Research Article

Impact of Grafting Techniques on Vegetative Growth of Different Avocado Cultivars

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Abstract | Avocado being an energetic fruit owing to its high nutritional value has gained global popularity. Its global production has witnessed a two-fold increase in the last decade. This scenario has led a pressure on avocado nursery production. Generally, avocado has been propagated through seed production that led to variability among off-spring and long juvenile period. Therefore, asexual propagation via grafting is the most appropriate method for producing high-quality, true to type plants. The current study was planned to evaluate four different grafting techniques (Cleft, Tongue, Patch and T-budding) in ten different cultivars of avocado. The outcomes suggested that Cleft grafting was most suitable one among all other evaluated techniques. The highest survival rate (27.40%) was recorded in cleft grafting. Moreover, vegetative characters, i.e., no. of leaves and leaf area, no. of internodes and internodal length, shoot length and diameter were also higher in cleft and tongue grafting as compared to other grafting method. Among cultivars, NARC-Feurte and NARC-Purple give the best outcomes.

Received | December 12, 2023; **Accepted** | January 28, 2024; **Published** | February 13,2024
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Citation | Kasana, M.I., R.I. Khan, N.U. Khan, M.N.S. Ali, S. Mumtaz, S. Rasheed and M.Q. Zaman. 2024. Impact of grafting techniques on vegetative growth of different avocado cultivars. *Pakistan Journal of Agricultural Research,* 37(1): 39-47.
DOI | https://dx.doi.org/10.17582/journal.pjar/2024/37.1.39.47
Keywords | Avocado, Asexual propagation, Grafting, Vegetative growth

Introduction

Avocado (*Persea americana* Miller), a fruit known for its delectable and nutritional quality is grown under tropical and Mediterranean regions. Originating from South-Central Mexico, avocado is a dicotyledonous plant in the Lauraceae family and has gained global popularity in consumption (Palma *et al*., 2016). It is recognized for its rich bioactive compounds. Its consumption has been increased from recent times, driven by its notable health benefits (Araújo *et al*., 2018). Consumed in various forms, avocado has diverse commercial applications (Migliore *et al*., 2018) including frozen products (Colombo and Papetti, 2019) and cosmetic (Saavedra *et al*., 2017).

The avocado usage in food items has shown a remarkable increment owing to the higher conc. of bioactives, along with vitamins, dietary fiber, phenolics and chlorophyll pigments (Kosińska *et al*., 2012; Wang *et al*., 2010).

Over the past decade, global avocado production has witnessed a significant increase and has doubled from last decade (FAOSTAT, 2022). This scenario has led a pressure on avocado nursery production. The sexual and asexual propagation technique are commonly used in providing plant material for commercial avocado orchards cultivation. Whereas, sexual propagation often results in variability along-with longer juvenile period (≥10 years) (Bender and Whiley, 2002). On the contrary, asexual propagation maintains true to type in-addition to better resistance against biotic and abiotic stresses. Variable techniques have been used for vegetative propagation in avocados across the globe involving cutting, budding, and grafting (Tripathi and Karunakaran, 2019). However, cutting in avocado is often less successful due to the absence of a tap root system that results in stunted tree growth and low yield. On the contrary, cuttings rooting has been another major limitation owing to the lower rates of root growth initiation, irregular rooting pattern, longer time period for root initiation with a low acclimatization success percentage (Hiti-Bandaralage *et al.*, 2017). Moreover, recently micropropagation has also been done to speed up avocado multiplication (Abo El-Fadl *et al.*, 2022). The micropropagation, particularly *in-vitro* multiplication has other pitfalls such as requires experienced hands on-training, specialized lab facilities along with expensive chemicals and ultimate care, thus making it a pricey technique. Furthermore, acclimatization of *in-vitro* produced plants is another hindrance (Asayesh *et al.*, 2017) in the adaptation of this technique.

