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Effects of growth media on rooting of stem cuttings of hybrid coffee varieties

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The objective of this study was to evaluate the effect of different growth media on rooting of stem cuttings of hybrid coffee varieties. The experiment was conducted on-station under a shade house at Tanzania Coffee Research Institute (TaCRI) from October 2013 to February 2014 using a split plot experiment in a Randomized Complete Block Design (RCBD) with four replications. The main factor consisted of five hybrid coffee varieties (KP423-1, KP423-2, N39-3, N39-2 and N39-7) and the sub-factor consisted of five types of rooting media (red soil, peat moss, decomposed saw dust, rice husk and forest soil + fine sand 2:1 (v/v) as a control). The stem cuttings were planted in each type of the media and four months after planting, the cuttings were evaluated based on number of rooted cuttings, total number of roots per cutting, number of lateral roots per cutting and root length. The data were subjected to analysis of variance using CoStat software and treatment means were separated based on Tukey's test at P ≤ 0.05. Results indicate that coffee varieties N39-2 and N39-3 produced the highest rooted stem cuttings of 64.2 and 63.9% respectively. Results also show that red soil media provided the highest rooted stem cuttings of 77.9% followed by sawdust with 68.0%. It is recommended that propagators should use red soil as a rooting media for improving rooting percentage of stem cuttings from improved coffee varieties. Further studies are required to improve chemical and physical properties of red soil media.

Key words: Hybrid coffee, mass multiplication, propagation, rooting media, stem cuttings.

INTRODUCTION

Coffee is vegetatively propagated using either stem cuttings or grafting. Vegetative propagation of coffee by stem cuttings guarantees uniformity as it maintains the genetic make-up of the planting materials while propagation by seeds leads to genetic variability due to segregation of genes during fertilization (Kumar et al., 2006). An ideal propagation medium for successful rooting must be friable, sterile, have pH of 5.5 to 6.5 and well drained to ensure availability of oxygen and nutrients for seed germination, root initiation and seedling growth (Holloway, 2008; Gopale and Zunjarrao, 2011; Yeboah et al., 2011). Mixtures of sand and perlite at 1:1 (v/v), peat

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Table 1. Characteristics of five improved hybrid Arabica coffee varieties.

Variety name	Yield (kg/ha) clean coffee	Bean size (AA+A, %)	Stem size (cm)	Leaf size (mm^2)
N39-2	2,708	77	3.76	5,650
N39-3	2,763	74	3.61	6,100
N39-7	2,700	72	3.49	6,375
KP423-1	2,225	80	3.53	5,219
KP423-2	1,851	68	3.57	7,434

Source: Teri et al. (2011).

moss and coarse perlite 2:1 (v/v), and vermiculite and composts at 1:1 (v/v) have been recommended to promote rooting of cuttings (Chong et al., 2008; Pijut et al., 2011). It has been reported that increased rooting ability is associated with the type of rooting media, plant juvenility or age and growing conditions (Paparozzi, 2008). For instance, Yeboah (2009) reported a significant number of roots on stem cuttings of shea nut tree (*Vitellarria paradoxa*) using rice husk medium against sand and sand plus top soil at 1:1 (v/v). Similarly, Parthiban et al. (1999) reported a significant rooting percentage when stem cuttings of neem (*Azadirachta indica*) and kapok tree (*Ceiba pentandra*) were propagated in media containing soil, sand and farm yard manure at 1:1:1 (v/v). Gopale and Zunjarrao (2011) also documented a significant rooting of 78.2% when stem cuttings of *Jatropha curcas* were propagated in sand, soil and vermicompost at 1:1:1 (v/v) against 64% rooting in fine sand alone.

Tanzania coffee research institute (TaCRI) has been multiplying its new improved hybrid coffee by stem cuttings and cleft grafting using top forest soil, decomposed husk or decomposed saw dust either singly or mixed with fine sand at 2:1 (v/v) (TaCRI, 2011). However, the average rooting of stem cuttings from these improved coffee varieties has remained as low as 50% (TaCRI, 2011).

