

**Seed Yield and Quality Performance in Crosses of Pot Miniature × Garden / Cut Roses**

Saksı Minyatür × Bahçe / Kesme Gül Melezlerinde Tohum Verimi ve Kalite Performansı

Ezgi DOĞAN MERAL<sup>1</sup>, Emine KIRBAY<sup>2\*</sup>, Tuğba KILIÇ<sup>3</sup>, Soner KAZAZ<sup>4</sup>**Abstract**

Roses are highly demanded ornamental plants widely cultivated as pot miniature roses, cut roses, and old garden roses. Given their popularity and economic importance, it is crucial to investigate the effects of hybridizing different forms on seed yield and quality to assess the success of such combinations in the development of new commercial rose varieties. This study investigated the effects of cross combinations between pot miniatures and garden/cut roses on seed yield and quality. Rosa White Star, a miniature rose, was used as the seed parent, while three garden roses (Spelwark, Gräfin Diana, and Genotype 1) and two cut rose varieties (Magnum and Tineke) served as pollen parents. Parameters observed included; fruit set, number of seeds per fruit, fruit weight, seed weight, and seed germination rate. The highest number of seeds per fruit was observed in 'Rosa White Star' × 'Tineke' (14.0), whereas the lowest was observed in 'Rosa White Star' × 'Genotype 1.' The highest germination rate was 15.31% in 'Rosa White Star' × 'Tineke,' while seeds of 'Rosa White Star' × 'Genotype 1' did not germinate. The findings indicate that hybrids between miniature roses and certain cut roses may be more productive than garden roses. Among the combinations tested, the cut rose variety Tineke showed the highest compatibility as a pollen parent with Rosa White Star. To improve seed yield and quality in miniature roses, future breeding efforts should prioritize the identification of genetically compatible parental combinations and the development of optimized hybridization strategies. Such an approach is expected to enhance the efficiency of breeding programs and support the development of high-value commercial rose varieties.

**Keywords:** Hybridization, Seed set, Miniature rose, Germination, Cross combination

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## Öz

Güller, saksıda yetiştirilen minyatür güller, kesme güller ve eski bahçe gülleri olarak yaygın şekilde kültüre alınan, süs bitkileri arasında yüksek talep gören türlerdir. Popülariteleri ve ekonomik önemleri göz önünde bulundurulduğunda, farklı formdaki güllerin melezlenmesinin tohum verimi ve kalitesi üzerindeki etkilerinin araştırılması; bu kombinasyonların yeni ticari gül çeşitlerinin geliştirilmesindeki başarısını değerlendirmek açısından büyük önem taşımaktadır. Bu çalışmada, saksı tipi minyatür güller ile bahçe ve kesme güller arasındaki melez kombinasyonların tohum verimi ve kalitesi üzerindeki etkileri incelenmiştir. Tohum ebeveyni olarak minyatür bir gül olan Rosa White Star kullanılırken, polen ebeveyni olarak üç bahçe gülü (Spelwark, Gräfin Diana ve Genotype 1) ve iki kesme gül çeşidi (Magnum ve Tineke) kullanılmıştır. Gözlemlenen parametreler arasında; meyve tutumu, meyve başına tohum sayısı, meyve ağırlığı, tohum ağırlığı ve tohum çimlenme oranı yer almaktadır. En yüksek meyve başına tohum sayısı 'Rosa White Star' × 'Tineke' kombinasyonunda (14.0 adet), en düşük ise 'Rosa White Star' × 'Genotip 1' melezinde tespit edilmiştir. En yüksek çimlenme oranı %15.31 ile yine 'Rosa White Star' × 'Tineke' kombinasyonuna aitken, 'Rosa White Star' × 'Genotip 1' melezinden elde edilen tohumlar hiç çimlenmemiştir. Bulgular, minyatür güller ile bazı kesme güller arasındaki melezlemelerin, bahçe güllerine kıyasla daha verimli olabileceğini göstermektedir. İncelenen kombinasyonlar arasında, kesme gül çeşidi 'Tineke', 'Rosa White Star' ile en yüksek uyumu gösteren polen ebeveyni olarak öne çıkmıştır. Minyatür güllerde tohum verimi ve kalitesinin artırılması amacıyla, ileriye dönük ıslah çalışmaları genetik açıdan uyumlu ebeveyn kombinasyonlarının belirlenmesine ve optimize edilmiş melezleme stratejilerinin geliştirilmesine odaklanmalıdır. Bu yaklaşımın, ıslah programlarının etkinliğini artırması ve yüksek katma değerli ticari gül çeşitlerinin geliştirilmesine katkı sağlaması beklenmektedir.

