickpea varieties' yield and yield parameters with descriptive statistics in Yozgat ecological conditions for two years in 2022 and 2023. In the study, 10 chickpea varieties (Azkan, Çağatay, Çakır, Gökçe, Hasanbey, İnci, Seçkin, Sezenbey, Uzunlu 99 and Zuhal) were used as materials. In the study, plant height (cm), first pod height (cm), biological yield (g), number of pods per plant (pcs), number of seeds per plant (pcs), seed yield per plant (g), hundred seed weight (g), harvest index. (%) and seed yield per decare (kg da$^{-1}$) characteristics were examined. As a result of the study, it was revealed that chickpea varieties were significantly affected by all the examined agronomic characteristics except the height of the first pod. According to the two-year averages of chickpea varieties, the number of pods per plant varied between 13.67-39.33 units, the number of seeds per plant varied between 12.00-28.67 units, seed yield per plant varied between 4.26-8.37 g, hundred seed weight varied between 28.67-36.37 g and seed yield per decare varied between 82.71-124.5 kg da$^{-1}$. It was observed that Gökçe, Çakır, and Çağatay chickpea varieties included in the study had high seed yield.

**Keywords:** Yozgat; Chickpea; Variety; Yield parameters; Descriptive statistics

## 1. Introduction

The chickpea plant is significant among pulses grown for food and is very important for Turkey. Besides its importance in human nutrition, pulses also have many benefits, including being a source of plant-based protein crucial for animal nutrition. Mainly because it requires less water compared to other pulses, the chickpea plant is suitable for arid conditions, with its cultivation dating back 7,000 years in the Middle East and 5,000 years in Anatolia (Pellet 1988). The chickpea plant is especially preferred due to its essential amino acids, vitamins, and protein content.

According to 2022 data, chickpea cultivation is carried out on 14.8 million hectares worldwide, with approximately 10 million hectares in India. In Turkey, chickpeas are grown in an area of 456,000 hectares, but

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chickpea cultivation in our country has shown a decreasing trend of about 10% in recent years (Burcu 2021). While the world average yield is reported as 122.18 kg da$^{-1}$, Turkey's yield is above this average at 127.06 kg da$^{-1}$, with China holding the top position among countries with a yield of 523 kg da$^{-1}$ (FAO 2022).

As the world population increases uncontrollably, migrations also force countries to change their plans. Consequently, due to future concerns, governments are trying to develop behavioural patterns beyond expectations. Food supply is the most significant concern (Dowd and Burke 2013; Ustaahmetoğlu and Toklu 2015). Joachim (2009) stated that countries are starting to face risks in terms of food supply, and those who are not self-sufficient may face much more significant problems in the near future. Thomas (2006) emphasized that controlling food security and trade will become necessary and that serious measures must be taken. Kıymaz and Şahinöz (2011) pointed out that ensuring food security requires the sufficient cultivation of the right products, highlighting the importance of strategic products.

The importance of chickpeas as a strategic product for our country continues to increase daily. The high cost of animal-based proteins drives consumers towards plant-based proteins (Topalak and Ceyhan 2015; Sözen et al. 2021). In addition to increasing productivity, conducting studies that protect the soil and enhance sustainability is necessary. While pulses for food possess these characteristics, chickpeas seem highly suitable for our country's ecology. Therefore, chickpea plants need improved yield and yield-affecting traits (Ceyhan et al. 2012a,b; 2013; Kahraman et al. 2016; Sözen and Karadavut 2019).

In this study, we aim to evaluate the cultivation of registered chickpea varieties under arid conditions in our country and determine whether these varieties are ready for the future. For this, it is necessary to see their performance in arid and semi-arid conditions. Care was taken to select the selected varieties and regions in accordance with the purpose of the study. Accordingly, developing appropriate models will help us in this effort (Karadavut et al. 2019). Growing plants under natural conditions in different locations and years will provide reliable information about their performance. The information obtained will help us in the selection of the best plants that can reduce the effects of drought.

## 2. Materials and Methods

The field trials of the research were established during the chickpea growing seasons of 2022 and 2023 on the agricultural land of a farmer named İbrahim Hakkı in Toprakpınar village, Sarıkaya district, Yozgat province.

### *2.1. Materials*

The materials of the research consist of 10 chickpea varieties (Azkan, Çağatay, Çakır, Gökçe, Hasanbey, İnci, Seçkin, Sezenbey, Uzunlu-99, and Zuhal) that were registered by research institutes affiliated with TAGEM in different years. The selected varieties are genotypes that have been tried to be grown under dry conditions in different regions of Turkey for many years. However, they have not been grown in the areas where the experiment was conducted except for Azkan and Gökçe. Their areas are also very limited and irrigated areas.

### *2.2. Soil Characteristics of the Trial Site*

The land where the research was conducted for two years is a first-class land with a nearly flat topography showing loamy characteristics. When evaluating the soil properties of the experimental field where the studies were conducted, it was determined that the soil is very slightly alkaline, has good organic matter, is sufficient in available phosphorus and potassium, is non-saline in salt content, and has shallow lime content.

In the study where the research was carried out for two years, soil analyses were carried out in the Ahi Evran University Central Laboratory. The trial area is a first-class land with almost flat topography, showing loamy characteristics. When the soil characteristics of the trial area where the studies were carried out were evaluated, it was determined that the soil was very slightly alkaline, had good organic matter, was sufficient in terms of available phosphorus and potassium, had no salt content and had shallow lime content. These evaluations were made according to Kaçar (1995).

*2.3. Climate Characteristics of the Research Area*

The climate values for the experimental years and long-term averages for the Sarıkaya district of Yozgat province, where the studies were conducted, are given in Table 1. When evaluating the table, it is seen that the average temperature in the experimental area during the growing seasons was the lowest in March (2.4 °C and 3.4 °C) and the highest in July (24.3 °C and 23.7 °C) for both years. These values are above the long-term average values. Regarding precipitation, March had the highest rainfall in the first and second years (83.3 mm and 71.5 mm), while the precipitation amounts in both years were below the long-term averages, except for March. As for humidity, no significant changes were observed in both years, with relative humidity values ranging between 48.6% and 77.1%. When Table 1 is examined, it is seen that while there is no significant change in humidity and temperatures compared to the average for many years, the precipitation in the region has decreased significantly in May and June. This is expected to be effective in the growth, development and differentiation of the varieties.

