

## Standardization of softwood grafting in Avocado (*Persea americana* Mill.) var. TKD1

### **ABSTRACT**

In recent years, Hass avocados (*Persea americana* Mill) have become more widely cultivated in Colombia. One of the difficulties facing the nation is boosting orchard output by ensuring graft plants have the best agronomic, genetic, and phytosanitary criteria. In this study, the growth and development of avocado rootstocks derived from seeds of various weight ranges will be monitored for 90 days. Four weights of avocado seeds (S<sub>1</sub>, S<sub>2</sub>, S<sub>3</sub>, S<sub>4</sub>) (30–40 g, 40–50 g, 50–60 g, and 60–70 g) and four scion maturity of (D<sub>1</sub>, D<sub>2</sub>, D<sub>3</sub>, D<sub>4</sub>) (60 days old, 70 days old, 80 days old, 90 days old) were used as treatments in a factorial completely randomized experimental design. The outcome showed that the best germination rate of 75% for S<sub>4</sub> and the highest survival percentage (94.98%) for S<sub>4</sub>D<sub>4</sub>. After 90<sup>th</sup> DAG the maximum number of new shoots per plant (5.75), number of leaves/plants (18.15), leaf area (20.83 cm<sup>2</sup>), and carbohydrate content (6.57%) were reported. Based on the results of the experiment, it was determined that the optimum method for propagating avocados was softwood grafting using 60–70 g seed size (rootstock) and 90-day-old scion. These plants had better vigor and faster germination rates, all of which could reduce the length of time spent in the nursery while still ensuring the quality of the material, which is influenced by improved seedling growth.

**Keywords:** Seed weight, Germination, Scion maturity, Carbohydrate, Avocados

### **Introduction**

The Avocado (*Persea americana* Mill) originated from tropical America mainly from Mexico and Central America. Increasing the production of the orchards by ensuring graft plants meet the finest agronomic, genetic, and phytosanitary standards is one of the nation's difficulties. One of the healthiest fruits, it has higher protein content (up to 4%), higher fat content (up to 30%), and lower sugar content (1.0%). Avocado is typically eaten raw, as a filling for sandwiches, or in salads. Additionally, the pulp can be kept by freezing and utilized in milkshakes and ice cream. Although avocados may thrive in a variety of climates and soil types, they are sensitive to poor drainage and cannot resist waterlogging. Early in the 20th century, Sri Lankan farmers brought avocados to India (Ghosh, 2000).

In some regions of Tamil Nadu, Kerala, Karnataka, and the North Eastern Himalayan states, it is grown on a small basis. However, many other states in the nation have gardens where plants can be seen growing. Avocado farming is currently becoming more and more popular due to its nutritional benefits and rising health consciousness. Avocado is planted as one of the mixed crops in the coffee-based cropping system in Kodagu (Karnataka), The Palani, Shervaroy Hills (Tamil Nadu), and other locations.

The production of seeds in various regions without fulfilling the minimal quality requirements has led to a large amount of planting material that, when used in the field, starts to pose issues, mostly at the root level. The cultures with a wide range of responses to edaphoclimatic and sanitary circumstances are a natural consequence of significant genetic variety (Ben-Ya'acov and Michelson, 1995). As a result, the

rootstock's seed must come from mature, fruitful trees that have produced at least two crops, are well-formed, and have excellent, healthy fruits Bernal *et al.*, (2014).

In terms of the growth and development of avocado fruit, the rootstock gives the tree nutrients, water, and other molecules like hormones and proteins through the root system that are important for healthy fruit development. Lazare *et al.*, (2020) state that while the scion produces the required photo assimilates through photosynthesis, an appropriate rootstock-scion connection is still required to ensure high yields and good fruit quality.

Yields and fruit quality are affected by abiotic elements including light intensity, water stress, temperature, and soil fertility, biotic ones like pests and diseases, and genetic factors like the rootstock (Mickelbart, 2012). An excellent root system that can withstand unfavorable conditions and ensures the early growth of the fruit can favor these elements, limiting the fruit's permanence over the tree (Olalde-Lira *et al.*, 2020). Therefore, seed weight and scion maturity for softwood grafting must be standardized as a result.

