The effect of propagation media and growth regulars on rooting potential of Kei apple (*Dovyalis caffra*) stem cuttings at different physiological ages

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Abstract: Kei apple (*Dovyalis caffra*) is a recent commercially promising indigenous fruit tree, but there is no documented literature on its propagation and germplasm management. This study was carried out to determine the best growth regulator, growing medium and cutting age on successful rooting of its stem cuttings under non-mist nursery conditions. The experiment was laid out as a 5 x 3 x 3 split plot factorial design. The three factors tested were (i)four growth regulators (Dynaroot 1, Dynaroot 2, Dynaroot 3, and Dip'n root) plus the control, (ii) three rooting media (River sand= SND, Commercial rooting media- hygrotex (CRM) and manure-ammended soil 50:50 v/v (M+S) and (iii) three stem cutting types (soft wood cuttings, semi-hard wood cuttings and hardwood cuttings. Parameters recorded were percent rooting, root length (cm) and root number. The effect of cutting type and growth regulator was highly significant (<0.0001). Soft wood cuttings did not produce any roots. There were significant differences between hardwood cuttings and semi hardwood cuttings where the former gave the higher rooting percent. The highest rooting percent and root length were obtained where cuttings were treated with Dip'n root. Dynaroot 3 gave the highest number of roots. There were no significant differences among the three media. However visual assessment showed that SND performed better, followed by M+S and then CRM. The treatments interacted significantly to affect the results. Dip'n root was identified as the best rooting enhancer and and hardwood cutting as the best cutting type for successful rooting of *D. caffra* cuttings.

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1. Introduction

Dovyalis caffra belongs to the family of *Flacourtiaceae* which consists of woody plants of more than 30 tree species commonly known as the apricot family (Van Wyk & Van Wyk., 1997). It inherited its name from its place of origin, the Kei River in the Eastern Cape, South Africa (Hacker, 2003). *D. caffra* is a heavily branched shrub that grows up to 9 meters tall with long sharp thorns which are few on the main stem and more on side branches. Its leathery and glossy leaves are arranged in clusters along the branches (Morton, 1987; Hacker, 2003; Van Wyk & Van Wyk, 1997). The stem is either single, several or multiple and is characterized by a greyish smooth bark which eventually becomes dark, deeply cracked and corky with age. (Palmer, 1977). The male and female flowers are borne on separate plants (Van Wyk & Gericke, 2000; Hacker, 2003). The flowers have no petals (Van Wyk & Van Wyk, 1997). Its fruits are nearly rounded and yellowish in color. They have a tough skin and apricot textured, acidic flesh with 5-15 seeds arranged in a double ring in the centre (Loots *et a*l., 2006).

Propagation of *D. caffra* is normally by seeds (Bujulu & Mkenda, 2002). This is because seeds germinate readily and propagation by seeds is much simpler compared to vegetative propagation. However, there are challenges that are associated with propagation of *D. caffra* by seeds. Plants that are propagated by seeds take two or more years before flowering compared to where vegetative propagation was used (Joyner, 2002; Jooste, 2004). The other challenge in sexual propagation of *D. caffra* is that seeds loose viability after a very short period of time.

Vegetative propagation by stem cuttings could help meet the current and future seedling demand of *D. caffra*. It could also act as an alternative to counteract challenges posed by storage behavior (recalcitrant). This approach of plant propagation is not a new concept as it has been extensively used in the field of biotechnology (Leakey *et al*., 1982b). Plant breeders prefer propagation by stem cuttings as it is economical, rapid, and simple and requires less space. The use of stem cuttings in propagation makes it possible to propagate young trees, which have not yet produced flowers (Hartmann *et al.*, 1997; Welch-Keesey & Lerner, 2002). The positive role vegetative propagation plays in the domestication of crops has been previously highlighted (Tchoundjeu *et al*., 2004; Awono *et al*., 2002; Leakey, 1985). However, successful rooting necessitates a propagation environment that keeps physiological stress at minimum levels (Leakey, 2004, Leakey *et al*., 1982a). Many systems ranging from sophisticated to simple and inexpensive locally developed propagators can be successfully used

(Leakey *et al*., 1990; Jeruto *et al*., 2008). Although some studies show that other tree species root without use of growth regulators (Trueman *et al*., 2006), the potentiality of stem cutting to root is also dependent on the use of root stimulators (Leakey *et al*, 1982b; Shiembo *et al*., 1996; LaPierre, 2001; Ozel *et al*., 2004; Blythe *et al*., 2004).

The other factor which creates a suitable environment for rooting of stem cuttings is the propagation medium (Laubscher & Nadakidemi, 2008). Other studies (LaPierre, 2001; Puri & Verma 1996; Kibbler *et al*., 2003; Negash, 2002; Agbo & Obi, 2007; Ozel *et al*., 2004) show that the physiological age of cutting should also be considered for successful root formation. There is a speculation that softwood and semi hard wood cuttings are the most likely to develop roots while hardwood cuttings are less likely (Welch-Keesey & Lerner, 2002) .The effects of all these factors (rooting media, rooting enhancers and type of stem cutting) are not known in the production of seedlings for this tree. The aim of this study is therefore to determine the effects of rooting enhancers, type of stem cuttings and growing media on rooting success of *D. caffra* stem cuttings.

