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Original article

The Investigation of Some Morphological Characteristics of Forage Kochia Genotypes Determined Emergence Ratio

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Abstract

Forage kochia is a semi-shrub forage plant tolerant to drought, cold and soil salinity. In addition to being a quality feed source for livestock, with its ability to remain green in the dry feed period when other fodder plants dry up, it also offers the opportunity to fight wildfire during this season. Despite these advantages of forage kochia, the fact that it loses its seed viability in a brief time causes the restriction of the cultivation of this plant. For this reason, the seeds of three different forage kochia genotypes (C1, C2, M5) harvested in November 2018 and stored under room conditions were periodically sown at five different periods; the day after harvest, 4th months, 7th months, 10th months, and 13th months after harvest in greenhouse conditions. The study's first objective was to determine the genotype with the most prolonged viable period of seed viability. At this study stage, the M5 genotype, sown 10th months after harvest, was recorded as the highest value with a 35.7% emergence ratio. The survey also obtained C1 and M5 genotypes that retained seed viability one year after harvest. In the second phase of the study, plants showing emergence were planted in the field conditions in November 2020, and plant height, canopy diameter, stem diameter, leaf length, leaf width, leaf color, and hairiness of the plants were examined throughout 2021 and 2022. When the averages of the two-year data were analyzed, it was determined that genotype C1 had the highest plant height with 105 cm when sown 13th months after harvest. Although the genotype M5, which was also sown in this period, had the shortest plant height with a plant height of 42.5 cm, it can be stated that this genotype also had the darkest leaf color (Scoring 7.25; 1: Red-Grey, 3: Grayish Green, 5: Bluish Green, 7: Green, 9: Dark Green). As a result of the study, it can be stated that C1 and M5 genotypes, which were sown 13th months after harvest, stand out from the other genotypes in terms of their long seed viability period and morphological characteristics for use as a gene resource in forage kochia breeding.

Keywords: Forage kochia, Emergence, Gen resource, Seed viability, Yield components.

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INTRODUCTION

Forage kochia (*Bassia prostrata* Syn. *Kochia prostrata*) is a semi-shrub C4 plant in the *Amaranthaceae* family and is used for the improvement of pastures with arid, semi-arid and salt-affected soils in the world (Harrison et al., 2000; Roth et al., 2017; Anonymous, 2019). Especially in the summer dry feed period, it provides animals with 3rd and 4th quality standard feed by remaining green (Acar et al., 2021; Koç Koyun, 2021). In addition, with this feature, it can be used as a fire prevention strip to protect against wildfires that often occur in summer (Harrison et al., 2002; Koç Koyun and Acar, 2022). In addition, it should not be forgotten that it has an essential place in soil and water conservation to prevent erosion with its deep-going root system. However, despite these advantages, the cultivation of forage kochia is limited in our country.

Forage kochia seeds are short-lived when storage temperatures exceed 5 °C and seed moisture content is not controlled. Significant losses in forage kochia seed viability have been reported as early as two months after harvest. However, losses usually do not occur during the first six months of storage. Haferkamp et al. (1990) associated poor emergence from 1-year-old forage kochia seeds with loss of seed viability and/or vigor (Kitchen and Monsen, 2008). Also, seed germination of fresh seeds varied between 0.05% and 17% in semi-arid climates, although in the laboratory, the germination rate was reported from 5-10% to 80-90% (Zadbar et al., 2007). Kitchen and Monsen (2008) also observed that seeds stored for more than two years at refrigerated and frozen temperatures retain entire viability and can delay germination sufficiently for successful stand establishment. However, it is crucial to minimize the storage cost and use of energy resources in terms of sustainability and environmental protection.

In addition, the plants used to increase the yield of pastures in semi-arid areas are not only desired to consume great products but also to show high germination in the planted area, to develop shoots again, or to have high emergence in the following year under the pressure of grazing or mowing. He et al. (2023) suggest that vegetation restoration of grazed rangeland increases the species diversity of the seedling bank and survival rate and high emergence rather than increasing the numbers of a few species. Therefore, in this study, forage kochia seeds stored under room conditions were sown at different periods. In the study, the emergence rate of the seeds and the growth performance of the emerged plants under field conditions for two years were examined to determine the plants that can be gene sources in plant breeding.

MATERIALS and METHODS

This research was carried out in two stages, the first stage, demermined emergence ratio, was to determine the viability of the seeds by using the emergence ratio, and the second stage, determination of the performance of emerging types under field conditions, was to examine the adaptation of the types whose seed viability was determined by the field conditions.

