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Antakya Koşullarında Bazı Kurutmalık Kırmızıbiber Hatlarının Verim ve Kalite Özelliklerinin Değerlendirilmesi

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ÖZ

Bu çalışma, Doğu Akdeniz Geçit Kuşağı Tarımsal Araştırma Enstitüsü tarafından Kahramanmaraş biberi popülasyonu içerisinden seleksiyon yoluyla geliştirilen S4 kademesindeki 12 genotipin ve 4 tescilli biber çeşidinin Antakya koşullarında verim ve kalite performanslarının incelenmesi amacıyla gerçekleştirilmiştir. Bitkisel materyal olarak 83, 331, 368, 373, 361, 378, 439, 449, 454, 472, 521 ve 69 numaralı hatlar ile Sena, Dila, Bozok ve Yesemek çeşitleri kullanılmıştır. Araştırma sonuçlarına göre, en yüksek taze verim 1106 g.bitki^{-1} ile 83 numaralı hattan, en yüksek kuru verim ise 270 g.bitki^{-1} ile 472 numaralı hattan elde edilmiştir. Suda çözünebilir kuru madde miktarı açısından %13,30 değeri ile 361 numaralı hat öne çıkarken, en yüksek kurutma randımanı %32,5 ile 454 numaralı hatta belirlenmiştir. Meyve sayısı açısından 439 numaralı hat 127 adet bitki^{-1} ile en yüksek değere ulaşırken, meyve ağırlığı 10,60 g.meyve^{-1} ile 472 numaralı hatta, meyve uzunluğu ise 7 cm ile 449 numaralı hatta en yüksek değer olarak kaydedilmiştir. Tohum sayısı bakımından en yüksek değer 347 adet meyve^{-1} ile 378 numaralı hatta, meyve genişliği ise 23 mm ile Dila çeşidinde tespit edilmiştir. Kapsaisinoid (acılık) analizi sonuçlarına göre, 472 numaralı hat 147483 (scoville heat unit) SHU ile en yüksek acılığa sahip olmuş ve bu yönüyle önemli bir kalite kriteri olarak öne çıkmıştır. Bunun yanında, en düşük meyve et kalınlığı 0,75 mm ile 378 numaralı hatta belirlenirken, 1000 tohum ağırlığı açısından 6,50 g ile 373 numaralı hat öne çıkmıştır. Genel olarak, özellikle kurutulmuş biber üretiminde önemli olan kuru verim ve acılık kriterleri dikkate alındığında, 472 numaralı hattın hem yüksek kuru verim hem de yüksek acılık değeri ile üstün bir performans sergilediği belirlenmiştir. Bu sonuçlar, Antakya koşullarının yüksek verim ve kaliteye sahip biber hatlarının yetiştirilmesi için uygun olduğunu göstermektedir. Ayrıca, bu genotiplerin ticari üretimde önemli bir potansiyele sahip olabileceği sonucuna varılmıştır.

Anahtar Kelimeler: Acılık, seleksiyon, toz ve pul kırmızı biber, *Capsicum annuum*

Evaluation of Yield and Quality Characteristics of Some Drying Red Pepper Lines in Antakya Conditions

ABSTRACT

This study aimed to evaluate the yield and quality performance of 12 S4-generation genotypes and 4 registered pepper varieties, developed through selection from the Kahramanmaraş pepper population by the East Mediterranean Transitional Zone Agricultural Research Institute, under the conditions of Antakya. The plant materials used were the genotypes 83, 331, 368, 373, 361, 378, 439, 449, 454, 472, 521, and 69, along with the varieties Sena, Dila, Bozok, and Yesemek. The results revealed that the highest fresh yield was obtained from genotype 83 with 1106 g.plant^{-1}, while the highest dry yield was recorded in genotype 472 with 270 g.plant^{-1}. The genotype 361 stood out with a total soluble solid content (SSC) of 13.30%, and the highest drying efficiency was observed in genotype 454 at 32.5%. In terms of fruit number, genotype 439 had the highest value with 127 fruits plant^{-1}, while genotype 472 showed the highest fruit weight of 10.60 g.fruit^{-1} and genotype 449 had the longest fruit length at 7 cm. The highest seed count was observed in genotype 378 with 347 seeds fruit^{-1}, while Dila had the largest fruit width at 23 mm. According to the capsaicinoid (pungency) analysis, genotype 472 exhibited the highest pungency level with 147483 scoville heat units (SHU), highlighting it as a notable quality trait. Furthermore, the lowest fruit flesh thickness was recorded in genotype 378 with 0.75 mm, and the highest 1000-seed weight was observed in genotype 373 with 6.50 g. Overall, considering the key criteria for dried pepper production, particularly dry yield and pungency, genotype 472 demonstrated superior performance due to its high dry yield and pungency levels. These findings suggest that the Antakya region is well-suited for the cultivation of high-yielding and high-quality pepper lines. Additionally, these genotypes hold significant potential for commercial production.

Keywords: Pungency, selection, red pepper powder and flakes, *Capsicum annuum*

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INTRODUCTION

The cultivation of the pepper plant dates back approximately 5,000 years in South America, as revealed by archaeological excavations [1]. Small hot peppers were introduced to Europe by Christopher Columbus, becoming popular, and before the discovery of the Americas, peppers were unknown in other continents [2]. The Maya, Inca, and Aztec civilizations regarded the pepper plant as a divine gift, believing in its mystical and spiritual powers [3]. Once its benefits for human health and agriculture were discovered, peppers rapidly spread worldwide. They began being cultivated in Central Europe, the Middle East, and the Mediterranean region after the 15th century, and in China, Japan, India, and the Far East after the 18th century [3, 4, 5]. In Turkey, peppers were first introduced during the Ottoman Empire in the 16th century, brought to Istanbul, and then spread to other regions [6]. Peppers were among the first crops cultivated along with maize, beans, New World crops, and various types of squash. Among the species, red peppers were the first to be used as spices [7].

The pepper plant belongs to the Plantae kingdom, Magnoliophyta division, Magnoliopsida class, Solanales order, and Solanaceae family [8]. Peppers currently cultivated fall under the *Capsicum* genus within the Solanaceae family, which contains 98 genera. The number of species in the *Capsicum* genus, previously 38, has now been revised to 43 with the discovery of five new species. Among these, five species-*C.annuum* L., *C.frutescens* L., *C.baccatum* L., *C.chinense* Jacq., and *C.pubescens* Ruiz & Pav.- are commonly cultivated [9, 10].

Capsicum annuum species is the most widely cultivated for commercial purposes globally. This species exhibits great morphological diversity in terms of color, shape, pungency, and flavor [11, 12]. The common names for *Capsicum* species differ from country to country, with terms such as aji, paprika, chili, cayenne, chilli pepper, tabasco, red chilli, hot red pepper, and *Capsicum* being used [13]. Although *Capsicum annuum* is often classified as an annual plant, this is not entirely accurate as some varieties can live for 4-5 years under suitable conditions. *Capsicum annuum* varieties are among the most commonly cultivated, with well-known varieties such as Kapya, Çarliston, Demre Sivrisi, and California Wonder types in Türkiye [14].