Under the above given scenario, grafting and budding are the most suitable vegetatively propagation techniques for avocados. The plants emerging from these techniques include early flowering with a compact, smaller size trees and early bearing of fruits (Awotedu *et al.*, 2021).

However, achieving a successful union between rootstock and scion is a crucial prerequisite for the propagation process, demanding careful selection of the appropriate rootstock, grafting time aligned with optimal growing conditions and skilled grafting techniques (Marin *et al.*, 2023). The success of budding or grafting relies heavily on favorable temperature conditions during cell division and multiplication, callus induction and regeneration. Following the current scenario, different other grafting techniques i.e., side, cleft, tongue and patch grafting are recommended methods for propagation and multiplication of horticultural crops including avocado (Sarker and Gomasta, 2023).

Avocado has been recently introduced in Pakistan, and its cultivation is on high verge therefore demand for avocado plants is consistently increasing. This scenario demands the standardization of propagation techniques for avocado. The current research experiment was carried to evaluate the impact of variant grafting techniques (cleft, tongue, patch and T-budding) in different avocado cultivars under Pothohar climatic conditions.

Materials and Methods

Experimental trial

The experiment was carried out at Horticulture Research Institute, NARC Islamabad (33.6701° N, 73.1261° E). The climate of the research area (Islamabad) is humid subtropical.

Plant materials

In the study, 1-year-old rootstocks (grown from seed) was grown in polythene bags (30cm × 25 cm) filled with media comprising soil: sand: FYM (1:1:1). Ten promising avocado genotypes i.e., NARC-Avocado-1, Narc-Avocado-2, Narc-Avocado-3, Narc-Avocado-4, Narc-Avocado-7, Narc-Avocado-8, Narc-Avocado-9, Narc-Avocado-10, NARC-Feurte and Narc-Purple. Scions of these promising varieties for grafting were obtained from ten-year-old stock.

Grafting process

Both of the asexual propagation techniques i.e., grafting and budding were done using sharp grafting/budding knife and vascular tissues were properly attached with each other to improve graft success (Hartmann et al., 2007). The inter-stock (graft union) was done at a height of 20 cm above the ground Hartmann and Kester (2011) followed by covering with silicone grafting tape. Afterwards, this graft union was covered with transparent polythene covers including some main stems of the rootstocks, for a clear visualization of initiation of growth and subsequent developmental phases. These plants were then kept under green-house for a duration of four weeks. All the cultural practices i.e., removal of suckers/water-shoots below the inter-stock, irrigation and weed control was done regularly.

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Experimental layout and statistical analysis

The research trial followed two factor factorial Complete Randomized Design (CRD). The treatment plan includes ten variables (genotypes) having three replications each. However, the data was subjected to ANOVA technique along-with LSD test at 5% probability level to determine the overall significance using the Statistix 8.1 software (Steel et al., 1997).

Data collection

Survival %: Total no. of green buds after 20 days of grafting were counted in each treatment and their percentage was calculated following the procedure of Ozturk et al. (2011).

$$\text{Green buds percentage} = \frac{\text{Total green buds}}{\text{Total grafts inserted}} \times 100$$

Shoot length (cm): Shoot length of newly induced growth above inter-stock was recorded after 80 days of grafting with measuring tape and expressed in cm (Rahman et al., 2017).

Shoot diameter (cm): Shoot girth of newly induced growth above inter-stock was recorded after 80 days of grafting using a digital vernier caliper and expressed in mm (Zenginbal et al., 2017).

Internodal length (cm): Internodal length was measured by recording the distance between two nodes with measuring tape and expressed in cm.

Number of internodes and leaves plant^{-1}

Number of internodes and leaves in newly induced growth above inter-stock was recorded after 80 days of grafting.

Results and Discussion

Survival %

The significant impact (P≤0.01) of propagation techniques on survival % of different avocado cultivars was observed (Appendix 1). The highest survival % (27.40%) was observed in cleft grafting followed by Tongue grafting (16.10%). The lowest survival rate (9.26%) was recorded in Patch grafting (Table 1). Among cultivars, NARC-Feurte recorded highest survival rate (21.83%) and the least (13.66%) was observed in NARC-Avocado-10.