Determined Emergence Ratio

The seed of determined three different genotypes grown in SUFA Forage Kochia Demonstration Garden in the fall of 2018 was used as material in the first stage, and these genotypes' properties are given in Table 1. These plant seeds were harvested on 14th November 2018 and stored at room conditions of 23-26°C until the end of 2019.

Table 2. The morphological properties of genotypes

Morphological Properties	**C1**	**C2**	**M5**
Stem Color	Red	Yellow green	Variable by season
Leave Color	Bluish Green	Green	Bluish Green
Leave hairiness	Hairy (Dense)	Hairy	Hairy (Medium)
Fresh shoot hairiness	Hairy	Hairless	Hairy

Sowing studies to determine the duration of seed viability were carried out in the Plant Breeding Greenhouse of the Department of Field Crops, Faculty of Agriculture Selcuk University. The seeds stored under room conditions were sown periodically (Figure 1A, B); these dates are given in Table 2. The trial was established according to the randomized plots experimental design with four replications.

Table 3. Sowing Time and date

Sowing Time	**Sowing Date**
The day after harvest	15.11.2018
4th month after harvest	15.03.2019
7th month after harvest	15.06.2019
10th month after harvest	15.09.2019
13th month after harvest	15.12.2019

It was grown in 16x16 cm pots, with seven seeds by sowing depth less than 1 cm in each pot, and in mixed 1:1 ratio turf and perlite. The mixture included trace amounts of microelements. The turf was used as the planting medium and had a pH of 6.5, an N content of 2.2%, a P_2O_5 content of 3.2%, and a K_2O content of 3.1%. The turf had an air capacity between 30% and 40%, a water holding capacity of 20-30%, and an Electrical Conductivity was 0.89 dS m^{-1}. Also, the perlite pH was close to the turf pH and did not contain organic matter. The perlite had been desalinated by sterilization and had a high water-holding capacity.

At this stage, only the emergence ratio was examined, emergence was observed 20 to 30 days after sowing (Everitt et al., 1983), and the values obtained were subjected to analysis of variance in JMP7 statistical package program. Significant values were grouped by Tukey HSD analysis. (Sall et al., 2017).

Figure 1. (A, B) The emergence and growth of forage kochia in 1st stage of the study, (C) growth and development of plants in the field in 2nd stage of the study (May 2022).

Determination of The Performance of Emerging Types under Field Conditions

In the second phase of the study, the plants of three different genotypes, which showed emergence when the seeds were sown at different periods, were planted in November 2020 in the experimental field of Prof. Dr. Abdülkadir AKÇİN, Faculty of Agriculture, Selcuk University, Konya, Türkiye. Climatic characteristics of the testing area are given in Figure 2-3.