Peppers are cultivated both in open fields and under cover, and they are important for producers, consumers, and the processing industry across many countries [15]. In 2023, global pepper production reached a total of 52.14 million tons, with China remaining the largest producer at 16.8 million tons. Mexico and Indonesia are also significant producers, each contributing around 3 million tons, while Türkiye maintains a strong position with 3 million tons of production [16]. In Türkiye, most of the pepper production occurs in the Aegean, Marmara, Mediterranean, Southeastern Anatolia, and Black Sea regions. In the Aegean region, open-field production is predominant, especially for table peppers. In the Mediterranean region, protected cultivation is common, particularly in Antalya and Mersin. The eastern parts of the Mediterranean region, especially Hatay, Kahramanmaraş, and Gaziantep, are important for dried red pepper production. In the Marmara region, both fresh table peppers and peppers for industrial purposes are produced, with processing facilities for sauces, preserves, and frozen products being significant. In the Black Sea region, pepper cultivation is concentrated in Samsun, especially in the Çarşamba and Bafra plains. In Southeastern Anatolia, particularly Şanlıurfa, the production of dried crushed red pepper (isot) is widespread [17]. In Türkiye, 44% of the pepper production is for paste, followed by 36% for slender peppers (sivri), 16% for bell peppers, and 4% for Çarliston.

The decline in the cultivation area and production volume of red peppers in Türkiye is largely attributed to issues with seeds and varieties. With cross-pollination rates between 3-30%, seed production does not adhere to certification standards or controlled conditions, leading to genetic mixing. Moreover, the lack of a distinct red pepper variety for drying in the country forces farmers to rely on self-sourced seeds, further exacerbating genetic variability [18]. Some local vegetable varieties have received geographical indication certification through the support of local governments. These certificates guarantee the purity and commercial value of the seeds. The Turkish Patent Institute has granted geographical indication certification to varieties such as Şanlıurfa pepper, Samandağ pepper, and Maraş pepper [19].

The East Mediterranean Transitional Zone Agricultural Research Institute conducts research and development activities in areas such as vegetable cultivation, medicinal and aromatic plants, industrial crops, plant health, biodiversity, and genetic resources. In 2006 and 2017, they introduced two registered dried pepper varieties (Sena and Dila) to the market. Additionally, two varieties (Bozok and Yesemek) received production licenses in 2017 and 2019 [20]. These varieties are known for their high yield and adaptability in the region. Farmers usually acquire dried red pepper seeds from processing plants, factories, or agricultural research stations, or

they use seeds from their own crops. However, many farmers are unaware of the specific variety they are growing, and due to the low quality of the seeds used, they cannot achieve high yields. This study aims to evaluate the yield and quality characteristics of dried pepper lines (pure line, 6th generation) developed by the East Mediterranean Transitional Zone Agricultural Research Institute under the conditions of Antakya.

MATERIALS AND METHODS

This study was conducted between 2020 and 2021 at Hatay Mustafa Kemal University, in the experimental fields of the Department of Horticulture and the Physiology Laboratory.

Material

The plant material used in the study consisted of genotypes 83, 331, 368, 373, 361, 378, 439, 449, 454, 472, 521, 69, which were selected from the Maraş pepper population through selection by the East Mediterranean Transitional Zone Agricultural Research Institute. Additionally, the dried pepper varieties Sena and Dila, registered between 2006-2017, and Bozok and Yesemek, which received production permits in 2017-2019, were also utilized.

The seeds of 12 genotypes and 4 varieties were sown on March 2, 2020, in trays filled with peat (class TS1) in a controlled greenhouse for seedling production (Figure 1-a). To ensure sufficient seedlings for the experiment, 3×30 seeds were planted for each replication. Deep plowing (30 cm) of the field was carried out on March 23, followed by shallow tilling for weed control on April 12. On April 15, the experimental design was outlined, and on April 19, a drip irrigation system was installed, and rows were covered with mulch. Seedlings were planted on April 21 with a spacing of 40×70 cm after root treatment against root rot (Figure 1-b). Fertilization was done according to [8], applying 24 kg N, 15 kg P_2O_5, and 24 kg K_2O per decare through drip irrigation. Pest and disease control was performed following the Ministry of Agriculture and Forestry's technical guidelines for greenworms, aphids, thrips, powdery mildew, and bacterial spot (Figure 1-c).

Dal and Ağca [21], reported that the soils of the Tarla 49 field have a basic reaction, with sandy-loam texture at 60-80 cm depth and loam texture at other depths [21]. The pH ranged from 7.56 to 8.33, salt content from 0.035% to 0.062%, lime content from 1.4% to 6.9% and organic matter from 0.20% to 1.13%.

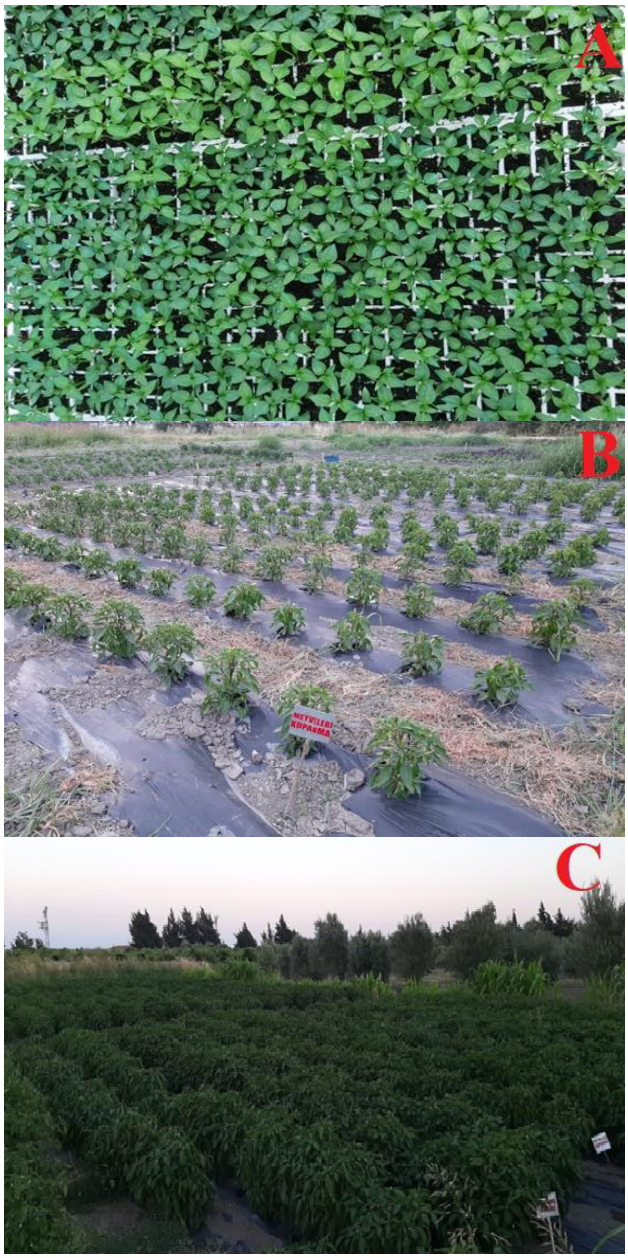

Figure 1. Appearance of seedlings grown in vials (a) before planting in the field, 90 days (b) and 150 days (c) after planting

Climate data during the experiment were collected from the nearest weather station (No.17371), noting the highest and lowest humidity, wind speed, temperature, and rainfall during different months. The lowest average wind speed was determined in October with 2.9 $m.s^{-1}$ and the highest average wind speed was determined in July with 7.0 $m.s^{-1}$. The lowest average temperature was determined in March and the highest average temperature was determined in August. The highest precipitation was observed in March and the lowest in July and August (Table 1).

