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Proceeding Paper

Evaluating Seven Macadamia Seedling and Cutting Rootstocks for Their Effect on Scion Growth †

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Abstract: This study evaluated the variability of seven seedling and cutting rootstock genotypes of macadamia for their effect on scion growth. Scion height varied from 384 cm to 524 cm in cutting and 378 cm to 450 cm in seedling rootstocks. This difference was minimal at an early age (year 1–3) while being statistically significant at year 4. A highly significant positive correlation was identified between grafted and ungrafted rootstocks for canopy area (r = 0.81, $p < 0.001$) while scion height correlated moderately with rootstock height (r = 0.36, $p < 0.001$). A wider genetic range is possibly required to be studied for precise conclusions.

Keywords: macadamia; vigour; rootstock; scion; propagation; seedling; cutting

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1. Introduction

Large tree size is one of the key obstacles to building an efficient orchard system of macadamia (*Macadamia integrifolia*, *M. tetraphylla*, and hybrids). Vigorous trees restrict high-density planting in commercial orchards and limit tree productivity due to intra-tree resource competition [1]. The introduction of vigour-reducing rootstocks in many horticultural crops has largely contributed to high planting density, better yield per hectare and, therefore, higher profitability for growers [2]. As a part of a dual plant system, rootstocks translocate water and nutrients [3] to the aboveground scion and thereby regulate resource supply for the growth and development of vegetative and reproductive parts. Rootstocks with strong root systems are known to provide resistance to several biotic and abiotic factors and increase adaptability to adverse environmental conditions [4]. Thus, rootstocks in tree crops like macadamia play a vital role in crop growth and vigour.

Commercial macadamias in Australia are mostly propagated through grafted seedlings, while cutting (clonal) rootstocks are rarely used [5]. Seedling rootstocks are mostly preferred because of their quality root systems and ease of production in comparison to clonal rootstocks [6]. 'H2' seedlings have been the most preferred rootstock for propagation methods in Australia since the early 1990s [7] due to their uniformity and thick stem diameter, which allows rapid graft formation [8]. However, seedling rootstocks are seen to influence tree nutrition, which eventually leads to variations in tree size and vigour of grafted orchards [9]. This variation can be reduced by clonal rootstocks—a method thought to be more effective and cost-efficient for rapid rootstock propagation [6]. The clonal rootstock of a hybrid cultivar, 'Beaumont', has been preferred in South Africa due to its high strike success and vigorous nursery growth [10]. However, one study reported that trees propagated through cutting rootstocks are vulnerable to strong wind [6]. Identification of rootstocks contributing to improved productivity and resilience to biotic and climatic factors is important for industry expansion.

Studies on rootstock propagation methods and their effect on scion growth in macadamia are limited. In a concurrent study by Alam et al. [11], 29 rootstock genotypes of macadamia were studied and compared for early nursery growth in both seedling and cutting rootstocks. In another study, Neal et al. [7] studied 12 macadamia cultivars and identified no significant interaction between rootstock genotype and propagation methods for tree height. Another study that evaluated the performance of seedling and cutting rootstocks found no significant variation in tree size due to the rootstock effect, although a significant scion effect was identified [12]. This preliminary study, therefore, aimed to identify the variation in growth traits and growth rates of a common scion due to the effect of seedling and cutting rootstocks of seven macadamia genotypes.

2. Materials and Methods

2.1. Rootstock Types and Plantation

Seedling and cutting rootstocks of seven macadamia genotypes ('A268', 'A4', 'BHI1', 'BHY1', 'Beaumont', '842' and 'H2') were selected from an existing macadamia rootstock trial planted in 2017 at the Maroochy Research Facility, Queensland Department of Agriculture and Fisheries Nambour QLD [13]. A common scion 'HAES 741' was grafted onto the rootstocks. Both grafted and ungrafted trees, planted side by side, were evaluated for this study.

2.2. Phenotyping

Phenotyping was performed for Scion height (ScHGT) and canopy area (CA). These traits were measured for 5 years following tree establishment.

Growth rates (*GR*) for each parameter over 5 years were calculated using the following formula:

$$GR = \frac{dx}{dt} \tag{1}$$

where *GR* = growth rate, *dx* = difference in growth over *dt* and *dt* = time between measurements (in days).

2.3. Statistical Analysis

Growth parameters were analysed using an REML (restricted maximum likelihood) mixed model in Genstat-21 [14]. A combined analysis of seedlings and cuttings was performed for growth traits. Analysis of growth rates included combined and separate seedling and cutting analyses. Phenotypic correlations between grafted scion and ungrafted rootstock traits were estimated.