Internodal length

Results expressed highly significant outcomes (P<0.01) of different propagation techniques on avocado cultivars (Appendix 2). Results concluded that the maximum internodal length (6.85 cm) was observed in cleft grafting followed by 4.72 cm in tongue grafting. While the minimum internodal length (2.16 cm) was observed in patch grafting (Table 2). Whereas in comparison, maximum internodal length (5.80 cm) was assessed in NARC-Avocado-3 that was statistically alike with NARC-Feurte.

Leaf area (cm^2)

The effect of different propagation techniques on leaf area of various avocado cultivars exhibited significant outcomes (P<0.01) presented in Appendix 2. Maximum leaf area (86.39 cm^2) was recorded in cleft grafted plants and minimum leaf area (65.26 cm^2) is recorded in patch grafted plants (Table 3). On the contrary, maximum leaf area (85.37 cm^2) was observed in NARC-Purple that was statistically alike with NARC-Feurte (Table 3).

Table 1: *Impact of grafting techniques on survival % of different avocado cultivars.*

Varieties	Cleft	Tongue	Patch	T-Budding	Mean
NARC-Avocado-1	27.33 B	15.66 F-J	15.66 F-J	11.66 J-N	17.58 CD
NARC-Avocado-2	27.33 B	14.66 G-K	9.00 M-O	12.66 I-M	15.91 D-F
NARC-Avocado-3	16.66 E-I	9.00 M-O	5.33 O	9.66 L-O	10.16 G
NARC-Avocado-4	20.66 DE	13.33 H-M	8.00 NO	14.66 G-K	14.17 EF
NARC-Avocado-7	29.33 B	20.00 D-F	9.33 L-O	13.66 H-L	18.08 B-D
NARC-Avocado-8	26.33 BC	17.00 E-I	7.66 NO	13.00 H-M	16.00 DE
NARC-Avocado-9	29.33 B	18.66 D-G	9.66 L-O	16.00 F-J	18.41 BC
NARC-Avocado-10	22.66 CD	14.66 G-K	7.33 NO	10.00 L-N	13.66 F
NARC-Feurte	38.33 A	21.00 DE	10.66 K-N	17.33 E-H	21.83 A
NARC-Purple	36.00 A	17.00 E-I	10.00 L-N	17.00 E-I	20.00 AB
Mean	27.40 A	16.10 B	9.26 D	13.56 C	

**Values are means of three replicates.*

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Table 2: *Impact of grafting techniques on internodal length of different avocado cultivars.*

Varieties	Cleft	Tongue	Patch	T-Budding	Mean
NARC-Avocado-1	8.30 B	4.43 GHIJ	1.73 OPQR	2.23 NOPQ	4.17 C
NARC-Avocado-2	5.20 FGH	3.73 IJKL	0.93 R	1.40 PQR	2.81 EF
NARC-Avocado-3	9.93 A	5.16 FGH	2.86 LMN	5.26 EFG	5.80 A
NARC-Avocado-4	7.83 BC	6.23 DE	1.10 R	2.30 NOP	4.36 C
NARC-Avocado-7	5.53 EF	1.33 PQR	1.50 PQR	1.80 OPQR	2.54 F
NARC-Avocado-8	4.53 GHI	4.16 IJ	1.30 QR	3.00 KLMN	3.25 DE
NARC-Avocado-9	7.06 CD	5.40 EFG	3.93 IJK	3.70 IJKL	5.02 B
NARC-Avocado-10	4.23 HIJ	4.13 IJ	2.53 MNO	3.46 JKLM	3.59 D
NARC-Feurte	9.73 A	6.93 CD	2.80 LMN	3.46 JKLM	5.73 A
NARC-Purple	6.13 DEF	5.70 EF	2.90 LMN	3.60 IJKL	4.53 BC
Mean	6.85 A	4.72 B	2.16 D	3.02 C	