**Tablo 1.** Climate data for Sarıkaya/Yozgat

| Months | Average Temperature ($^0$ C) | | | Total Rainfall (mm) | | | Average Relative Humidity (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2022 | 2023 | Long Years | 2022 | 2023 | Long Years | 2022 | 2023 | Long Years |
| **March** | 2.4 | 3.4 | 3.4 | 83.3 | 71.5 | 68.2 | 77.1 | 72.8 | 70.9 |
| **April** | 6.7 | 7.1 | 8.5 | 20.4 | 35.9 | 57.8 | 73.9 | 69.3 | 64.9 |
| **May** | 15.8 | 15.2 | 13.4 | 41 | 52 | 59 | 54.3 | 59.6 | 62.9 |
| **June** | 20.2 | 19.5 | 16.9 | 33 | 28 | 63 | 57.8 | 58.3 | 59.3 |
| **July** | 24.3 | 23.7 | 20.2 | 18 | 10 | 23.1 | 48.6 | 51.3 | 52.8 |
| **Total** | | | | 195.3 | 197.4 | 271.1 | | | |

*2.4. Method*

The research was conducted on the agricultural land of a farmer named İbrahim Hakkı in 2022 and 2023 and was established according to a randomized block design with three replications. In both years, the plot areas were arranged as 5 x 1.2 = 6 square meters, with each plot consisting of 4 rows. Throughout both years, sowing was performed at 30 cm row spacing, and 5-8 cm on the rows opened with a marker, and no space was left between the plots. Sowing was carried out on March 23 in the first year and on March 25 in the second year, and along with sowing, 15 kg of DAP fertilizer (2.7 kg N $da^{-1}$ and 6.9 kg $P_2O_5$ $da^{-1}$) per decare was applied to the trial area, with hoeing done twice during the growing seasons. The harvest of the chickpea varieties in the trial areas during the research years was done manually between July 5 and July 25, when they reached harvest maturity. Plants in the 2.4 square meters area (4.0 m x 0.6 m) were harvested by excluding one row from each side of each plot and 50 cm from the beginning and end of the plot as border effects. In both years, plant height, first pod height, biological yield, number of pods per plant, number of seeds per plant, seed yield per plant, hundred seed weight, and harvest index were determined in 10 randomly selected plants from each plot, and the averages were calculated to determine the average values per plant.

Additionally, the seed yields per decare in kg $da^{-1}$ were calculated from the plants harvested from each plot after removing the border effects. The results obtained over two years were primarily analyzed for descriptive statistics according to the examined characteristics, followed by variance analysis. The Duncan ($p<0.05$) multiple comparison test was applied to determine the differences among varieties. The effects of variety, year, and variety*year interactions were examined, and their significance was determined. Furthermore, the distribution of varieties by year was graphically analyzed to see the distribution of data for the varieties. The MINITAB 17 V statistical software package was used in the study.

## 3. Results

*3.1. Plant Height*

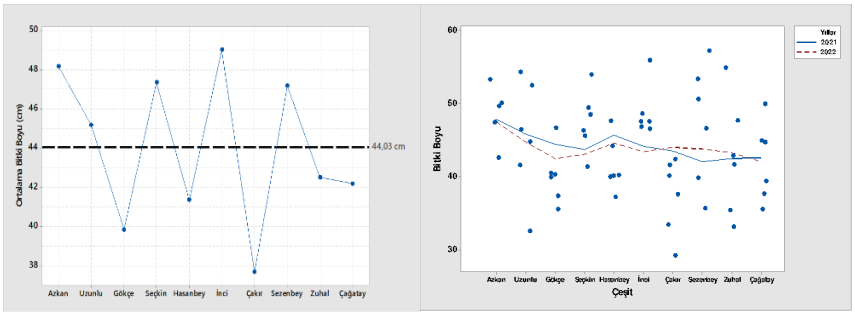
Descriptive statistics ve post hoc test results for the plant height of chickpea varieties are given in Table 2. When the table is examined, it is observed that the highest plant height was found in the İnci variety at 49.00 cm, followed by the Azkan variety at 48.17 cm. The çakır variety had the lowest value. According to variance analysis the differences between the years and the variety*year interactions were not found to be statistically

significant. The lack of substantial changes across the years was attributed to the minimal climatic differences observed during the study period.

**Table 2.** Descriptive statistics of varieties for plant height

| Varieties | Average | Gruplandırma |
|---|---|---|
| Azkan | 48.17±1,17 | AB |
| Uzunlu 99 | 45.17±2,41 | AB |
| Gökçe | 39.83±1,32 | AB |
| Seçkin | 47.33±1,29 | AB |
| Hasanbey | 41.33±1,13 | AB |
| İnci | 49.00±1,10 | A |
| Çakır | 37.67±1,67 | B |
| Sezenbey | 47.17±2.50 | AB |
| Zuhal | 42.50±2,47 | AB |
| Çağatay | 42.17±1,74 | AB |

When the average values of the varieties are examined, it is seen that the average height is 44.03 cm (Figure 1a). It was determined that the Azkan, Uzunlu, Seçkin, İnci, and Sezenbey varieties have values above the average plant height. In contrast, the Gökçe, Hasanbey, Çakır, Zuhal, and Çağatay varieties have values below the average. The İnci variety deviated the most above the average, while the Çakır variety deviated the most below the average. The distribution of plant heights by year for the varieties is shown in Figure 1b. When the figure is examined, it is seen that the distribution does not differ between years. Although the average curves appear different by year, their difference is insignificant.




**a** **b**

**Figure 1.** Distribution of plant heights around the average and change in plant height over the years

The soil structure of the cultivated land is open to variability. The amounts of rainfall, humidity, and sunshine need to support this. However, this was different. In the study, among the differences between varieties, the İnci variety, with a height of 49.00 cm, was categorized in Group A, distinguishing it from the others. Conversely, the Çakır variety, with a height of 37.67 cm, was placed in Group B, while all other varieties fell into the AB category, indicating they were in the same group. There was no statistical significance among varieties within the same group. in her study on chickpea plants in Ayrancı / Karaman, found that plant height values vary between 41.0 and 52.0 cm in dry conditions. Ölmez et al. (2020) stated that the influence of environmental conditions on plant height was low in their density study conducted in Siirt. Similarly, Ali et al. (2008) found that the influence of environmental conditions on plant height variation was lower than for other traits in their study conducted in Pakistan. The first thing affected by drought conditions is generally plant height and it is expected that they will be short in general. The fact that plant height is similar to the results of other researchers suggests that the response of the varieties to drought is limited. This is considered promising considering that drought will increase slightly in the future.

*3.2. First Pod Height*

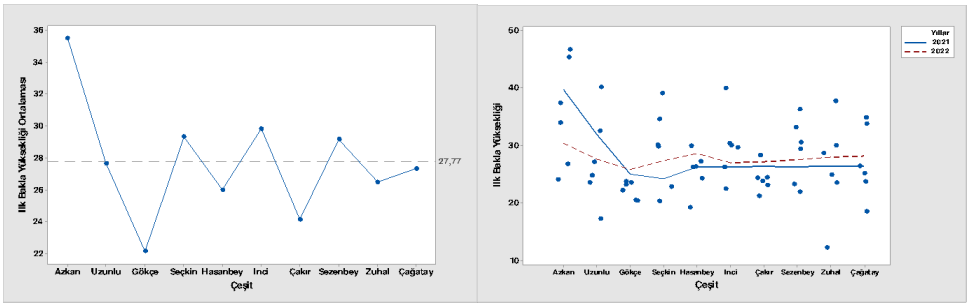
This trait is evaluated alongside plant height, and the first pod height should be as high as possible, mainly because it affects mechanical harvesting and the development of diseases. When examining the descriptive statistics for the first pod height, it is seen that the Azkan variety has the highest value at 32.67 cm (Table 3).