Several factors affect rooting such as rooting media, plant age and growing environment (Paparozzi, 2008). Rooting media is one of the major factors which determine rooting of coffee stem cuttings (Gopale and Zunjarrao, 2011; Yeboah et al., 2011) and this therefore underscores the need to evaluate alternative growth media for improving rooting ability of coffee stem cuttings. The objective of this study was to determine best growth media for improving rooting of stem cuttings from different new hybrid coffee varieties.

MATERIALS AND METHODS

Study area and plant

This experiment was conducted under a shade house on-station at TaCRI, Lyamungu, Moshi, Tanzania from October 2013 to February 2014. Top forest soil was collected at a depth of 1 to 10 cm from "Sawe" forest reserve in Moshi, Tanzania (Amri et al., 2009; Adugna et al., 2015). Peat moss was purchased from Balton Tanzania Limited in Arusha and fine sand soil was collected from Weruweru River. Red soil was collected at a depth of about 5 to 50 cm from Lushoto in Tanga region, Tanzania and sawdust was collected from carpentry workshops in Moshi town.

Uniform orthotropic stem cuttings of five improved hybrid coffee varieties of Bourbon type and pleasant aroma beverage quality were used and are shown in Table 1. Stem cuttings with 4 to 8 internodes were harvested in the early morning from 10 year old vigorous mother stocks at TaCRI nursery. The stem cuttings were prepared under a shade into three nodes with six leaves as described by Twardowski et al. (2012). Leaves were cut half to reduce water loss by transpiration (Rezende et al., 2010; TaCRI, 2011).

Growth media

Top forest soil, red soil and fine sand were sorted to remove rotten plant roots and leaves, and sieved using 2 mm sieve whereas rice husk and saw dust were left to decompose for two months. Forest soil was then mixed with fine sand at a ratio of 2:1 by volume (TaCRI, 2011). All types of the media were sterilized by heating at 80°C for 1 h, cooled for 24 h to 15°C and then moistened to 20 to 35% moisture content (Pijut et al., 2011; Yeboah et al., 2011). The physical and chemical characteristics of the rooting media were determined at the beginning of the experiment and are shown in Table 2. Remarks on the level of nutrients were based on FAO (1984) and Landon (1991). Nitrogen fertilizer (N.P.K-20: 10: 10) at a rate of 33.3 g/m^3 was incorporated into the rooting media prior to planting of the stem cuttings (Rezende et al., 2010; TaCRI, 2011).

Experimental design and treatments applications

A split plot experiment in a completely randomized design with four replications was used. The main factor consisted of five improved hybrid coffee varieties (N39-2, N39-3, N39-7, KP423-1 and KP423-2) and the sub-factor consisted of four types of rooting media (top forest soil + fine sand at 2:1 (v/v), red soil, rice husk, saw dust and peat moss).

Each rooting media was filled in a cement propagation box with a dimension of 4 m long, 1 m wide and 0.9 m deep and adjacent boxes were spaced at 0.2 m apart (TaCRI, 2011). The box had three layers of media namely gravels at the base (0.15 m thick) followed by each of the rooting media (0.15 m thick) and a top empty space (0.6 m). The basal ends (2 to 3 cm) of stem cuttings were sterilized by dipping into 5 g/L solution of copper oxychloride (50 WP) to control fungal diseases, and air-dried for 5 min and immediately planted into the rooting media (Rezende et al., 2010). A dibble was used to create a spacing of 5 × 5 cm and holes of 2.5 cm depth into which stem cuttings were planted (Akwaturila et al.,

Table 2. Physical and chemical characteristics of the growth media used for the study.

