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Grafting Experience and Shade Influences Graft Take of Avocado Scions

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Avocado is an important tree crop grown in the tropics, including Ghana. Avocados are primarily propagated by seed into trees, which grow to provide shade for young cocoa trees and, subsequently, food and income. Cultivation of this crop as a monocrop is limited in Ghana; hence, there is a considerable risk of losing desirable genetic materials. There has been an effort by scientists at the University of Ghana to collect and curate available avocado germplasm to preserve, multiply, and disseminate to growers. Nurserymen have been tasked with germplasm multiplication through grafting. Unfortunately, the outcome of this grafting practice has been inefficient due to the high incidence of grafting failure. This study assessed the effects of the grafting experiences of four nurserymen under no shade, traditional, and adjusted shade conditions on the graft success of two avocado scions (Fuerte and Hass). The results of this study indicated that the absence of shade led to complete graft failure. Nevertheless, modifying the conventional shade to 70% using shade net resulted in a 10–20% enhancement in graft success. The success of grafting was found to be more associated with the skill of the grafters rather than their age or years of grafting experience. In general, the low graft success rate in avocados was most probably attributed to variations in the skills of individual grafters. Grafter A achieved a graft success rate of 23–29% higher than the other grafters, suggesting variations in the skill levels employed. Significantly (p = 0.05), graft success was higher in the Fuerte cultivar than in the Hass cultivar

Keywords: grafter’s skill, graft success, nurserymen, saplings, shading

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INTRODUCTION

Avocado (*Persea americana* Miller) is a popular tropical tree crop cultivated for its nutritious fruits. This crop has been commercially propagated globally because of its value as a fruit or for its oil (Xagoraris *et al*. 2022).

Farmers in Ghana have been adopting sparse cultivation of avocado trees in their cocoa plantations. Like in related countries, farmers have primarily planted avocado trees to provide shade for tender cocoa trees (Burbano-Figueroa 2019). Furthermore, the avocado serves as an additional source of food and income in the long run for farmers, which mainly helps during the lean period of cocoa cultivation. The propagation method of avocados on farmers' fields has been a challenge in obtaining optimum benefits for the plant. Usually, the intercropped avocado plants are propagated through the sexual (seedling) method, which reduces yield potential and fruit quality. Such propagated trees are tall, difficult to manage, and lack true-to-types to transfer quality parameters to the offspring (Nakasone and Paull 1998). This practice has drawbacks and hampers the germplasm conservation process of avocados in Ghana, as reported by Honja (2014).

Recently, a few growers have attempted to cultivate avocados as a monoculture. The work of Nkansah *et al*. (2013), for example, established a germplasm museum at the University of Ghana Forest and Horticultural Crops Research Centre to conserve, characterize, multiply, and disseminate to farmers. Maintaining the plant's true characteristics and achieving other benefits requires an asexual propagation method through grafting (Mudge *et al*. 2009). Grafting is the union between a scion and a rootstock (Nito *et al*. 2005), both of which are from the same family. Grafting reduces the time to tree productivity and has been reported by Rouphael *et al*. (2018) as a potential propagation method for curbing food insecurity issues as it is rapid and produces disease-free planting materials.

The effort of multiplying planting materials through grafting has been a diligent one. However, graft take/graft success (GT/GS) has been quite low. Some studies revealed that GT is affected by the method of grafting (Suleimani *et al.* 2010), the type of rootstock used (Bally 2006; Mukherjee and Litz 2009; Mng'omba *et al*. 2010), and the skills and knowledge of grafters (Akinnifesi *et al*. 2008). Other studies have concentrated on the method and timing of grafting (Beshir *et al*. 2019; Ghosh and Bera 2015).

Palm fronds have traditionally been used to shade sensitive crops, particularly grafted plants. After three to four weeks of sun exposure, the leaves of the palm fronds dry out, and their capacity to produce enough shade diminishes. This difficulty renders the traditional shade ineffective in maintaining adequate shading for tender crops. Graft success in Hass avocado was high when 75% shade was provided (Raharjo and Litz 2005). Additionally, the findings of Vazquez-Hernandez *et al*. (2004) and Fathi *et al.* (2015) showed that 50% shade increased the GT of avocado compared to the unshaded.

