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Research Article

STUDIES ON THE FERTILIZATION BIOLOGY OF 'UZUN' AND 'SIIRT' PISTACHIO CULTIVARS IN THE MANISA ECOLOGY

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ABSTRACT. This study aimed to determine the most suitable pollinator types for the 'Siirt' and 'Uzun' pistachio varieties in the Demirci district of Manisa. 'Atlı', 'Buttum', 'Uygur', and the naturally growing 'Melengiç' (*Pistacia terebinthus* L.) types were used as pollinators. According to phenological observations, the flowering periods of all pollinator types and female varieties occurred between April 5–25. The 'Uzun' variety overlapped in flowering time with the 'Uygur' type, while the 'Siirt' variety overlapped only with the 'Buttum' type. According to the TTC test, the pollen viability rates were 90% and 93% for 'Melengiç' and 'Buttum' types, respectively, while 'Atlı' and 'Uygur' types had viability rates of 81% and 79%. The IKI method showed that all pollinator types had high pollen viability levels. The pollen germination rates ranged between 45% and 62%. For the 'Uzun' variety, the 'Uygur' type had the lowest fruit drop rate (68%) and was evaluated as the best pollinator. On the other hand, the highest fruit drop rate (85%) was observed in the open-pollination treatment. For the 'Siirt' variety, fruit drop rates were higher compared to the 'Uzun' variety, with the lowest drop rate observed in the 'Buttum' combination (78%). In terms of fruit set, all pollinators significantly improved the fruit set rate for the 'Uzun' variety, with 'Uygur' and 'Melengiç' producing the best results. For the 'Siirt' variety, 'Buttum' and 'Atlı' pollinators achieved higher fruit set rates compared to the other pollinators and open-pollination treatment.

Keywords: *Pistachio, pollinator, fruit set, pollen, fertilization biology*

INTRODUCTION

Pistachio can grow in arid, stony, and rocky areas that are not suitable for agriculture. For this reason, it is an important fruit species that allows the use of lands other than fertile agricultural areas. In addition, due to the high nutritional value and unique aromatic characteristics of its fruit, particularly in the form of green kernel pistachios, it holds significant economic value both in the domestic market and in international trade. This situation not only provides substantial income for producers but also contributes to the national economy through foreign exchange earnings [1].

Türkiye is located in the original center of pistachio and is one of the primary regions where this species naturally spreads. In particular, the Southeastern Anatolia Region holds significant importance as one of the centers with high genetic diversity of pistachio and as the area where it was first domesticated. The region's unique ecological conditions allow for the successful cultivation and widespread distribution of pistachio [2]. However, pistachio cultivation is not limited to the Southeastern Anatolia Region alone; it is also widely practiced in the interior parts of the Aegean Region, the southern slopes of the Taurus Mountains in the Mediterranean Region, as well as in certain parts of Central and Eastern Anatolia. These areas provide favorable conditions for pistachio growing due to their climate, characterized by hot and dry summers and relatively cold winters [3, 4].

Since pistachio flowers become active at different times, the species is classified among plants that exhibit dichogamy. Pollination occurs when pollen from male flowers is transferred to the stigma of female flowers, and germination begins within approximately four hours,

initiating the fertilization process. Depending on ecological conditions, pollen tubes reach the embryo sac within 20 to 48 hours to complete fertilization. The period from pollen germination on the stigma to fruit ripening is approximately 90 days [5, 6, 7, 8, 9].

There are several important factors that must be considered to achieve successful fertilization. Due to dichogamy, the flowering times of male and female flowers must overlap. In Türkiye’s Southeastern Anatolia Region, where pistachio cultivation is most intensive, flowering generally occurs during the first two weeks of April. Although the flowering durations of male and female flowers vary, female flowers typically remain receptive for 10–12 days, while male flowers bloom for about 3–7 days. Moreover, male flowers generally bloom earlier than female ones [10, 11]. Therefore, the selection of appropriate pollinator cultivars and the accurate planning of planting strategies are of great importance for successful pollination.