Table 1. Meteorological data of the trial area between March and October 2020

Months	Monthly maximum temperature (°C)	Monthly minimum temperature (°C)	Average monthly temperature (°C)	Average monthly relative humidity (%)	Monthly average wind speed ($m.s^{-1}$)	Monthly total precipitation ($mm.kg.m^2$)
March	25.50	2.10	14.40	73.20	3.40	136.20
April	30.40	7.00	17.50	68.90	3.80	77.50
May	41.20	11.00	22.90	54.20	4.30	73.70
June	41.30	13.90	25.20	58.10	5.90	32.50
July	39.40	20.70	29.00	64.20	7.00	0.00
August	42.00	18.10	29.40	58.10	5.80	0.00
September	42.60	17.40	28.50	64.20	4.30	1.40
October	35.40	9.90	23.60	55.80	2.90	1.40

Parameters Analyzed

In this study, morphological observations of 12 genotypes and 4 varieties were conducted using the pepper descriptor guide [22] and the descriptors developed by [23]. The 22 characteristics used to describe the Maraş pepper genotypes were evaluated as follows:

•*Plant height (cm):* Measured using a tape measure when 50% of the plants had reached the first mature fruit and at the end of the third harvest. The distance from the soil line to the tip of the longest branch was recorded in centimeters.

•*Canopy width (cm):* Measured using a tape measure as the distance between the farthest leaves on the lateral branches at 50% fruit maturity and after the third harvest.

•*Plant habit:* This characteristic was calculated as the ratio of plant height to canopy width. A value less than 1 indicated a spreading habit, 1 indicated a moderate habit, and greater than 1 indicated an upright and narrow habit.

•*Days to flowering:* This was recorded as the number of days from seed sowing in trays until at least one flower had opened in 50% of the plants.

•*Number of flowers per node:* This was determined by ranking the number of flowers observed in over 50% of the plant nodes on a scale from 1 to 5.

•*Number of fruits per plant:* This was recorded as the total number of fruits harvested at the end of each harvest, reported in units.

•*Days to fruit maturity:* This was recorded as the number of days from seed sowing until the first mature fruit was observed in the first node of 50% of the plants.

•*Immature fruit color:* Prior to maturity, fruit color was categorized by variety into one of the following groups: 1 for light green, 2 for green, and 3 for dark green.

•*Mature fruit color:* Ripe fruits were classified into three groups: 1 for light red, 2 for red, and 3 for dark red.

•*Fruit shape:* Mature fruits were classified into categories such as elongated, round, triangular, bell, or blocky based on their shape (Figure 2).

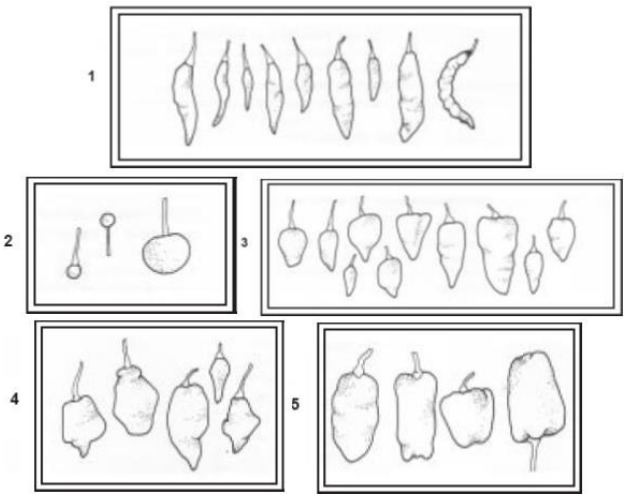

Figure 2. Fruit shape groups according to the pepper identification guide [22]

•*Fruit length (cm):* During each harvest, 15 mature fruits from each plot were selected, measured using a ruler, and the average value was recorded in centimeters.

•*Fruit width (mm):* During harvests, 15 fruits from each plot were measured using calipers, and the average width was recorded in millimeters.

•*Fruit weight (g):* Fifteen mature fruits from each plot were weighed on a digital scale, and the average weight was recorded in grams.

•*Flesh thickness (mm):* The flesh thickness of 15 mature fruits was measured using calipers and recorded in millimeters.

•*Fruit position:* Fruit position was classified as upright, intermediate, or pendent.

•*Pungency of ripe fruit:* Pungency analysis was conducted using HPLC, and the results were expressed in Scoville heat units (SHU) [24].

•*Soluble solid content (%):* This parameter was measured using a digital refractometer and expressed as a percentage.

•*Thousand seed weight (g):* For each line, 100 seeds were weighed, and the average was multiplied to determine the thousand seed weight in grams.

•*Number of seeds per fruit:* The number of seeds from 15 mature fruits was counted, and the average number was recorded.

•*Total fresh yield ($g.plant^{-1}$):* The fruits of 5 plants per plot were weighed at the end of the harvest, and the average yield was recorded in grams per plant.

•*Total dry yield (g.plant^{-1}):* The fruits harvested were dried and weighed in grams, and the average dry yield was calculated.

•*Drying efficiency (%):* This was determined as the ratio of dry fruit weight to fresh fruit weight, expressed as a percentage.

Statistical Analyses

After the characterization of dried red pepper genotypes, the data were evaluated using mean values. For statistical comparison of the obtained data, analysis of variance (ANOVA) was performed using the JMP 5.0.1 software package. Lines with statistically significant differences in means were compared using the LSD test.

RESULTS AND DISCUSSION

Total Fresh Yield

Findings related to total fresh yield, total dry yield, dry yield ratio, and soluble solids content (SSC) for the Kahramanmaraş pepper lines and varieties included in the experiment are presented in Table 2. Significant differences in dry yield values between lines and varieties were found to be statistically significant ($p \leq 0.01$). In terms of total fresh yield, the highest yield was obtained from line 83 with 1106 g.plant^{-1}, and from the Sena variety with 1102 g.plant^{-1}. The lowest fresh yield was recorded from the Bozok variety with 549 g.plant^{-1}, followed by the Yesemek variety with 660 g.plant^{-1}.