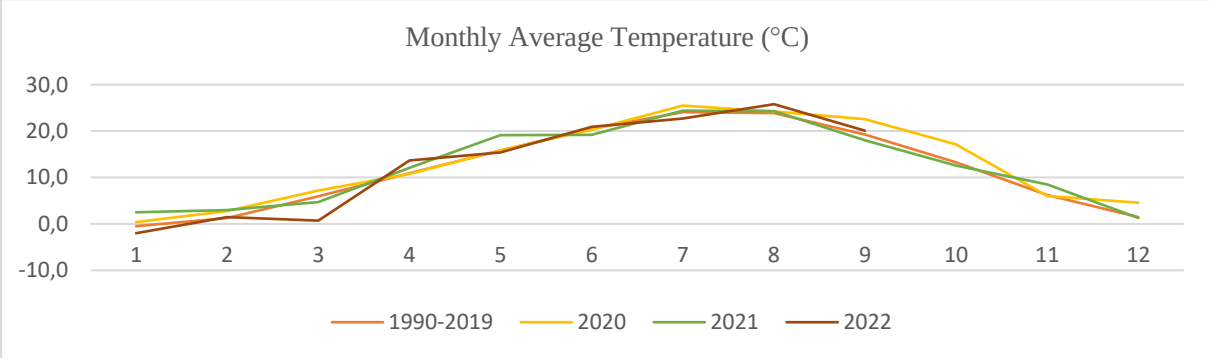

Figure 2. The monthly average temperature (°C) of the experimental field

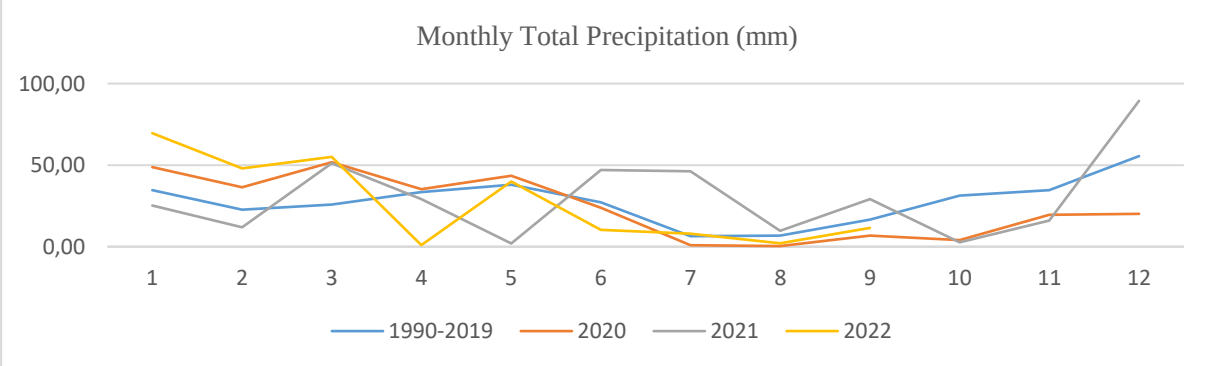

Figure 3. The monthly total precipitation (mm) of the experimental field

Table 4. Soil characteristic of the experimental field

Parameters	**Values**	**Proficiency Level**
Electrical Conductivity (dS $m^{-1)}$	0.88	Non-saline
$CaCO_3$ (%)	25.0	Very High
Ca (%)	0.69	Very High
K (%)	0.03	High
P (mg kg^{-1})	1.83	Insufficient
B (mg kg^{-1})	3.07	Sufficient
Cu (mg kg^{-1})	2.07	Medium
Fe (mg kg^{-1})	1.19	Insufficient
Zn (mg kg^{-1})	0.91	Medium

According to the long-term climate average, total precipitation is 330 mm; 290 mm was recorded in the planting year (2020), 360 mm in 2021, and 245 mm in 2022 (January to September). According to soil analysis results, the soil of the experimental field is slightly alkaline (pH 8.12) and has low organic matter (1.98%). Also, the soil texture is clayey, and other soil characteristics are given in Table 3.

The plants were planted in November 2020 with a row spacing of 1.5 m and an intrarow of 1.0 m. Since the plants started to regrow in March 2021, the blooming period of the plants occurred in September 2021, and observations and measurements were taken during this period. Whereas in 2022, the plants started to awaken in April (Figure 1C), and the blooming period occurred in October 2022. Therefore, observations and measurements were taken during this period. The traits examined during these periods were plant height, canopy diameter, stem diameter, leaf length, leaf width, leaf color, and hairiness. Also, it was determined by measuring the plant height from the soil surface and canopy diameter by calculating the average of the maximum and minimum diameter. While we surveyed stem diameter 5 cm from the soil surface (Aygün and Olgun, 2018), leaf length and width were gauged on five leaves, showing the best evolving by a digital caliper. Leaf color was scored by scoring 1-9 (1: Red-Grey, 3: Grayish Green, 5: Bluish Green, 7: Green, 9: Dark Green). Leaf hairiness was determined by scoring 1-9 (1: very sparse or absent, 3: sparse, 5: moderate, 7: frequent, 9: very frequent). The plants were cut 10 cm from the soil surface at the end of the growing season for cleaning and mowing (Koç Koyun, 2021). The data obtained at this stage of the study were subjected to descriptive statistics (Coefficient of Variance, Mean, Standard Error) in the JMP7 package program (Sall et al., 2017).

RESULTS and DISCUSSION

The research results will be given as a separate heading for each stage since the study was conducted in two phases. In 1st stage, results related to determined emergence ratio were given and discussed, while in 2nd stage results related to determination of the performance of emerging types under field conditions were given and discussed.

Determined Emergence Ratio

The results of the analysis of variance performed with the data obtained in the study are given in Table 4, the mean values are shown in Table 5, and the interaction means are provided graphically in Figure 4. When the values given in Table 5 are examined, the highest value of 18.6% in terms of genotype averages, was obtained from the M5 genotype, and the highest value of 23.8% in terms of sowing time was recorded, and this value was obtained in the sowings made 10th months after harvest (MAH).

Table 5. The analysis of variance belongs to the emergence ratio.