This is followed by the İnci variety at 29.83 cm. The lowest first pod height value was found in the Gökçe variety at 22.17 cm. Regarding standard deviation and variance, the Zuhal variety showed the highest values, with a standard deviation of 8.26 and a variance of 68.30, indicating that the Zuhal chickpea variety has broader limits for variability. The lowest standard deviation and variance were found in the Gökçe variety, with a standard deviation of 1.329 and a variance of 1.747. The highest coefficient of variation was also observed in the Zuhal variety, with a value of 31.19%. According to the results of the variance analysis, the variety*year interaction and the differences between varieties and years were not statistically significant. The insignificance of the differences in first pod height suggests that the varieties' responses in this regard are similar and that this difference will diminish over time. The insignificance of the interaction is particularly noteworthy.

**Table 3.** Importance of varieties, years, and interactions according to first pod height

| Varieties | Average | Post Hoc |
|---|---|---|
| Azkan | 32.67±2.44 | A |
| Uzunlu99 | 27.67±2,47 | A |
| Gökçe | 22.17±0,42 | A |
| Seçkin | 29.33±2,21 | A |
| Hasanbey | 26.00±1,08 | A |
| İnci | 29.83±1,82 | A |
| Çakır | 24.167±0,73 | A |
| Sezenbey | 29.17±1,83 | A |
| Zuhal | 26.50±2,61 | A |
| Çağatay | 27.33±1,93 | A |

In terms of first pod height, the Azkan, İnci, Sezenbey, and Hasanbey varieties have values above the average. In contrast, the Seçkin, Uzunlu, Çağatay, Zuhal, Çakır, and Gökçe varieties have values below the average (Figure 2a). Notably, the Gökçe variety, having the lowest first pod height value, will seriously and negatively impact mechanical harvesting. When examining the first pod heights of the varieties by year, it is seen that the curves move similarly (Figure 2b). Notably, the Azkan variety has the highest first pod height in both years.




**a** **b**

**Figure 2.** Distribution of first pod heights around the average and change in first pod height over the years

Since the first pod height is influenced by plant height, the insignificant interaction, similar to plant height, is considered an expected result. Pandey and Rastogi (2003) stated in their study with 33 chickpea genotypes that the first pod height is essential for chickpeas, but due to climatic conditions, the plant height remained relatively high. Therefore, the first pod height did not increase significantly either. They noted that improving climatic conditions would increase the first pod height. Aarif et al. (2014) emphasized in their study that many traits, including first pod height, are controlled by genetic factors and that this should be given special attention in breeding programs.

Santos et al. (2017) obtained similar results in their genetic diversity study. Aswathi et al. (2019), in their genetic diversity studies with 52 genotypes, stated that genetic factors largely determine the first pod height. In the conducted research, it was observed that environmental factors did not significantly affect the first pod height. This suggests that genetic factors have a strong influence. The results obtained are similar to those of the researchers. Considering this issue in future studies will affect the success of breeding programs.

*3.3. Biological Yield*

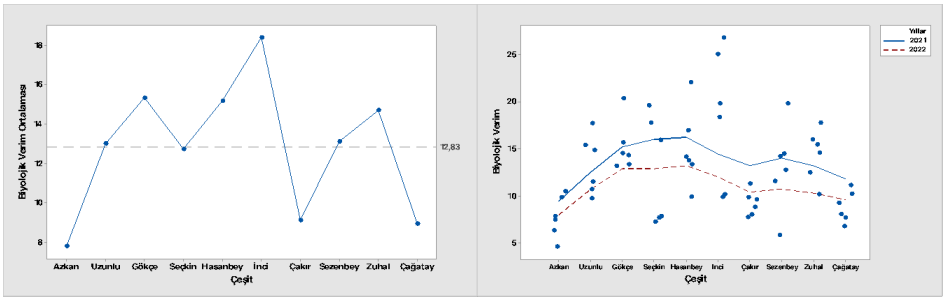
Biological yield is considered one of the critical indicators of plant growth and development, and the growth status of the plant's habitus directly affects the biological yield. Descriptive statistics for varieties regarding biological yield are presented in Table 4. When the table is examined, the highest biological yield value is observed in the İnci variety, 18.40 kg, followed by the Gökçe variety, 15.33 kg. The lowest value is observed in the Azkan variety, which is 7.797 kg. It can be said that the İnci and Seçkin varieties have quite variable characteristics in terms of biological yield. The most stable variety is the Çakır variety. Significantly, the slight variance suggests that it is resistant to variability. Regarding sources of variation, the Seçkin variety is in the first place with 44.32%. The variance analysis for biological yield determined a significant interaction between variety and year, and varieties and years differ significantly (Table 7). It was found that the İnci variety achieved the highest value, while the Azkan variety obtained the lowest value. Looking at the years, the average value for the first year was 14.43, and for the second year, it was 12.12.

The observed difference between them was found to be statistically significant. The significant difference between the years suggests that the year factor should be considered one of the crucial factors determining yield. The interaction's significance indicates that the varieties' environmental responses vary significantly from year to year, directly affecting the yield depending on the conditions.

**Table 4.** Importance of varieties, years, and interactions according to biological yield

| Varieties | Average | Post Hoc |
|---|---|---|
| Azkan | 7.797±0,65 | C |
| Uzunlu99 | 13.00±0,95 | ABC |
| Gökçe | 15.33±0,85 | AB |
| Seçkin | 12.73±1,78 | ABC |
| Hasanbey | 15.17±1,31 | ABC |
| İnci | 18.40±2,23 | A |
| Çakır | 9.125±0,41 | BC |
| Sezenbey | 13.11±1,43 | ABC |
| Zuhal | 14.70±0,83 | ABC |
| Çağatay | 8.940±0,47 | BC |

In terms of biological yield, it is observed that the Uzunlu 99, Gökçe, Hasanbey, İnci, Sezenbey, and Zuhal varieties have values above the yield average. In contrast, the Azkan, Seçkin, Çakır, and Çağatay varieties fall below the average (Figure 3a). Notably, the İnci variety stands out as significantly above the average, whereas the Azkan and Çakır varieties are notably below the average. Significant differences between the years are observed when examining the changes in the biological yield of the varieties over the years (Figure 3b). The average value is higher in 2021, while lower values are recorded in 2022. This decline in the second year is thought to be determined by the changes in climatic conditions.