In previous studies conducted in Kahramanmaraş, Trening [25], reported that the average red pepper yield was 225-275 kg.da^{-1}, while Yüksek et al. [26] reported an average yield of 325 kg.da^{-1}. In the Narlı region of Kahramanmaraş, Çakan [27] reported that the average red pepper yield was 180-326 kg.da^{-1}, while Anonymous [28] reported that the fresh yield varied between 2-3 tons/da. In their study in Antakya, Sermenli and Mavi [29], examined the yield and quality parameters of local varieties, such as 'Chili Jalapeno', 'Pical', and 'Geyik Boynuzu'. They reported significantly higher yields for the 'Chili Jalapeno' and 'Pical' varieties, with yields of 1951 kg.da^{-1} and 1818 kg.da^{-1}, respectively, compared to 1593 kg.da^{-1} for the Geyik Boynuzu variety. Keleş et al. [30], observed that the pure line 1278-14 produced 6258 kg.da^{-1}, outperforming other lines in their trials. According to the findings of Aytop and Akbay [31], the average yield was 1558 kg.da^{-1}. Arpacı et al. [32], developed a variety from the Kahramanmaraş red pepper population with a mature red pepper yield of 2748 kg.da^{-1}. In a study conducted in 2009, [7] reported a fresh yield of 2674 kg.da^{-1} from the Sena variety, while the hybrid K211×P-67×46 yielded 2769 kg.da^{-1}. In 2008, the highest yield was obtained from the K211×P-67×46 hybrid with 2790 kg.da^{-1}, followed by 2383 kg.da^{-1} from line 46, while the Sena variety yielded 2294 kg.da^{-1}. In our experiment conducted under Antakya conditions, a yield of approximately 5100 kg.da^{-1} was obtained from the Sena variety. These results suggest that higher yields are achieved from the Sena variety under Antakya conditions due to factors such as growth conditions and climate. Akıncı and Akıncı [33], examined the Kahramanmaraş red pepper population and reported that the yield of mature peppers per plant ranged from 82.5 g to 567.7 g. Considering that approximately five thousand plants are grown per decare in red pepper cultivation, the population has a red pepper yield potential ranging from 400 to 2800 kg.da^{-1}. Based on previous studies and the results of this study, it is evident that fresh fruit yield is relatively high. The higher yields obtained from the Kahramanmaraş red pepper under Antakya conditions may be attributed to factors such as earlier ripening compared to Kahramanmaraş, growth environment, pesticide and fertilizer use, mulching, drip irrigation, climate, and plant spacing, all of which contribute to yield improvement.

Total Dry Yield

According to Table 2, the highest total dry yield was obtained from line 472 with 270 g.plant^{-1}, while the lowest yield was recorded from the Bozok variety with 132 g.plant^{-1}. The registered variety Sena and the approved variety Dila yielded 201 g.plant^{-1} and 199 g.plant^{-1} of dry yield, respectively.

In the production of Kahramanmaraş pepper, fresh yield is crucial for producers who market fresh peppers, whereas dry yield is just as important for those processing the final product into powder or flakes. While farmers focus on fresh yield, processing companies prioritize dry yield. Akıncı and Akıncı [33], reported yields of dried red pepper per plant ranging from 13.4 g to 94.6 g. Arpacı et al. [32], obtained an average dry yield of 377 kg.da^{-1} from the Kahramanmaraş red pepper population, and developed the Sena variety, achieving 500 kg.da^{-1} of dry yield. In our study, 201 g.plant^{-1} was obtained from the Sena variety, which aligns with previous findings. Çakan [27], reported that the average dry red pepper yield for Kahramanmaraş pepper ranges between 180 to 326 kg.da^{-1}. Based on the plant density used in our experiment, it is estimated that the number of plants per decare is around 4700. When the per-plant yield is converted to a per-decare basis, it is calculated that line 472 achieved a dry yield of 1269 kg.da^{-1}. The longer growing season under Antakya

conditions compared to Kahramanmaraş, as well as the sandy loam soil texture on the surface and loam texture in deeper layers, positively influenced yield. Additionally, the use of mulch, fertigation, and wider planting spacings contributed to the increased yield.

Table 2. Total dry yield, total fresh yield, drying yield, drying efficiency and SCC values of varieties and lines

Variety and lines	Total fresh yield (g.plant^{-1})	Total dry yield (g.plant^{-1})	Drying efficiency (%)	SCC (%)
69	1047 ac	256 ab	24.5 ce	9.97 ef
83	1106 a	248 ab	22.7 e	6.93 i
331	938 ad	231 ac	24.6 ce	9.57 fg
361	879 bd	247 ab	28.1 bc	13.30 a
368	1088 a	242 ac	22.2 ef	9.10 gh
373	776 de	226 cd	29.3 ab	11.37 d
378	864 cd	255 ab	29.5 ab	10.03 ef
439	936 ad	250 ab	26.8 bd	9.27 gh
449	1084 a	255 ab	23.6 de	11.97 cd
454	794 de	249 ab	32.5 a	11.63 d
472	1056 ab	270 a	25.8 be	12.77 ab
521	952 ad	233 ad	24.5 ce	9.50 fgh
Bozok	549 f	132 f	24.1 ce	10.33 e
Dila	1076 a	199 de	18.6 fg	8.83 h
Sena	1102 a	201 ce	18.2 g	7.53 i
Yesemek	660 ef	162 ef	24.7 ce	12.43 bc

Soluble Solid Content (SSC) (%)

The highest SSC value was obtained from line 361 with 13.30%, while the lowest values were observed in line 83 with 6.93% and the Sena variety with 8.83% (Table 2). Öntürk [34] reported that the highest SSC value among 50 pepper genotypes grown by farmers in Hatay was 9.0%, and the lowest was 6.47%. Hesham et al. [35] found SSC values ranging from 8.00% to 11.00% in *Capsicum annuum* varieties. Previous studies align with the values obtained in this experiment. High SSC values are more suitable for processing into sauces or paste.

Drying Efficiency (%)

The highest drying efficiency was achieved by line 454 with 32.5%, while the lowest efficiencies were recorded for the Sena variety at 18.2% and the Dila variety at 18.6% (Table 2). Arpacı et al. [36] reported that the highest efficiency in the Kahramanmaraş pepper population was 57% from line 265, while the lowest was 47% from line 390. The efficiency values in this study reflect the ratio of dried pepper yield to fresh yield, while Arpacı et al. [36] calculated the efficiency of powdered pepper from dried peppers, hence the differing results (Figure 3).

Number of Fruits

The number of fruits, seed count per fruit, average fruit weight, average fruit length, and average fruit width for the Kahramanmaraş pepper lines and varieties are presented in Table 3. Significant differences in fruit number among lines and varieties were observed ($p \leq 0.01$). The highest fruit count was recorded for line 439, with 127.33 fruits per plant, while the lowest counts were obtained from the Bozok variety with 65.33 fruits per plant and the Yesemek variety with 86.00 fruits per plant.