**Values are means of three replicates.*

Table 3: *Impact of grafting techniques on leaf area of different avocado cultivars.*

	Cleft	Tongue	Patch	T-Budding	Mean
NARC-Avocado-1	88.17 D-F	80.87 G-I	63.07 S-U	74.73 J-M	76.70 B
NARC-Avocado-2	66.70 P-T	70.87 K-Q	58.30 UV	63.77 R-U	64.90 F
NARC-Avocado-3	76.17 I-K	66.30 Q-T	61.47 T-V	72.67 K-O	69.15 DE
NARC-Avocado-4	63.30 S-U	69.10 N-R	63.00 S-U	73.53 J-N	67.23 EF
NARC-Avocado-7	75.63 I-L	68.17 N-S	57.00 V	80.27 G-I	70.26 D
NARC-Avocado-8	96.87 C	84.50 E-G	65.90 Q-T	67.33 O-S	78.65 B
NARC-Avocado-9	96.00 C	71.83 K-P	58.47 UV	66.13 Q-T	73.11 C
NARC-Avocado-10	88.92 DE	65.87 Q-T	83.40 F-H	66.77 P-T	76.23 B
NARC-Feurte	102.53 B	89.02 DE	70.17 L-Q	78.83 H-J	85.13 A
NARC-Purple	109.67 A	90.22 D	71.87 K-P	69.77 M-Q	85.37 A
Mean	86.39 A	75.67 B	65.26 D	71.38 C	

**Values are means of three replicates.*

Table 4: *Impact of grafting techniques on no. of leaves of different avocado cultivars.*

	Cleft	Tongue	Patch	T-Budding	Mean
NARC-Avocado-1	6.00 I-N	10.66 B-D	3.66 O-T	4.33 M-S	6.16 BC
NARC-Avocado-2	5.33 J-P	8.33 E-H	5.66 J-O	4.66 L-R	6.00 CD
NARC-Avocado-3	12.00 BC	7.33 F-J	4.00 N-T	2.66 R-U	6.50 BC
NARC-Avocado-4	8.00 E-I	6.33 H-M	2.00 T-V	3.33 P-U	4.91 D
NARC-Avocado-7	9.33 D-F	12.66 B	5.00 K-Q	5.33 J-P	8.08 A
NARC-Avocado-8	16.00 A	6.66 H-L	2.33 S-U	4.00 N-T	7.25 AB
NARC-Avocado-9	6.00 I-N	10.00 C-E	4.66 L-R	2.33 S-U	5.75 CD
NARC-Avocado-10	9.00 D-G	7.00 G-K	2.33 S-U	1.33 UV	4.91 D
NARC-Feurte	15.33 A	12.00 BC	1.33 UV	3.00 Q-U	7.16 AB
NARC-Purple	8.00 E-I	11.00 B-D	3.66 O-T	3.00 Q-U	6.41 BC
Mean	9.50 A	9.20 A	3.46 B	3.10 B	

**Values are means of three replicates.*

No. of leaves

Results regarding number of leaves in different avocado varieties exhibited significant impact ($P<0.01$) of propagation techniques (Appendix 4). The maximum no. of leaves (9.50) was recorded in cleft grafted plants while the minimum (3.10) in T-budding propagated plants (Table 4). Among cultivars, NARC-Avocado-7 recorded highest leaf numbers (8.08) and the least no. of leaves (4.91) were recorded in NARC-Avocado -4 that were statistically alike with NARC-Avocado-10 (Table 4).