**a** **b**

**Figure 3.** Distribution of first pod heights around the average and change in biological yield over the years

Pramanik et al. (1990) conducted studies in Bangladesh, indicating that biological yield increases with plant density, but the primary determinant is the variability in environmental conditions. As long as the environmental conditions are conducive to cultivation, there is a tendency for an increase in biological yield. Still, conversely, a decrease is expected in adverse conditions. Akdağ and Şehirali (1995) suggested that increasing the number of plants per square meter is necessary for increasing biological yield, but favourable environmental conditions should support it. Similar conclusions were presented by Khan et al. (2001)

regarding biological yield. Çancı and Toker (2009) stated in their study that temperature changes and drought significantly affect yield and its influencing factors. Agrawal et al. (2018) reported that biological efficiency significantly and positively correlated with grain yield in dry conditions. The unpredicted exacerbation of drought with increasing temperatures is considered especially possible. The recent climate changes indicate that we will face this problem more severely in the coming years. Therefore, we must reconsider our thoughts and plans regarding drought and temperature.

*3.4. Number of Pods per Plant*

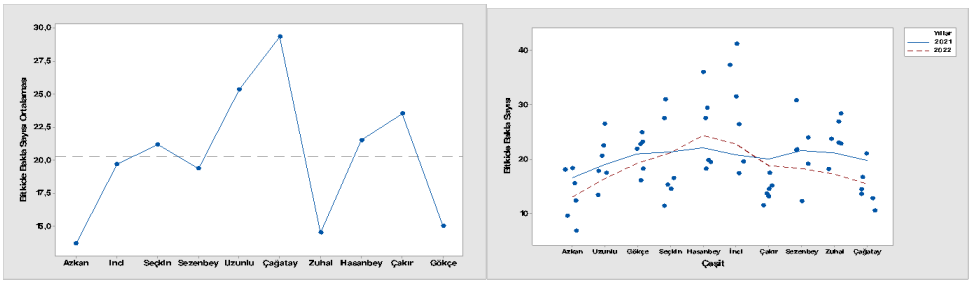
Descriptive statistics for this trait were determined and presented in Table 5. Upon examination of the table, the highest number of pods per plant, 29.33, was observed in the İnci variety, followed by the Hasanbey variety with 25.33. The lowest value, 13.67 pods per plant, was observed in the Azkan variety.

Regarding the number of pods per plant, the Seçkin, Uzunlu, Çağatay, Hasanbey, and Çakır varieties are found to have values above the average number of pods per plant, while the Azkan, İnci, Sezenbey, Zuhal, and Gökçe varieties are below the average (Figure 4a). It is observed that, except for the Sezenbey variety, the varieties below the average significantly diverge from the mean. Among the varieties above the average, Çağatay has shown a distinct divergence behaviour.

**Table 5.** Importance of varieties, years, and interactions according toThe number of pods per plant

| Varieties | Average | Post Hoc |
|---|---|---|
| Azkan | 13.67±1,42 | C |
| Uzunlu99 | 19.67±1,54 | ABC |
| Gökçe | 21.17±1,09 | ABC |
| Seçkin | 19.33±2,58 | ABC |
| Hasanbey | 25.33±2,24 | AB |
| İnci | 29.33±3,12 | A |
| Çakır | 14.50±0,71 | BC |
| Sezenbey | 21.50±1,77 | ABC |
| Zuhal | 23.50±1,07 | ABC |
| Çağatay | 15.00±1,09 | BC |

When evaluating the varieties by years in terms of the number of pods per plant, it is seen that there is a significant difference between the years (Figure 4b). While the varieties exhibited more stable behaviour in the first year, there was more variation in the second year. Hasanbey and İnci varieties have shown this change more prominently.




**a** **b**

**Figure 4.** Distribution of first pod heights around the average and change in the number of pods per plant over the years

The variance analysis results indicate that the variety*year, variety, and year factors are statistically significant for the number of pods per plant. The significance of the variety*year interaction suggests that changes over the years significantly affect the number of pods per plant for different varieties. Environmental factors, especially climatic variations, are thought to play a crucial role in creating these differences. The values obtained in the first year are higher compared to the second year. Therefore, the conditions in the first year were more favourable for plant growth and development than in the second year. Significant differences between the varieties are observed. Especially the İnci and Azkan varieties stand out distinctly compared to

others. It is understood that the variations in other varieties are relatively lower. Atta et al. (2008) examined the variation of quantitative traits in chickpea plants. They emphasized that variables, including the number of pods per plant, depend on location, time, and cultivation conditions. Fang et al. (2010) mentioned that water deficits during plant growth and development can adversely affect traits that contribute to yield. Based on the study, climate conditions are the primary determinant of traits influencing yield.

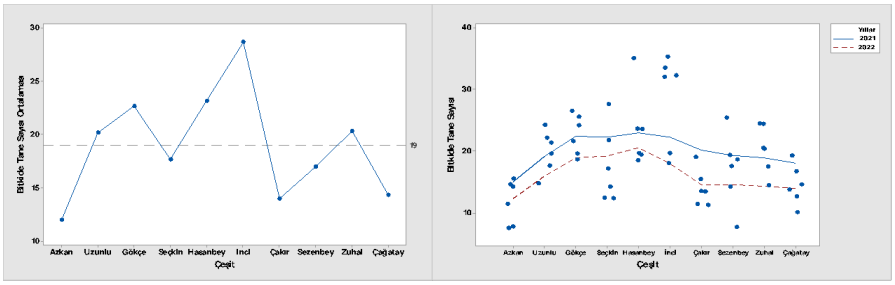
*3.5. Number of Seeds per Plant*

When the number of seeds per plant for different varieties is examined, it is observed that the highest number is 28.67 for the İnci variety, followed by 23.17 for the Hasanbey variety (Table 6). The lowest value is observed to be 12.0 for the Azkan variety. The analysis results for the number of seeds per plant indicate that the interactions between variety*year and the differences between varieties and years are statistically significant. The significance of the variety*year interaction implies that varieties are significantly influenced by changing environmental conditions from year to year. The high variability between years is considered necessary for indicating the stability of varieties.

**Table 6.** The number of seeds per plant

| Varieties | Average | Post Hoc |
|---|---|---|
| Azkan | 12.00±1,11 | C |
| Uzunlu 99 | 20.17±1,02 | ABC |
| Gökçe | 22.67±0,96 | AB |
| Seçkin | 17.67±1,96 | BC |
| Hasanbey | 23.17±1,97 | AB |
| İnci | 28.67±2,42 | A |
| Çakır | 14.00±0,93 | BC |
| Sezenbey | 17.00±2,00 | BC |
| Zuhal | 20.33±1,29 | ABC |
| Çağatay | 14.33±1,07 | BC |

According to the average number of seeds per plant for different varieties, it is observed that Uzunlu, Gökçe, Hasanbey, İnci, and Zuhal varieties have values above the average. In contrast, Azkan, Seçkin, Çakır, Sezenbey, and Çağatay varieties fall below the average (Figure 5a). Particularly noteworthy are the deviations of Azkan and İnci varieties from the mean. Seçkin and Zuhal varieties are found to be the closest to the mean. When examined over the years, significant differences between years are observed (Figure 5b). All varieties had higher values in the first year than in the second year. It is noticed that the Azkan variety has the lowest values in both years, whereas the Hasanbey variety has the highest values.