**Anahtar Kelimeler:** Melezleme, Tohum tutumu, Minyatür gül, Çimlenme, Melez kombinasyonu

## 1. Introduction

Roses are a widely cultivated ornamental plant, with a range of varieties developed for various purposes, including cut flowers, landscaping, and pot plants (Yucel and Kıvan, 2018; Bitrak and Hatırlı, 2025). The development of new rose varieties through hybridization is an important area of research, as it can lead to the creation of varieties with desirable characteristics, such as improved yield, disease resistance, and aesthetics. High levels of heterozygosity, difficulties encountered in the sexual reproduction process from pollination to seed germination, and varying ploidy levels are among the challenges that must be overcome in the rose breeding process (Leus et al., 2018.)

Rose hybridization has been a subject of significant interest among horticulturists and botanists, as the process of combining different rose varieties can lead to the creation of new and improved varieties with desired characteristics. One important aspect of rose hybridization that has garnered attention is the number of seeds or germination rate of the seeds obtained from the process (Meral, 2023; Şener et al., 2023). The number of seeds produced can be an indicator of the success of the hybridization process. A higher number of seeds suggests that the hybridization was successful in creating viable offspring, which can then be evaluated for desirable traits. Additionally, the germination rate of the seeds can provide insights into the genetic compatibility of the parent plants, as well as the overall vigor and health of the resulting seedlings (Gottlieb, 1972).

The success of a hybridization program can be assessed by the number of viable offspring produced, which is closely related to the number of seeds obtained and their germination rate. This information can be used to guide future breeding efforts, allowing breeders to focus on the most productive and successful hybridization combinations. Moreover, the number of seeds or germination rate can be particularly important in cases where traditional seed propagation is not successful, such as in plant species with heterozygous seeds or reduced endosperm. In these situations, the ability to obtain a high number of viable seeds and successfully germinate them can be crucial for the development of new varieties (Turna, 2022; Kılıç, 2023). Overall, the number of seeds or the germination rate of seeds obtained from rose hybridization is an important factor in the development of new and improved rose varieties, due to the generally low seed set and germination rates in roses (Şener et al., 2023). In addition to understanding the factors that influence seed production and germination, by selecting combinations that produce seeds with higher germination potential, breeders can optimize their hybridization strategies and ensure the success of their breeding programs (Kılıç, 2023). The present study aimed to investigate the seed yield and quality performance of crosses between pot miniature roses and garden/cut roses.

## 2. Materials and Methods

The cross-pollination procedures were conducted between May 2020 and May 2021 in a fully automated, plastic-covered greenhouse located at Ankara University, Ankara, Türkiye (39°57'40.2"N, 32°51'51.7"E).

### 2.1. Plant Material

Six different varieties were utilized. Three garden rose varieties (Spelwark, Gräfin Diana, and Genotype 1), two commercial standard cut rose varieties (Magnum and Tineke) as pollen parents and a commercial potted miniature rose variety (Rosa White Star) as seed parent were used. The most popular and/or traded genotypes in the world were selected for use as the parents. 'Rosa White Star' is a miniature rose variety with white flowers approximately 6.5 cm in diameter, odorless, and displaying a scattered-round flower form (Doğan, 2022). 'Gräfin Diana,' belonging to the garden rose group, stands out with its dark pink color, large flowers, and fragrant structure (Anonymous, 2025a). 'Spelwark' is a peach-colored, fragrant variety with a flower diameter of approximately 12 cm (Anonymous, 2025b). 'Genotype 1' is a garden rose genotype grown in the greenhouse where the study was conducted, with purple flowers, a flower diameter of approximately 6.5 cm, and a light fragrance. Among cut rose varieties, 'Tineke' is white and unscented and is a variety commonly used in cut flower production (Anonymous, 2025c). 'Magnum' is described as a dark red, unscented cut rose variety with a flower diameter of approximately 5–6 cm (Kılıç, 2020). All parent plants were one year old throughout the crossing trials. The parents were grown in the pot culture with the mixture (1:1 w/w) of cocopeat and perlite. The temperature of the greenhouse was maintained between 23°C and 30°C during the vegetation period, and its relative humidity ranged from 60% to 70%. The plants were fertilized using the nutrient solution that Mercurio (2007) reported.