Sources of Variation	DF	SS	MS	F
Total	59	9673,36	.	.
Genotype (G)	2	1163,31	581,65	6,41**
Sowing time (ST)	4	2802,37	700,59	7,72**
G*ST	8	1625,89	203,24	2,24*
Error	45	4081,80	90,71	
CV (%)	74,07			

*: p<0.05, **: p<0.01

Table 6. Mean values, standard errors (SE) and groupings of genotypes and sowing times.

Genotype Avarages	Mean
C1	7,9^{B}
C2	12,1^{AB}
M5	18,6^{A}
SE	2,1
$LSD_{0.01}$	9,237

Sowing Time Avarages	Mean
The day after harvest (DAH)	13,1^{AB}
4th month after harvest (MAH)	15,5^{AB}
7th month after harvest (MAH)	8,3^{B}
10th month after harvest (MAH)	23,8^{A}
13th month after harvest (MAH)	3,6^{B}
SE	2,7
$LSD_{0.01}$	13,45

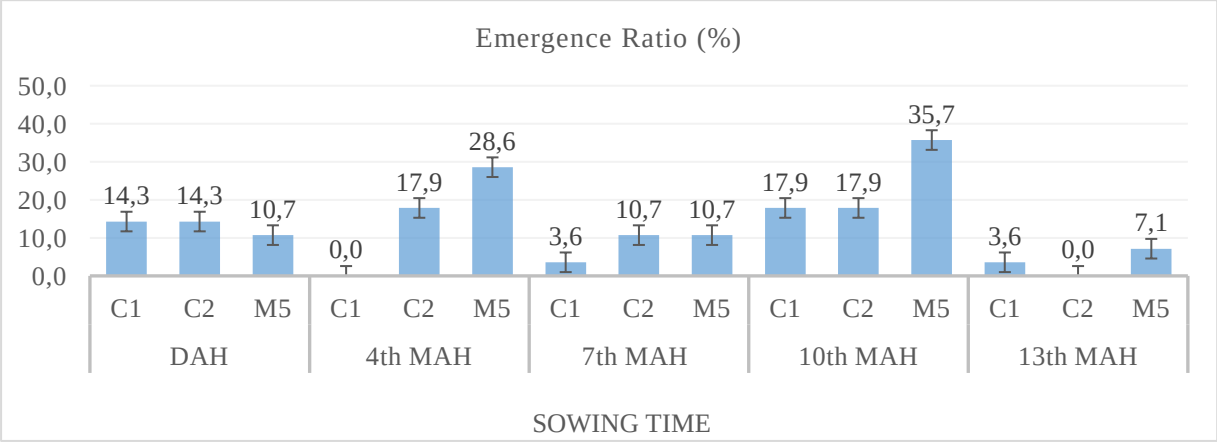

Figure 4. Mean values of genotype x planting time interaction for emergence rate and standard error (LSD: 24.15)

The highest value was obtained when the M5 genotype was planted 10th MAH, recorded in group a given in Figure 4. The lowest value was obtained when the C1 genotype was sown in the 4th MAH, and the C2 genotype was sown approximately one year after harvest, and these interactions can be stated to be in group c.

According to our literature review, there need to be more studies on the emergence rate of forage kochia. Thus, discussion was made with germination studies in forage kochia and plants in the same family as forage kochia. Seeds germination of forage kochia in the laboratory, due to ecotype and site conditions, varied from 5-10% to 80-90% (Zadbar et al. 2007). Initial dormancy (0-75%) and rate of after-ripening forage kochia seeds vary among ecotypes and years of harvest. After-ripening requires from 0 to 12 months at room temperature and longer cold storage. Also, germination after ripened or chilled seeds occurs across various temperatures and osmotic potentials (Kitchen and Monsen, 2008). Waller et al. (1993), who studied the storage of forage kochia at different temperatures for three months, reported a germination rate between 30% and 52% at 21°C.

Everitt et al. (1983), who studied *Bassia scorpia* belongs to the *Amaranthaceae* family, stated that kochia seeds' germination rate was ≥88% at continuous temperatures of 5 to 25°C, and kochia seeds left subjected on the soil surface with 74% emergence percentage was significantly higher than for those planted at a depth of 3 mm with 57% emergence ratio. The emergence rate is usually lower than the germination rate, and the low emergence rate in the sowings made the day after harvest in our study may be due to dormancy, as stated by Kitchen and Monsen (2008). He et al. (2023) periodically investigation to examine the variation in seedling emergence of herbaceous plants under four grazing intensities, including light (LG), moderate (MG), heavy (HG), and non-grazed (NG), in a semiarid sandy grassland. The one of main plant species in the study area include *B. dasyphylla*. The results showed that seedling emergence dynamics varied with grazing. 75% of the seedlings in HG emerged during early spring in April, while approximately 50% of the seedlings in LG, MG, and NG emerged in May.