2. Materials and Methods

Source of stock plants and propagators

Stock plants of cuttings were obtained from *D. caffra trees*, which are grown as a hedge at a location in Mafikeng town (25º51S´ 25º38 E´-25.85, 25.633). The cuttings were taken to a greenhouse at the Northwest University Farm (Molelwane). The planting stock was obtained from both male and female trees. Male plants were determined by the absence of fruits while females were determined by presence of fruits. From the planting stock, 10 cm cuttings were prepared using the procedure of Brown (2002). A flat cut was made at the base and an angled one above the node. Well drained plastic trays (100 x 100 cm and 8cm high) with holes at the bottom to allow adequate drainage were used as propagator (Badji *et al*., 1991). Four trays were put together and considered as the main plots while a single tray was considered to be a subplot.

Effect of propagation medium on rooting of D. caffra stem cuttings

The influence of propagation medium on the rooting success of *D. caffra* cuttings was determined by using River sand (RSND), Commercial Propagation medium (Hygrotex T^+ (CPM) and manure-amended soil (M+S) (50:50 by volume). The planting material was collected at different physiological ages of growth (softwood, semi-hard wood and hardwood). Softwood cuttings were taken from parts of the tree where the wood was still relatively soft, succulent and the wood had not yet lignified. Semi-hardwood cuttings were taken from parts of the tree where the lower portion of the cutting had lignified. They were taken three weeks after collection of softwood cuttings. Hardwood cuttings were taken from fully matured or where the entire stem had lignified (Hamilton and Midcap, 1981). Cuttings were then grouped according to physiological age and wrapped with a wet paper towel and put in black plastic bags (Agbo & Obi, 2007)

Effect of growth regulators on rooting of D.caffra stem cuttings

To determine the effects of growth regulators on rooting success of the cuttings, four different regulators in different forms (Dyna root 1, 2, 3 (powder form) and Dip 'n root (liquid) (Kibbler *et al,* 2004) were used. All growth regulators were prepared using the dilute soaking method of Hamilton and Midcap (1981). A concentrated solution of each growth regulator in alcohol was prepared by mixing 500 ppm of growth regulators (except Dip 'n root) to 10,000 ppm of alcohol. Dynaroot was prepared by mixing 10 ml with 10 drops as outlined in the manual. The basal ends (lower 1cm) of the cuttings were dipped in the solution according to treatment for 24 hours. Untreated cuttings were used as a control.

Data collection

Percent rooting success (take) was determined by using the formula of Brown (2002) as follows: % T = N /n x 100, where: T = % take or rooted cuttings, N = number of successful cuttings, n = total number of cuttings planted. Root length was measured with a ruler while number of roots was by direct counting. Composition of each rooting hormone used is shown in Table 1.

Experimental design and data analysis

The experiment was set as a splitplot with four replications. In each main plot there were three propagation media such that there were 12 cuttings per propagation medium. At sub-plot level four growth regulator treatments with the control were applied to different stem cutting types and were allocated at random to each plot. A 5 x 3 x 3 factorial combination of four growth regulators plus control, three propagation media and three cutting physiological ages were used. All data collected was subjected to Analysis of variance using Statistical Analysis System (SAS) program (SAS Institute., 1985). Mean separation was performed by using Tukey's Test.

3. Results

The effect of cutting type on rooting, root length and root number of stem cuttings is presented in Table 2. The basis of classification of these cuttings was age. Data recorded from this experiment indicated that root formation of *D. caffra* stem cuttings was dependent on age of the cuttings. None of the softwood cuttings produced root regardless of growth regulator or propagation medium used. Rooting occurred where semi-hardwood and hardwood cuttings were used. High significant differences (P<0.0001) were recorded between the rooting capacity of these two cutting types. Hardwood cuttings yielded the highest rooting percent which was 73 % higher than that of semi-hardwood cuttings. The cutting type affected root length significantly. With an increase in the age or growth stage there was an increase in root length. There were high significant differences (P<0.0001) due to cutting age on root length recorded. Maximum root length (12±0.6cm) was recorded where hardwood cuttings were used. Number of roots per rooted cutting differed among the cutting type used. Hard wood cuttings produced in the highest number of roots (1.8 ± 0.1) which was significantly higher (P<0.0001) than that of semi-hardwood cuttings.