## 2.2. Hybridization

The crosses were made from July 20-30, 2020. As soon as the flower bud appeared, apical buds of the varieties were cut off. Flowers produced on branches growing from axillary buds were used for the crossing. The weakly developing branches were not used. A total of 20 crosses were performed in each combination. At 8:00 am, one-third of the flowers were open, and emasculation was carried out by removing the petals of the seed parent (Chimonidou et al., 2007; Crespel, 2003). The pollen parents' anthers were collected and put in glass vials at the same time as the emasculation. Anthers were stored in a climate cabinet with a temperature of  $20 \pm 2^\circ\text{C}$  and a relative humidity of 60% to 65% in order to ensure pollen dispersal. A brush was used to apply pollen grains onto the stigma at the conclusion of the 24-hour period. Paper bags were used to isolate the genotypes for four days following the crossing (Crespel, 2003; Kılıç et al., 2024; Spethmann, 2003).

When the fruits accomplished harvest maturity, which is when their color changes from green to orange and red, they were harvested 10-15 December 2020. The fruit set rate (%) for each combination was calculated by counting the quantity of fruits. For every combination, the average fresh weight per fruit (g) was also recorded. The average number of seeds per fruit for each combination was calculated by separating the seeds from the fruits. For every combination, the average weight of seed (mg) was also recorded. The seeds were placed in polyethylene bags with moist perlite and stratified in cold storage at  $4^\circ\text{C}$  for 12 weeks in order to calculate the germination rates (%). A total of 342 seeds were used in the germination tests. After stratification, seeds were planted in vials filled with peat. According to Nadeem et al. (2015), the seeds were determined to have germinated when they displayed cotyledon and hypocotyl development above the growing media. Germination conditions included a temperature of  $23 \pm 1^\circ\text{C}$  and a relative humidity of 60% to 70%. A heat shade drape that provided 55% shade was employed to protect the plants from the intense light.

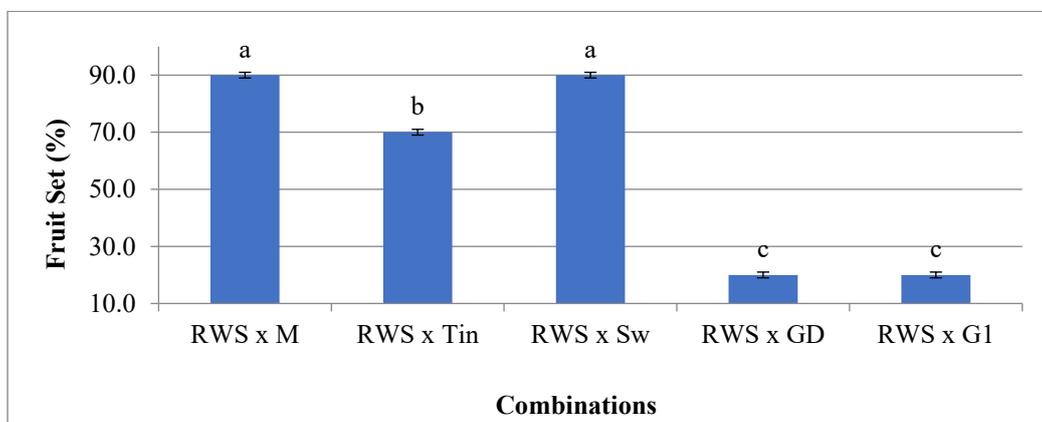
### 2.2. Experimental Design and Statistical Analysis

The experiment has been set up according to a completely randomized design. The experiment was conducted in a four-replication design, with five pollinations performed in each replication, resulting in a total of 20 crosses. Data analysis was conducted using IBM SPSS Statistics version 22. Variance analysis (one-way ANOVA) was performed to assess the statistical significance of differences among groups. Subsequently, Duncan's Multiple Range Test ( $p \leq 0.05$ ) was applied to compare means and identify statistically distinct groups. Pearson correlation analysis was employed to quantify and evaluate the relationships between the traits.

