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EARLY GROWTH CHARACTERISTICS OF AVOCADO PLANTS RESULTING FROM SCION GRAFTING DUE TO STORAGE DURATION AND LENGTH OF SCION

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Abstract

Avocado (*Persea americana* Mill.) propagation is generally done by grafting, and the scion used as the material is usually taken from the mother plant with superior properties. Often, the location of the mother plant is far from the nursery, so the scion must be stored during the delivery process, which causes the grafting to be delayed. This study aims to determine early growth characteristics of avocado plants resulting from scion grafting due to storage duration and length of scion. This study applied a factorial, completely randomized design method involving two treatment factors with three repetitions. The first factor is the scion with various storage durations (0, 3, 6, and 9 days), and the second factor is the length of the scion (5, 7.5, and 10 cm). The observed variables were the age of bud break, number of buds, length of buds, number of leaves and percentage of successful grafts. Interaction between storage duration and scion length affected the age of bud break. A storage duration of 0 days yielded an optimal age for bud break, length of buds, number of leaves, and percentage of successful grafting. A scion length of 10 cm led to the best age of bud break, number of buds, and number of leaves, while a 5 cm length resulted in the optimal length of buds.

Keywords: Storage duration, Scion length, Avocado plant

INTRODUCTION

Avocado (Persea americana Mill.) has become one of the most popular crops in Indonesia, leading to high production levels. According to data from the Badan Pusat Statistik, in 2022, avocado production in Indonesia reached 865,780 tons (BPS, 2023). This high avocado production is inseparable from plant propagation activities, which play an important role in ensuring the availability of quality plant seeds.

Like most other fruit plants, avocado plants can be propagated by vegetative or generative methods. However, seedlings from generative propagation have disadvantages. Generally, plants derived from generative propagation will only reach optimal height and begin to bear fruit after 6 to 8 years after planting. Meanwhile, seedlings propagated through vegetative methods can generally bear fruit within three years after planting. Even at high altitudes, they can bear fruit faster, around two years (Anwari et al., 2021).

Scion used as shoot grafting material needs to be kept fresh to ensure successful grafting. However, in the field, grafting activities are often delayed after the collection of scion from the mother plant. These delays are generally caused by the long distance between the location of the mother plant and the nursery place and require the scion to be stored during the shipping process.

Such a situation can result in a decrease in the freshness of the scion, which can affect the quality and potential success of grafting. Once taken from the mother plant, the scion must be spliced because of delays in grafting since taking the entry can inhibit plant growth (Bahri et al., 2018). During storage, the scion continues to respire. The longer this process takes place, the more food reserves are used, which can have an impact on the growth of the scion after the grafting process is carried out. (Larekeng et al., 2017). Scion length is another factor that can affect the growth of plants produced through shoot grafting. Because the length of the scion is related to the amount of energy reserves available. Thus, longer scions have more energy reserves supporting plant recovery and growth. (Bahri et al., 2018).

LITERATURE REVIEW

Plant Propagation

Plant propagation is the process of producing plant seeds. It can be done in many ways, ranging from simple to complex. Plant propagation is classified into two major groups: generative and vegetative propagation (Hakim et al., 2019).

Generative plant propagation is the sexual propagation of plants using one part of the plant, which is using seeds. Seeds, as a breeding organ, are formed in the fruit due to the maturation of fertilized ovules (Gunawan, 2014). Generative plant propagation has advantages and disadvantages. The advantages of generative plant propagation are that it can be done quickly and cheaply and does not require special skills. The disadvantages of generative propagation are that plants take longer to produce fruit, the quality of the fruit is only known when the plant bears fruit, and the a low possibility of obtaining true-to-type seeds or having the same characteristics as their parents (Roslinda et al., 2022).

Vegetative plant propagation is the propagation of plants without going through the process of fertilization. Vegetative plant propagation can be done by taking parts of the plant such as stems, leaves, bulbs, shoots, and others. Vegetative plant propagation can be done in several ways, such as cutting and grafting (Nur'aini, 2019). Vegetative plant propagation is an alternative to obtaining quality seeds that are guaranteed the level of production and quality and have the same characteristics as the parent plant. The advantage of vegetative plant propagation is that the characters in the mother plant will be passed on to the offspring. In addition, vegetative propagation can obtain massive plants relatively quickly (Mashudi & Adinugraha, 2015). The disadvantage of vegetative propagation is that the breeding process is more complex than that of generative propagation because it requires special skills, but the resulting plants are more uniform (Zuyasna, 2014).

Grafting

Grafting is a vegetative propagation technique carried out by combining the scion and rootstock of different plants so that both can grow and develop together into one whole plant. (Hidayat et al.,

2018). The scion is the part that will become the crown of the plant and will later produce fruit, so the scion used must be taken from a mother plant that has superior quality (Wahyudi et al., 2017). Meanwhile, the rootstock is the part that functions as the lower stem of the plant, with the root system in charge of taking nutrients in the soil to be supplied to the upper stem (Husni & Pratama, 2022).