**a** **b**

**Figure 5.** Distribution of first pod heights around the average and change in the number of seeds per plant over the years

When examining the varieties, it is observed that the İnci variety stands out in Group A, while similarly, the Azkan variety is segregated at the lowest level in Group C. Fang et al. (2011) pointed out that the number of seeds per plant is one of the most sensitive periods during growth and development. Environmental changes during this period can affect seed numbers. Kalefetoğlu and Ekmekçi (2009) stated that during seed maturation in chickpea plants, phytochemical and physiological activities increase, but the primary determinant of these activities is the amount of water in the environment. In the study, the changes observed in all traits in the second year were attributed to the decrease in rainfall compared to the previous year. This

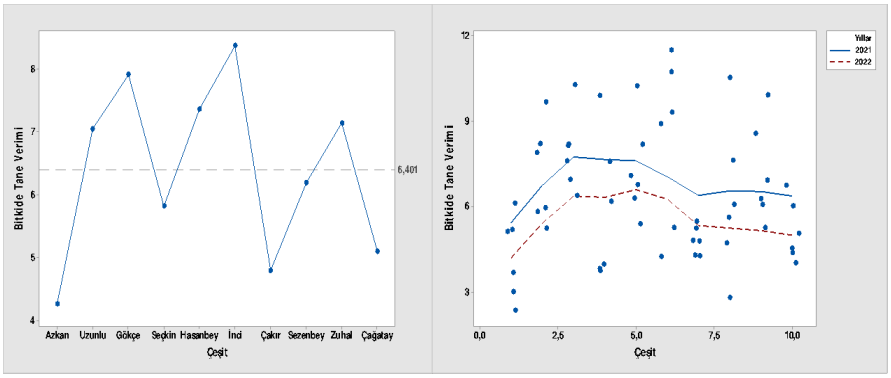
explanation aligns with the findings of Kashiwagi et al. (2006), who reported that a reduction of soil moisture negatively affects root development, leading to a decrease in pod and seed formation in plants.

*3.6. Seed Yield Per Plant*

Descriptive statistics for this trait are provided in Table 7. The highest seed yield per plant was determined to be 8.37 g for İnci, followed by 7.91 g for the Gökçe variety. The lowest value was recorded as 4.26 g for the Azkan variety. It has been determined that Azkan, Seçkin, Çakır, Sezenbey, and Çağatay varieties have values below the average weight of 6.401 g for seed yield per plant. In contrast, Uzunlu, Gökçe, Hasanbey, İnci, and Zuhal varieties are observed to exceed the average value. The deviation of the Azkan and İnci varieties from the average is higher than the others. According to the variance analysis conducted for seed yield per plant, it has been determined that the differences between variety*year, varieties, and years are statistically significant. The average values for the first year (7.23 g) are observed to be higher than those for the second year (6.02 g). Essential changes are observed in the İnci and Azkan varieties, while the others appear similar or close. Considering that Azkan and İnci varieties exhibit similar behaviour in other traits, these results can be regarded as expected.

**Table 7.** Importance of varieties, years, and interactions according to seed yield per plant

| Varieties | Average | Post Hoc |
|---|---|---|
| Azkan | 4.26±0,42 | C |
| Uzunlu99 | 7.48±0,53 | ABC |
| Gökçe | 7.91±0,41 | AB |
| Seçkin | 5.82±0,78 | ABC |
| Hasanbey | 7.36±0,53 | ABC |
| İnci | 8.37±0,89 | A |
| Çakır | 4.79±0,14 | BC |
| Sezenbey | 6.19±0,81 | ABC |
| Zuhal | 7.14±0,54 | ABC |
| Çağatay | 5.10±0,31 | ABC |




**a** **b**

**Figure 6.** Distribution of first pod heights around the average and change in seed yield per plant over the years

Shrestha et al. (2006) examined the physiology of seed yield and emphasized that environmental conditions significantly influence yield more than genetic factors. They noted that soil water deficiency directly impacts seed yield, drastically reducing seed weight under insufficient water conditions. Fogelberg and Martensson (2021) highlighted that factors such as soil properties and nutrient adequacy play crucial roles in plant productivity beyond the characteristics of varieties. They suggested that suitable soil conditions are essential for plants to achieve their potential yield. Slafer et al. (2009) indicated that environmental conditions and genetic control should be considered together to enhance plant yield. Our study observed that the yield per plant significantly decreased in the second year compared to the first year. Poor rainfall distribution during

the growing season adversely affected plant growth and development, hindering seed maturation and reducing seed yield.

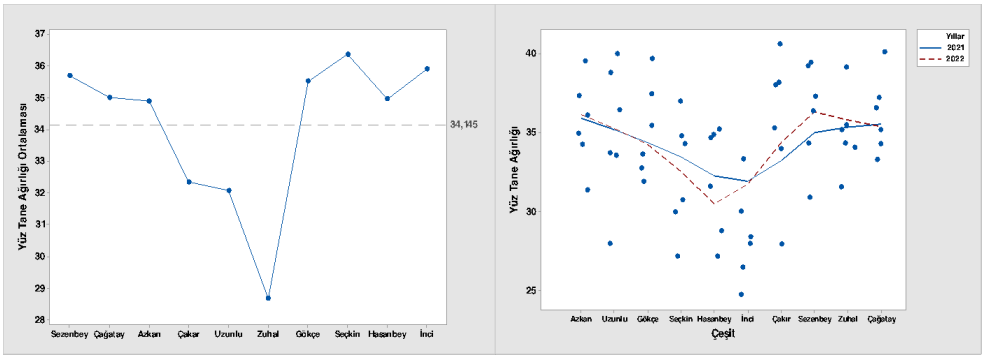
*3.7. Hundred Seed Weight*

One of the determinants of yield is hundred seed weight, where the desired size of seeds can only be achieved under suitable environmental conditions. Descriptive statistics for this characteristic are presented in Table 8. While differences among varieties are statistically significant, years and variety*year interaction are insignificant. Sezenbey, Çağatay, Azkan, Çakır, and Uzunlu varieties are grouped, while İnci variety stands apart from the others. The highest hundred seed weight value, 36.37 g, was observed in the Sezenbey variety, followed by 35.91 g in the Çağatay variety. The lowest value, 28.67 g, was observed in the İnci variety.

**Table 8.** Importance of varieties, years, and interactions according to 100 seed weight

| Varieties | Average | Post Hoc |
|---|---|---|
| Azkan | 35.70±0,88 | A |
| Uzunlu99 | 35.01±1,37 | A |
| Gökçe | 34.90±0,94 | AB |
| Seçkin | 32.34±1,12 | AB |
| Hasanbey | 32.07±1,08 | AB |
| İnci | 28.67±0,93 | B |
| Çakır | 35.52±1,40 | A |
| Sezenbey | 36.37±1,02 | A |
| Zuhal | 34.96±0,74 | AB |
| Çağatay | 35.91±0,73 | A |

When we look at the distribution around the mean of hundred-seed weight, Çakır, Uzunlu, and Zuhal varieties are below the average, with Zuhal notably diverging (Figure 7). On the other hand, Sezenbey, Çağatay, Azkan, Gökçe, Seçkin, Hasanbey, and İnci varieties are above the average, showing no significant deviation from the mean value. Examination of the variation in hundred-seed weight over the years reveals no significant differences. The average for the first year was 35.31 g, whereas for the second year, it was 35.34 g.