The effect of growth regulator on rooting percentage, root length and root number of *D. caffra* cuttings is shown in Table 3. The growth regulator used was identified in this experiment as an important factor that influences rooting percent of cuttings. There were significant differences (P<0.0001) between the performances of different growth regulators. However, Dynaroot 1 and 2 did not show any significant differences (P<0.001) in their ability to influence rooting. Cuttings rooted better (62.6 ± 2.9 %) when Dip 'n root was used compared to all other growth regulators. The second best rooting was Dynaroot 3 and Dynaroot 2. The lowest rooting percentage (27.5±2.9) was produced by Dynaroot 1 but it was significantly different (P<0.0001) from the control

The cutting type affected root length significantly. With an increase in the age or growth stage there was an increase in root length. There were high significant differences (P<0.0001) due to cutting age on root length recorded. Maximum root length (12±0.6cm) was recorded where hardwood cuttings were used. Number of roots per rooted cutting differed among the cutting type used. Hard wood cuttings produced the highest number of roots (1.8 ± 0.1) which was significantly higher (P<0.0001) than that of semi-hardwood cuttings. Root length responded to growth regulator treatments. There were no significant differences (P<0.0001) between cuttings treated with Dynaroot 1, Dynaroot 2 and the control. However root growth was more (23.4 ± 0.9 cm) where Dip 'n Root was used which was highly significant comparatively (Fig 1). The second in performance in root length (11.9 ± 0.9 cm) was associated with Dynaroot 3 which was significantly different from the other two growth regulators and the control. Root number did not respond well to the use of different growth regulators. There were no significant differences (P<0.0001) observed between the capability of Dynaroot 1, Dynaroot 2, Dip 'n Root and the control for root number per rooted cutting. The only obvious significant difference compared to the control was for Dynaroot which gave the highest root number (3.3 ± 0.2).

The results of this experiment also indicated that propagation media used did not affect rooting percentage (Table 4) There were no significant differences (P<0.0001) among propagation media treatments. Propagation media used also did not show any effect on root length and number of roots (Table 4). Interactive effect of cutting type x growth regulator on rooting percentage, root length and root number was not significant. Generally, hardwood cuttings rooted better than semi-hardwood cutting inspite of the rooting growth regulator used. The highest rooting percentage on SND where hardwood cuttings were used whilst the lowest rooting percentage was obtained from CPM on both hardwood cuttings and semi-hardwood cuttings. Even though there is evidence of differences in percent rooting due to cutting x propagation medium interaction, statistically, there were no significant differences due to this interaction (P<0.0001). The highest number of roots and the longest roots were obtained with the use of CPM in all growth regulators used. These effects however were still not significantly different (P<0.0001). Where regulator treatments were not applied (control), the highest number of roots was obtained in semi-hardwood cuttings. Statistically, there were no significant differences observed between the cutting type x propagation medium interaction (P<0.0001). Nevertheless, Fig 2 shows that the best rooting percent was obtained where cuttings were rooted in SND. The performance of Semi-hardwood cuttings in SND was however not significantly different from that of S+M. In general terms the superior performance was obtained when hardwood cuttings are rooted in SND. The interaction between root number and root length was not significant but when hardwood cuttings are rooted in CRM the highest root number and root length were obtained.

Propagation media x regulator interaction had a significant effect (P<0.05) on percent rooting and number of roots per rooted cutting but not on root length (Fig 2). In general terms, Dip 'n root produced superior rooting where hardwood cuttings were used. The performance of Dip 'n root was exceptionally high in all growing media. The use of Dynaroot 3 resulted in similar rooting percent in all three rooting media treatment. On the other hand, Dynaroot 2 outperformed Dynaroot 3 where M+S and SND were used. Dynaroot gave the lowest rooting percent in all three cutting types but comparable with the control. Root number was at its highest where cuttings were treated with Dip and root and rooted in SND and CPM while M+S gave the poorest root length. Growth regulator x propagation medium x cutting age interaction was significant

($P<0.0001$) on rooting percentage (Table 5). Hardwood cuttings showed a greater rooting capacity (83.3 ± 6.9%) when treated with Dip and Root and rooted in SND. This was followed by semi-hardwood cuttings (80.0 ± 6.9%) treated with the same growth regulator but rooted CPM. The other exceptional rooting capacity (71.67 ± 6.9%) was recorded where hardwood cuttings were treated with Dynaroot 3 and rooted in SND. The control (untreated cutting) did now respond well to media x cutting x regulator interaction. However, where hardwood cutting were rooted in SND, highly significant differences were evident ($P<0.0001$). The interactive effect of growth regulator x cutting age and propagation medium has also generally (except in very few cases) showed significant influence on number of root per rooted stem cutting of Kei apple. Table 6 shows that the highest root number (4.0±0.44) was recorded where semi-hardwood cutting were treated with Dip and root and rooted in SND. This was followed by 3.7±0.44 which was obtained where hardwood cuttings were rooted in SND. Table 7 shows that significant interaction was also recorded on root length due to the rooting media, cutting type and growth regulator used. In this case, the highest root length was observed where hardwood cuttings were treated with Dip and root and rooted in CPM.