## 3. Results and Discussion

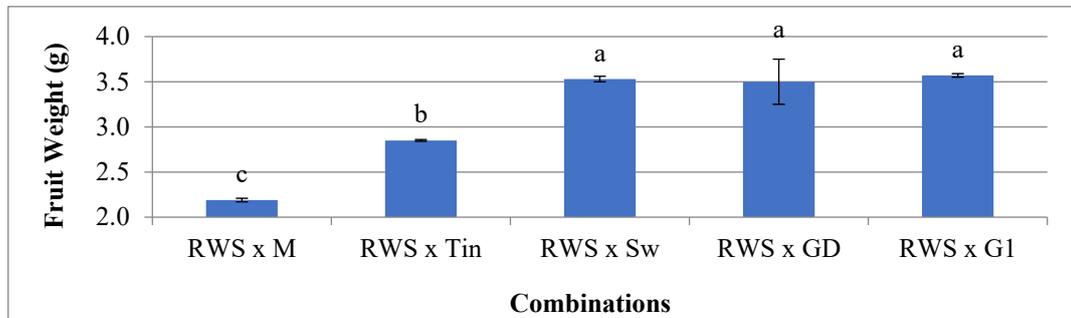
### 3.1. Results

Statistically significant differences were observed between the combinations in terms of fruit set ( $p \leq 0.05$ ). The highest fruit sets rate was determined in 'Rosa White Star  $\times$  Magnum' (90.0%) and 'Rosa White Star  $\times$  Spelwark' (90.0%) followed by 'Rosa White Star  $\times$  Tineke' respectively, whereas the lowest fruit set rate was recorded from 'Rosa White Star  $\times$  Gräfin Diana' and 'Rosa White Star  $\times$  Genotype 1' cross combinations (Figure 1).



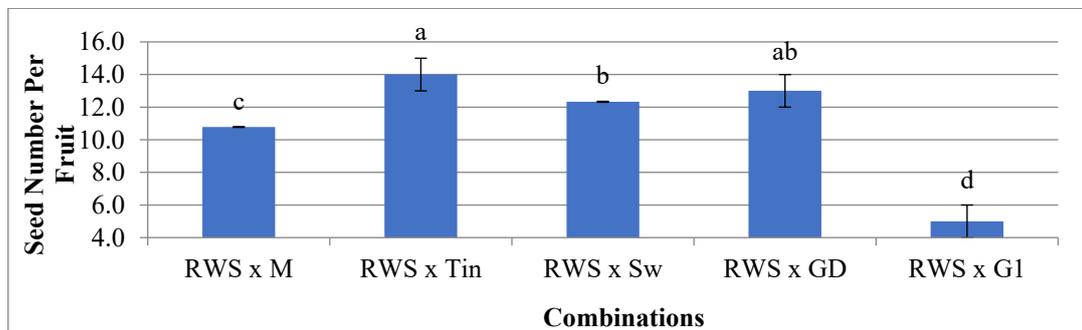
**Figure 1. Fruit set rate in different cross combinations. RWS: Rosa White Star, M: Magnum, Tin: Tineke, Sw: Spelwark, GD: Gräfin Diana, G1: Genotype 1 ( $p \leq 0.05$ ).**

The mean fruit weight across the cross combinations was calculated as 3.13 g, with individual values varying between 2.19 g and 3.57 g. Among these, the ‘Rosa White Star × Genotype 1’, ‘Rosa White Star × Gräfin Diana’, and ‘Rosa White Star × Spelwark’ combinations showed the highest fruit weights, and there was no statistically significant difference among these combinations. In contrast, fruit weights were significantly lower in the ‘Rosa White Star × Tineke’ and ‘Rosa White Star × Magnum’ combinations ( $p \leq 0.05$ ) (Figure 2).