Figure 3. Appearance of dried fruits

Table 3. Number of fruits, number of seeds in fruit, fruit weight, fruit length and fruit width values of varieties and lines

Variety and lines	Number of fruits (pcs.plant^{-1})	Number of seeds in fruit (pcs)	Fruit weight (g.fruit^{-1})	Fruit length (cm.fruit^{-1})	Fruit width (mm.fruit^{-1})
69	116.7 abc	197.0 i	8.51 cde	6.91 cde	18.31 cdef
83	104.7 bcde	348.0 a	11.01 a	6.76 cdef	19.36 bc
331	104.7 bcde	248.3 e	10.09 ab	6.47 ef	20.13 b
361	103.3 bcde	225.3 g	8.11 de	6.78 cdef	18.06 def
368	112.3 abc	276.7 bcd	9.70 abc	6.68 def	19.79 b
373	90.7 de	242.7 ef	8.41 cde	7.54 ab	17.41 f
378	103.0 bcde	347.0 a	7.76 de	7.00 cd	15.84 g
439	127.3 a	172.0 j	7.44 e	6.01 g	19.46 bc
449	120.0 ab	233.7 fg	9.01 bcd	7.82 a	19.07 bcde
454	102.3 bcde	265.3 d	8.58 cde	7.64 a	19.17 bcd
472	107.3 abcd	270.3 cd	10.60 a	7.19 bc	19.48 bc
521	98.0 cde	284.3 b	9.71 abc	6.33 fg	19.73 b
Bozok	65.3 f	278.0 bc	7.36 e	5.92 g	17.86 ef
Dila	108.3 abcd	182.3 j	10.57 a	6.84 cde	23.65 a
Sena	110.0 abcd	213.3 h	10.06 ab	6.76 cdef	22.89 a
Yesemek	86.0 ef	268.0 cd	7.30 e	6.63 def	17.18 f

Number of Fruits

In previous studies, Khristov et al. [37] reported fruit counts ranging from 9-12 fruits per plant, while Akıncı et al. [41] found 12-17 fruits per plant. Alparslan [42] reported counts ranging from 75.93-156.93 fruits per plant. Arpacı [7] identified the CM×PB-81 genotype as having the highest fruit count (81 fruits per plant), followed by K211×PB-14 with 72 fruits per plant. The lowest fruit count was observed in K12×K211-4 with 11 fruits per plant. Akıncı and Akıncı [33] reported that fruit counts in Kahramanmaraş red pepper ranged from 13 to 86

fruits per plant. In our study, some lines matched the fruit counts of Indian genotypes reported by [39]. The number of fruits in larger-fruited genotypes used for drying in Bulgaria [37] was considerably lower compared to our findings. The number of fruits in this study aligns with the Kahramanmaraş population evaluated by Alparslan [42].

Number of Seeds Per Fruit

According to Table 3, the highest number of seeds per fruit was found in line 378 with 347 seeds and line 83 with 348 seeds, while the lowest counts were observed in line 439 with 172 seeds and the Dila variety with 182 seeds. Vinod et al. [38] examined the yield and quality changes in the *C.annuum* (Kt-P1-19) variety harvested at eight different times, reporting 159 seeds per fruit after 60 days of flowering. The number of seeds is important in powder pepper production, as seeds are nutrient-rich, but fewer seeds are preferred in varieties for flake pepper production.

Fruit Weight

As shown in Table 3, the highest fruit weight was recorded in line 83, with 11.0 g.fruit^{-1}, followed by line 472 with 10.60 g.fruit^{-1}, Dila variety with 10.57 g.fruit^{-1}, line 331 with 10.09 g.fruit^{-1}, and the Sena variety with 10.06 g.fruit^{-1}. The lowest fruit weights were observed in the Yesemek variety (7.30 g.fruit^{-1}) and the Bozok variety (7.36 g.fruit^{-1}). Anonymous [28] recorded 8-14 g.fruit^{-1} for Kahramanmaraş pepper. Arpacı [7] noted that the K12×K211-46 genotype had the highest fruit weight (10.50 g.fruit^{-1}), followed by K12×K211-27 (10.23 g.fruit^{-1}). Genotypes K211×334-44 and K211×334-75 had the lightest fruit weights at 4.56 g and 4.40 g, respectively. In this study, the Sena variety had the highest fruit weight (13.21 g). These results are consistent with previous studies. Anonymous [28] reported that the fruit weight of the Kahramanmaraş pepper registered in 2002 ranged from 8 g to 14 g. Considering the processing techniques for red peppers in the region, smaller fruit sizes are preferred, as larger surface areas are required for sun-drying. The size of the pepper fruits is determined by the preferences of producers and processing plants. All lines used in this experiment fall within the desired size range.

Fruit Length

According to the observations, the longest fruits were found in line 449 (7.82 cm.fruit^{-1}) and line 454 (7.64 cm.fruit^{-1}), while the shortest fruits were observed in the Bozok variety (5.92 cm.fruit^{-1}) and line 439 (6.01 cm.fruit^{-1}), as shown in Table 3 and Figure 4.

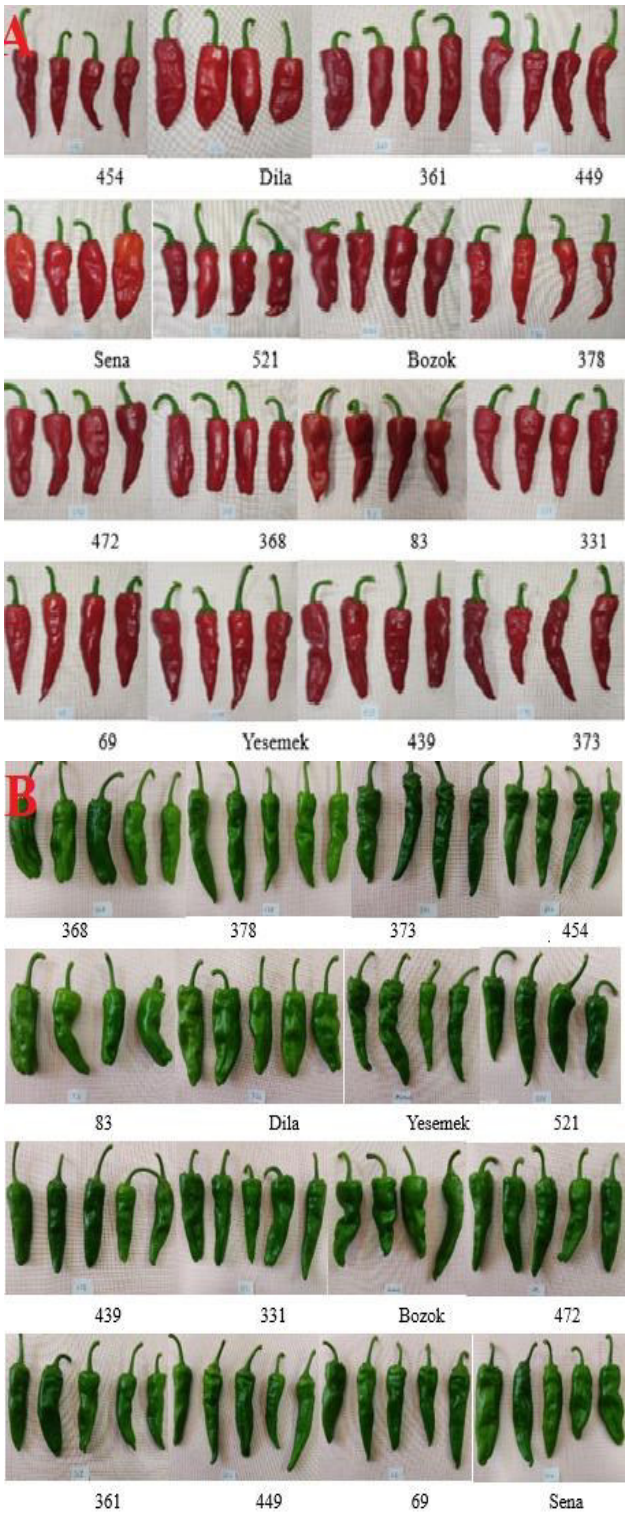

Figure 4. Views of mature (a) and immature (b) fruits on scaled paper (square size 1×1 cm)