4. Discussion

Vegetative propagation of *D. caffra* by stem cuttings was achieved after five months. The results of this experiment show the possibility of successfully propagating *D. caffra* by stem cuttings. Non-mist technology has been identified as the cheapest technique that poor farmers can adopt in their plant propagation activities (Leakey *et al*., 1990). In this research, the cutting type was based on the age or stage of maturity of the cuttings. The cutting type has been identified as an important factor, which influences rooting capacity of stem cuttings. Hardwood cuttings rooted more than semi-hardwood cuttings, while softwood ones failed to root at all. There is quite a lot that has been done on the effects of cutting age on rooting of stem cutting. Kibbler *et al.* (2003) and Shah *et al*. (2006) studied the effect of stock age on rooting ability of *Backhousia citridora* and found significant effects due to this factor. However, their results do not agree with that obtained in this study as in their case younger stock rooted more than the mature one. This could have been due to differences in species.

The effect of stock age was also studied by Puri & Verma (1996); Shah et al., 2006 and Kibbler *et al.* (2003). From their studies, they concluded that hardwood-cuttings root better than softwood cuttings. The variation in rooting potential of cuttings as influenced by cutting age is attributed to differences in physiological nature. Softwood cuttings may root fast in certain species but they do not have enough material stored. Hardwood cuttings on the other hand have enough stored foodstuffs to sustain cutting for a long period of time. Softwood cutting may have failed completely due to their being more prone to desiccation.

With reference to the composition of rooting enhancers used in this experiment, it is clear that the only difference between Dynaroot 1, Dynaroot 2 and Dynaroot 3 is the concentration of IBA (Table 1). Dip 'n Root differs from the other three because it contains IBA and NAA. When comparisons are made between Dynaroot 1, Dynaroot 2 and Dynaroot 3, there is evidence of an increase in rooting percent with an increasing concentration of IBA. Results obtained in this study were also reported by Mensèn *et al.* (1997). These results agree with those of Blythe *et al*. (2004) who obtained similar results where stem cuttings of *Ficus benjamina* and *Gardenia augusta* were used in percent rooting, root number and root length. On the contrary, where they used *Agloamena modestrum* cuttings, rooting success increased with increasing concentration of IBA, but there was no trend experienced in root number and root length.

The study of Ibanèz-Torres (2004) also showed that the use of NAA other than IBA resulted in increased rooting percent, root number and root length. The results of this study were similar to those reported by Ibanèz -Torres (2004). There were highly significant differences in root length due to the use of Dip 'n Root. This could be attributed to the presence of NAA in Dip 'n root. This behavior suggests that when rooting enhancers are used in vegetative propagation of *D. caffra,* the growth regulator should contain both IBA and NAA. This study showed that rooting medium affected rooting ability of *D. caffra* stem cuttings. Even though statistically there was no significant difference ($P<0.0001$) in rooting percentage, due to growing medium, SND gave the best performance. This agrees with the study of Atangana *et al*. (2006) whose results indicated that SND did better than saw dust. The interactive effect of enhancer composition and cutting type had a significant influence on rooting of *D. caffra* cuttings. This suggests that the two factors are important in maximizing rooting capacity in vegetative propagation by stem cuttings. Likewise the interaction between cutting type and rooting media should not be overlooked. It was recorded in this trial that this interaction had a significant effect on rooting of stem cuttings. Generally the best rooting percentages were obtained with hardwood cuttings were rooted in SND. On the contrary, root number and root length were greater where hardwood cuttings were rooted in CPM.

Medium x regulator x cutting age interaction is another contributor on rooting success of *D. caffra* cuttings as evidenced in this study. The highest performance in rooting percentages, root length and root number due to this interaction was observed where hard wood cuttings were treated with Dip ‘n Root. The interaction between propagation medium, growth regulator and cutting age affected rooting percent, root length and root number significantly. In general terms percent rooting, root length and root number was superior where hardwood cuttings were treated with Dip ‘n Root and rooted in RSND. This indicates that all the three factors have to be given consideration for successful rooting of stem cuttings.

5. Conclusions

The results of this research show that if vegetative propagation is to be used in the domestication of *D. caffra*, the best rooting media is river sand (RSND). The choice of a good rooting enhancer is very important especially as there is a wide array of rooting hormones in the market. The other factor of major importance in rooting of stem cuttings is the age of cuttings. Hardwood cuttings are the best cuttings that can be used for rooting success in the domestication of *D. caffra*. The results of this research can also be used as a basis for propagation by stem cutting even in other tree species to meet future seedling demands.

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Table 1. A comparison showing active ingredients in growth regulators used.

Commercial name	Composition
Dynaroot 1	4-indole-3-butyric acid: 1g/kg
Dynaroot 2	4-indole-3-butyric acid: 3g/kg
Dynaroot 3	4-indole-3-butyric acid: 8g/kg
Dip ‘n root	4-indole-3-butyric acid: 10g/l + 1-Naphthy-acetic acid 5g/l

Source: PBR Int. Trading (1947) & Efekto Trading (2006)

Table 2. Effect of cutting type on percent take, root length and number of roots on *D. caffra* stem cuttings.