In studies on fertilization biology, evaluating pollen viability and germination capacity is crucial, as successful fertilization largely depends on the vitality of pollen. Additionally, monitoring fruit set and fruit drop provides important insights into the effectiveness of pollination and fertilization under specific ecological conditions. High pollen viability and strong germination ability generally lead to higher fruit set rates, while environmental stresses or incompatibilities can increase fruit drop. Therefore, assessing these parameters is essential to better understand reproductive success in pistachio cultivation.

In the current study, it was aimed to determine the most suitable pollinator types for the ‘Siirt’ and ‘Uzun’ pistachio varieties grown in Demirci district of Manisa province. Within the scope of fertilization biology, phenological observations, pollen viability and germination rates, fruit set and drop rates were determined.

MATERIALS AND METHODS

In this study, ‘Uzun’ and ‘Siirt’ cultivars were used as the female parents in Demirci, Manisa. As pollinators, the cultivars ‘Uygur’, ‘Buttum’, and ‘Atlı’, along with the naturally growing Melengiç (*Pistacia terebinthus* L.), were used. The characteristics of the varieties and types are given below:

Siirt: A semi-upright cultivar with vigorous growth. It produces cream-colored flowers that bloom in the mid-early period. Its inflorescences are loose, and the nuts are easily detached. The fruits, which have a yellow kernel, are generally consumed as snack nuts. It has a low tendency toward biennial bearing [12].

Uzun: A semi-upright and vigorous cultivar. It bears yellowish-green flowers that bloom in the mid-early period. The inflorescences are moderately dense, and the nuts are easily detached. The fruits, with a green kernel, are typically used for snacking. It tends to show biennial bearing [12].

Buttum: It is widely found in the Eastern and Southeastern Anatolia Region, especially around Siirt, Hakkari and Bitlis. It prefers calcareous and well-drained soil. It is one of the best rootstocks adapted to clay soils [13].

Uygur: An early-blooming pistachio type. With an eight-day flowering period, it serves as a good pollinator for early flowering female cultivars [14].

Atlı: Grows in tree form, reaching heights of 4 to 5 meters. It blooms in March–April. It grows well in hot and dry climates with alkaline soils and is widespread in Southeastern Anatolia [13, 14].

Melengiç (*P. terebinthus*)**:** In Türkiye, it grows as a shrub or tree reaching heights of 2 to 10 meters. Its leaves have a resinous aroma. It produces reddish-purple flowers in March–April. It thrives in light, dry, alkaline soils [13, 14].

Geographical and Climatic Characteristics of Demirci

Demirci is situated in a transitional zone between the Mediterranean and Continental climates. The annual average temperature is approximately 12 °C, with around 50% of the total yearly precipitation occurring during the winter months. The town center lies at an elevation of 900 meters (Table 1). These climatic conditions are generally favorable for pistachio (Pistacia vera) cultivation, which thrives in hot and dry environments. However, due to local climatic variability, careful selection of appropriate cultivars is essential. The experimental are used in this study is located within the Demirci district, between the coordinates 39°01'48.5"N, 28°35'50.9"E and 39°01'53.1"N, 28°39'37.2"E. A photo of the experimental area is shown in Fig. 1.

Table 1. *The annual climatic characteristics of the Demirci district.*

Month	Max Temp (°C)	Min Temp (°C)	Avg Temp (°C)	Max Humidity (%)	Min Humidity (%)	Avg Humidity (%)	Avg Wind (m/s)
January	14.8	2.7	5	100	60.9	78.7	2.5
February	22	4.8	8	99	44.4	64.8	2
March	18.3	4.4	8.4	100	40.1	65.4	2.1
April	28.9	13.1	17.8	100	30	50.7	2.6
May	29.9	12.3	17.2	100	34.8	57.7	2.4
June	39.4	21.8	27.4	86	19.9	38.1	2.6
July	39.1	23.6	28.5	83	23.8	41.0	3
August	34.6	15.9	26.5	91	28.1	66.1	2.2
September	33.8	17.0	21.6	99	29.1	50.3	1.8
October	32.1	12.2	17	87	25.5	47.2	1.4
November	28.9	5.5	11.3	100	29.2	65.5	1.4
December	15	3.6	6.2	100	55.6	80.7	1.7