Grafting is divided into three groups: bud-grafting, scion grafting, and grafting by approach or inarching (Butarbutar, 2016). Bud-grafting or graft involves the attachment of buds from the scion plant to the rootstock plant, both of which are superior (Mirasari, 2019). Scion grafting involves the union of shoots as scion with rootstock plants. Grafting by approach or inarching is a method of grafting scion and rootstock where each plant is still associated with its roots (Butarbutar, 2016).

According to Wirawan et al. (2018), the advantages of grafting on plants:

1. Improve the quality and quantity of crop yields.
2. Produce new plant combinations that have advantages in terms of rooting and production.
3. Accelerate flowering and fruiting time (early maturing plants).
4. Produce plants whose fruiting characteristics are the same as their parents.

The success of grafting is indicated by the connection between the scion and the well-attached rootstock; the scion is fresh, and there is plant growth and development (Azizah et al., 2020). Wirawan et al. (2018) added that the success of the connection would be characterized by several signs, such as the cambium of the scion and rootstock merging and the emergence of buds on the scion. The connection of the scion and rootstock occurs due to the formation of a callus on the surface of the connection, which then differentiates to form cambium and vascular tissue, including xylem and phloem (Fitriady et al., 2019).

METHOD

The research used a factorial completely randomized design (CRD) that included two treatment components as part of the experimental design. Storage duration as the first factor had four levels (0 days, three days, six days, and nine days) and length of scion as the second factor had three levels (5 cm, 7.5 cm, and 10 cm). There were 36 experimental units with 12 treatment combinations, and each was repeated three times with ten plant samples per experimental unit, resulting in a total of 360 plant samples. The observed variables were the age of bud break, number of buds, length of buds, number of leaves and percentage of successful grafting. Data from each observed variable were analyzed using Analysis Of Variance (ANOVA), and the results were followed by Tukey's further test at the α = 5% level.

RESULTS AND DISCUSSION

Age of Bud Break

Table 1 shows that the earliest age of bud break was obtained in the combination of scion stored for 0 days with a length of 10 cm (6.89 DAG). However, it was not significantly different from the combination of scion stored for 0 days with a length of 7.5 cm (8.00 DAG). Meanwhile, the most extended age of bud break occurred in the combination of scion stored for nine days with a length of 5 cm (11.33 DAG). The combination of scions stored for 0 days with an entry length of 10 cm accelerated the bud break by about 4.44 days compared to the combination of scions stored for nine days with an entry length of 5 cm.

Table 1. Average Age of Bud Break in Avocado Grafting as a Result of Combination Treatment between Storage Duration and Scion Length.

Storage Duration (day)	Age of Bud Break (Day After Grafting)		
	Scion Length (cm)		
	5	7.5	10
0	9.22 bc	8.00 ab	6.89 a
3	9.89 cd	9.78 cd	8.33 b
6	10.78 de	10.11 cd	10.00 cd
9	11.33 e	10.67 de	10.67 de
Tukey 5%	1.28		

Description: The average value followed by the same letter indicates that the value is not significantly different in the 5% Tukey test.

The combination of scion stored for 0 days and 10 cm scion length (6.89 DAG) produced the fastest age of bud break compared to other treatment combinations because the scion in the treatment combination was still fresh and stored more food reserves. The content of food reserves in the scion can stimulate the growth of bud eyes, and the more food reserves stored, the faster bud growth can accelerate. According to Maulana et al. (2020), scions with many food reserves can optimize the transformation process of food reserves, nutrients, and water in the entry, thus stimulating the production of auxin and cytokinin hormones. Cytokinin hormones can stimulate the process of cell division by increasing the speed of protein synthesis, while auxin hormones play a role in triggering cell elongation. Supriyanto Yulianto (2022) added that endogenous auxin and cytokinin hormones at optimal amounts and in the appropriate balance will spur the process of cell division and differentiation. According to Kartika et al. (2021), the availability of many food reserves accelerates the formation of callus, which is helpful in wound healing and the formation of a network of vessels at the connection so that the process of bud break becomes faster.

Number of Buds

Table 2 shows that the storage duration treatment did not significantly affect all weeks of observation. However, in the second and third weeks, the highest number of buds appeared on

unstored scion (0 days). Meanwhile, from the fourth to the tenth week, the highest number of buds was seen in the scion stored for six days. Table 2 also shows that the 10 cm length of scion produced the highest number of buds in the second week, and this result was not significantly different when compared to the 7.5 cm length of scion but was significantly different from the 5 cm length of scion. From the fourth to the tenth week, the 10 cm length of the scion continued to show the highest number of buds and was significantly different from the 7.5 cm and 5 cm lengths.