	Parameter		
Cutting type	**Take (%)**	**Root length (cm)**	**Number of roots**
Softwood	0	0	0
Semi hard wood	28.2 ± 1.8^{a}	7.4 ± 0.6^{a}	1.4 ± 0.1^{a}
Hardwood	49.0 ± 1.8^{b}	12.1 ± 0.6^{b}	1.8 ± 0.1^{b}

Values are means ± S.E (n=180); Values in the same column bearing the same letter are not significantly different according to Tukey’s Test.

Table 3. Effect of growth regulators on rooting percent, root length and number roots on *D. caffra* stem cuttings.

	Parameter		
GrowthRegulator	Take (%)	Root length (cm)	Number of roots
Control	11.4 ± 2.9^{a}	2.9 ± 0.9^{a}	1.0 ± 0.2^{a}
Dynaroot1	27.5 ± 2.9^{b}	3.1 ± 0.9^{a}	1.6 ± 0.2^{a}
Dynaroot 2	43.3 ± 2.9^{c}	7.5 ± 0.9^{b}	1.7 ± 0.2^{a}
Dynaroot 3	48.3 ± 2.9^{c}	11.9 ± 0.9^{c}	3.3 ± 0.2^{b}
Dip ‘n root	62.5 ± 2.9^{d}	23.4 ± 0.9^{d}	1.0 ± 0.2^{a}

Values are means ± S.E (n=180); Values in the same column bearing the same letter are not significantly different according to Tukey’s Test.

Table 4 Effect of propagation medium on percent take, root length and number of roots on *D.caffra* stem cuttings**.**

	Parameter		
Propagation media	**Take (%)**	**Root length (cm)**	**Number of roots**
M+S	39.8 ± 2.2^{a}	9.0 ± 0.7^{a}	1.5 ± 0.1^{a}
CPM	34.6 ± 2.2^{a}	10.6 ± 0.7^{a}	1.8 ± 0.1^{a}
SND	41.3 ± 2.2^{a}	9.8 ± 0.7^{a}	1.6 ± 0.1^{a}

Values are means ± S.E (n=180); Figures in the same column bearing the same letter are not significantly different according to Tukey’s Test.

Table 5 Interactive effect of growth regulator, propagation medium and cutting age on root number of rooted stem of *D. caffra* stems cuttings.

Root number ± SE

Cutting type	GR	M+S	CPM	SND
Semi-hardwood	Control	1.0 ± 0.44*	0.7 ± 0.44^{ns}	0.3 ± 0.44^{ns}
	Dyna root 1	1.0 ± 0.44*	0.7 ± 0.44^{ns}	0.7 ± 0.44^{ns}
	Dyna root 2	1.0 ± 0.44*	2.0 ± 0.44*	1.0 ± 0.44*
	Dyna root 3	1.7 ± 0.44*	1.0 ± 0.44*	1.0 ± 0.44*
	Dip 'n root	1.7 ± 0.44*	3.7 ± 0.44***	4.0 ± 0.44***
Hardwood	Control	0.7 ± 0.44^{ns}	1.0 ± 0.44^{ns}	1.3 ± 0.44^{ns}
	Dyna root 1	1.0 ± 0.44*	1.0 ± 0.44*	1.3 ± 0.44*
	Dyna root 2	2.0 ± 0.44***	2.0 ± 0.44***	1.7 ± 0.44*
	Dyna root 3	2.0 ± 0.44***	2.7 ± 0.44***	2.0 ± 0.44***
	Dip 'n root	3.0 ± 0.44***	3.7 ± 0.44***	3.7 ± 0.44***

Values are means ± S.E (n=180); Values in the same column bearing the same letter are not significantly different according to Tukey's Test. M+S=Manure amended soil; CPM=commercial propagation medium; SND=sand and GR=growth regulator. ***= Significant at P< 0.001 and *=P<0.05

Table 6 Interactive effects of growth regulator, propagation medium and cutting type on rooting capacity of *D. caffra* stem cuttings.

Rooting (%) ±SE

Cutting type	GR	Propagation medium M+S	CPM	SND
Semi-hardwood	Control	10.0 ± 6.9***	11.7 ± 6.9*	6.7 ± 6.9^{ns}
	Dyna root 1	10.0 ± 6.9^{ns}	13.3 ± 6.9^{ns}	15.0 ± 6.9^{ns}
	Dyna root 2	30.0 ± 6.9***	23.3 ± 6.9***	40.0 ± 6.9***
	Dyna root 3	33.3 ± 6.9***	43.3 ± 6.9***	48.3 ± 6.9***
	Dip 'n root	65.0 ± 6.9***	43.3 ± 6.9***	30.0 ± 6.9***
Hardwood	Control	20.0 ± 6.9***	3.3 ± 6.9***	16.7 ± 6.9***
	Dyna root 1	30.0 ± 6.9***	46.7 ± 6.9***	50.0 ± 6.9***
	Dyna root 2	65.0 ± 6.9***	30.0 ± 6.9***	71.7 ± 6.9***
	Dyna root 3	61.7 ± 6.9***	51.7 ± 6.9***	51.7 ± 6.9***
	Dip 'n root	73.3 ± 6.9***	80.0 ± 6.9***	83.3 ± 6.9***