Fig. 1. *Experimental area*

Phenological Observations

The following phenological stages were determined in the female and pollinator varieties constituting the study material [10]. First bloom date: the stage when at least 5% of anthers in pollinator genotypes shed pollen, and in the female varieties, 5% of stigmas become receptive (cream-green in color). Peak bloom date: the stage when at least 75% of anthers in pollinator genotypes shed pollen, and in the female varieties, at least 75% of stigmas are receptive. Last bloom date: the stage when the vast majority of anthers in pollinator genotypes have shed pollen, and in the female varieties, all stigmas have turned light brown.

Pollen Collection

To collect pollen from different Pistacia species used as pollinators, inflorescences at the first flowering stage, when the anthers begin to dehisce and release pollen, were collected. In laboratory conditions, the inflorescences were spread out on paper and shaken and sieved twice daily for 4–5 days. The collected pollen was then stored in glass bottles and kept in a refrigerator until pollination was carried out.

Fig. 2. *Pollen collection*

Controlled Pollination

In order to prevent open pollination in female trees, isolation was performed before anthesis during the early flowering stage, when lateral buds had not yet opened but inflorescences had begun to develop. For this purpose, three trees were selected from each cultivar. On each tree, 12 distinct shoots were identified to allow the application of four different pollinators. The flowers in the inflorescence were counted and noted. On each shoot, three inflorescences near the shoot tip were individually isolated using waterproof white paper. The isolation covers were removed once the stigmas had lost receptivity. When the flowers reached their receptive stage, pollen from each pollinator was mixed with 50% dusting powder and applied using separate hand sprayers. Since the inflorescences did not mature uniformly, the pollination procedure was repeated after a two-day interval [15].

Fig. 3. *Controlled pollination*

Open Pollination

For open pollination, three shoots were marked on each tree. The flowers in the inflorescences were counted and noted.

Determination of Flower and Fruit Drop

The flowers in the inflorescences were counted before pollination. The first flower drops in these inflorescences occurred approximately one week after pollination; the bags were removed, and the flowers were counted again, and flower drop was determined as a percentage. Later, in June, the fruit drop rate was determined based on the counts. The counts were carried out on all the inflorescences where the treatment was applied.

Determination of Fruit Set Rate

The number of fruits at harvest time was determined. The fruit set rate in each combination was determined as a percentage, taking into account the number of initial flowers.

Pollen Viability and Germination Tests

The viability of the pollen was demonstrated using TTC (2, 3, 5 Triphenyl tetrazolium chloride) and IKI (Iodine Potassium Iodide) tests. The average pollen viability rates were calculated through counting. In the pollen germination test, saturated Petri dish method containing 1% agar and 20% sucrose was employed. Following the addition of pollen to the media, Petri dishes were sealed with moistened filter paper and incubated at 20°C for 4-5 hours to facilitate pollen germination. The average pollen germination rates were calculated based on the counts. Viability and germination tests were performed in 3 replicates [16].

Data Evaluation

The experiment, designed according to a randomized block design, was carried out with three replications, where each set of three trees was considered as a replication. The obtained data were analyzed using the IBM SPSS Statistics 19 software (IBM, NY, USA). Differences between treatments were determined using the Duncan test ($P \leq 0.05$).