Table 2. Average Number of Buds in Avocado Grafting Plants as a Result of Storage Duration and Length of Scion.

Number of Buds									
Treatment	WAG (Week After Grafting)								
	2	3	4	5	6	7	8	9	10
Storage Duration (day)									
0	1.93	2.56	3.30	3.37	3.37	3.37	3.37	3.37	3.37
3	1.56	2.48	2.93	3.00	3.04	3.04	3.04	3.11	3.11
6	1.59	2.44	3.59	3.67	3.67	3.67	3.67	3.67	3.67
9	1.41	2.19	2.85	3.07	3.11	3.11	3.11	3.15	3.15
Tukey 5%	-	-	-	-	-	-	-	-	-
Scion Length (cm)									
5	1.31 a	2.31	2.67 a	2.69 a	2.69 a	2.69 a	2.69 a	2.75 a	2.75 a
7.5	1.58 ab	2.31	3.08 a	3.14 a	3.17 a	3.17 a	3.17 a	3.17 a	3.17 a
10	1.94 b	2.64	3.75 b	4.00 b	4.03 b	4.03 b	4.03 b	4.06 b	4.06 b
Tukey 5%	0.40	-	0.50	0.61	0.64	0.64	0.64	0.66	0.66

Description: The average value followed by the same letter indicates that the value is not significantly different in the 5% Tukey test.

The average number of buds at 10 cm can give the highest results because it has more bud eyes. According to Dewi et al. (2022), using different lengths of scion also makes the number of bud eyes different; the longer the scion is used, the more bud eyes are likely to grow. According to Mayanti et al. (2021), bud eyes are plant buds located in the stem segments, where these buds are at the base to the end of the stem with alternating positions on the right and left; these bud eyes will later grow buds.

Length of Buds

Table 3 shows that scions that were not stored (0 days) gave the best length of buds in the second, fifth, and sixth weeks with lengths of 1.46 cm, 4.91 cm, and 4.98 cm, respectively. These results were significantly different from those of scion stored for nine days but not significantly different from those stored for three and six days. Table 3 also shows that the 5 cm scion length gave the best length of buds from the sixth to the ninth week, with lengths of 4.90 cm, 5.05 cm, 5.25 cm, and 5.49 cm, respectively. These results were significantly different from those of the 10 cm length but did not show a significant difference when compared to the 7.5 cm length.

Table 3. Average Bud Length in Avocado Grafting Plants as a Result of Storage Duration and Scion Length.

Length of Buds (cm)									
Treatment	WAG (Week After Grafting)								
	2	3	4	5	6	7	8	9	10
Storage Duration (day)									
0	1.46 b	3.32	4.38	4.91 b	4.98 b	5.04	5.12	5.28	5.61
3	1.23 ab	3.01	4.02	4.57 ab	4.67 ab	4.87	5.03	5.22	5.58
6	1.14 ab	3.07	3.61	4.05 ab	4.19 ab	4.25	4.41	4.61	4.94
9	0.89 a	2.56	3.20	3.46 a	3.57 a	3.70	3.83	4.01	4.24
Tukey 5%	0.41	-	-	1.25	1.22	-	-	-	-
Scion Length (cm)									
5	1.30	3.19	4.14	4.74	4.90 b	5.05 b	5.25 b	5.49 b	5.74
7.5	1.13	3.06	3.90	4.32	4.36 ab	4.49 ab	4.58 ab	4.71 ab	4.95
10	1.11	2.71	3.36	3.69	3.79 a	3.84 a	3.97 a	4.14 a	4.58
Tukey 5%	-	-	-	-	0.87	0.90	0.94	1.02	-

Description: The average value followed by the same letter indicates that the value is not significantly different in the 5% Tukey test.

The length buds have the highest average in the 5 cm length treatment because the scion in this treatment has a smaller number of buds per plant, affecting the growth of buds length, which becomes higher. Nurmaningrum et al. (2017) explained that bud length has an inverse relationship with the number of shoots. When the number of buds increases, each bud tends to grow shorter because it has to compete for nutrients and space. Conversely, if the number of buds decreases, each bud has the opportunity to grow longer due to less competition in obtaining the required energy sources. Lutfiani et al. (2022) added that in one plant, the energy that should be used to elongate the shoots is often allocated to form new buds, resulting in limited growth in bud length.

Number of Leaves

Table 4 shows that unstored scion (0 days) produced the highest number of leaves from the second to the fourth week, with 5.56 leaves, 10.41 leaves, and 17.19 leaves, respectively. These results showed a significant difference compared to those stored for nine days but were not significantly different from those stored for three and six days. In addition, the 10 cm long scion gave the highest number of leaves in the eighth to tenth week, with 19.28 leaves, 19.64 leaves, and 21.61 leaves, respectively. These results differed significantly from those of the 5 cm long scion but did not show a significant difference compared to the 7.5 cm long scion.