Values are means ± S.E (n=180); Values in the same column bearing the same letter are not significantly different according to Tukey's Test. M+S=manure amended soil; CPM=commercial propagation medium and SND=Sand and GR=growth regulator

Table 7 Interactive effect growth regulator, propagation medium and cutting age on root length of rooted stem cuttings of *D. caffra*

Root length ± SE (cm)

Cutting type	GR	M+S	CPM	SND
Semi-hardwood	Control	2.5±2.3^{ns}	7.6±2.3^{ns}	4.0±2.3^{ns}
	Dyna root 1	2.3±2.3***	3.3±2.3*	1.6±2.3*
	Dyna root 2	9.3±2.3*	6.2±2.3*	7.9±2.3*
	Dyna root 3	6.7±2.3*	7.5±2.3*	8.9±2.3*
	Dip 'n root	12.7±2.3***	16.8±2.3***	13.2±2.3***
Hardwood	Control	2.9±2.3^{ns}	0.5±2.3^{ns}	0.1±2.3^{ns}
	Dyna root 1	3.8±2.3^{ns}	2.5±2.3^{ns}	5.3±2.3*
	Dyna root 2	8.2±2.3*	8.7±2.3*	4.6±2.3*
	Dyna root 3	13.4±2.3***	16.3±2.3***	18.2±2.3***
	Dip 'n root	27.7±2.3***	37.0±2.3***	32.9±2.3***

Values are means ± S.E (n=180); Values in the same column bearing the same letter are not significantly different according to Tukey's Test. M+S=Manure amended soil; CM=commercial propagation medium and SND=sand; GR=growth regulator. ***= Significant at P< 0.0001 and *=P<0.05

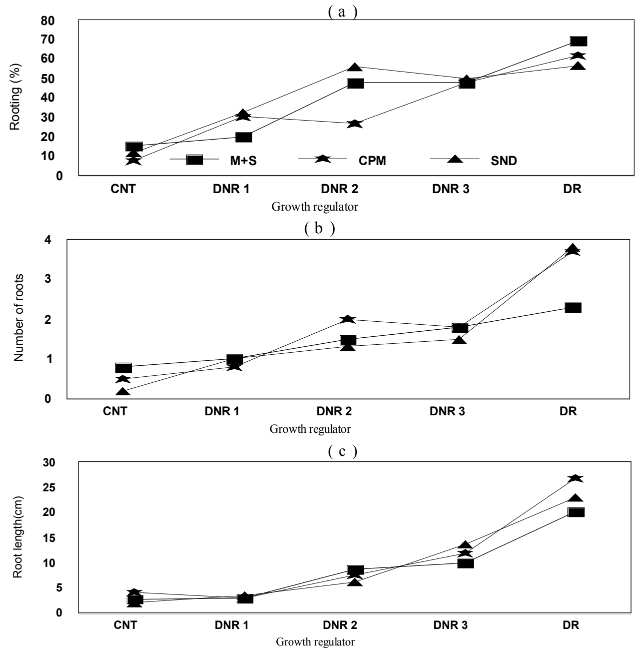

Fig 1 Interactive effect of propagation medium and growth regulator on (a) rooting percent (b) number of roots and (c) root length of *D. cafra* stem cuttings. Values are means ± S.E (n=180); M+S=manure amended soil; CPM=commercial propagation medium and SND=Sand; CNT=control; DNR 1=Dynaroot 1; DNR 2=Dynaroot 2; DNR 3 = Dynaroot 3 and DR =Dip 'n root.

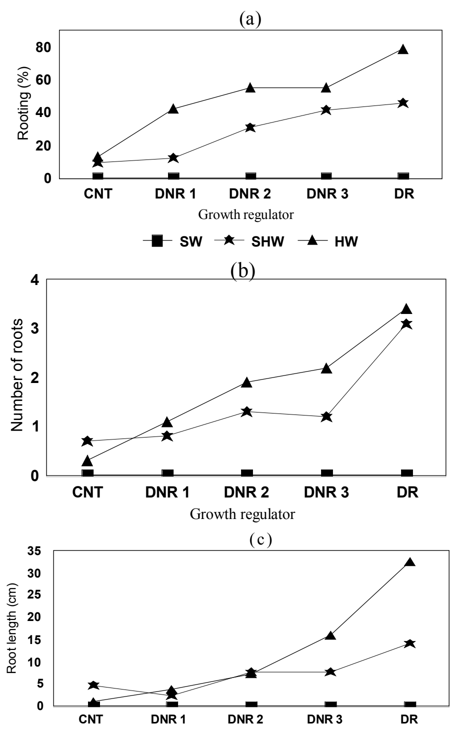

Fig 2 Interactive cutting type and growth regulator on (a) rooting percent (b) number of roots and (c) root length of *D. cafra* stem cuttings. Values are means ± S.E (n=180); SW=softwood cuttings; SHW=semi-hardwood cuttings and HW=hardwood cuttings. CPM=commercial propagation medium and SND=Sand; CNT=control; DNR 1=Dynaroo1; DNR 2=Dynaroot 2; DNR 3 = Dynaroot 3 and DR =Dip 'n root.