In addition, the low emergence in the 7th MAH in our study may be the cause of the experiment being carried out under greenhouse conditions. The 13th MAH sowings showing the lowest emergence after the 7th MAH sowings are poor establishment from one-year-old forage seeds to loss of seed viability and/or vigor, as stated by Heferkamp et al. (1990). It can be stated that the seeds of forage kochia, which is one of the objectives of the research, can be used as gene sources for breeding studies to increase seed viability and survival period in forage kochia by obtaining seeds that can remain viable for a longer time by minimizing the storage cost of seeds.

Determination of The Performance of Emerging Types under Field Conditions

In the second stage of the study, plants obtained from different genotypes sown in different periods were subjected to natural selection in terms of seed viability. For this reason,

this stage was carried out to have information about the performance of these genotypes under field conditions, and the number of plants that survived because of natural selection observed at this stage of the study is given in Table 6. The averages of the observations and measurements taken from the plants grown under field conditions during 2021 and 2022 in the second phase of the study are given in Table 7.

Table 7. Number of plants observed in the study.

Sowing Time	**C1**	**C2**	**M5**
The day after harvest (DAH)	3	2	2
4th month after harvest (MAH)	0	4	4
7th month after harvest (MAH)	1	3	3
10th month after harvest (MAH)	3	3*	4
13th month after harvest (MAH)	1	0	2

*In 2022, this number decreased to 2.

When the figures given below are evaluated, the C1 genotype did not emerge at the 4th MAH planting time, and the C2 genotype did not appear at the 13th MAH planting time. Therefore, these treatments were excluded from the evaluation. When the values given in Figure 5 are examined, the highest plant height of 105.0 cm, was obtained from the 13th MAH planting time of the C1 genotype, while the shortest plant height (42.5 cm) was obtained from the M5 genotype at the same planting time.

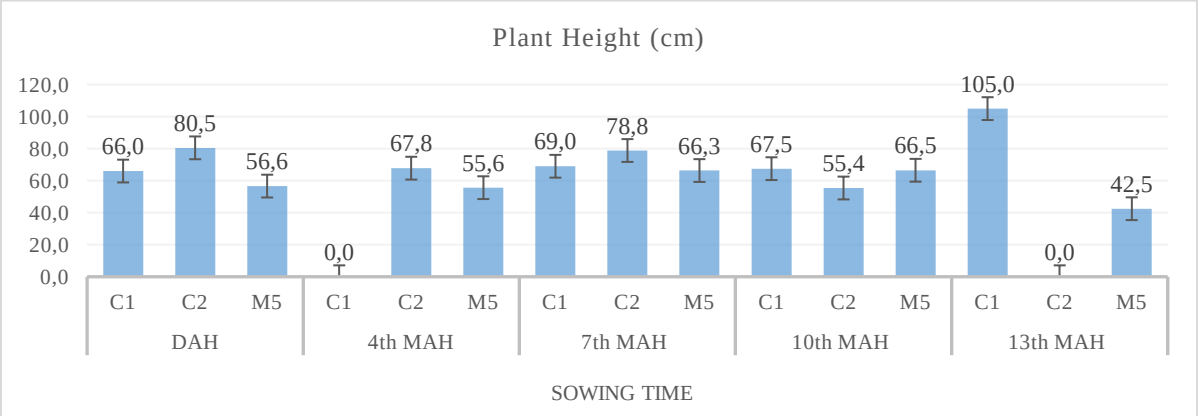

Figure 5. Two-year mean values of interactions of plant height

The highest canopy diameter of 133.4 cm was obtained at the DAH planting time of the C2 genotype, while the minor diameter of 98.5 cm was received at the DAH planting time of the C1 genotype (Figure 6). As for the stem diameter, the thickest (6.49 mm) interaction was recorded at the 10th MAH planting time of the C1 genotype (Figure 7).