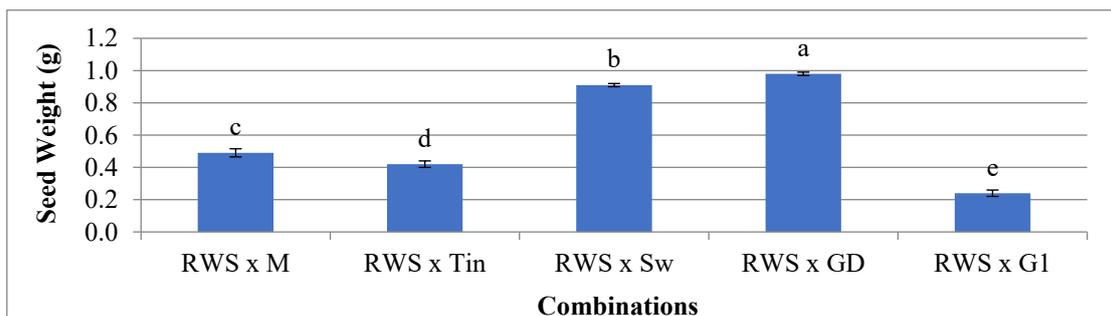
**Figure 2. Fruit weight (g) in different cross combinations. RWS: Rosa White Star, M: Magnum, Tin: Tineke, Sw: Spelwark, GD: Gräfin Diana, G1: Genotype 1 ( $p \leq 0.05$ ).**

Statistical analysis revealed that the number of seeds per fruit varied significantly among the different cross combinations ( $p \leq 0.05$ ). The mean seed count across all combinations was 11.02. The cross ‘Rosa White Star × Tineke’ produced the highest number of seeds per fruit (14.0), followed by ‘Rosa White Star × Gräfin Diana’ (13.0). In contrast, the lowest seed number per fruit was recorded in the ‘Rosa White Star × Genotype 1’ combination (Figure 3).



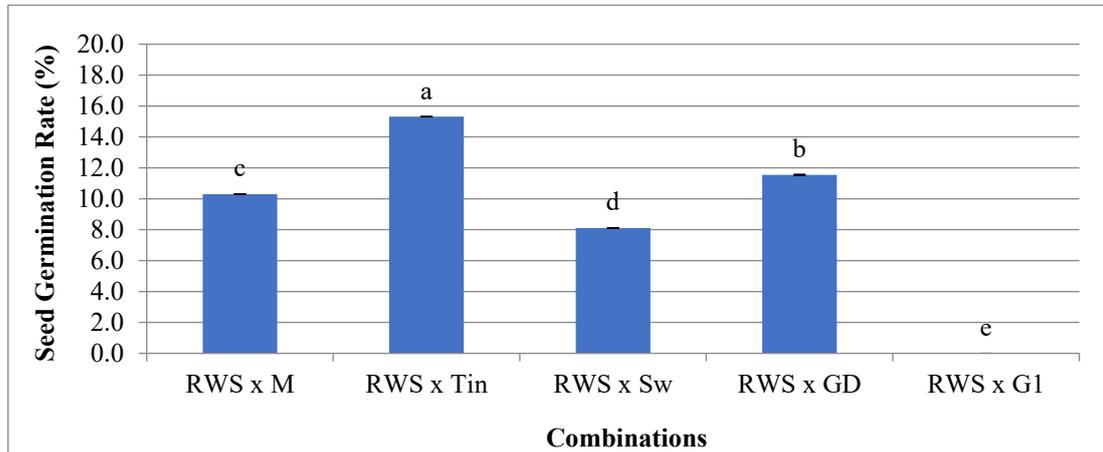
**Figure 3. Seed number per fruit in different cross combinations. RWS: Rosa White Star, M: Magnum, Tin: Tineke, Sw: Spelwark, GD: Gräfin Diana, G1: Genotype 1 ( $p \leq 0.05$ ).**

Seed weight among the cross combinations exhibited variation, ranging between 0.24 g and 0.98 g, with an overall average of 0.61 g. The greatest seed weight was recorded in the cross ‘Rosa White Star × Gräfin Diana’, followed by ‘Rosa White Star × Spelwark.’ Conversely, the lowest seed weight was observed in the ‘Rosa White Star × Genotype 1’ combination (Figure 4).