RESULTS AND DISCUSSION

Phenological Observations

The phenological periods for the female and pollinator varieties, including the First bloom date, Peak bloom date, and Last bloom date in 2024, were determined (Fig. 4). Based on the phenological observations, the earliest first bloom date was recorded in the 'Uzun' female variety and the 'Uygur', 'Atlı', and 'Melengiç' pollinator varieties (April 5). The earliest peak bloom date was observed in the 'Uzun' female variety (April 8), whereas the pollinator varieties 'Uygur', 'Melengiç', and 'Atlı' reached peak bloom on April 7. The last bloom date was determined to occur between April 10 'Melengiç' and April 13 'Uzun'.

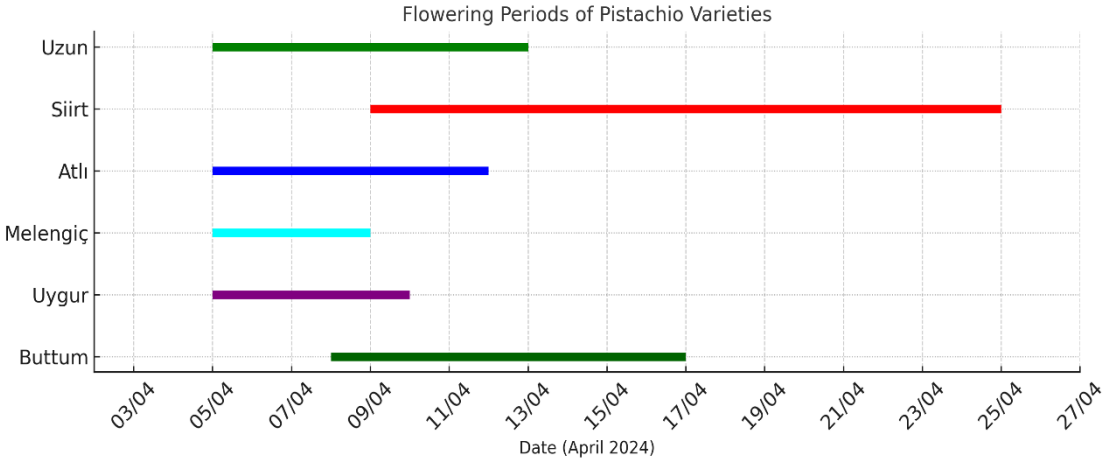

Fig. 4. *Flowering dates of female and pollinator genotypes (2024)*

As a result of the phenological observations, the flowering duration was determined to be 9 days for the 'Uzun' variety and 17 days for the 'Siirt' variety. For the pollinator types, the flowering duration was 5 days for 'Melengiç', 6 days for 'Uygur', 8 days for 'Atlı', and 10 days for 'Buttum'.

In phenological observations conducted by Kır [17] in Gaziantep, flowering in the 'Uzun' variety occurred between April 10 and 22, while in the 'Siirt' variety, it was determined between April 12 and 26. Among the pollinator types, '12-119' flowered between April 16 and 27, and '9-64' flowered between April 17 and 26. In a study conducted in Gündoğdu village, Bucak district, Burdur province, flowering in the 'Uzun' variety occurred between April 8 and 28, and in the 'Siirt' variety, between April 11 and May 2. Flowering in the pollinator variety began earlier (April 3-4), reached full bloom on April 12-13, and ended on April 21-22 [18].

Flower and Fruit Drop

In this study, the effects of different pollinators on flower and fruit drop in 'Uzun' and 'Siirt' varieties were determined (Table 2). The initial flower drop was recorded one week after pollination, and the fruit drop was recorded in June. The results of these observations are presented below in the tables.

Statistically significant differences were observed in flower drop rates among the pollinators used in the 'Uzun' variety. The 'Uygur' variety exhibited the lowest flower drop rate at 15.28%, indicating that this variety is a suitable pollinator. In contrast, the highest flower drop rate, 45.96%, was recorded in the 'Uygur' × 'Buttum' combination. This shows that a significant

portion of the flowers do not turn into fruit and fall off. The flower drop rate in the 'Melengiç' pollination combination was 23.60%, while the open pollination rate was 40.57%.