### **Materials and Methods**

The experiment on "Standardization of softwood grafting in avocado (*Persea americana* Mill) var. TKD1" was carried out in a mist chamber from February to August 2023 at the Horticultural Research station Thadiyankudisai. The latitude and longitude of the location are 10°S and 77°E with an elevation of 1098 m above Mean Sea Level. The average rainfall per year is about 1400 mm. The experiment had 16 treatments and 3 replications, and it was set up in a factorial completely randomized design (FCRD). In this softwood grafting is followed and scion materials are

collected from a 20-year-old avocado tree of variety TKD 1 at the Horticultural Research Station Thadiyankudisai, scion materials for softwood grafting were gathered.

**Factor 1: Size of Seed (Rootstock)**

S<sub>1</sub> – 30-40g

S<sub>2</sub> – 40-50g

S<sub>3</sub> – 50-60g

S<sub>4</sub> – 60-70g

**Factor 2: Age of Scion (Softwood)**

D<sub>1</sub> – 60 days old

D<sub>2</sub> – 70 days old

D<sub>3</sub> – 80 days old

D<sub>4</sub> – 90 days old

**Treatment combinations**

The biometrical observations were made on five randomly chosen plants from each replication to evaluate the morphological traits, for rootstock such as the number of days taken for sprouting, plant height, leaf area, shoot length, and observations after grafting with scion number of days taken to bud sprouting, number of new shoots/plants, survival percentage of grafting, leaf area (cm<sup>2</sup>), carbohydrate content. The data for the number of days taken for sprouting for rootstock was recorded after the emergence of 1st sprouting and expressed in numbers. The plant height of rootstock plants was measured on the 30th, 45th, and 60th day after sprouting and expressed in cm. The leaf area was calculated at 60 days after sprouting.

The after-grafting data regarding the number of days taken to sprouting was calculated by observation of plants on alternate days from the days of planting and their mean value was used to calculate the days taken

S*D	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>
S <sub>1</sub>	S <sub>1</sub> D <sub>1</sub>	S <sub>1</sub> D <sub>2</sub>	S <sub>1</sub> D <sub>3</sub>	S <sub>1</sub> D <sub>4</sub>
S <sub>2</sub>	S <sub>2</sub> D <sub>1</sub>	S <sub>2</sub> D <sub>2</sub>	S <sub>2</sub> D <sub>3</sub>	S <sub>2</sub> D <sub>4</sub>
S <sub>3</sub>	S <sub>3</sub> D <sub>1</sub>	S <sub>3</sub> D <sub>2</sub>	S <sub>3</sub> D <sub>3</sub>	S <sub>3</sub> D <sub>4</sub>
S <sub>4</sub>	S <sub>4</sub> D <sub>1</sub>	S <sub>4</sub> D <sub>2</sub>	S <sub>4</sub> D <sub>3</sub>	S <sub>4</sub> D <sub>4</sub>

**List 1. List of Treatment combinations used for the study**

for the first sprout. The number of shoots per plant and number of new leaves per plant were recorded of fully developed plants were recorded 30,60,90 days after propagation The data on the percentage of survival

were recorded after 90 days of planting the grafting/budding/cutting, carbohydrate content, and leaf area calculated after 90 days of propagation. The data were then statistically evaluated using the Panse and Sukhtame (1954) approach.

**Result and Discussion**

**1. Germination percentage (%)**

Avocado seed germination rates varied according to seed size, with S<sub>4</sub> (60–70 g) showing the highest rate and S<sub>3</sub> (50–60 g), S<sub>2</sub> (40–50 g), and S<sub>1</sub> (30–40 g) showing the lowest (Figure 1). Seed size and germination percentage were shown to be directly correlated, with 85% for S<sub>4</sub> (60-70 g), 75% for S<sub>3</sub> (50-60 g), 69% for S<sub>2</sub> (40-50 g), and 60% for S<sub>1</sub> (30-40 g). The size and quantity of seed reserves, which should be related to a stronger nutritional reserve in bigger seeds, are related to the success of seed germination and the establishment of seedlings. During the formation of the avocado fruit, significant starch reserves build up in the seed, generating a pool of carbohydrates reserves that are gradually broken down to sucrose, which is then used for the initial growth of the embryo and seedling Tefay *et al.*, (2012). This outcome is related to the avocado studies by Mejia *et al.*, (2022), Ndoro (2018), and Adjei *et al.*, (2011).