Media property	Peat moss	Saw dust	Rice husk	Red soil	Forest soil
Physical					
Moisture (%)	39.13***	39.13***	33.42**	27.8**	34.7**
Bulk density (g cm^{-3})	0.23*	0.23*	0.28**	0.81***	0.48**
Chemical					
pH	7.00***	6.30**	5.80**	4.00*	4.9*
Salt concentration (dS m^{-1})	0.10*	0.12*	0.14*	0.27*	0.46*
CEC (cmol (+) kg^{-1})	96.0***	51.0***	72.0***	4.00*	14.0**
Exchangeable Ca (cmol (+) kg^{-1})	54.67***	1.66*	1.48*	0.48*	6.23*
Exchangeable Mg (cmol (+) kg^{-1})	0.95*	0.58*	0.58*	0.39*	0.77*
Exchangeable K (cmol (+) kg^{-1})	0.96*	0.25*	0.91*	0.13*	0.82*
Available P (mg kg^{-1})	11.11*	18.69*	41.27**	0.66*	12.95*
Total N (%)	0.24**	0.17**	0.12**	0.06*	0.17**
Organic Carbon (%)	4.92***	11.14***	11.91***	0.73*	4.72***
Exchangeable Al (cmol (+) kg^{-1})	0.10*	0.10*	0.50*	2.66***	0.3*
Total Cu (mg kg^{-1})	0.44*	24.65***	8.53**	2.93**	4.25**
Total Fe (mg kg^{-1})	4.59*	216.31***	275.76***	402.61***	393.3***
Exchangeable Mn (mg kg^{-1})	41.98**	142.33***	132.40**	135.82**	102.50**
Exchangeable Zn (mg kg^{-1})	0.69*	13.18***	8.29**	12.02***	5.42**

Source: FAO (1984) and Landon (1991). *Low, **Medium and ***High.

2011; TaCRI, 2011). The total number of experimental units was 100 each with 30 stem cuttings. The media moisture content was monitored using a digital moisture meter (Ridde AG) and was adjusted to 20 to 35% by spraying with water using a knapsack sprayer (Gopale and Zunjarrao, 2011; TaCRI, 2011).

The planted stem cuttings were sprayed with 5 g/L solution of copper oxychloride (50 WP) using knapsack sprayer to control fungal diseases. The propagation boxes were covered with a transparent polythene sheet of 5 mm thickness under the black shade net with a shading capacity of 30%. These sheets were supported by semi-circular iron rods to preserve humid condition. Irrigation in fine droplets using a knapsack sprayer was applied when needed to maintain the water holding capacity at 20 to 35% of the rooting media. A relative humidity of 60 to 85% inside the propagation box was monitored by using hygrometer and maintained by misting using a knapsack sprayer (Pandey et al., 2011). Fungal diseases on the stem cuttings were controlled by applying 5 g/L solution of copper oxychloride (50 WP) whenever signs of fungal infections were observed (TaCRI, 2011).

Data collection and analysis

Data were collected four months from the date of planting by gently uprooting the stem cuttings as recommended by Yeboah et al. (2009). A stem cutting was considered to be rooted if it had at least one visible lateral root of ≥2 cm long (Ou-Yang et al., 2015). The following data were collected as described by Pandey et al. (2011):
(1) Number of rooted cuttings: Rooted stem cuttings was counted and converted into percentage.
(2) Number of lateral and fibrous roots: Laterals and fibrous roots were counted for each stem cutting.
(3) Root length: Longest lateral roots (cm) were measured with a graduated ruler from the collar to its apex.

Data collected were subjected to analysis of variance using CoStat software version 6.311 at $P \leq 0.05$. The differences between the treatment means were separated based on Tukey's test at $P \leq 0.05$.

RESULTS

Effect of hybrid coffee varieties on rooting of stem cuttings

Coffee varieties had a highly significant (P = 0.00) effect on rooting percentage of stem cuttings and number of lateral roots per cutting and a significant (P = 0.02) effect on root length. However, coffee varieties did not have significant (P = 0.11) effect on the total number of roots per cutting (Table 3).

Effect of media on rooting of stem cuttings of hybrid coffee varieties

Rooting media had a highly significant (P = 0.00) effect on rooting percentage, number of roots per cutting and root length, and a significant (P = 0.02) effect on number of lateral roots per stem cutting (Table 4).