3. Results and Discussions

3.1. Effect of Rootstocks on Variability in Growth Traits

A combined analysis of both seedling and cutting rootstock effect showed no significant variation between rootstock genotypes for ScHGT and CA, while a significant variation between seedlings and cuttings for ScHGt was identified in Y4 (Table 1)—cuttings had higher average ScHGT than the seedlings of most genotypes, except for 'A4' (Figure 1). For cuttings, 'A4' (384 cm) had the lowest ScHGT, while 'H2' (524 cm) had the highest values. Similarly, in seedlings, ScHGT varied from 378 cm to 450 cm, with 'BHI1' and 'A4' having the highest and lowest values, respectively. No significant variation between rootstock genotypes and types for CA was observed.

Table 1. F probabilities from REML mixed model analysis of growth traits (Age4) of seedlings and cutting rootstock effects.

Components	ScHGT	CA
Genotype	0.365	0.353
Type (Seedling vs. Cutting)	0.025	0.196
Genotype × Type	0.15	0.342

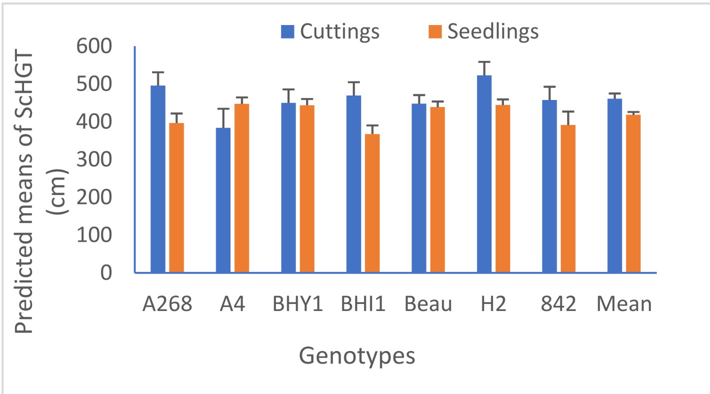


Figure 1. Effect of rootstock propagation types and genotypes on variability in scion height. Error bars show the standard errors (SE) of each mean. Mean bars on *x*-axis show average values across the genotypes.

Similarly, no significant variations for rootstock effect on ScHGT were observed in early ages (Y1–Y3) (data not shown), while the effect was significant at Y4. In a similar trial of 12 cultivars grafted as clonal and seedling rootstocks, Hardner and McConchie [12] found no significant effect of rootstocks on field growth in 2-year-old trees. These findings, along with the result of the current study, suggest that the rootstock effect on scions may not become apparent until later stages of maturity.

3.2. Effect of Rootstocks on Variability in Growth Rates

Initial combined analysis of seedlings and cuttings identified a significant variation between propagation types for GR (Y0-Y4) of ScHGT and CA (Table 2). Cuttings had a higher average GR for ScHGT and CA than seedlings (Figure 2). A significant Genotype X Type interaction existed for rootstock effect on GRCA. In terms of the genotypes 'A268', 'BHI1', 'Beau' and 'H2', cuttings had higher GRCA than their respective seedlings. Inversely, seedlings of 'BHY1', 'A4' and '842' had higher GRCA than cuttings (Figure 2b).

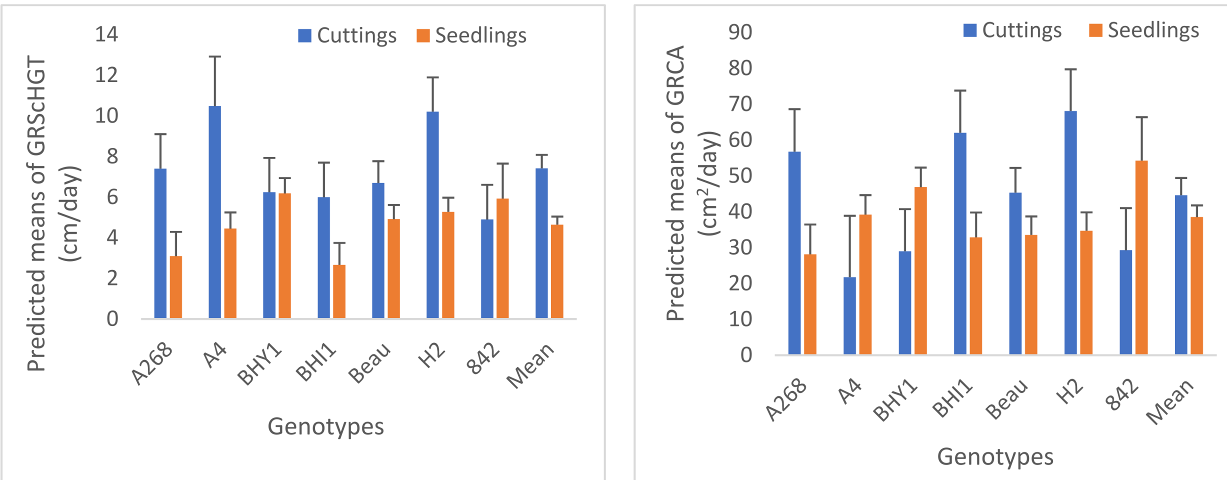
This result is in contrast with several other findings, which indicate that scions grafted on seedling rootstocks grow to be more vigorous than those on cutting rootstocks [6,12,15,16]. Conversely, a pairwise comparison of seedling and cutting rootstocks of 19 genotypes by Alam et al. [11] on early nursery growth reported similar results where relative growth rates for height and diameter of cutting rootstocks were higher than those of seedling rootstocks. The contrasting results could be due to the difference in genotypes selected for each study. Cutting propagated rootstocks in this study consisted of superior genotypes like 'Beaumont' and 'A268' with superior strike rate, growth rate and growth budding success when propagated as cuttings [12], while the seedlings were open-pollinated progeny and may have shown variability due to the differences in pollen source. The significant Genotype X Type interaction, showing higher GR for cuttings of 'Beaumont' and 'A268', also justifies this contrasting result.