**a** **b**

**Figure 7.** Distribution of first pod heights around the average and change in 100 seed weight over the years

Dua (1992) emphasized that excessive chloride levels in the environment are highly affected by chickpea genotypes, which can limit plant growth and development. Increased chloride levels due to salinity in dry areas could negatively impact yield and yield-related traits, warranting caution. Aswathi et al. (2019) highlighted significant variations in morphological and biometric characteristics among 52 genotypes, emphasizing that seed-filling periods are critical. Notably, the high hundred-seed weight indicates successful seed filling, hence requiring special attention. In our study, the weight of the hundred seeds varied among varieties but showed no significant changes across the years. Therefore, it can be concluded that the overall condition of the soils where cultivation is carried out is suitable for chickpea farming. Maintaining acceptable salinity levels also ensures that chloride does not directly harm plants.

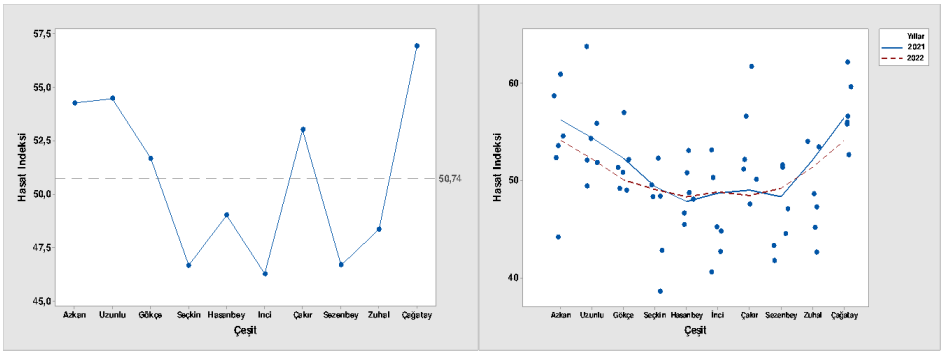
*3.8. Harvest Index*

Harvest index, considered a significant yield indicator, exhibited considerable variability among varieties. The highest harvest index value was observed in Çağatay variety at 56.94%, followed by Uzunlu 99 at 54.48%. The lowest value was recorded in the İnci variety at 46.29% (Table 9).

**Table 9.** Importance of varieties, years, and interactions according to harvest index

| Varieties | Average | Standard Deviation |
|---|---|---|
| Azkan | 54.26±1,81 | 5.74 |
| Uzunlu99 | 54.48±1,62 | 5.13 |
| Gökçe | 51.67±0,86 | 2.72 |
| Seçkin | 46.67±1,62 | 5.14 |
| Hasanbey | 49.02±0,86 | 2.74 |
| İnci | 46.29±1,49 | 4.73 |
| Çakır | 53.01±1,64 | 5.19 |
| Sezenbey | 46.69±1,31 | 4.13 |
| Zuhal | 48.37±1,54 | 4.88 |
| Çağatay | 56.94±0,98 | 3.14 |

In terms of harvest index, Azkan, Uzunlu, Çakır, and Çağatay varieties were observed to exceed the average index value of 50.74 (Figure 8). Conversely, Seçkin, Hasanbey, İnci, Sezenbey, and Zuhal varieties fell below the average. Çağatay variety surpassed the average, whereas the İnci variety deviated below the average. Similar to other traits, the variability observed among varieties is generally attributed to environmental factors that shape genetic characteristics. When examining various responses across years, no statistically significant differences were observed between years. Upon reviewing the movement of curves, it can be seen that they exhibit similar patterns. Although changes were observed across years in harvest index values, these variations did not lead to significant differences.




**a** **b**

**Figure 8.** Distribution of first pod heights around the average and change in harvest index over the years

In the study, significant differences were observed among varieties, while years and the interaction between year and variety were found to be insignificant. The lack of significance of years could indicate that varieties exhibit similar responses in terms of harvest index across different years. Additionally, the insignificance of interaction suggests that variations among varieties across years are not substantial enough to create significant differences, indicating stability in this trait.

Mohammed et al. (2015) stated that the harvest index is a crucial determinant for yield-related traits in chickpeas when conducting their study to ascertain genetic variability. They emphasized that the harvest index is mainly associated with traits such as plant height and seed filling, urging attention to these factors in future research. Additionally, Sohail et al. (2018) indicated that chickpeas' relationships among yield and yield-related traits are primarily genetic, with high heritability estimates. Akhtar et al. (2011) determined that the extent of inter-trait relationships influences the effects of yield-related traits. The conducted study supports that harvest index is notably correlated with traits such as plant height, first pod height, pod number per plant, and seed number per plant. However, the high genetic correlation between these traits will remain a fundamental determinant.

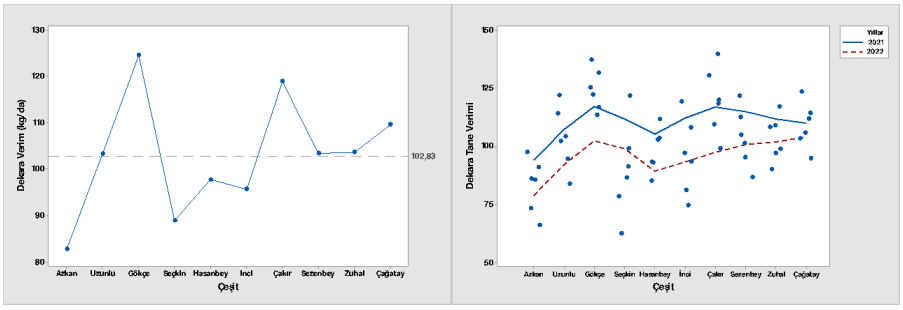
*3.9. Seed Yield*

Significant differences were observed when evaluating varieties for seed yield per hectare (Table 10). The highest seed yield was obtained from the Gökçe variety, with 124.51 kg/ha, followed by the Çakır variety, with 118.92 kg/ha. The lowest seed yield value was observed in the Azkan variety, with 82.71 kg/ha. Considering the Azkan variety's consistently lower values across all examined traits, this outcome was anticipated. In terms of overall yield levels, Azkan, Seçkin, Hasanbey, and İnci varieties have been observed to exhibit values below the average yield. In contrast, Uzunlu 99, Gökçe, Çakır, Sezenbey, Zuhal, and Çağatay varieties have shown yields above the average. However, Uzunlu 99 (103.27 kg/ha), Sezenbey (103.43 kg/ha), and Zuhal (103.61 kg/ha) varieties have yields very close to the average yield of 102.83 kg/ha. Analysis of yield values across years reveals that the first year (112.78 kg/ha) had a significantly higher yield than the second year (99.97 kg/ha). This difference is attributed to the adverse environmental conditions prevailing in the second year, negatively impacting all traits. Among the varieties, Gökçe stands out distinctly with the highest value, while Azkan also significantly differs from other varieties due to its lower yield performance.