Arpacı [7] found that line 46 had the longest fruit (93.15 mm), while the shortest fruit was observed in genotype K211×CM-75 (55.00 mm). Akıncı and Akıncı [33] reported that fruit length in the

Kahramanmaraş red pepper population ranged from 47 mm to 156 mm, and Demir [39] reported fruit lengths of 70 mm to 90 mm in the same population. Anonymous [28] stated that the fruit length of the Kahramanmaraş pepper registered in 2002 ranged from 60 mm to 115 mm. The values found in previous studies are consistent with the results obtained in this study.

Fruit Width

As shown in Table 3, the Dila variety had the highest fruit width at 23.65 mm/fruit, followed by the Sena variety with 22.89 mm/fruit. The narrowest fruit width was observed in line 378 with 15.84 mm/fruit. Arpacı [7] reported that the widest fruit was from the PB×PM-65 genotype with 28.66 mm, while PB×PM-2×46 and CM×PM-52×S genotypes had the narrowest fruit width at 12.92 mm. The Sena variety, which had a fruit width of 26.09 mm in previous studies, was measured at 22.89 mm under Antakya conditions, and the values are consistent. Arpacı et al. [40] found that the fruit width in the Kahramanmaraş pepper population ranged from 18.3 mm to 32.5 mm, while Akıncı and Akıncı [33] reported a range of 9 mm to 36 mm. Anonymous [28] stated that the Kahramanmaraş pepper registered in 2002 had a fruit width between 25 mm and 35 mm. Most lines and varieties used in this study had fruit widths below 25 mm, which is likely influenced by climatic conditions.

Flesh Thickness

The findings related to fruit flesh thickness, 100 seed weight, plant height, canopy width, and height-to-width ratio for the Kahramanmaraş pepper lines and varieties are presented in Table 4. The highest flesh thickness was measured in line 449 at 1.40 mm, while the lowest flesh thickness was observed in line 361 with 0.72 mm and in the Yesemek variety with 0.77 mm.

Öntürk [34] reported that the thicknest (3.28 mm) and thinnest (2.34 mm) fruit flesh thicknesses were measured in plant samples from the Altınözü population. Arpacı [32] found that the highest fruit flesh thickness was 1.84 mm in the K211×P-8×S genotype, while the lowest was 0.59 mm in the K211×CM-75×46 genotype. Korkutata and Kavaz [40] identified varying thicknesses among different regional pepper varieties, with Şanlıurfa peppers showing the highest average thickness (1.92 mm) and Kilis peppers the lowest (1.04 mm). Anonymous [28] reported thicknesses between 1.2 mm and 1.6 mm. Thin fruit flesh is crucial for rapid drying without aflatoxin formation.

Table 4. Fruit flesh thickness, 1000 seed weight, plant height, plant crown width and height to width ratio values of cultivars and lines

Variety and lines	Flesh thickness (mm)	1000 seed weight (g)	Plant height (cm)	Canopy width (cm)	Plant habitus (height to width ratio)
69	1.32 bc	5.57 d	65.67 ab	68.47 a	0.96 h
83	1.28 abc	6.00 c	61.13 c	49.40 f	1.24 b
331	1.15 cd	5.10 fg	62.53 bc	61.80 bc	1.01 gh
361	0.72 h	6.33 ab	64.67 abc	64.67 b	1.00 h
368	1.21 bcd	4.67 h	63.93 abc	55.93 e	1.15 cd
373	1.04 de	6.50 a	61.93 bc	44.73 g	1.39 a
378	0.75 h	6.40 ab	61.47 c	54.67 e	1.13 cde
439	0.85 fgh	5.00 g	64.80 abc	62.47 bc	1.04 efgh
449	1.40 a	6.00 c	65.60 ab	59.73 cd	1.10 defg
454	0.96 efg	5.00 g	64.40 abc	55.67 e	1.16 bcd
472	0.98 ef	4.63 h	64.93 abc	54.27 e	1.20 bc
521	1.33 ab	5.23 ef	62.07 bc	63.33 bc	0.98 h
Bozok	0.79 gh	5.40 de	61.80 bc	59.73 cd	1.03 fgh
Dila	1.16 bcd	5.90 c	64.27 abc	57.47 de	1.12 cdef
Sena	1.22 bc	6.22 b	61.47 c	62.80 bc	0.98 h
Yesemek	0.77 h	5.87 c	67.53 a	64.33 b	1.05 efgh

Plant Height

Among the lines and varieties, the highest plant height was measured in the Yesemek variety at 67.53 cm, while the lowest was recorded in line 83 at 61.13 cm, line 378 at 61.47 cm, and the Sena variety (Figure 5). Khristov et al. [37], in their study to find a new dried red pepper variety in Bulgaria, crossed the *Capsicum fasciculatum* and *Capsicum annuum* cv. Grogled 6 varieties, resulting in the new variety Buketen 50, which was reported to have a plant height of 40-45 cm. Similarly, Fırat et al. [43] also determined the plant height as 60 cm in hybrid varieties [43]. Anonymous [28] reported the Maraş pepper height to be around 60 cm, consistent with our findings.

Canopy Width

In Table 4, the highest canopy width was recorded in line 69 at 68.47 cm, while the lowest was in line 373 at 44.73 cm (Figure 5). Although the Sena variety, which had the highest fresh yield, also had above-average canopy width, there was no significant correlation between canopy width and yield.

1000 Seed Weight

According to Table 4, the highest 1000 seed weight was found in line 373 at 6.50 g, while the lowest was in line 472 at 4.63 g and line 368 at 4.67 g. Vinod et al. [38] observed that the 1000 seed weight for the *C.annuum* (Kt-P1-19) variety, harvested 60 days after flowering, was 8.29 g. The smaller size of Kahramanmaraş pepper seeds directly affects their weight, but seed germination strength is more important than seed weight for red pepper cultivation. Lower seed weight is beneficial for transportation.