In the case of the second female parent, the 'Siirt' variety, no statistically significant differences in flower drop rates were found among the pollinators. However, the lowest flower drop rate was recorded at 26.99% in the 'Atlı' genotype, and the highest was 42.99% in the 'Buttum' genotype.

Table 2. *Flower drops in female varieties (%)*

Female Variety	Pollinator	Flower number	First fruit number	Flower drop (%)
UZUN	Uygur	916	778	15.28±7.77 a
	Atlı	1492	1175	21.33±2.48 a
	Melengiç	1184	906	23.60±3.54 a
	Buttum	1752	929	45.96±5.79 b
	Open	1129	671	40.57±7.36 b
SİİRT	Uygur	1323	735	45.36±4.43
	Atlı	1144	806	26.99±10.73
	Melengiç	1426	800	42.93±3.38
	Buttum	1575	860	42.99±10.42
	Open	457	276	36.65±14.29

In the 'Uzun' variety, the effect of pollinators on fruit drop rates showed statistically significant differences (Table 3). As observed, the 'Uzun' × 'Uygur' combination had the lowest fruit drop rate at 68.56%, indicating that the 'Uygur' pollinator also demonstrated superior performance in fruit set. In open pollination, the fruit drop rate was highest at 85.92%. In the 'Atlı' and 'Melengiç' pollination combinations, the fruit drop rates were found to be 82.88% and 74.38%, respectively.

In the 'Siirt' variety, the fruit drop rates remained high in June as well. 'Buttum' exhibited the lowest fruit drop rate in June, at 78.67%, indicating that fruit set was more successful during this period compared to other pollinators. 'Melengiç' and open pollination exhibited the highest fruit drop rates in June, with values of 86.43% and 84.66%, respectively.

Table 3. *Fruit drops in female varieties (%)*

Female Variety	Pollinator	First Fruit Count (count)	June Fruit Count (count)	June Fruit Drop (%)
UZUN	Uygur	778	244	68.56±0.97 a
	Atlı	1175	200	82.88±2.94 c
	Melengiç	906	231	74.38±1.77 b
	Buttum	929	236	75.64±4.95 b
	Open	671	93	85.92±2.93 c
SİİRT	Uygur	735	105	85.29±2.66 b
	Atlı	806	123	85.11±2.74 a
	Melengiç	800	111	86.43±2.51 a
	Buttum	860	182	78.67±2.20 a
	Open	276	43	84.66±3.63 a

In a study conducted by Kır [17], the effects of artificial and open pollination on flower and fruit drop were examined on a monthly basis. In the 'Uzun' variety, the most intense drop

occurred in May, with a lower intensity in June, and no further drop was recorded in the following months. In the 'Siirt' variety, intense drop was also observed in May, and it was found that pollinations with types 9-64 and 21-125 in June caused more drop.

In a study by Acar [6], conducted in Ceylanpınar, the effect of different pollinator types on flower and fruit drop was investigated. In the 'Kırmızı' variety, the most intense drop started after flowering and lasted for 25-30 days, with more severe drop in June and before harvest. The total flower and fruit drop rates were determined to be 84.28% and 89.30%, respectively. In the 'Siirt' variety, drop started after flowering and lasted for 28-40 days, with lower drop rates in June and before harvest. The total drop rates for the 'Siirt' variety (93.50% and 94.16%) were found to be higher than those of the Kırmızı variety.

Flower drop varies according to pollination combinations. Flower drop rate may depend on genotype. In addition, extreme climate factors during the blooming period may also be effective. Although the average temperature during the blooming period should be 25-30 degrees, as stated by Yılmaz and İlikçioğu [19], the low average temperature in March negatively affected the period in question.

On the other hand, the probable cause of fruit drop in June, which covers the fruit development period, may be due to the relatively low temperature values. In addition, the lack of plant nutrition and irrigation practices may also be effective in this situation. Insufficiency of carbohydrate reserves during this period is also among the possible causes of drop [20].