Table 5: *Impact of grafting techniques on no. of shoots of different avocado cultivars.*

	Cleft	Tongue	Patch	T-Budding	Mean
NARC-Avocado-1	2.3 E-H	2.33 E-H	1.33 HI	1.00 I	1.75 D
NARC-Avocado-2	3 C-F	2.00 F-I	2.33 E-H	2.00 F-I	2.33 A-C
NARC-Avocado-3	3 C-F	2.00 F-I	1.00 I	1.33 HI	1.83 CD
NARC-Avocado-4	2 F-I	2.66 D-G	1.33 HI	1.33 HI	1.83 CD
NARC-Avocado-7	4.0 A-C	3.00 C-F	1.66 G-I	1.33 HI	2.50 AB
NARC-Avocado-8	4.3 AB	2.33 E-H	1.33 HI	1.66 G-I	2.41 AB
NARC-Avocado-9	1.6 G-I	2.33 E-H	2.00 G-I	1.00 I	1.75 D
NARC-Avocado-10	3.66 B-D	2.33 E-H	1.66 G-I	1.33 HI	2.25 B-D
NARC-Feurte	5.00 A	4.00 A	1.33 HI	1.00 I	2.83 A
NARC-Purple	2.66 D-G	3.33 B-E	1.66 G-I	1.00 I	2.16 B-D
Mean	3.16 A	2.63 B	1.56 C	1.30 C	

**Values are means of three replicates.*

Table 6: *Impact of grafting techniques on No. of internodes of different avocado cultivars.*

	Cleft	Tongue	Patch	T-Budding	Mean
NARC-Avocado-1	6.00 H-M	9.33 C-F	4.33 L-O	5.33 L-N	6.25 CD
NARC-Avocado-2	9.00 D-G	5.33 L-N	4.66 L-O	8.00 E-I	6.75 CD
NARC-Avocado-3	10.66 C-E	6.00 H-M	2.00 O	4.66 L-O	5.83 D
NARC-Avocado-4	9.00 D-G	6.66 F-K	3.00 NO	4.66 L-O	5.75 D
NARC-Avocado-7	11.00 CD	4.33 K-O	3.66 L-O	6.33 G-L	6.33 CD
NARC-Avocado-8	11.00 CD	8.66 G-L	4.33 L-O	6.33 G-L	7.00 CD
NARC-Avocado-9	12.00 C	8.66 D-H	3.33 M-O	6.33 G-L	7.25 C
NARC-Avocado-10	15.33 AB	11.33 CD	3.00 NO	5.33 L-N	8.75 B
NARC-Feurte	15.00 B	9.33 C-F	6.33 G-L	7.66 F-J	9.58 B
NARC-Purple	18.00 A	10.66 C-E	6.66 F-K	11.00 CD	11.58 A
Mean	11.70 A	7.80 B	4.13 D	6.40 C	

**Values are means of three replicates.*

No of shoots

Results expressed highly significant outcomes (P<0.01) of different propagation techniques on avocado cultivars (Appendix 5). Results concluded that the maximum no. of shoots (3.16) were recorded in cleft grafting followed by 2.63 in tongue grafting. While the minimum no. of shoots (1.30) was observed in T-budding (Table 5). Whereas regarding varietal comparison, maximum shoot number (2.83) was observed in NARC-Feurte and least (1.75) in NARC-Avocado-1 and NARC-Avocado-9, respectively.

No. of internodes

The effect of different propagation techniques on no. internodes of various avocado cultivars exhibited significant outcomes (P<0.01) presented in Appendix 6. The highest no. of internodes (11.70) was recorded in cleft grafted plants and minimum internodes (4.13) were recorded in patch grafted plants (Table 6). On the contrary, maximum no. of internodes (11.58) was observed in NARC-Purple that was followed by NARC-Feurte exhibiting 9.58 internodes respectively (Table 6).

Shoot diameter (cm)

Results regarding shoot diameter of different avocado varieties exhibited significant impact (P<0.01) of propagation techniques (Appendix 7). The highest shoot diameter (1.97 cm) was recorded in cleft grafted plants while the minimum (0.87 cm) in T-budding propagated plants (Table 7). Among cultivars, NARC-Feurte recorded highest shoot diameter (2.15 cm) while NARC-Avocado-2 exhibited the least shoot diameter (Table 7).