References

1. Agbo, C. U. and Obi, I. U., 2004. Variability in propagation Potentials of stem cuttings of different physiological ages of G*ongogromena latifolia* Benth. *World J. Agri Scie.* 3, 576 – 581.
2. Atangana AR, Tchoundjeu Z, Asaah EK, Simons AJ, Khasa DP 2006. Domestication of
3. *Alanblackia floribunda*: Amenability to vegetative propagation. *For. Ecol. Manage.* 237: 246 – 251.
4. Awono, A., Ndoye, O., Schreckenberg, K., Tabuna, H., Isseri, F. & Temple, L., 2002. Production and Marketing of Safou (*Dacryodes edulis)* in Cameroon and internationally: market development issues. For. Trees & livelihoods. 12, 125 – 147.
5. Badji, S., Ndiaye, I., Danthu, P. & Colonna, J.P., 1991. Vegetative propagation studies of Gum Arabic Trees: Propagation of *Acacia Senegal* (L) Wild. using lignified cuttings of small diameter with eight nodes. *Agrofor. Syst.* 14, 183-191.
6. Blythe EK, Sibley JL, Ruter JM, Tilt KM 2004. Cutting propagation of foliage crops using a foliar application of auxin. *Scie. Hort.* 103: 31 – 37.
7. Brown, L.V., 2002. Applied Principles of Horticultural Science. Butterworth, Heinemann. New York.
8. Brown, A.H.D. & Moran, G.F. 1979. Isozymes and the genetic resources of forest trees. Proc. Symposium on Isozymes of North American Forest Trees and Forest Insects, held at Berkley, California 27 July 1979. Pacific SW Forest and Range Expt Station, Berkley, California, USA.
9. Bujulu E, Mkenda E 2002. Propagation of Kei apple (*Dovyalis caffra* Warb.). Proceedings of the horticulture seminar of sustainable production in the tropics, 3rd to 6th October 2002. Jomo kenyatta university of agriculture and technology.
10. Hacker B 2003. Kei apple – *Dovyalis caffra* – Yet another thorny weed? Brain newsletter. No. 24, may 2003.
11. Hamilton DF, Midcap TJ 1981. Seed Propagation of Woody Ornamentals. Circular 414. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences. University of Florida.
12. Hartmann HT, Kester DE, Davies FT, Geneve LR 1997. Plant propagation: Principles and practices. Prentice-Hall International Editions, Eaglewood Cliffs, New Jersey, USA.
13. Ibanez-Torres A 2004. Rooting experiments with *Euphorbia lagascae* cutting. *An. Biol.* 26: 101 – 104.
14. Ibanez-Torres, A., 2004. Rooting experiments with *Euphorbia lagascae* cutting. *An. Biol.* 26, 101 – 104.
15. Jeruto P, Lukhoba C, Ouma G, Mutai C 2008. Propagation of some indigenous trees from South Nandi District Kenya using cheap, non mist and IBA concentration technology. *ARPN J.Agric & Biol. Scie.* 3: 1- 6.
16. Jooste M 2004. *Dovyalis caffra*. (Hook & Harv) Warb. Ecoport country programme. Republic of South Africa.
17. Joyner G 2002. The Kei apple. Manatee. Rare fruit news. September 2002.
18. Kibbler H, Johnston ME, Williams RR 2003. Adventitious root formation in cuttings of *Backhousia citriodora* F. Muell. L. Plant genotype, juvenility and characteristics of cuttings. *Scie. Hort.* 102: 133 – 143.
19. Laubscher, C.P., & Ndakimedi, P.A. 2008. The effects of Indole Acetic Acid and rooting mediums on rooting of *Leucadendron laxum* (Proteaceae) in a shed tunnel environment. *Am. Euras. J. Agric & Environ. Scie.* 4, 326 – 331.
20. Lapierre LM 2001. Vegetative propagation of *Cercropia obtusifolia* (Cercopiaceae). *Rev. Biol. Trop.* 49: 973 – 976.
21. Leakey RRB, Mensen FT, Tchoundjeu Z, Longman KA, Dick JM, Newton AC, Matin A, Grace J, Munro RC, Muthoka PN 1990. Low technology techniques for vegetative propagation of tropical trees. *Comm. Weal. For. Rev.* 69: 247 – 257.
22. Leakey RRB 2004. Clonal approaches to hardwood forestry in the tropics: In prospects for high value hardwood timber plantations in the dry tropics of Northern Australia, Mareeba, 19th – 21st October 2004. p1-12.
23. Leakey RRB, Last FT, Longman KA 1982b. Domestication of tropical trees: An approach securing future productivity and biodiversity in managed ecosystems. *Comm Weal. For. Rev.* 61: 33-42.
24. Leakey RRB 2002. The domestication of indigenous trees as the basis of a strategy for sustainable land use. TWNSO Africa regional workshop: Promoting best practices for conservation and sustainable use of biodiversity of global significance in arid and semi-arid zones. Muscat, Oman 22-24 April 2002.
25. Leakey RRB, Chapman VR, Longman KA 1982a. Physiological studies for tropical tree improvement and conservation: factors affecting root initiation in cuttings of *Triplochiton Scleroxylon*. *For. Ecol. Manage*. 4:53-66.
26. Leakey RRB 1985. Capacity for vegetative propagation in trees. p.110-133. *In:* Camell MGR, Jackson J (eds.). Attributes of trees as crop plants. Institute of Terrestrial Ecology, Monks Wood Huntingdon, England.