**2.Number of days taken for sprouting (days)**

According to a study of the data in (table 1), different seed sizes and scion maturities, as well as the minimum (19.25) number of days required for sprouting in S<sub>4</sub>, were documented. The minimal number of days required for avocados to sprout (20.75) was seen in D<sub>4</sub>, indicating that the scion's maturity had a major impact on this factor. The interplay between avocado seed weight and scion age also affected the length of time it took for avocados to sprout, with S<sub>4</sub> (60-70 g) and D<sub>4</sub> (90 days old) requiring the least amount of time 17 days to sprout. In softwood grafting the size of the seed and scion maturity plays a major role in seedling growth, whereas larger seed size and 90 days old scion should be used for grafting. During avocado fruit development, substantial starch reserves build up in the seed, generating a pool of carbohydrate reserves that are gradually broken down to sucrose, which is needed for initial embryo and seedling growth. The results conformed with those of Cordula *et al.*, (2014), Tefay *et al.*, (2012), and Ndoro (2018) in avocado.

**3.Number of shoots per plant**

The results showed that the highest (5.37) and minimum (2.55) shoots per plant were recorded in S<sub>4</sub> and S<sub>1</sub>, depending on the seed size and scion maturity (Table 2). The maximum (4.46) and minimum (3.78) shoots were seen during D<sub>4</sub> and D<sub>1</sub>, indicating that the scion maturity had a substantial impact on the time taken for avocado seeds to sprout. The interaction between avocado seed size and scion maturity also had an impact on the number of shoots, with the greatest (5.75) and minimum (1.95) values seen in S<sub>4</sub> D<sub>4</sub> and S<sub>1</sub> D<sub>1</sub>, respectively. The average number of stems on the seedlings with the largest seeds (above 70 g) was three,

which is the most stems ever seen Paixo *et al.*, (2016). This is probably because larger seeds contain more nutrients, which encourages the development of multi-stem rods. The number of shoots produced is more influenced by the greater seed size and the scion's age in days. Similar results were obtained in avocados by Souza *et al.*, (2020) and Paixo *et al.*, (2016).

#### 4. Number of leaves per plant

The effect of seed size and scion maturity on the number of leaves per plant showed that the highest value (17.59) and lowest value (12.40) of leaves were recorded in S<sub>4</sub> and S<sub>1</sub>. The effect of scion maturity was also significant with respect to the time it took for avocados to sprout, with the highest (15.62) and lowest (14.43) leaves being observed during D<sub>4</sub> and D<sub>1</sub>. The interaction effect of seed size and scion maturity in avocados also had an impact on the number of leaves, with the highest (18.15) and lowest (11.98) values found in S<sub>4</sub>D<sub>4</sub> and S<sub>1</sub>D<sub>1</sub> (Table 3). The rootstock and scion have an impact on how quickly grafts grow by increasing the production of photosynthates and dry matter, improving soil nutrient and water intake, and increasing the amount of synthetic food material. The scion's ideal maturity aids in the production of additional leaves. These findings concur with those in avocados from Mejia *et al.*, (2021) and Olorunmaiye *et al.*, (2011). Nimbalkar (2011) on karonda attained similar outcomes.

#### 5. Survival percentage (%)

According to (Table 4) the study's findings, S<sub>4</sub> and S<sub>1</sub> had the highest and lowest survival rates, respectively (93.98% and 60.83%). Regarding the avocado's taken-to-survival percentage, the effect of scion maturity was also significant; the highest (84.53%) and lowest (74.27%) percentages were seen on the D<sub>4</sub> and D<sub>1</sub>, respectively. The interaction between seed size and scion maturity in avocados also had an impact on survival percentage, with S<sub>4</sub>D<sub>4</sub> and S<sub>1</sub>D<sub>1</sub> showing the highest and lowest survival percentages (94.98 and 52.34%, respectively). The sufficient amount of carbohydrates and other food components in the scion and rootstock, as well as the mobilization of the stored food components for new development, maybe the