Shoot length (cm)

Results expressed highly significant outcomes (P<0.01) of different propagation techniques on shoot length of avocado cultivars (Appendix 8). Results concluded that the maximum shoot length (22.18 cm) were recorded in cleft grafting followed by 18.13 in tongue grafting. While the minimum shoot length (6.59 cm) was observed in patch grafted plants (Table 8). Whereas regarding varietal comparison, maximum shoot number (19.27 cm) was observed in NARC-Feurte that was statistically alike with NARC-Purple, respectively.

Sexual propagation is majorly avoided in propagation of horticultural crops, mainly fruit crops to prevent from variation in up-coming generations. Thus, the Asexual propagation provides the provision of genetically true-to-type plants ensuring healthy growth and sustainable yield for commercial adaptation. However, not all Asexual techniques are perfect for every crop and under variant climatic conditions. Thus, the favorable outcomes of propagation technique are dependent upon numerous internal and external factors, including the genetic relationship among scion-stock, along with the prevailing climatic conditions during and afterwards the propagation activity.

Except these, other factors comprise health and developmental stage of scion and rootstock, time of propagation activity, management practices, plant nutrition and growth-regulating agents (Beshir *et al*., 2019). Thus, it is hereby evident that propagation techniques, in-particularly grafting success is majorly dependent upon the type of grafting and time of year of practicing.

The outcomes from current study exhibited that Cleft grafting gives the best results followed by Tongue grafting and T-budding respectively. Whereas, Patch grafting made the worst results. The results could be attributed to the strength of the graft union. However, this union-strength or compatibility is often dependent upon anatomical structures of scion and stock which affects the molecular and physiological cross-talks in scion-stock compatibility (Wang *et al*., 2017; Rasool *et al*., 2020).

Table 7: *Impact of grafting techniques on Shoot Diameter of different avocado cultivars.*

	Cleft	Tongue	Patch	T-Budding	Mean
NARC-Avocado-1	1.26 H-K	2.16 D-F	0.9 J-N	0.80 K-O	1.28 E-G
NARC-Avocado-2	0.63 M-O	1.10 I-M	0.5 NO	0.30 O	0.63 H
NARC-Avocado-3	2.56 C-E	1.53 G-I	1.3 H-J	1.53 G-I	1.75 BC
NARC-Avocado-4	2.13 EF	2.00 FG	1.2H-K	0.90 J-N	1.57 B-D
NARC-Avocado-7	2.66 CD	3.03 BC	0.9 J-N	0.60 M-O	1.80 B
NARC-Avocado-8	3.20 AB	0.93 J-N	0.7 L-O	0.73 L-O	1.39 D-F
NARC-Avocado-9	0.96 J-N	1.56 G-I	0.83 K-N	1.06 I-M	1.10 G
NARC-Avocado-10	1.66 F-H	1.06 I-M	1.0 I-M	1.16 H-L	1.24 FG
NARC-Feurte	3.70 A	3.30 AB	0.86 J-N	0.73 L-O	2.15 A
NARC-Purple	0.93 J-N	3.36 AB	0.86 J-N	0.90 J-N	1.51 C-E
Mean	1.97 A	2.00 A	0.92 B	0.87 B	

**Values are means of three replicates.*

Table 8: *Impact of grafting techniques on shoot length of different avocado cultivars.*