Determination of Fruit Set Rates

Fruit set rates are an important criterion for evaluating the effectiveness of pollinators. The fruit set rates for the 'Uzun' and 'Siirt' varieties are detailed in the tables.

In the 'Uzun' variety, the highest fruit set rate was observed in the 'Uygur' pollination combination, with a rate of 26.59% (Table 4). This value was the lowest in the open pollination treatment, at 8.24%. In the combinations with 'Melengiç' and 'Buttum' as pollinators, the fruit set rates were determined to be 19.57% and 13.03%, respectively.

In the 'Siirt' variety, 'Buttum' achieved the highest fruit set rate at (12.12%) This result indicates that the 'Buttum' pollinator has a good compatibility with the 'Siirt' variety. 'Atlı' (10.84%) and open pollination (9.38%) showed medium fruit set rates. 'Melengiç' (7.70%) and 'Uygur' (8.05%) exhibited lower fruit set rates.

Table 4. *Fruit set rates in different pollination combinations in female varieties (%)*

Pollinator/Female	Uzun	Siirt
Uygur	26.59±1.64 a	8.05±1.71 b
Atlı	13.42±1.88 c	10.84±2.23 ab
Melengiç	19.57±1.57 b	7.70±1.13 b
Buttum	13.03±2.09 c	12.12±2.24 a
Open	8.24±0.98 d	9.38±0.66 ab

Flower and fruit drop reached their highest levels in both varieties, particularly in May and June. In the 'Uzun' variety, the 'Uygur' pollination combination stood out as the most effective pollinator with both low flower and fruit drop rates and high fruit set. In the 'Siirt' variety, the 'Buttum' pollination combination exhibited the lowest June fruit drop and the highest fruit set, demonstrating superior performance. These findings highlight the critical impact of pollinator selection on flower and fruit set in pistachio cultivation.

In a study conducted by Kır [17], it was determined that pollinator types had significant effects on fruit set rates. In the 'Uzun' variety, the highest fruit set rate was observed at 21.48% (Uzun x 21-125) and 18.53% (open pollination), while the lowest rate was found to be 11.03% with the 16-32 pollinator. It was noted that the '21-125' and '9-64' pollinators performed

better. In the 'Siirt' variety, the highest fruit set rate was recorded at 19.12% (21-125), while the lowest rate was 11.32% (9-64). Open pollination rates varied between 8.72% and 10.34%.

In a study conducted by Açar [6] in Ceylanpınar, it was found that pollinator types significantly influenced fruit set in female varieties. In the 'Kırmızı' variety, the highest fruit set was recorded at 15.01% (pollinator number 23), while the lowest was 10.50% (pollinator number 16). In the 'Siirt' variety, the highest fruit set was observed at 7.90% with pollinator number 7, followed by a fruit set of 7.18% with open pollination.

Pollen Viability and Germination Tests

The viability of the pollen was determined using TTC and IKI tests. The average pollen viability rates are presented in (Table 5). Statistical analysis revealed that the differences between the data were significant in the TTC and germination tests. According to the obtained results, the viability of the pollen was found to be 79% in 'Uygur', 81% in 'Atlı', 90% in 'Melengiç', and 93% in 'Buttum'. In the IKI test results, the viability rate of all genotypes ranged from 99% 'Uygur', 'Atlı', 'Melengiç' to 100% 'Buttum'. The pollen germination rates were recorded as 45% for 'Uygur', 62% for 'Atlı', 57% for 'Melengiç', and 57% for 'Buttum'. 'Melengiç' and 'Buttum' showed high performance in both viability and germination rates, the germination rate came to the fore in 'Atlı'. 'Uygur' exhibited a lower germination rate compared to the other varieties.