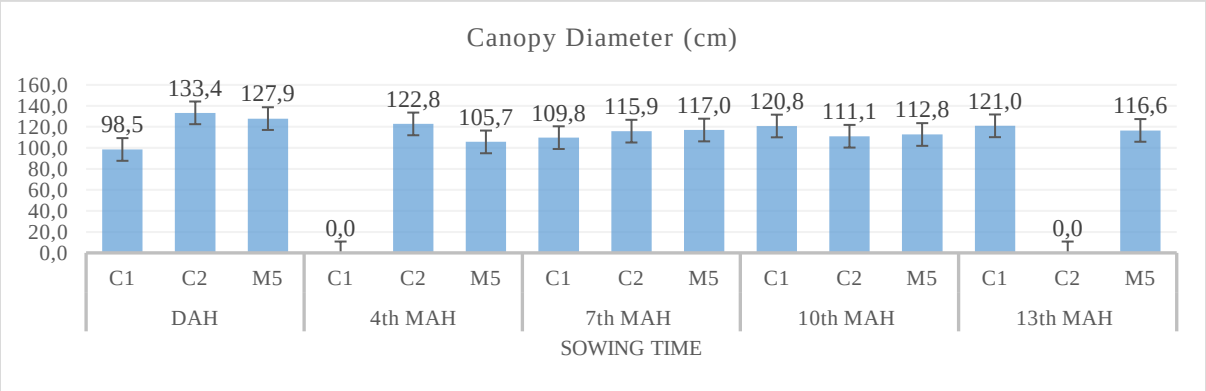

Figure 6. Two-year mean values of interactions of canopy diameter

When the leaf characteristics were examined, the longest leaf length of 17.6 mm was obtained from the 4th MAH planting time of C2 genotype (Figure 8), the widest leaf blade with 1.49 mm was obtained from the 10th MAH planting time of C1 genotype (Figure 9), and the darkest leaf color with 7.25 score was accepted from the 13th MAH planting time of M5 genotype (Figure 10). When the leaf hairiness averages given in Figure 11 are analyzed, it can be stated that the hairiest leaf structure with a score of 7.33 was obtained from the 7th MAH planting time of the M5 genotype.