After successful graft placement, the next hazard to graft success is scion desiccation caused by full exposure to sunshine or poor shading effect. Sunlight exposure is accompanied by high temperatures, which may have an unfavorable physiological effect on saplings with insufficient or no shade. Vu *et al.* (2013) reported that graft success declines with increasing temperature. The findings of Nordey *et al*. (2020) emphasized the importance of keeping grafted plants at low temperatures (15–20 °C) during the healing and recovery periods. Shade provision might traditionally be used to reduce excessive temperatures caused by sunshine, as indicated by Lon *et al.* (2022). In the context of traditional shading, mango saplings demonstrate a notably high success rate in grafting, whereas avocado saplings typically exhibit lower rates under similar conditions. This observation suggests the need for additional work to understand environmental factors accounting for low graft take in avocado, thus making it more difficult to graft. While there is a lack of accessible literature on the main factors mitigating a successful avocado graft take in Ghana, studies done elsewhere suggest that the skill of grafters as a human factor (Akinnifesi *et al*. 2008; Majd *et al.* 2019; Beshir *et al.* 2019; Monir *et al.* 2021) and the type and level of shade (Anushma *et al.* 2014) affect graft take. Low grafting experience and poor traditional shading are, thus, suspected to be the causes of increased avocado graft failure in Ghana. This study, therefore, investigated the effect of grafting experience/skills and shade on the graft take of two avocado (scions) cultivars in the country.

MATERIALS AND METHODS

Study Location and Propagation of Planting Materials

The study was conducted between 02 Apr–23 Jun 2022 at the University of Ghana Forest and Horticultural Crops Research Centre (FOHCREC) in Kade, located in the semi-deciduous forest agro-ecological zone. The study site is in Ghana's Eastern Region (6° 05' N; 0° 05' W), 150 m above sea level, with a mean annual rainfall of 1500–2000 mm and relative humidity of 66–92% (Nkansah *et al*. 2007).

The rootstocks were propagated from seeds collected from a local tree (an accession) on the same avocado plot. The collected seeds were sorted into comparable sizes. The seeds were sown in a pre-nursery containing carbonated rice husk as the growing medium. The germinated seeds were transplanted into polybags measuring (12 x 17 cm) filled with carbonated rice husk 21 d after sowing. All polyembryonic seedlings were pruned to the most vigorously growing seedlings. The seedlings were fertigated twice daily (with 0.5 g L^{-1} NPK 15:15:15) until they reached graft-able girth of 5–7 mm and height of 25–30 cm at 60 d (Ahsan *et al*. 2019) after transplanting. Avocado scions from the Hass and Fuerte cultivars were collected from avocado plots at FOHCREC. On the day of grafting, the scions characterized by prominent active buds were harvested from 10-yr-old fruiting trees between 06:00–07:00 AM. To minimize desiccation, the harvested scions were stored in a moist towel and conveyed to the nursery for immediate grafting.

Treatments

Three factors were considered in this study. Factor 1 was two avocado cultivars (Hass and Fuerte), whose scions were used for the study. Factor 2 was the grafting (job) experiences/skills of four nurserymen/grafters (A, B, C, and D). However, the nurserymen were unaware that this grafting exercise was an experiment to test their efficiency in terms of a highly successful graft take. This evaluation was based on their ability to precisely join and judiciously tie the scions to the rootstocks ensuring a successful union of cambial layers from both parts to achieve a successful graft take. All grafters adopted the wedge method of grafting, as shown in Figure 1c. Shading was provided since it is noted to reduce solar radiation, which significantly reduces the ambient temperature of saplings (Lon *et al.* 2022). The third factor was the level of shade (0, 50, and 70%). The 0% was no shade; the 50% shade was represented by using palm fronds (Figure 1a), a traditional practice that could provide 45–50% shade for the grafted materials; the 70% shade (Figure 1b)

Figure 1. Traditional shade (a), modified shade (b), wedge grafted avocado (c), microclimate induced with transparent plastic bag (d), successful graft (e), and unsuccessful graft (f).

was provided using improved shade net. Light intensity was determined in the traditional shade, shade net area, and unshaded (control) area using a Smart Sensor Digital Lux Meter (AS813). The percentage of shade in the shaded area was calculated using the equation below:

$$\text{Percent shade} = \frac{Li_u - Li_s}{Li_u} \times 100 \qquad (1)$$

Li_u = light intensity in the unshaded area
Li_s = light intensity in the shaded area

Table 1 summarizes the treatments. Scions were further covered with transparent plastic bags (Figure 1d) to create microclimate conditions for increased scion ambient humidity. After 7–21 d, the saplings were observed for bud sprouts on the scions (Figure 1e) as an indication of successful graft take. Conversely, saplings that showed dead scions with no scion-bud sprout (Figure 1f) were considered unsuccessful graft or graft failure.