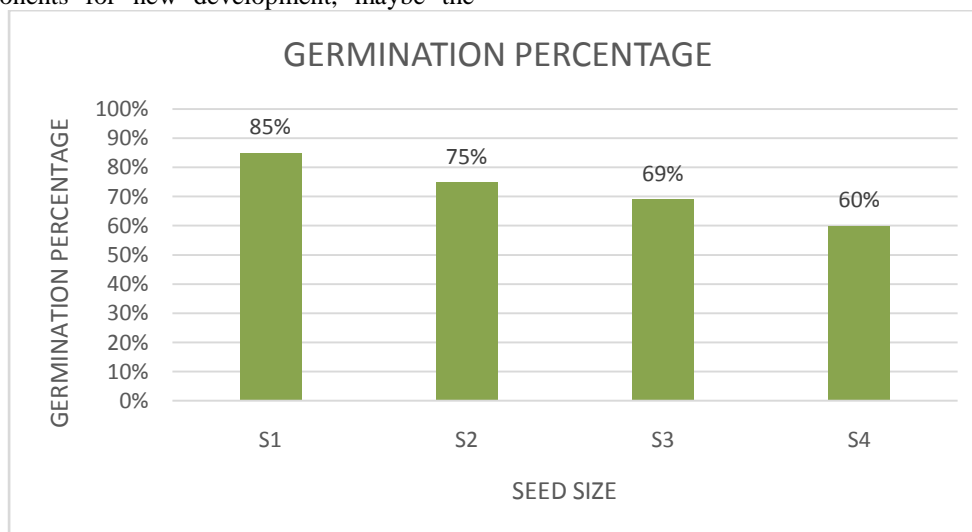
cause of the survival percentage. This in turn leads to high meristematic activity in the scion. Tanuja and Thippesha (2017) in the sapota study, Maheswari and Nivetha (2015) in the jackfruit study, and Angadi *et al.*, (2011) in the wood apple study all provided support for this conclusion.

#### 6. Leaf area (cm<sup>2</sup>)

Analysis of the results (Table 5) showed that S<sub>4</sub> and S<sub>1</sub> had the highest and lowest leaf areas among seeds of various sizes and scion maturities, respectively, measuring 19.99 cm<sup>2</sup> and 16.03 cm<sup>2</sup>. Regarding avocado leaf area, the maximum (18.81) and minimum (17.29) values were noted in D<sub>4</sub> and D<sub>1</sub> as the effect of scion maturity. The interaction impact of avocado seed size and scion maturity, which was found to have maximum (19.20) and minimum (15.16) values in S<sub>4</sub>D<sub>4</sub> and S<sub>1</sub>D<sub>1</sub>, also affected the time it took for avocado buds to sprout. The early and vigorous union formation, better nutrient uptake, sufficient scion development, and suitable rootstock may have contributed to the increased number of leaves per plant and leaf area. The same outcomes were observed in studies on sapota by Tanuja and Thippesha (2017), mango by Alam *et al.*, (2006), and guava by Rajatiya *et al.*, (2022).

#### 7. Carbohydrate content (%)

Carbohydrate levels were found to vary with seed size and scion age, with S<sub>4</sub> and S<sub>3</sub> having the highest (6.13%) and lowest (5.72%) levels, respectively (Table 6). About the carbohydrate content of avocados, the effect of scion maturity was likewise significant; the highest (6.08%) and lowest (5.60%) values were seen on days D<sub>4</sub> and D<sub>1</sub>. The interplay between avocado seed size and scion maturity also had an impact on the fruit's carbohydrate content, with maximum (6.57%) and minimum (5.28%) levels found in S<sub>4</sub>D<sub>4</sub> and S<sub>1</sub>D<sub>1</sub>. The buildup of higher carbohydrate contents is highly dependent on the scion maturity and seed size of the rootstock. Increased carbohydrate content, which promotes high graft take and increases the success rate, is a result of the proper seed size and maturation level. This finding agreed with Karna *et al.*, (2017) for mango.



**Figure: 1 Effect of seed size on germination percentage**

**Table 1: Influence of the size of the seed, scion maturity, and their interaction effect on the number of days taken to bud sprouting of Avocado**

Size of seed	Scion maturity				Mean
	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>	
S <sub>1</sub>	35.25	32.72	26.24	24.68	29.72
S <sub>2</sub>	28.61	26.82	24.55	22.74	25.68
S <sub>3</sub>	27.93	25.72	22.85	20.13	24.15
S <sub>4</sub>	22.69	20.74	19.58	17.62	20.15
Mean	28.62	26.50	23.30	21.29	24.92
	Seed size		Scion maturity		Interaction (S X D)
SE(d)	0.208		0.208		0.417
CD(p=0.05)	0.425		0.425		0.850