**Figure 4. Seed wight in different cross combinations. RWS: Rosa White Star, M: Magnum, Tin: Tineke, Sw: Spelwark, GD: Gräfin Diana, G1: Genotype 1 ( $p \leq 0.05$ ).**

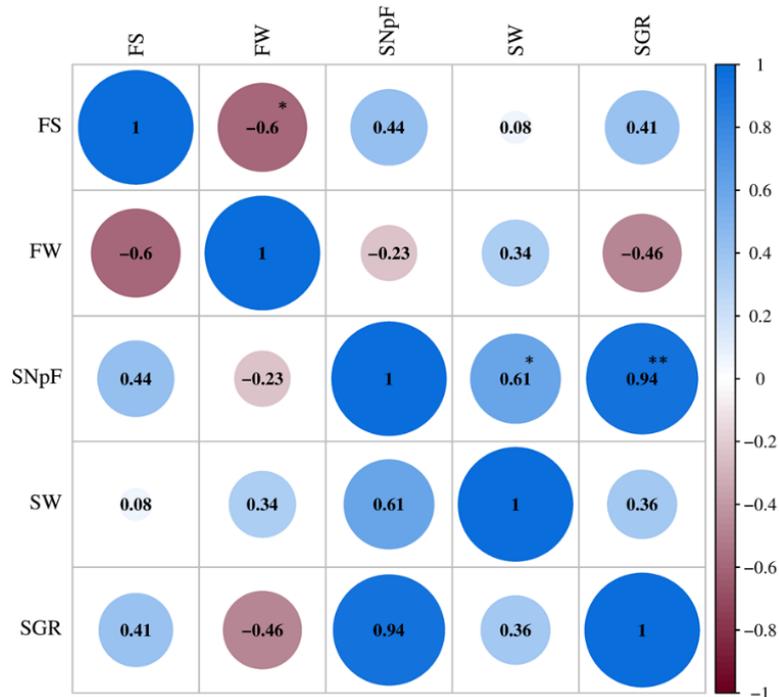
The mean germination rate across all hybrid combinations was calculated as 9.05%. The highest germination was observed in seeds derived from the ‘Rosa White Star × Tineke’ cross, reaching 15.31%, while the ‘Rosa White Star × Gräfin Diana’ combination followed with a germination rate of 11.54%. Notably, seeds obtained from the ‘Rosa White Star × Genotype 1’ cross failed to germinate (Figure 5).



**Figure 5. Seed germination rate (%) in different cross combinations. RWS: Rosa White Star, M: Magnum, Tin: Tineke, Sw: Spelwark, GD: Gräfin Diana, G1: Genotype 1 ( $p \leq 0.05$ ).**

### 3.1.1. Correlation Matrix of Traits

There was a significant negative correlation between fruit set and fruit weight ( $r = -0.588$ ), suggesting that as fruit weight increases, fruit set may decrease. There was a significant positive correlation between seed number per fruit and seed weight ( $r = 0.605$ ). It may indicate that the growing conditions of the plants are suitable. There is a very strong, highly significant positive correlation between seed number per fruit and seed germination rate ( $r = 0.925$ ), suggesting that as the number of seeds increases, the chances of obtaining germinated seeds may also increase. These findings may indicate a trade-off between fruit weight and fruit set and suggest that seed number is closely tied to seed weight and germination success (Figure 6).



**Figure 6. Pearson correlation analysis of fruit set (FS), fruit weight (FW), seed number per fruit (SNpF), seed weight (SW), and seed germination rate (SGR). (\* $p \leq 0.05$ ; \*\* $p \leq 0.01$ ).**