Table 4. Average Number of Leaves in Avocado Grafting Plants as a Result of Storage Duration and Length of Scion.

Number of Leaves									
Treatment	WAG (Week After Grafting)								
	2	3	4	5	6	7	8	9	10
Storage Duration (day)									
0	5.56 b	10.41 b	17.19 b	20.15	19.52	18.85	18.67	19.19	20.74
3	4.78 b	9.41ab	15.67ab	17.85	17.89	17.96	18.04	17.96	18.96
6	4.33 ab	9.41ab	15.74ab	18.74	18.78	18.19	18.22	18.30	19.22
9	3.07 a	6.96 a	12.70 a	15.56	15.63	15.44	15.48	16.26	17.26
Tukey 5%	1.48	2.59	3.24	-	-	-	-	-	-
Scion Length (cm)									

5	3.78	8.72	14.22	16.61	16.00	16.06	15.50 a	16.31 a	16.67 a
7.5	4.56	8.94	15.06	18.00	18.89	18.00	18.03ab	17.83 ab	18.86a b
10	4.97	9.47	16.69	19.61	18.97	18.78	19.28 b	19.64 b	21.61 b
Tukey 5%	-	-	-	-	-	-	2.58	2.63	3.40

Description: The average value followed by the same letter indicates that the value is not significantly different in the 5% Tukey test.

The average number of leaves at 0 days of storage gave the highest results because the connection experienced a linkage and faster growth of the buds of the scion. Leaves on the scion will form when the connection has been linked and nutrients are distributed between the scion and the rootstock. According to Bahri et al. (2018), leaf growth highly depends on available nutrients, including macro and microelements. Among the various elements, nitrogen plays a crucial role in supporting the growth of the whole plant, especially in stems, leaves, and branches. Siswanto et al. (2021) explain that new leaf formation begins when specific cells in the tip dome divide and develop meristem tissues that produce swellings known as protuberances. These swellings increase in size and enclose the tip of the primordia, which then develop into leaf necks and subsequently form leaf blades.

The average number of leaves at the length of 10 cm gave the highest results because a more significant number of shoots grew on the scion, thus affecting the number of leaves that grew. According to Amelia et al. (2020), as the number of buds on the scion increases, the number of leaves produced will also increase, and the scion with more buds tends to produce more leaves.

Percentage of Successful Grafting

Table 5 shows that the highest percentage of successful grafting was found in the scion stored for 0 days at 92.22%, and this result did not show a significant difference with scion stored for three days (83.33%) and six days (80.00%). The lowest percentage of finished connections was found in the scion stored for nine days, with a result of 74.44%. Furthermore, the scion length did not significantly affect the percentage of finished connections. However, the highest percentage was achieved in a 10 cm long scion (86.67%), while the lowest was in a 5 cm long scion (76.67%).

Table 5. Average Percentage of Successful Grafting in Avocado Grafting Plants as a Result of Storage Duration and Length of Scion.

Treatment	Percentage of Successful Grafting (%)
Storage Duration (day)	
0	92.22 b

3	83.33 ab
6	80.00 ab
9	74.44 a
Tukey 5%	13.30
Scion Length (cm)	
5	76.67
7.5	84.17
10	86.67
Tukey 5%	-

Description: The average value followed by the same letter indicates that the value is not significantly different in the 5% Tukey test.

The 0-day storage duration provided the highest average for the percentage of successful grafting, but the three-day and six-day storage durations still gave results that were not significantly different. Using banana fronds as a scion storage medium effectively helps maintain moisture. It reduces the possibility of losing food reserves in the scion so that the freshness of the scion is maintained. It is based on the statement of Wahyudi et al. (2017) that banana fronds are effective in maintaining the moisture of the scion during storage, preventing a decrease in excess water content and reducing the quality of the scion. The high humidity of banana fronds also helps maintain a low temperature, which suppresses the transpiration rate of the scion and slows down the loss of water content, thus maintaining the freshness of the scion for longer.

CONCLUSION

Based on the results of the research that has been carried out, it can be concluded that:

1. The interaction of storage duration and length of entries influences the age of bud break, with the best results found in the storage duration of 0 days and 10 cm entries length.
2. Storage duration of 0 days gave the best average results on the variable of the age of bud break, entries length at the age of 2, 5, and 6 WAG, the number of leaves at the age of 2, 3, and 4 WAG and the percentage of successful grafting.
3. The scion length of 10 cm gave the best average results in age of bud break, the number of buds at 2 WAG and 4 to 10 WAG, and the number of leaves at 8 to 10 WAG. In contrast, the treatment of 5 cm scion length gave the best average results in the variables of bud length at 6 to 9 WAG.

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