**Table 10.** Importance of varieties, years, and interactions according to seed yield

| Varieties | Average | Standard Deviation |
|---|---|---|
| Azkan | 82.71±3,49 | 11.05 |
| Uzunlu 99 | 103.27±4,36 | 13.80 |
| Gökçe | 124.51±2,87 | 9.07 |
| Seçkin | 88.92±4,33 | 20.08 |
| Hasanbey | 97.72±3,14 | 9.94 |
| İnci | 95.63±4,17 | 16.36 |
| Çakır | 118.92±3,73 | 14.95 |
| Sezenbey | 103.43±3,72 | 11.77 |
| Zuhal | 103.61±3,07 | 9.71 |
| Çağatay | 109.57±3,11 | 9.82 |

Saeed et al. (2012) determined that the traits influencing yield significantly impact yield. Therefore, they suggested that evaluating yield based on individual characteristics and considering all components would provide a better assessment. Yadav et al. (2001) emphasized that understanding the traits associated with seed yield is essential for accurately defining yield potential. Palta et al. (2005) stated that besides traits influencing yield, plant nutrients also play a crucial role in determining seed yield. They highlighted that inadequate plant nutrients can decrease seed protein content, thereby reducing yield. The conducted study identified that traits associated with yield are effective. These traits are particularly influential during variable climatic conditions (Nayak and Altekar, 2015).




**a** **b**

**Figure 9.** Distribution of first pod heights around the average and change in seed yield over the years

## 4. Conclusions

Ecologically, environmental conditions are always fundamental in shaping and influencing factors affecting yield. Variations occurring within the same year can be influential, while differences between years can also be decisive. Breeders conducting breeding programs aim to identify genotypes least affected by changes in environmental conditions and exhibiting high stability. However, achieving this is highly

challenging and time-consuming, yet necessary. Studies involving environmental conditions can consider years as ecological factors, and they can also investigate environmental effects by taking different locations within the same year. In this study, changes over the years have been examined. Overall, it has been observed that varieties show significant responses to changes in climate. The significance of variety, year, and variety-year interactions indicates that environmental conditions strongly influence genetic factors. The Gökçe variety has generally exhibited successful performance in yield and yield-affecting traits, consistently ranking high. It can adapt better to changing environmental conditions than other varieties. In contrast, the Azkan variety's generally low performance in yield and yield-affecting traits indicates its weak tolerance to changing environmental conditions. When looking at the long-term average, there is no serious change in humidity, while the temperature has increased by 3.5-4.0 degrees. If the necessary precautions are not taken, it can be expected to increase a little more. It is seen that the amount of precipitation has decreased significantly with the increase in temperature. The fact that it has decreased by about half in 2022 and more than half in 2023 is worrying for the future, and also poses a problem in terms of plant cultivation. It can be said that chickpea plants have difficulty in showing their real yields in these locations. Considering that conditions will become a little more difficult in the future, it will be beneficial to grow drought-resistant varieties instead of drought-tolerant varieties. Additionally, while the Çakır variety typically received low values except for the hundred seed weight and harvest index, it showed good performance in terms of yield. According to the study, it is understood that varieties show differences in stability. Particularly under changing ecological conditions, such studies provide valuable insights for the future.

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**References**

Aarif M, Rastogi NK, Johnson PL, Chandrakar PK (2014). Genetic analysis of seed yield and its attributing traits in *kabuli* chickpea (*Cicer arietinum* L.). *Journal of Food Legumes* 27 (1): 24-27.

Agrawal T, Kumar A, Kumar S, Kumar, A, Kumar RR, Kumar S, Singh PK (2018). Correlation and path coefficient analysis for grain yield and yield components in chickpea (*Cicer arietinum* L.) under normal and late sown conditions of Bihar, India. *International Journal of Current Microbiology and Applied Sciences* 7 (2): 1633-1642.

Akdağ C, Şehirali S (1995). Effects of bacterial inoculation, nitrogen doses, and planting frequency on yield and yield components of chickpea. *Journal of Gaziosmanpaşa University Faculty of Agriculture* 12: 122-134.

Akhtar LH, Pervez MA, Nasim M (2011). Genetic divergence and inter-relationship studies in chickpea (*Cicer arietinum* L.). *Pakistan Journal of Agricultural Research* 48(1): 35-39.

Ali MA, Nawab NN, Rasool G, Saleem M (2008). Estimates of variability and correlations for quantitative traits in Cicer arietinum. *Journal of Agriculture and Social Sciences* 4: 177-179.

Aswathi PV, Ganesamurthy K, Jayamani P (2019). Genetic variability for morphological and biometrical traits in chickpea Cicer arietinum. *Electronic Journal of Plant Breeding* 10 (2): 699-705.

Atta BM, Haq MA, Shah TM (2008). Variation and inter-relationships of quantitative traits in chickpea (*Cicer arietinum* L.). *Pakistan Journal of Botany* 40 (2): 637-647.

Burcu D (2021). Product report. *Agricultural Economics and Policy Development Institute Tepge*, Tepge Publishing Number: 342, Ankara.

Ceyhan E, Kahraman A, Önder M, Ateş MK, Karadaş S, Topak R, Avcı MA (2012a). Physiological and biochemical responses to drought stress of chickpea genotypes. *International Journal of Agricultural and Biosystems Engineering* 6(6): 352-357.

Ceyhan E, Önder M, Kahraman A, Topak R, Ateş MK, Karadas S, Avcı M (2012b). Effects of drought on yield and some yield components of chickpea. *International Journal of Agricultural and Biosystems Engineering*, 6(6): 347-351.

Ceyhan E, Kahraman A, Ateş MK, Topak R, Şimşek D, Avcı MA, Önder M, Dalgıç H (2013). Konya koşullarında nohut (*Cicer arietinum* L.) genotiplerinin tane verim ve verim unsurlarının belirlenmesi. *Türkiye X. Tarla Bitkileri Kongresi*, 10 – 13 Eylül, Konya, Türkiye. Cilt 1, pp. 789-796.

Çancı H, Toker C (2009). Evaluation of yield criteria for drought and heat resistance in chickpea (*Cicer arietinum* L.). *J. Agronomy & Crop Science,* 195: 47-54.

Dowd K, Burke KJ (2013). The influence of ethical values and food choice motivations on intentions to purchase sustainably sourced foods. *Appetite* 69: 137-144.

Dua RP (1992). Differential response of chickpea (*Cicer arietinum* L.) genotypes to salinity. *The Journal of Agricultural Science* 119 (3): 367-371.