### 3.2. Discussion

In the present study, cross combinations between miniature and cut/garden rose varieties showed fruit set rates and seed numbers per fruit ranging from 20.0% to 90.0% and 5.0 to 14.0, respectively. In hybridization studies, it is important to obtain more seeds per fruit in order to provide more genetic variation and to increase the rate of obtaining a successful hybrid. Variations in the genetic composition of the parents, such as their capacity to form seeds and their compatibility with one another, as well as variations in the quality of pollen parents, could account for the discrepancy between cross combinations under identical circumstances. Previous studies have demonstrated that both seed number per fruit and fruit set percentage vary significantly depending on the specific rose species and/or cultivar combinations used in hybridization. Abdolmohammadi et al. (2014) reported that crosses involving modern rose cultivars and old garden roses yielded between 0 and 35.33 seeds per fruit, with fruit set rates ranging from 0% to 90.0%. Similarly, Nadeem et al. (2014) observed fruit set rates between 30.0% and 83.0%, and seed counts per fruit ranging from 15.0 to 33.0 in modern rose hybridizations. According to Farooq et al. (2016), old garden rose crosses exhibited fruit set percentages from 0% to 83.0%, and seed numbers varied between 0 and 17.0 per fruit. Doğan (2022) documented that in hybrid tea rose × old garden rose crosses, fruit set rates ranged from 20.0% to 100%, while seed numbers per fruit varied from 9.14 to 31.50. In crosses involving miniature and modern roses, the fruit set rate fluctuated between 0% and 61.90%, and seed numbers ranged from 0 to 13.25. Notably, some miniature rose combinations failed to produce any seeds (Doğan, 2022). The discrepancies in fruit set and seed output across these studies may be attributed to several factors, including the use of genotypes with different genetic backgrounds, variation in crossing techniques, and environmental conditions during pollination (Meral, 2023). In the present study, which employed miniature roses as female parents, the average seed number per fruit was lower (4.73) when compared to values reported in other rose hybridizations, such as modern × old garden or modern × modern combinations-21.0 (Nadeem et al., 2015), 11.09 (Farooq et al., 2016), 16.39 (Doğan et al., 2020), and 8.17 (Doğan, 2022). This reduced seed production may be attributed to factors such as the smaller stigma diameter typically observed in miniature roses, their tendency toward female sterility due to their dwarf growth habit, and genetic incompatibilities in combinations involving miniature roses with garden or cut rose varieties (Meral, 2023).

The evaluation of seed and fruit weights is a critical indicator in determining the success of crossbreeding efforts in roses. In the present study, seed weights ranged from 0.24 g to 0.98 g, while fruit weights were between

2.19 g and 3.57 g. In comparison, Nadeem et al. (2014) reported a maximum fruit weight of 4.89 g. Ercişli and Eşitken (2004) observed that fruit weights across different rose species varied from 3.12 g to 5.20 g. Farooq et al. (2016) found that hybridizations among five distinct rose species resulted in fruits weighing between 0 and 2.00 g. Similarly, Khan et al. (2021) indicated that fruit weights in their study ranged from 0 to 5.63 g, depending on the specific cross combinations. In a separate study, de Vries et al. (2000) reported a broader range of fruit weights, spanning from 3.50 g to 14.30 g. With regard to seed weight, Pipino et al. (2011) documented an average of 66.30 mg per seed. Doğan (2022) reported seed weights between 40.0 mg and 166.0 mg in crosses involving miniature and other rose types, while Turna (2022) found values ranging from 120.0 mg to 260.0 mg. These differences in fruit and seed weights may be attributed to multiple biological and genetic factors, including the characteristics of the maternal genotype used in hybridizations. Variations in seed coat thickness and fruit flesh development could contribute to discrepancies in fruit weight, while differences in embryo and endosperm mass, along with the total number of seeds per fruit, may influence seed weight outcomes.