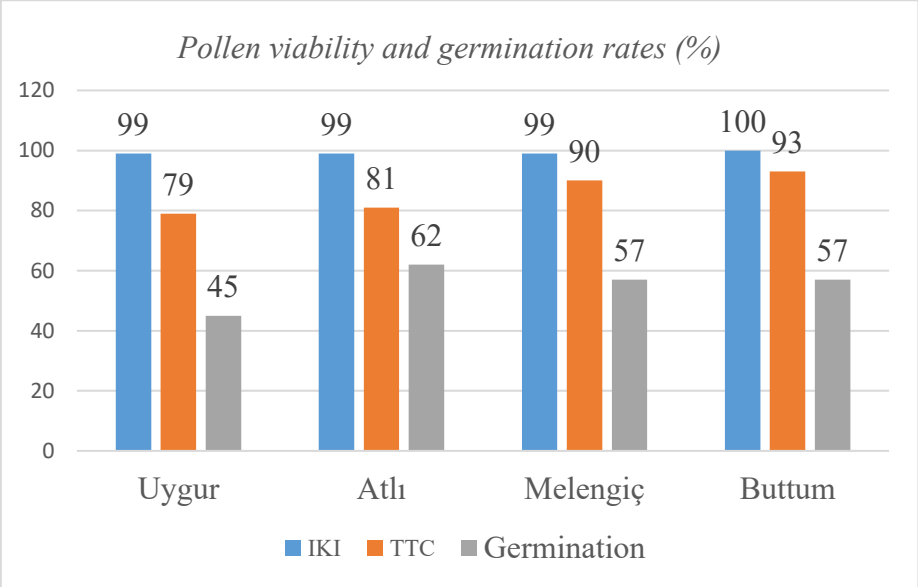

Fig. 5. *Pollen viability and germination rates (%)*

In a study by Aldahadha et al. [21], conducted on six pistachio cultivars under both fresh and stored conditions, Batouri and Lazaourdi exhibited the highest fresh pollen viability (87%) and germination rates (69.7%), while Nab-El Jamal had the lowest (43.7% viability, 40.3% germination). Storage caused a significant reduction in viability around 30% and no germination was observed after one month. Additionally, a weak correlation ($r^2 = 0.149$) was found between fresh pollen viability and germination rates.

In Aydın ecological conditions, the highest pollen viability rate in the TTC test was determined as 79.95% (Type 4), while the lowest was 70.18% (Type 3). Type 2 showed a viability rate of 78.90%, and Type 1 had a rate of 73.68%. In the IKI test, the highest viability was recorded as 85.33% (Type 2), and the lowest as 70.38% (Type 4). Type 1 (79.39%) and Type 3 (78.11%)

showed similar values [22]. These findings indicate that pollen viability and germination capacity may vary depending on the variety and the test methods used. The combined use of TTC and IKI tests is an effective approach for a more comprehensive assessment of pollen viability levels.

CONCLUSION

This study evaluated the pollination efficiency of different male genotypes for the 'Siirt' and 'Uzun' pistachio cultivars under the ecological conditions of Demirci district, Manisa province. The findings highlight the critical importance of flowering synchrony between male and female cultivars in influencing fruit set and minimizing fruit drop. In the 'Uzun' cultivar, the 'Uygur' genotype emerged as the most effective pollinator, owing to its synchronized flowering period and low fruit drop rates. For the 'Siirt' cultivar, the 'Buttum' and 'Atlı' genotypes showed superior performance as pollinators. High pollen viability and germination rates across all tested male genotypes further confirmed their reproductive potential. These results suggest that selecting male genotypes adapted to local environmental conditions can significantly improve fertilization success and ultimately enhance yield. For pistachio orchard establishment in Demirci and similar ecological zones, the use of compatible pollinators such as 'Uygur', 'Buttum', and 'Atlı' is strongly recommended. In addition, ongoing research into flowering phenology, pollen characteristics, and pollination dynamics is essential to ensure sustainable and productive pistachio cultivation in the face of changing climatic conditions.

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