Plant Habit

The highest plant habit value was observed in line 373 at 1.39, while the lowest values were found in lines 69 and 521, as well as the Sena variety, with values between 0.96 and 0.98. These results indicate that the Sena, 521, and 69 varieties have a more spreading habit (values less than 1), while the other lines and varieties exhibit a more upright and compact habit (values greater than or equal to 1).

Pungency of Ripe Fruit

The findings for ripe fruit pungency, immature fruit color, and mature fruit color for the Kahramanmaraş pepper lines and varieties are presented in Table 5. Significant differences in fruit number among lines and varieties were observed ($p \leq 0.01$). The highest pungency in ripe fruit was recorded in the Yesemek variety with 41873 SHU, while the lowest was observed in the Dila variety with 185 SHU.

Arpacı et al. [36] examined the morphological traits of the Kahramanmaraş pepper population and found the highest pungency value of 48,690 Scoville from line 187, while the lowest was 3,585 Scoville from line 3. Pungency is a crucial factor determining the quality of both powdered and flaked pepper. In this study, the Dila and Sena varieties showed significantly lower pungency levels than those reported by Arpacı et al. [36], while the lines reflected the typical pungency traits of the population.

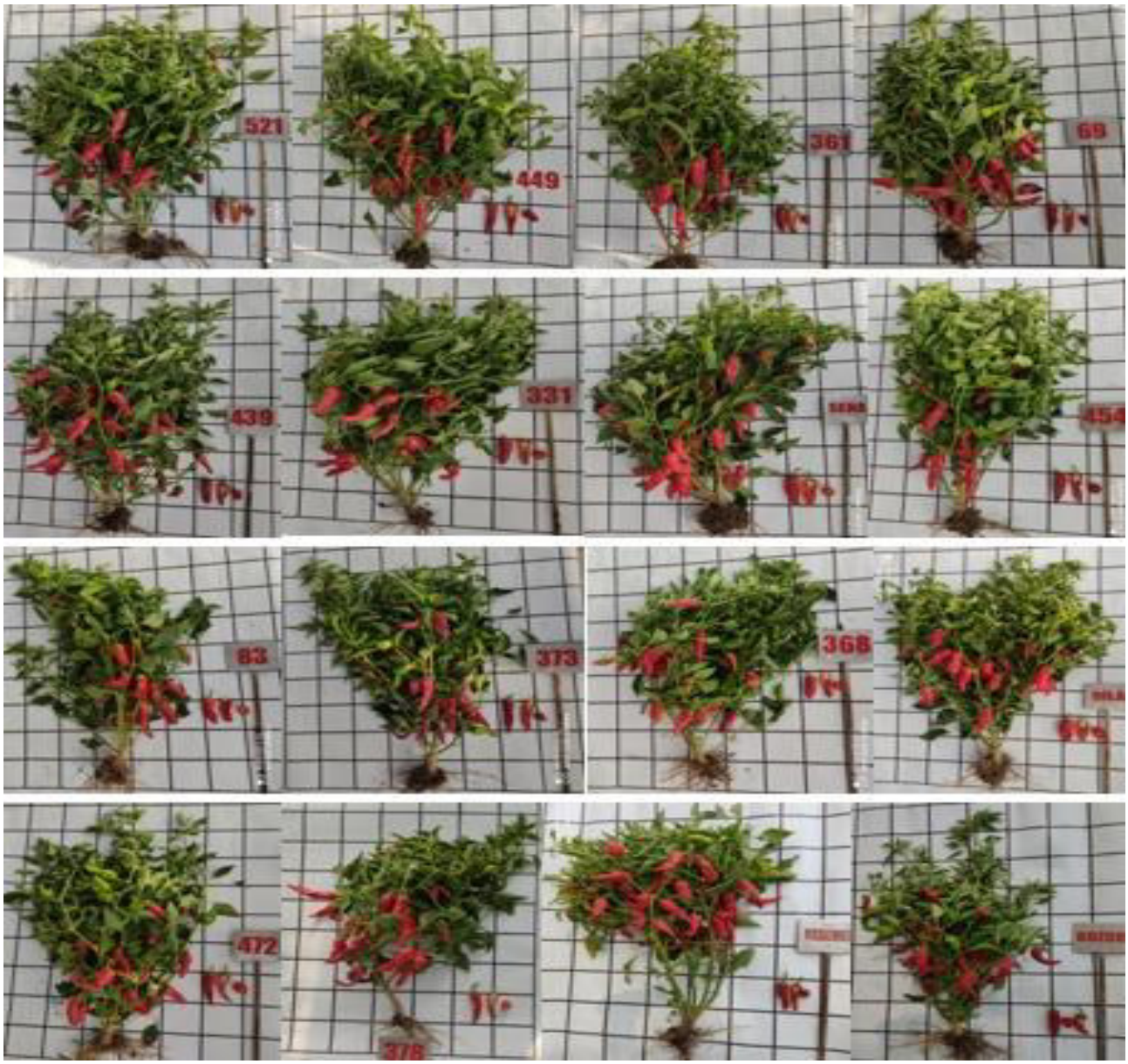

Figure 5. Views of harvested plants on scale paper (square size 10×10 cm)

Table 5. Ripe fruit pungency, immature fruit colour, mature fruit colour values of lines and cultivars

Varieties and lines	SHU	Fruit position	Immature fruit color	Mature fruit color
69	5936 f	3	2 b	2 b
83	8321 e	3	1 c	2 b
331	39921 b	3	2 b	3 a
361	18365 c	3	2 b	3 a
368	30080 bc	3	2 b	3 a
373	13843 ef	3	3 a	3 a
378	31016 bc	3	1 c	1 c
439	14393 d	3	3 a	3 a
449	8068 e	3	2 b	2 b
454	15874 cd	3	2 b	3 a
472	147483 a	3	1 c	3 a
521	1976 g	3	3 a	3 a
Bozok	8400 e	3	2 b	3 a
Dila	185 i	3	1 c	1 c
Sena	369 h	3	1 c	1 c
Yesemek	41873 b	3	2 b	2 b

Fruit Position

According to Table 5 and Figure 6, all lines and varieties exhibited pendant fruit position. Anonymous [28] indicated that the Kahramanmaraş pepper, registered in 2002, displayed either pendant, horizontal, or mixed fruit positions.

Figure 6. Views of the position of mature fruits on the branch

Color of Immature Fruits

Among the important traits, the color of immature fruits varied from green to different shades of green. Lines 521, 439, and 373 displayed dark green fruits, while lines 83, 378, 472, and the Dila and Sena varieties showed light green fruits, as observed in Table 5. Arpacı et al. [36] also reported that the color of immature fruits varied between light green (1), green (2), and dark green (3). Anonymous [28] stated that the immature fruits of Kahramanmaraş pepper were green. Although red is important for dried red peppers, the color of immature fruits is less significant for drying purposes (Figure 7-a). Brightness and uniformity of color are important for fruit quality.