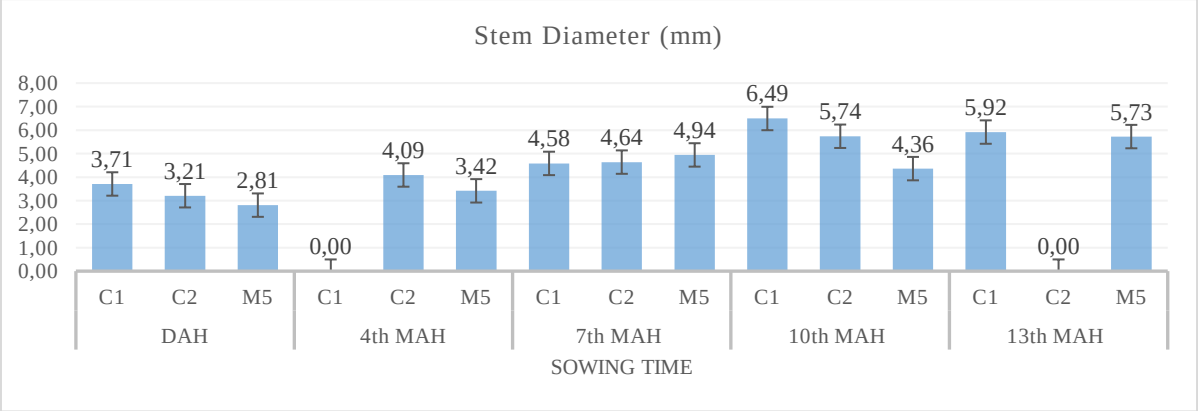

Figure 7. Two-year mean values of the interactions of stem diameter

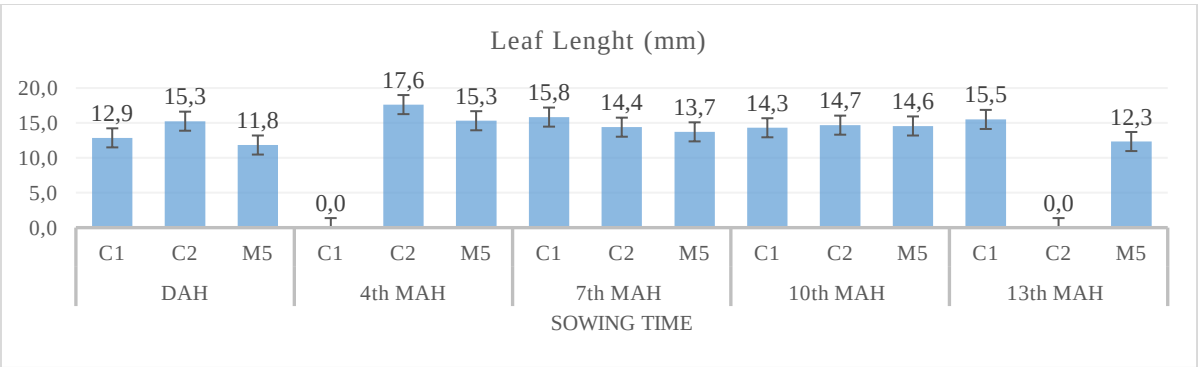

Figure 8. Two-year mean values of interactions of leaf length

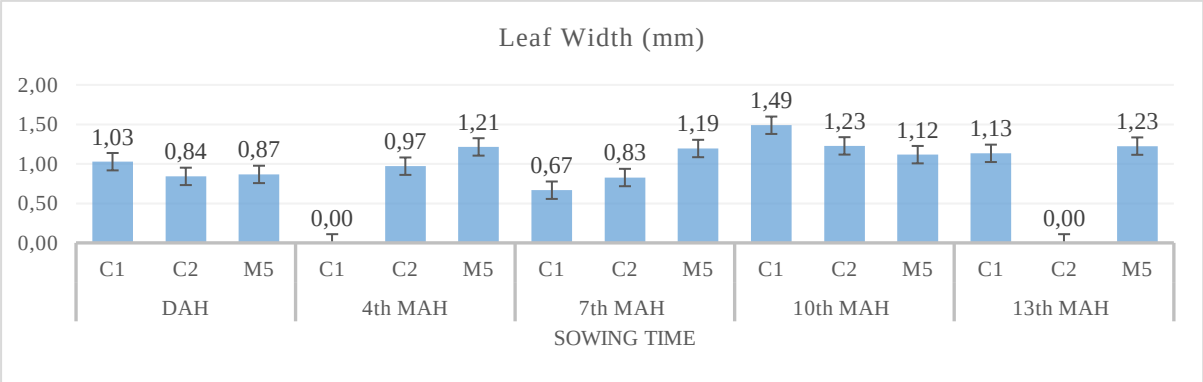

Figure 9. Two-year mean values of interactions of leaf width

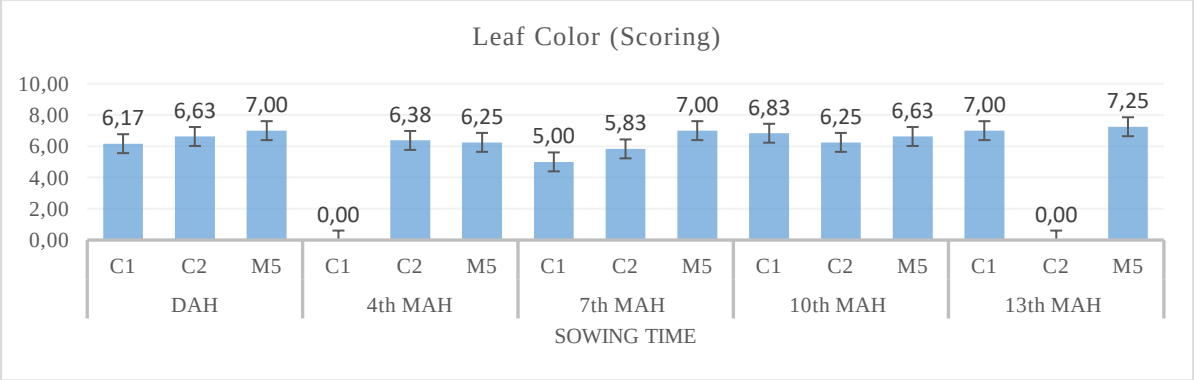

Figure 10. Two-year mean values of interactions of leaf color (1: Red-Grey, 3: Grayish Green, 5: Bluish Green, 7: Green, 9: Dark Green)