Interaction effect of varieties and rooting media on rooting of stem cuttings

Interactions between varieties and rooting media were significant (P = 0.04) on percentage rooted cuttings,

Table 3. Effect of hybrid coffee varieties on rooting of stem cuttings.

Variety	Rooting percentage	Total no. of roots per cutting	Lateral root length (cm)	No. of lateral roots per cutting
N39-2	64.2[a]	35.3	11.0[ab]	2.3[a]
N39-3	63.9[a]	34.1	11.3[a]	2.1[ab]
N39-7	52.6[b]	34.6	10.0[b]	2.0[b]
KP423-2	58.5[ab]	33.6	11.1[ab]	2.3[a]
KP423-1 (control)	54.3[b]	29.5	10.2[ab]	2.3[a]
Mean	58.73	33.46	10.70	2.19
CV (%)	25.08	39.86	23.17	27.39
P-values	0.00	0.11	0.02	0.00

Means followed by the same letter in the same column are not significantly different at P ≤ 0.05 according to Tukey's Test.

Table 4. Effect of rooting media on rooting of stem cuttings of hybrid coffee varieties.

Rooting media	Rooting percentage	Total no. of roots per cutting	Lateral root length (cm)	No. of lateral roots per cutting
Top forest soil + Sand (2:1)	63.0[b]	20.0[c]	10.9[b]	2.35[a]
Red Soil	77.9[a]	40.1[b]	10.7[b]	2.24[ab]
Rice husk	64.7[b]	33.8[b]	10.3b[c]	2.08[b]
Saw dust	68.5[b]	54.1[a]	12.2[a]	2.19[ab]
Peat moss	19.6[c]	19.2[c]	9.5[c]	2.12[ab]
Mean	58.73	33.46	10.70	2.19
CV (%)	31.70	46.50	20.28	23.64
P-values	0.00	0.00	0.00	0.02

Means followed by the same letter in the same column are not significantly different at P ≤ 0.05 according to Tukey's Test.

significant (P = 0.01) on lateral root length and highly significant (P = 0.00) on number of roots per cutting and number of lateral roots per cutting (Table 5).

DISCUSSION

Effects of hybrid coffee varieties on rooting of stem cuttings

In this study, hybrid coffee varieties exhibited differences in rooting percentage with varieties N39-2 and N39-3 producing the highest rooting percentage. This difference in rooting percentage is associated with their variation in genetic makeup which influence the amount of root promoting substances and interactions between genetic and environmental factors as reported earlier (Amissah and Bassuk, 2007; Gopale and Zunjarrao, 2011; Pijut et al., 2011). Previous studies have also documented that increasing rooting percentage was related to large leaves and stem sizes (Islam et al., 2010; Gehlot et al., 2015; Ou-Yang et al., 2015). For instance, stem cuttings from neem (*A. indica* A. Juss) with 0.5 to 1.5 cm diameters significantly increased rooting compared to cuttings with diameter of less than 0.5 cm (Gehlot et al., 2015). Similarly, the size of stem cuttings of pomegranate (*Punica granatum* L) with three buds had longer roots than those with a single bud (Alikhani et al., 2010).

Effects of media on rooting of stem cuttings of hybrid coffee varieties

The significant differences in rooting percentage observed among hybrid coffee varieties in this study were due to variation in chemical and physical properties of the growth media. The effect of chemical and physical characteristics of growth media on rooting of various tree species has been widely reported (Khayyat et al., 2007; Beyl, 2008; El-Naggar and El-Nasharty, 2009; Akwatulira et al., 2011). In the present study, red soil media resulted in the highest rooting percentage of the stem cuttings of hybrid coffee varieties. This high root ability of the cuttings in red soil media is associated with its lower pH of 4.0 and highest amount of micronutrients, namely, iron, manganese and zinc, which are known to stimulate rooting (Schwambachi et al., 2005). Harbage and Stimart (1996) have observed that rooting was significantly

Table 5. The effect of interaction between varieties and rooting media on root growth characteristics of hybrid coffee varieties.