	Cleft	Tongue	Patch	T-Budding	Mean
NARC-Avocado-1	21.16 E-H	13.26 L-N	13.40 L-N	15.60 J-M	15.85 BC
NARC-Avocado-2	23.53 C-F	18.30 H-K	4.13 T	11.23 N-P	14.30 CD
NARC-Avocado-3	20.23 F-I	19.13 G-J	7.50 Q-T	7.20 Q-T	13.51 DE
NARC-Avocado-4	16.86 I-L	15.40 K-M	4.20 T	10.73 N-Q	11.80 EF
NARC-Avocado-7	13.86 L-N	10.36 N-Q	5.53 R-T	8.63 O-R	10.20 FG
NARC-Avocado-8	11.73 NO	12.90 MN	4.96 ST	11.20 N-P	9.60 G
NARC-Avocado-9	26.16 CD	18.26 H-K	7.93 P-S	12.56 MN	16.23 B
NARC-Avocado-10	26.96 BC	22.76 D-G	6.00 R-T	10.46 N-Q	16.55 B
NARC-Feurte	30.93 A	24.70 C-E	5.96 R-T	15.50 J-M	19.27 A
NARC-Purple	30.40 AB	26.26 CD	6.30 R-T	13.50 L-N	19.11 A
Mean	22.18 A	18.13 B	6.59 D	11.66 C	

**Values are means of three replicates.*

Among various factors influencing grafting success, the grafting technique stands out as the most crucial determinant (Soleimani *et al.*, 2010). The notable success in cleft grafting could be attributed to the better arrangement of parenchymatous tissues in the graft-union as a diagonal cut on both sides of the scion correspond with the root-stock flip thus strengthens graft union and interlocking of vascular bundles (Tripathi and Karunakaran, 2019). This could also be attributed to the identical diameter of the scion and rootstock in cleft grafting that promotes uniform callusing of cambium cells on both sides of the graft (Rasool *et al.*, 2020).

Conversely, lower success % in T-budding, Tongue grafting and patch budding may be attributed to reduced contact with actively growing cells as fewer cambium connecting surface area has been observed in budding.

Earlier reports by Chithiraichelvan *et al.* (2006) highlighted the best outcomes through cleft grafting in avocado multiplication. The improved vegetative growth observed in cleft grafting under the current study may be attributed to swift and precise connection among scion-stock in grafting facilitates the seamless translocation of nutrients from the rootstock to the actively growing tips thus enhances vegetative characters (Spiegelman *et al.*, 2015). The effectiveness of the cleft grafting technique extends to various other fruit crops, including mango (Beshir *et al.*, 2019), walnut (Ahmed *et al.*, 2012), and tamarind (Mayavel *et al.*, 2022).

Similarly, the higher shoot length and diameter of avocado plants could be directly correlated with the length of the scion utilized for multiplication. Longer scion lengths in grafting lead to accelerated growth, whereas the single bud employed in budding methods takes a longer time to develop (Tripathi and Karunakaran, 2019). This could also be attributed to fact that early graft union in cleft grafting resulted in early growth and led to greater number of leaves which in turn elevates photosynthetic rate thus providing the photosynthates for growth and development of grafted plants.

Conclusions and Recommendations

The current study concludes, Cleft grafting as the best asexual propagation technique for avocadoes followed by Tongue grafting and T-budding. While the patch grafting recorded the worst results. Among cultivars, NARC-Feurte and NARC-Purple yields the best outcomes in terms of propagation capability and growth and development.

Acknowledgement

This research was supported by Research Fund NARC. We thank our colleagues from department who provided insight and expertise that greatly assisted the research outcomes.

Novelty Statement

Determination of suitable propagation technique in newly inducted avocado cultivars and elite lines will help to improve the graft success % and healthy nursery establishment.

Author's Contribution

Imran Kasana: Designed and Conducted the study,
Rashid Iqbal Khan: Formal analysis and writing original draft preparation.
Noor Ullah Khan: Reviewing data analysis and manuscript.
M. Noman: Data collection and Research trial.
Shahid Ali: Advised about practical research trial.
Saima Mumtaz: Data curation and formal analysis.
Shamaila Rasheed: Statistical Data Analysis and Data Collection.
M. Qamar-Uz-Zaman: writing and editing of manuscript draft.

Conflict of interest

The authors have declared no conflict of interest.

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