Fang X, Turner NC, Yan G, Li F, Siddique KHM (2010). Flower numbers, pod production, pollen viability, and pistil function are reduced and flower and pod abortion increased in chickpea (*Cicer arietinum* L.) under terminal drought. *Journal of Experimental Botany* 61: 335-345.

Fang X, Turner NC, Li FM, Siddique KHM (2011). An early transient water deficit rendece flower number and pod production but increases seed size in chickpea (*Cicer arietinum* L.). *Crop and Pasture Science* 62(6): 481-487.

FAO (2022). https://www.fao.org/faostat/en/#home Roma, İtalya.

Fogelberg F, Martensson AM (2021). Aspects on cultivation of vegetable soybean in Sweden-cultivars, soil requirements, inoculation and nitrogen contribution. *Acta Agriculturae Scandinavica, Section B-Soil & Plant Science* 71 (7): 633-644.

Joachim VB (2009). Addressing the food crisis: Governance, market functioning and investment in public goods. *Food Security* 1: 9-15.

Kaçar B (1995). Chemical Analyzes of Plants and Soil 3: Soil Analyzes. *Ankara University Faculty of Agriculture Education Research and Development Foundation Publications* 3, Ankara, Türkiye, p. 705.

Kahraman A, Önder M, Ceyhan E, Ulukuş F (2016). Nohut genotiplerinde cluster analizi ve önemli kalite parametreleri arasındaki ilişkiler. *Tarla Bitkileri Merkez Araştırma Enstitüsü Dergisi* 25(1): 196-200.

Khan RU, Ahad A, Rashid A, Khan A (2001). Chickpea production as influenced by row spacing under rainfed conditions of Dera Ismail Khan. *Online Journal of Biological Science* 3: 103-104.

Kalefetoğlu MJ, Ekmekçi Y (2009). Alterations in photochemical and physiological activities of chickpea (*Cicer arietinum* L.) cultivars under drought stress. *Journal of Agronomy & Crop Science* 195: 335-346.

Karadavut U, Sözen Ö, Yağmur M (2019). Estimation of root growth of chickpea plants grown at different sowing times with the Weibull model. *Turkish Journal of Agricultural and Natural Sciences* 6(4): 893-903.

Kashiwagi J, Krishnamurthy L, Crouch JH, Serraj R (2006). Variability of root length density and its contributions to seed yield in chickpea L.) under terminal drought stress. *Field Crops Research* 95: 171-181.

Kıymaz T, Şahinöz A (2011). World and Turkey food security situation. *Economic Approach* 21(76): 130.

Mohammed AA, Tahir IS, Elhashimi AM (2015). Assessment of genetic variability and yield stability in chickpea (*Cicer arietinum* L.) cultivars in River Nile State, Sudan. *Journal of Plant Breeding Crop Science* 7: 219-225.

Nayak G, Altekar N (2015). Effect of biofield treatment on plant growth and adaptation. *Journal of Environmental Health Sciences* 1: 1-9.

Ölmez M, Erman M, Erden Z, Çöçen E (2020). Determination of the effect of different row and plant frequency applications on plant growth and yield in 'Aziziye-94' chickpea cultivar. *Journal of Bahri Dagdas Crop Research* 9 (2): 166-177.

Palta JA, Nandwal AS, Kumari S, Turner NC (2005). Foliar nitrogen applications increase the seed yield and protein content in chickpea (*Cicer arietinum* L.) subject to terminal drought. *Australian Journal of Agricultural Research* 56: 105-112.

Pandey RL, Rastogi NK (2003). Attributes of seed yield in relation to seed size in chickpea (*Cicer arietinum* L.). *Indian Journal of Plant Genetic Resources* 16(1): 24-28.

Pellet P (1988). The place of lentils and chickpeas in human nutrition. *Lentils Symposium for Everyone* (29-30 September), Soil Crops Office Publications, Ankara, Türkiye, pp. 37-135.

Pramanik MHR, Khan MAH, Mushi AAA, Sadeque MA (1990). Optimum plant population for chickpea in Bangladesh. *Progressive Agriculture* 1(1): 61-67.

Saeed U, Ali Q, Naveed MT, Saleem M (2012). Correlation analysis of seed yield and its components in chickpea (*Cicer arietinum* l.) Genotypes. *IJAVMS* 6 (4): 269-276.

Santos HB, Bharadwaj C, Santos S, Raghavendra KP, Kumar J (2017). Genetic diversity analysis for productivity enhancement through *desi-kabuli* introgression breeding in chickpea. *Electronic Journal of Plant Breeding* 8 (1): 125-133.

Shrestha R, Turner NC, Siddique KHM, Turner DW (2006). Physiological and seed yield responses to water deficits among lentil genotypes from diverse origins. *Australian Journal of Agricultural Research,* 57: 903-915.

Slafer GA, Kantolic AG, Appendino ML, Miralles DJ, Savin R (2009). Crop development: genetic control, environmental modulation and relevance for genetic improvement of crop yield. Eds: Sadras VO, Calderini DF, *Crop Physiology: Applications for Genetic Improvement and Agronomy*, Academic Press, San Diego, CA, USA, pp.277-308.

Sohail A, Ahmad S, Rahman H, Burni T, Shah SMA, Ali S, Hussain Q (2018). Genetic variability, heritability, genetic advance as per cent of mean and correlation studies among $F_7$ populations of chickpea (*Cicer arietinum* L.). *Pure Applied Biology* 7(1): 57-65.

Sözen Ö, Karadavut U (2019). Correlation and path analysis of some chickpea genotypes grown in kırşehir ecological conditions for yield components. *Science and Technique in the 21st Century* 2 (12): 29-40.

Sözen Ö, Yağmur M, Aydoğan Y (2021). Evaluation in terms of agricultural characteristics of some chickpea (*Cicer arietinum* L.) varieties grown in Eskisehir ecological conditions. *Manas Journal of Agriculture Veterinary and Life Sciences* 11(1): 35-47.

Topalak C, Ceyhan E (2015). Nohutta farklı ekim zamanlarının tane verimi ve bazı tarımsal özellikler üzerine etkileri. *Selçuk Tarım Bilimleri Dergisi* 2(2): 130-139.

Thomas H (2006). Trade reforms and food security, country case studies and synthesis. FAO, Roma, ftp://ftp.fao.org/docrep/fao/009/a0581e/ a0581e00.pdf.

Karaman G (2023). A Study on determination of agronomic characteristics of some chickpea varieties in Karaman ecological conditions. Master's Thesis, Kırşehir Ahi Evran University (unpublished), Türkiye.

Ustaahmetoğlu E, Toklu İT (2015). A survey on the effect of attitude, health consciousness, and food safety on organic food purchase intention. *The International Journal of Economic and Social Research* 11 (1): 197-211.

Yadav NP, Sharma CH, Haque MF (2001). Correlation and regression study of seed yield and its components in chickpea (*Cicer arietinum* L.). *Journal of Research, Birsa Agricultural University* 13: 149-151.