**Table 2: Influence of the size of the seed, scion maturity, and their interaction effect on the number of shoots per plant of Avocado**

Size of seed	Scion maturity				Mean
	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>	
S <sub>1</sub>	1.95	2.20	2.90	3.10	2.55
S <sub>2</sub>	3.64	3.75	3.95	4.10	3.86
S <sub>3</sub>	4.50	4.79	4.89	4.90	4.77
S <sub>4</sub>	4.99	5.20	5.55	5.75	5.37
Mean	3.78	3.98	4.32	4.46	4.13
	Seed size		Scion maturity		Interaction (S X D)
SE(d)	0.050		0.050		0.100
CD(p=0.05)	0.137		0.137		0.274

**Table 3: Influence of the size of the seed, scion maturity, and their interaction effect on the number of leaves per plant of Avocado**

Size of seed	Scion maturity				Mean
	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>	
S <sub>1</sub>	11.98	12.14	12.56	12.95	12.40
S <sub>2</sub>	13.45	13.98	14.32	14.89	14.16
S <sub>3</sub>	15.32	15.85	16.21	16.52	15.97
S <sub>4</sub>	16.98	17.34	17.89	18.15	17.59
Mean	14.43	14.82	15.24	15.62	15.03
	Seed size		Scion maturity		Interaction (S X D)

SE(d)	0.169	0.169	0.338
CD(p=0.05)	0.344	0.344	0.689

**Table 4: Influence of the size of the seed, scion maturity, and their interaction effect on survival percentage of Avocado**

Size of seed	Scion maturity				Mean
	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>	
S <sub>1</sub>	52.34	60.73	65.07	65.2	60.83
S <sub>2</sub>	65.43	67.53	84.04	85.96	75.74
S <sub>3</sub>	87.08	88.86	89.65	91.99	89.39
S <sub>4</sub>	92.24	93.99	94.72	94.98	93.98
Mean	74.27	77.77	83.37	84.53	79.98
	Seed size		Scion maturity		Interaction (S X D)
SE(d)	0.910		0.910		1.821
CD(p=0.05)	1.855		1.855		3.710

**Table 5: Influence of the size of the seed, scion maturity, and their interaction effect on the leaf area of Avocado**

Size of seed	Scion maturity				Mean
	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>	
S <sub>1</sub>	46.06	48.02	50.61	50.83	48.88
S <sub>2</sub>	50.9	57.78	59.66	64.77	58.27
S <sub>3</sub>	65.84	65.96	66.94	71.73	67.61
S <sub>4</sub>	72.06	73.73	91	102.08	84.71
Mean	58.71	61.37	67.05	72.35	64.87
	Seed size		Scion maturity		Interaction (S X D)
SE(d)	0.188		0.188		0.376
CD(p=0.05)	0.383		0.383		0.767

**Table 6: Influence of the size of the seed, scion maturity, and their interaction effect on the carbohydrate content of Avocado**

Size of seed	Scion maturity				Mean
	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>	
S <sub>1</sub>	5.19	5.28	5.55	5.72	5.43
S <sub>2</sub>	5.72	5.77	5.82	6.05	5.84
S <sub>3</sub>	6.09	6.10	6.12	6.13	6.11
S <sub>4</sub>	6.26	6.29	6.30	6.57	6.35
Mean	5.81	5.86	5.94	6.11	5.93
	Seed size		Scion maturity		Interaction (S X D)
SE(d)	0.055		0.055		0.110
CD(p=0.05)	0.112		0.112		0.225

## Conclusion

According to the experiment's findings, for softwood grafting the seeds that are 60–70 g in weight and scions that are 90 days old are optimal for propagating avocados, followed by seeds that are 50–60 g in weight and scions that are 80 days old or older. Farmers have trouble propagating avocados because there aren't any standard rootstock and scion available. Therefore, standardizing rootstock and scion maturities for softwood grafting will enable the large-scale manufacture of high-quality planting material to farmers' advantage. It will also boost growth and yield, which will increase the farmers' revenue.