Achieving effective germination of hybrid seeds is a crucial factor in the success of rose breeding programs. A high germination rate significantly enhances the potential for hybrid survival and development, whereas low germination may result in the loss of viable seeds and ultimately reduce the breeding program's overall efficiency. Reported germination rates for rose seeds generally vary between 30.0% and 45.0% (Leus et al., 2018). However, there are also studies indicating the occurrence of both complete (100%) and zero germination in different hybrid combinations (Doğan et al., 2020; Pipino et al., 2011). In the present study, germination rates ranged from 0% to 15.31%, with an average value of 9.05%. It was observed that cross combinations involving cut roses—such as ‘cut rose × cut rose’ or ‘cut rose × old garden rose’—tended to result in higher germination rates compared to combinations involving miniature roses, such as ‘miniature rose × cut rose’. For instance, Nadeem et al. (2013) and Muller (2020) reported mean germination rates of 12.50% and 9.20% for modern rose combinations, respectively. In contrast, Pipino et al. (2011) documented a substantially higher average germination rate of 58.90% in hybrid tea roses. Additionally, Ueckert (2014) reported a germination percentage of 28.50% in ‘garden rose × garden rose’ crosses. The germination rate for ‘modern rose × old garden rose’ combinations was reported as 14.61% and 14.42% by Kılıç (2020) and Doğan et al. (2020), respectively. Multiple biological and physiological mechanisms may underlie the variability observed in germination rates among different cross combinations. These include post-pollination reproductive barriers, altered stratification requirements due to differences in seed coat characteristics, and increased levels of embryo abortion resulting from incompatibility between parental genotypes (Alp et al., 2009). It has also been proposed that rose seeds may exhibit both embryo and seed coat dormancy (Kılıç, 2020; Şener et al., 2023). Factors such as differences in genetic background, stratification protocols, environmental conditions during seed development, and variations in parental ploidy levels may further influence germination success (MacPhail and Kevan, 2009; Muller, 2020). Notably, the coefficient of variation for the traits assessed in this study fluctuated considerably across different hybrid combinations. Among these, seed germination rate demonstrated the highest level of variability, suggesting its prominent role in determining hybrid fertility in rose breeding efforts.

In the present study, a positive association was observed between the number of seeds per fruit and the overall seed weight. One plausible explanation for this relationship is the possibility of incomplete fertilization of ovules. Although the number of seeds in roses is generally expected to match the number of stigmas, a lower seed set may allow the plant to allocate sufficient resources to each developing seed, potentially enhancing their individual weight. Prior research has indicated a statistically significant correlation between seed weight and germination success (Saeed and Shaukat, 2000; Upadhaya et al., 2007). Heavier seeds are generally expected to exhibit higher germination rates, likely due to the greater mass of the embryo and endosperm, which supports initial seedling development. However, it should be noted that seed weight also includes the contribution of the seed coat. In roses, a thicker seed coat can act as a physical barrier, inhibiting germination despite substantial seed mass. In this study, it is possible that certain seeds with relatively high total weight failed to germinate due to disproportionately thick seed coats and insufficient internal tissue mass (embryo and endosperm). Conversely, seeds with thinner seed coats but well-developed internal tissues may have demonstrated improved germination performance, highlighting the importance of both internal and external seed structures in determining germination potential.

#### **4. Conclusions**

The findings indicate that hybridization between miniature roses grown in pots and some cut roses has potential for obtaining F<sub>1</sub> individuals. Nevertheless, the ‘pot miniature rose × garden rose’ cross combinations of tiny rose seed production efficiency are low. ‘Tineke’ and ‘Gräfin Diana’ were found to be more compatible with ‘Rosa White Star’ because of seed yield and quality performance. It is believed that this study can help in the breeding success of the miniature roses since cross-combinations can be identified utilizing the currently available data on parental performance. The combinations selected in this way have a higher chance of success than those selected at random. To improve the effectiveness of their breeding programs and provide their market with more novel varieties, breeders can quickly embrace the practice of carefully selecting their parents and cross-combinations. Further research is needed to explore alternative hybridization strategies and identify other compatible combinations that could improve seed yield and quality in miniature roses, ultimately contributing to the development of more productive and commercially viable rose varieties.

#### **Acknowledgment**

This study was presented as an oral presentation at the VIII. International Seed Congress (December 9-12, 2024, Antalya, Türkiye).

#### **Ethical Statement**

There is no need to obtain permission from the ethics committee for this study.

#### **Conflicts of Interest**

We declare that there is no conflict of interest between us as the article authors.

#### **Authorship Contribution Statement**

Concept: Meral Doğan, E.; Kırbay, E.; Kılıç, T. Design: Meral Doğan, E.; Kazaz S. Data Collection or Processing: Meral Doğan, E.; Kırbay, E.; Kılıç, T. Statistical Analyses: Meral Doğan, E.; Kılıç, T.; Literature Search: Meral Doğan, E.; Kırbay, E. Writing, Review and Editing: Meral Doğan, E.; Kırbay, E.; Kılıç, T.; Kazaz S.

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