Statistical Analysis

Forty-five (45) seedlings were grafted per nurseryman per treatment. Data collected were analyzed using the GenStat (Rothamsted Research, Harpenden, UK) statistical software, version 12. Tukey's honestly significant difference ($HSD_{0.05}$) was used to separate the means. Data collected was percent GT/GS and expressed as a ratio of the number of saplings with bud sprouts (successful graft take) to the total number of grafted saplings.

RESULTS AND DISCUSSION

The grafter's grafting (job) experience significantly influenced the GT/GS of avocados (Table 2). Grafter A outperformed the other grafters by 23–29%. In the Fuerte cultivar, Grafter A achieved a 100% success rate, whereas the other grafters achieved 27–40% lower. However, GT – as recorded in Hass – was lower than it was in the Fuerte cultivar. Grafters A and D had the highest success rates in the Hass cultivar (86.7 and 80%, respectively) when compared to the other grafters. There was an inverse significant association between GT and the grafting experience or age for the Fuerte cultivar (Table 5). In contrast, the Hass cultivar had no significant relationship between GT and grafting experience or age.

The shading of grafted avocado cultivars significantly affected GT (Table 3). Saplings that did not receive any shade had no GT. Graft success was similar in the two cultivars when shade was provided. GT in the avocado cultivars was significantly affected by the grafting experience and shade interaction. When subjected to 70% shade, each cultivar recorded significantly higher graft success than the traditional practice. The higher rate of GT in the Fuerte compared to the Hass was not consistent with the interactions between the grafting experience and the shade effect. Additionally, shade provision significantly correlated with grafting experience in the two scions. A significant inverse correlation existed between grafting experience and GT (Table 5). However, the correlation between the two factors for the two scions (cultivars) was not consistent.

Table 1. Nurserymen of various ages and grafting experiences assigned to graft avocado scions in various shade conditions

Nurseryman			Shade (%)	Scion (Cultivar)
Grafter	Grafting experience (yr)	Age (yr)		
A	13	41	0	Hass
B	13	42	50	Fuerte
C	27	47	70	
D	39	58		

The study was a 4 × 3 × 2 factorial experiment arranged in a randomized complete block design with three replications

Table 2. Graft success of avocado scions as influenced by the grafter.

Grafter	Graft take (%)		GRAND MEAN
	Fuerte	Hass	
A	100.0a	86.7a	93.35a
B	73.3ab	53.3b	63.51b
C	66.7b	66.7ab	66.7b
D	60.0b	80.0a	70.0a
HSD (0.05)	27.46	22.09	
Grand mean	75.0a	71.7b	

Values with the same letter are not significantly different at $p < 0.05$; [HSD] Tukey's honestly significant difference

Table 3. Effect of shade on graft take of avocado.

Variety	Graft take (%)		
	0% shade	50% shade	70% shade
Fuerte	0	73.3b	93.3a
Hass	0	76.7b	86.7a
HSD (0.05)		8.8	
Grand mean	0	75.0b	90.0a

Values with the same letter in a column are not significantly different at $p < 0.05$; [HSD] Tukey's honestly significant difference

Table 4. Avocado varietal response to graft take (%) as influenced by skill and shade.

Grafter	Variety	Graft take (%)		
		0% shade	50% shade	70% shade
A	Hass	0	53.3abc	86.7def
	Fuerte	0	93.3ef	100.0f
B	Hass	0	93.3ef	66.7abcde
	Fuerte	0	53.3abc	66.7abcde
C	Hass	0	46.7ab	53.3abc
	Fuerte	0	46.7ab	73.3bcdef
D	Hass	0	40.0a	80.0cdef
	Fuerte	0	46.7ab	60.0abcd
HSD (0.05)			18.1	

Values with the same letter in a column are not significantly different at $p < 0.05$; [HSD] Tukey's honestly significant difference

Table 5. Correlation between grafter's age, grafting experience, shade, and avocado graft take.