## REFERENCES

- Adjei, P. Y., Banful, B. K., & Idun, I. A. (2011). Seed size and seed cut-length effects on germination behavior and seedling growth of avocado (*Persea americana* Merr.). *International Journal of Agricultural Research*, 6(3), 299-305.
- Alam, M. A., Islam, M. S., Uddin, M. Z., Barman, J. C., & Quamruzzaman, A. K. M. (2006). Effect of age of seedling and variety of scion in stone grafting of mango. *Int. J. Sustain. Crop Prod*, 1(2), 27-32.
- Ben-Ya'acov, A., & Michelson, E. (1995). Avocado rootstocks. *HORTICULTURAL REVIEWS-WESTPORT THEN NEW YORK*, 17, 381-429.
- Córdula, E., Morim, M. P., & Alves, M. (2014). Morphology of fruits and seeds of Fabaceae occurring in a priority area for the conservation of the Caatinga in Pernambuco, Brazil. *Rhodriguesia*, 65, 505-516.
- Ghosh, S. P. (2000). Avocado production in India. *Avocado production in Asia and the Pacific*, 24-30.
- Karna, A. K., Varu, D. K., Panda, P. A., & Hota, D. (2017). Standardization of grafting time and height on success of softwood grafting in mango (*Mangifera indica* L.). *Journal of Pharmacognosy and Phytochemistry*, 6(5), 2803-2807.
- Lazare, S., Haberman, A., Yermiyahu, U., Erel, R., Simenski, E., & Dag, A. (2020). Avocado rootstock influences scion leaf mineral content. *Archives of Agronomy and Soil Science*, 66(10), 1399-1409.
- Maheswari, T. U., & Nivetha, K. (2015). Effect of age of the rootstock on the success of softwood grafting in jack (Artocarpus heterophyllus Lam.). *Plant Arch*, 15, 823-825.
- Mejía-Jaramillo, L., Barrera-Sánchez, C., & Córdoba-Gaona, O. (2022). Effect of the seed weight on the growth of young avocado rootstock seedlings. *Bioagro*, 34(2), 183-194.
- Mickelbart, M. V., Robinson, P. W., Witney, G., & Arpaia, M. L. (2012). 'Hass' avocado tree growth on four rootstocks in California. II. Shoot and root growth. *Scientia horticultrae*, 143, 205-210.
- Ndoro, L. L. (2018). Effect of seed size on germination and seedling performance on grafted avocado.
- Nimbalkar, S. D., Haldankar, P. M., Pujari, K. H., Dhekale, J. H., & Somavanshi, A. V. (2011). Effect of maturity of scion and polythene bag cover on softwood grafting of karonda (*Carissa carandus* L.). *Indian Journal of Horticulture*, 68(3), 429-432.
- Olalde-Lira, G. G., Raya Montaña, Y. A., Apéaz Barrios, P., Vargas-Sandoval, M., Pedraza Santos, M. E., Raymundo, T., ... & Blanca, M. (2020). Characterization of *Fusarium* spp., avocado phytopathogen (*Persea americana* Miller var. *drymifolia* (Schltdl. and Cham.)) in Michoacán, Mexico. *Journal of the Faculty of Agricultural Sciences. National University of Cuyo*, 52(2), 301-316.
- Olorunmaiye, K. S., Fatoba, P. O., Olorunmaiye, P. M., & Oreoluwa Adeyemi, C. (2012). Seed weight and Morpho-physiological parameters in Mango(*Mangifera indica*) seedlings. *Pomologia croatica*, 17(3-4), 77-86.
- Souza, J. A. C., Prates, G. C., Ferreira, J. T., Castro, G. D. M. D., & Salomão, L. C. C. (2020). Avocado: Is it possible to produce two seedlings with one seed?. *Revista Ceres*, 67, 152-155.
- TAMAYO-VÉLEZ, Á. D. J., Bernal-Estrada, J. A., Díaz-Díez, C. A., Cano-Gallego, L. E., & CÓRDOBA-GAONA, O. D. J. (2022). Effect of rootstock/scion compatibility on fruit and foliar nutrient composition in avocado (*Persea americana* Mill.) cv. Hass in Colombia. *Revista Colombiana de Ciencias Hortícolas*, 16(3).
- Tanuja, P., & Thippesha, D. (2017). Effect of different age groups of scion on success rate of softwood grafting in sapota. *Journal of Pharmacognosy and Phytochemistry*, 6(4), 1886-1889.
- Tesfay, S. Z., Bertling, I., Bower, J. P., & Lovatt, C. (2012). The quest for the function of 'Hass' avocado carbohydrates: clues from fruit and seed development as well as seed

germination. *Australian Journal of Botany*, 60(1),  
79-86.