No significant variation between rootstock types and genotypes for GRScHGT and GRCA was observed in the first three consecutive years of measurement (data not shown). This study identified that growth rates measured over one year did not vary significantly between seedling and cutting rootstocks, while a significant difference was observed when a large gap of Y0–Y4 was considered. This again suggests that the rootstock effect on scion growth due to propagation type may not be visible at an early age and requires a longer period of growth to be evaluated. Further monitoring over the coming years is required to reach a more accurate conclusion.

A separate analysis of each propagation type showed no significant difference within seedling and cutting genotypes for growth rates (Table 2). This non-significant variation among the genotypes could be because the genotypes do not represent a large range of vigour. As this study did not use any dwarf genotypes, the inclusion of those genotypes to increase the range of genetic material could better help to understand any variation between genotypes, if it exists.

Table 2. F probabilities from REML mixed model analysis of growth rates (Y0–Y4) of seedling and cutting rootstocks effect.

Components	Seedlings vs. Cuttings		Seedlings Only		Cuttings Only	
	GRScHGT	GRCA	GRScHGT	GRCA	GRScHGT	GRCA
Genotype	0.337	0.957	0.526	0.212	0.682	0.324
Type (Seedling vs. Cuttings)	<0.001	0.036	-	-	-	-
Genotype × Type	0.214	0.015	-	-	-	-



(**a**) (**b**)

Figure 2. Effect of rootstock propagation types and genotypes on variability in growth rates (Y0—Y4). (**a**) Growth rate scion height. (**b**) Growth rate of canopy area. Error bars show the standard errors (SE) of each mean. Mean bars on *x*-axis show averages across genotypes.

3.3. Phenotypic Correlation between Ungrafted and Grafted Rootstock Genotypes

To investigate the transmission of trait expression from rootstock to scion, we conducted phenotypic correlations between scion growth traits with that of ungrafted rootstocks of the same genotype. A strong positive correlation (r = 0.81, $p < 0.001$) was identified between grafted scions and ungrafted rootstocks for CA (Table 3). Rootstock heights of ungrafted genotypes were positively and moderately correlated with scion heights of the grafted ones (r = 0.36, $p < 0.001$). This shows that rootstock vigour is closely related to scion vigour. Thus, a scion grafted onto a vigorous rootstock is likely to grow to be vigorous, and a selection of rootstocks can be made accordingly. This has been widely studied and identified in many other horticultural crops [17]. However, this study consists of a single scion grafted onto all rootstock genotypes. Hence, a large combination of different rootstock and scion cultivars is recommended for further studies.

Table 3. Pearson's phenotypic correlations of growth parameters between grafted and ungrafted rootstock genotypes.

	Canopy Area-Ungrafted	Scion Height-Grafted
Canopy Area-Grafted	0.81 ***	-
Rootstock Height-Ungrafted	-	0.36 ***

*** $p < 0.001$.

4. Conclusions

This study found a significant variation in the effect of rootstock types (seedlings and cuttings) on scion vigour. Scions grown on cutting rootstocks were generally more vigorous than those on seedling rootstocks. Results here also indicate that the rootstock effect on scion growth is likely to become more apparent with greater tree maturity. In addition, a strong positive relationship between grafted and ungrafted rootstock genotypes for scion height indicate that scion vigour can be predicted from the vigour of the rootstocks. Since this study was limited to a few genotypes, investigating a more diverse range of germplasm and assessing growth until later stages of maturity are required for improved accuracy in future studies.

Supplementary Materials: The poster presentation can be downloaded at: https://www.mdpi.com/article/10.3390/IECPS2021-12040/s1.

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