Factor	r-Fuerte	r-Hass
Grafter's age	–0.5131 (0.0103)	–0.3025 (0.1508)
Grafter's grafting experience	–0.451 (0.0270)	–0.255 (0.2293)
Shade	0.8884 (0.001)	0.8893 (0.001)

[r] correlation coefficient; values in parenthesis are p-values at < 0.05

In the Fuerte cultivar, grafters' age and grafting experience significantly correlated with GT. However, the grafter's age and grafting experience did not significantly correlate with GT in the Hass cultivar. The grafting experience, cultivar, and shade interaction significantly affected GT (Table 4). The two (scions) cultivars did not respond to grafting under no-shade conditions. The Fuerte scion responded best when grafted by grafter A in traditional and enhanced shade conditions. Aside from the graft results of A and B, none of the cultivars responded well to grafting under the conventional (50%) shade conditions.

Avocado GT is significantly influenced by grafters' grafting (job) experience. Additionally, avocado cultivars differ in their responses to GT. In general, the Hass cultivar recorded lower GT compared to the Fuerte. This indicates that the Hass is a more difficult-to-graft cultivar than the Fuerte. Results from this study showed that a grafter's experience significantly affects GT. This result agrees with those of Akinnifesi *et al.* (2008) and Mng'omba *et al.* (2010), who reported that graft success depends on grafters' skills and the size of the rootstock, which was uniform under this study. This was because there was the need to skillfully align parenchymatous tissues of both scions and rootstocks (Pina and Errea 2005), which was likely to be low among many unskilled grafters.

Mng'omba *et al.* (2010) pointed out that as inexperienced grafters gained grafting experience, their GT increased with time. In this study, however, GT was not consistent with the grafter's age and experience. From this study, the 41-yr-old grafter with 13 yr of grafting experience was more productive and skillful than the 58-yr-old grafter with 38 yr of grafting experience.

Grafting experience regarding the number of years of service showed a significant positive moderate association with GT for the Fuerte cultivar. However, the weak inverse association of grafting experience with GT was not significant in the Hass cultivar. This may be because the Hass variety might be difficult to graft (Mckenzie *et al.* 1988; Rodrigues *et al*. 1960), which is attributable to the thicker bark of its scions (Goldhamer *et al*. 2005; Lahav and Kushnir 2017; Wu and Ferguson 2018; Sievert 2019). Length of service (grafting experience) and age of the grafters did not consistently correlate with graft success for the two cultivars. From the correlation result, it could be inferred that the grafting experience and age of the grafters provided little information to explain the cause of graft failure and inconsistency, especially in the Hass cultivar.

The age of nurserymen (grafters) was significant and showed a weak inverse association with GT for the Fuerte cultivar. This observation was not significant in the Hass cultivar. The result of this study showed that GT might be associated with the alignment of scion-rootstock unions, which has been reported earlier by Simons (1987) and Mng'omba *et al.* (2010). The grafter's experience may range from accuracy to absolute precision in inserting the scion into the rootstock. GT is determined by properly aligning the scion with the rootstock (Pina and Errea 2005); hence, the grafter may be experienced, but graft failure will still occur if the scion is not thoroughly and precisely inserted.

Providing saplings with poor or no shading reduced GT. It was evident that saplings that were not shaded showed no graft success. This observation is possibly due to elevated temperature induced by high sunlight. The incidence of high sunlight, which induced high scion desiccation, might have resulted in the scion's eventual death. However, increasing the intensity of shade increased the GT of avocado. When the regular conventional shade was adjusted to 70%, GT increased by 15%. The result of this study is in line with the report by Saharjo and Litz (2005) that graft success in Hass avocado was found to be high when 75% shade was provided.

The findings of Vu *et al*. (2013) further show that graft success declines with an increase in temperature induced by high sunlight. Keeping avocado saplings at low temperatures (reduced sunlight) between 15–20 °C during healing and recovery increases graft take (Nordey *et al.* 2020). Palm fronds, traditionally used for shade, usually dry out with time, which consequently becomes inadequate in reducing the temperature for saplings. In contrast to the use of ineffective palm fronds, the shade net is more dependable for providing adequate and sustainable shade for saplings.

CONCLUSIONS

The grafting experience of the nurseryman, coupled with an enhanced shade, improves the graft success of avocados. Some grafters are more efficient than others, indicating that grafting experience is not homologous with efficiency. A nurseryman may be experienced in grafting but not efficient or skillful. Because of this, such efficient grafters should be selected and assigned to important grafting duties. However, cultivars respond differently to GT, and as such, the grafter requires extra tact, patience, and precision to enhance GT. Also, the traditional shade is not adequate in supporting avocado graft success; hence, the traditional shade should be replaced with a shade net, which can provide 70% shade.

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