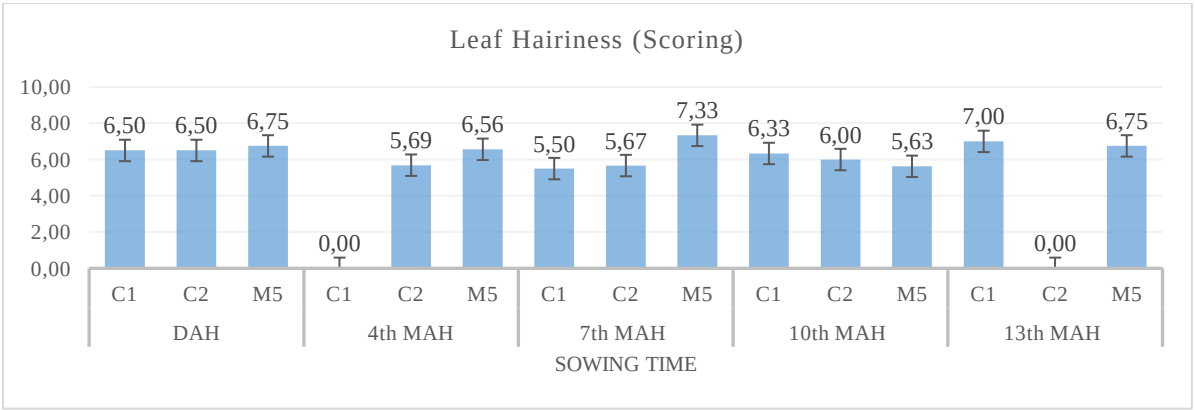

Figure 11. Two-year mean values of interactions of leaf hairiness (1: Very Sparse or Absent, 3: Sparse, 5: Moderate, 7: Frequent, 9: Very Frequent)

When the general average values were examined, plant height was obtained as 58.5 cm, which agrees with Clements et al. (2020). Clements et al. (2020) determined the plant height of forage kochia cv. Immigrant and Snowstorm was 45 cm and 76 cm, respectively, during the blooming period. Acar and Koç (2019) recorded a 76.75 cm mean of plant heights of forage kochia at the seed maturation stage in November 2018, while the average canopy diameter of the same plants was 107.92 cm.

In our study, 12.5 mm leaf length and 0.9 mm leaf width were recorded (Table 7). While Gintzburger et al. (2003) determined the leaf length of forage kochia as 3-5 mm, some researchers, such

as Tilley et al. (2012), found it to be longer, such as 3-12 mm. Therefore, leaf width was determined as 0.5-2.0 mm by Gintzburger et al. (2003).

Table 8. Minimum, maximum, and average values of observations and measurements taken in 2021 and 2022.

	Plant Height (cm)	Canopy diameter (cm)	Stem Diameter (mm)	Leaf Length (mm)	Leaf Width (mm)	Leaf Color (Scoring[1])	Leaf Hairiness (Scoring[2])
Mean	58,50	100,90	4,00	12,50	0,90	5,60	5,50
Max.	120,00	166,00	11,67	31,00	3,33	9,00	9,00
Min.	20,00	58,00	1,33	6,83	0,10	5,00	3,00
CV	47,12	41,47	48,53	42,19	46,31	41,81	41,77

[1] 1: Red-Grey, 3: Grayish Green, 5: Bluish Green, 7: Green, 9: Dark Green

[2] 1: Very Sparse or Absent, 3: Sparse, 5: Moderate, 7: Frequent, 9: Very Frequent

The leaves examined in our study have a color between Bluish Green and Green, with a score of 5.6, and leaf hairiness between moderate and frequent, with a score of 5.5. It may be causing the genotypes (mother plant) whose seeds were used in our study (Table 1) showed Bluish-Green and Green leaf color and moderate to dense leaf hairiness.

In addition, it can be stated that the results of this research are different from the findings) with 39.81 cm plant height, 43.75 cm canopy diameter, 2.96 mm stem diameter, and 1.21 mm leaf width of Koç Koyun and Acar (2021), 4.6 scored leaf color and 5.99 scored leaf hairiness of Koç Koyun (2021). This difference is because the study in question was conducted under extreme climate and soil conditions. In contrast, in this study, since the plants were grown in non-extreme conditions, it can be stated that the plant can show its growth potential when grown without boron toxicity, high lime, and salinity problems in the soil. The similarity of the 12.47 mm leaf length with the findings of Koç Koyun and Acar (2021) may be because the seeds used as material in the study were progenies of the SUFA Forage Kochia Demonstration Garden Population of Koç Koyun and Acar (2021). In addition, the same responses in two different soil and climate conditions can be evaluated as a separate study subject.

Conclusion

As a result of the study, among the forage kochia genotypes stored under room conditions and sown at different periods, genotypes that could remain viable for more than six months under storage conditions were identified. In the study, the highest emergence rate (35%), in other words, seed viability, was obtained from the 10th MAH sowing of the M5 genotype. This value was higher than the sowing made on the day after harvest (DAH), and this can be interpreted that this situation causes dormancy to break after a particular time under room conditions. In addition, according to the results of the second phase of the study, it can be stated that C1 and M5 genotypes sown 13th month after the harvest (MAH)

stand out from the other genotypes in terms of both the long seed viability period and morphological characteristics for use as a gene source in forage kochia breeding.

Acknowledgement

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Decleration of Interest

There is no conflict of interest.

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