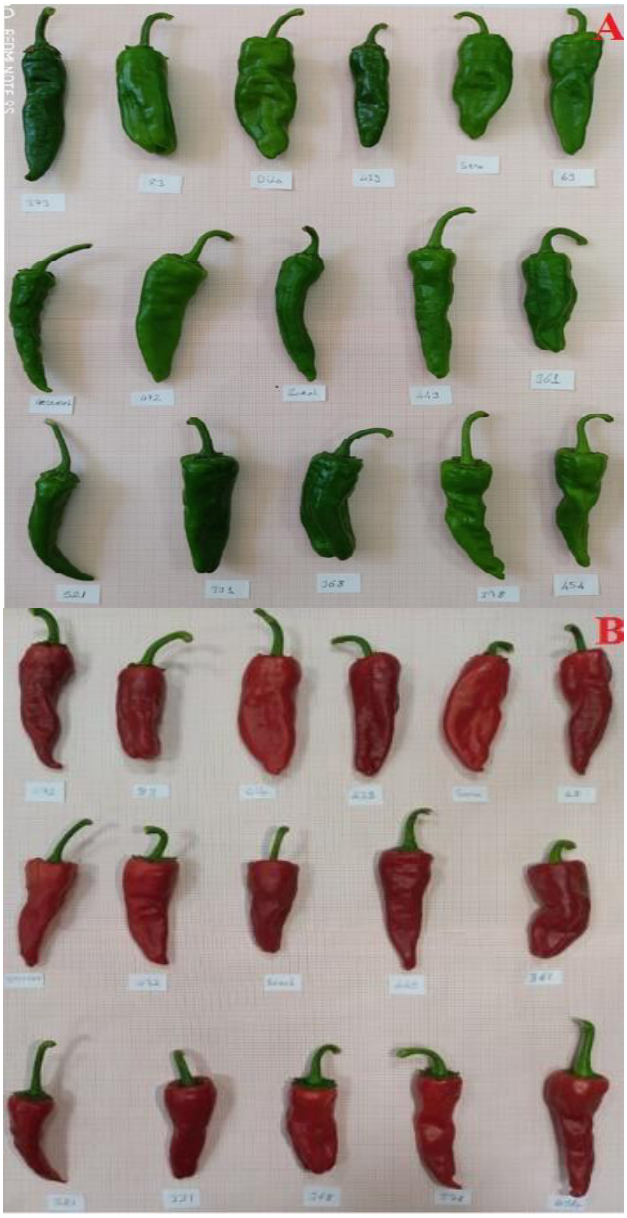

Figure 7. Views of immature (a) and mature (b) fruits on scale paper (square size 1×1 cm)

Color of Mature Fruits

In terms of mature fruit color, the varieties and lines studied exhibited red and various shades of red. Dark red fruits were notably observed in lines 331, 361, 368, 373, 439, 454, 472, and 521, as well as the Bozok variety. In contrast, light red fruits were found in line 378 and the Sena and Dila varieties (Table 5). Anonymous [28] described the Kahramanmaraş

pepper as having red mature fruits. The red color is one of the most critical qualities sought after in dried Kahramanmaraş pepper, commonly known as red flake pepper, for both marketing and consumption purposes. A bright and homogeneous red color is crucial for the pepper's marketability. The varieties and lines tested showed bright and uniform colors suitable for marketing (Figure 7-b).

Flowering Time

According to Table 6, the flowering time varied by 25 days across the varieties and lines. The earliest flowering was observed in the Yesemek and Bozok varieties at 73 days, while the latest flowering was observed in the Sena variety at 98 days, followed by the Dila variety at 95 days. Arpacı et al. [36] found that the earliest flowering times were 62 days and 65 days for lines 333 and 3, respectively, and the latest was 81 days for lines 390 and 442. Varieties with later flowering times also exhibited later fruit ripening, which was attributed to their genetic characteristics.

Table 6. Flowering time, number of flowers in the axil, fruit ripening time, fruit shape, fruit position values of varieties and lines

Varieties and lines	Flowering time (days)	Number of flowers in the axil	Fruit ripening time (days)	Fruit shape
69	90 c	2 a	130 b	3 b
83	85 d	1 b	130 b	5 a
331	85 d	1 b	127 c	3 b
361	79 f	1 b	123 e	3 b
368	85 d	1 b	130 b	5 a
373	82 e	1 b	123 e	3 b
378	82 e	2 a	123 e	3 b
439	82 e	2 a	125 d	3 b
449	85 d	1 b	125 d	3 b
454	82 e	1 b	127 c	3 b
472	85 d	2 a	127 c	3 b
521	83 de	1 b	130 b	3 b
Bozok	73 f	1 b	111 g	3 b
Dila	95 b	1 b	135 a	3 b
Sena	98 a	1 b	135 a	3 b
Yesemek	73 f	1 b	115 f	3 b

Number of Flowers Per Node

As shown in Table 6, there was no significant variation in the number of flowers per node among the lines and varieties. Lines 69, 378, 439, and 472 had two flowers per node, while the other lines and varieties had one flower per node. The Sena variety, which had the highest fresh yield, exhibited one flower per node, suggesting that the number of flowers per node had no significant impact on yield.

Fruit Ripening Time (Days)

According to Table 6, the Yesemek and Bozok varieties, with ripening times of 115 days and 111 days, respectively, were early-ripening varieties. The Sena and Dila varieties, with ripening times of 135 days, were late-ripening varieties. The difference in ripening times between early- and late-ripening varieties was 24 days. Fruit ripening time is a key indicator of whether a variety is early- or late-ripening. A parallel relationship was observed between flowering time and fruit ripening time.

Fruit Shape

Based on the pepper descriptor guide [22] and as shown in Figure 2, lines 83 and 368 had blocky fruit shapes, while the other lines and varieties had triangular fruit shapes, as seen in Table 6 and Figure 4. Anonymous [28] described the Kahramanmaraş pepper, registered in 2002, as having a conical fruit shape, with the tip being either pointed or blunt, and a smooth surface, with the part where the fruit attaches to the stem usually flat or sometimes raised. The small surface area and smooth shape of Kahramanmaraş pepper fruits provide advantages for drying, marketing, and export. The shapes of the varieties and lines used in this experiment are consistent with the characteristics of dried peppers.

CONCLUSION

In this study, genotypes 83, 331, 368, 373, 361, 378, 439, 449, 454, 472, 521, and 69, developed through selection from the Maraş pepper population by the East Mediterranean Transitional Zone Agricultural Research Institute, were used alongside the registered varieties Sena and Dila, and the approved varieties Bozok and Yesemek. Twenty-two different morphological traits were characterized in detail, including plant height, canopy width, flowering time, number of fruits per plant, fruit color, and fruit weight.

The results revealed significant variation in fresh yield (ranging from 1106 to 549 g.plant^{-1}), dry yield (270 to 132 g.plant^{-1}), drying efficiency (32.5% to 18.2%), and pungency levels (147483 to 185 SHU). The flowering period varied from 73 to 98 days, while fruit ripening ranged from 111 to 135 days. The data demonstrated that Antakya provides suitable conditions for red pepper production, particularly for genotype 472, which showed both high dry yield and pungency, making it an excellent candidate for commercial dried pepper production.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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