27. Loots D, van Westhuizen FH, Jerling J 2006. Polythenol composition and anti-oxidant activity of Kei apple *(Dovyalis caffra)* juice. *J. Agric. & Food Biochem*. 54:1271 - 1276.
28. Martins, C.C., Marilene, L., Bovi, A. & Nakagawa, J., 2003. Desiccation effects on germination and vigor of King Palm seeds. *Hort. Bras.* 21, 88-92.
29. Mensen, F., Newton, A.C. & Leakey. 1997. Vegetative propagation of *Cordia alliodora* (Ruiz & Pavon) Oken: the effects of IBA concentration, propagation medium and cutting origin. *For. Ecol. & manage. 92, 45 – 54.*
30. Morton J 1987. Kei apple (*Dovyalis caffra* Warb.) in fruits of warm climate. Miami, Florida.
31. Ozel CA, Khawar KM, Mirici S, Arslan O, Sebahattin O 2004. Induction of ex vitro adventitious roots on softwood cuttings of *Centaurea tchihatchaffii* Fisch. Et. May. Using indole-3-butyric acid and α- naphthalene aceteic acid. *Int. J. Agric. Biol. 8:66-69.*
32. Negash, L., 2002. Successful vegetative propagation techniques for threatened African pencil cedar (*Junipers procera* Hoeschst Ex Endl). *For. Ecol. & Manage.* 161, 53 – 64.
33. Ozel, C.A., Khawar., K.M., Mirici, S., Arslan, O. & Sebahattin, O., 2004. Induction of Ex vitro adventitious roots on softwood of *Centaurea tchihatchaffii* Fisch. Et. May. using Indole-3-Butyric Acid and a- Naphthalene Aceteic Acid. *Int. J. Agric. Biol. 8, 66-69.*
34. Palmer, E., 1977. A Field Guide To The trees of Southern Africa. William Collins Sons and Co. Ltd. Johannesburg, South Africa.
35. Puri S, Verma RC 1996. Vegetative propagation of *SDalbergia sissoo* roxb. Using softwood and hardwood cuttings. *J. Arid Environ*. 34:235-245.
36. Sas Institute Inc., 1985. Sas users guide: Statistics. Version 5th ed., Sas Institute, Cary, NC.
37. Shah M, Khattak MA. Amin N 2006. Effect of different growing media on the rooting of *Ficus binnendijkii* "amstel queen" cuttings. *J.Agric. Biol. Scie*. 1:15 -17.
38. Shiembo PN., Newton AC, Leakey RRB 1996. Vegetative propagation of *Irvingia gabonesis*, a West African fruit tree. *For. Ecol.Manage*. 87:185-192.
39. Trueman, S.J. & Peters, R.F., 2007. Propagation of Wollemi pine from tip cuttings and lower segments does not require rooting hormone. *Scie. Hort.* 109, 394 – 397.
40. Tchoundjeu Z, Ngo-Mpeck ML, Asaah E, Amougou A 2004. The role of vegetative propagation in the domestication of *Pausinystalia johimbe* (K.schum), a highly threatened medicinal species of West and Central Africa. *For. Ecol. Manage*. 188, 175 – 183.
41. Van Wyk B, Gricke N 2000. Peoples plants: a guide to useful plants of South Africa. Briza Publishers. Pretoria, South Africa.
42. Van Wyk B van Wyk P 1997. Field guide to trees of Southern Africa. Struik Publishers, Cape Town. South Africa.
43. Hamilton DF, Midcap TJ 1981. Seed Propagation of Woody Ornamentals. Circular 414. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences. University of Florida.
44. Welch-Keesey M, Lerner BR 2002. New plants from cuttings. Purdue University Cooperative extension service. West Lafayette, IN.

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