Varieties × Rooting media	Rooting percentage	Total no. of roots per cutting	Lateral root length (cm)	No. of lateral roots
KP423-2 × Top forest soil + sand (2:1)	65.41^{ab}	57.7^{a}	10.9^{a-d}	2.5^{ab}
KP423-2 × Red soil	77.8^{ab}	21.5^{e-g}	10.9^{a-d}	2.4^{ab}
KP423-2 × Rice husk	72.9^{ab}	36.3^{b-f}	10.9^{a-d}	2.3^{ab}
KP423-2 × Saw dust	75.6^{ab}	20.0^{fg}	12.55^{ab}	2.2^{ab}
KP423-2 × Peat moss	29.4^{c-e}	41.2^{a-e}	9.6^{c-e}	2.3^{ab}
N39-3 × Top forest soil + sand (2:1)	59.4^{abc}	20.0^{fg}	11.9^{a-d}	2.2^{ab}
N39-3 × Red soil	83.7^{a}	15.7^{g}	11.5^{a-d}	2.1^{ab}
N39-3 × Rice husk	78.0^{ab}	28.6^{d-g}	10.7^{a-d}	1.9^{b}
N39-3 × Saw dust	74.6^{ab}	57.4^{a}	13.0^{a}	2.1^{ab}
N39-3 × Peat moss	23.9^{de}	49.1^{a-c}	9.2^{de}	2.0^{ab}
N39-7 × Top forest soil + sand (2:1)	65.4^{ab}	20.0^{fg}	10.2^{a-d}	2.1^{ab}
N39-7 × Red soil	77.1^{ab}	21.6^{e-g}	10.4^{a-d}	2.0^{ab}
N39-7 × Rice husk	47.1^{b-d}	35.8^{b-g}	9.6^{c-e}	2.0^{ab}
N39-7 × Saw dust	58.3^{a-c}	56.9^{a}	12.3^{a-c}	2.0^{ab}
N39-7 × Peat moss	15.2^{de}	38.9^{a-f}	7.4^{e}	1.8^{b}
KP423-1 × Top forest soil + sand (2:1)	59.4^{a-c}	20.0^{fg}	10.2^{a-d}	2.6^{a}
KP423-1 × Red soil	73.7^{ab}	15.7^{g}	10.1^{b-e}	2.3^{ab}
KP423-1 × Rice husk	61.7^{ab}	32.3^{c-g}	9.85^{b-e}	2.2^{ab}
KP423-1 × Saw dust	59.6^{a-c}	44.3^{a-d}	11.2^{a-d}	2.3^{ab}
KP423-1 × Peat moss	17.3^{de}	35.3^{b-g}	9.6^{c-e}	2.2^{ab}
N39-2 × Top forest soil + sand (2:1)	65.4^{ab}	20.0^{fg}	11.1^{a-d}	2.4^{ab}
N39-2 × Red soil	77.1^{ab}	21.5^{e-g}	10.6^{a-d}	2.4^{ab}
N39-2 × Rice husk	63.7^{ab}	36.1^{b-f}	10.5^{a-d}	2.1^{ab}
N39-2 × Saw dust	74.4^{ab}	54.3^{ab}	11.8^{a-d}	2.3^{ab}
N39-2 × Peat moss	12.1^{e}	36.1^{b-f}	11.5^{a-d}	2.2^{ab}
Mean	58.73	33.46	10.70	2.19
CV (%)	31.70	46.50	20.28	23.64
P-values	0.041	0.000	0.000	0.019

Means followed by the same letters in the same columns are not significantly different at P ≤ 0.05 according to Tukey's Test.

influenced by pH of 5.5 against pH of 7.0 in three cultivars of apple. Furthermore, manganese has been involved in root growth and elongation in micro-cuttings of *Eucalyptus globulus* (Schwambach et al., 2011).

The longest lateral roots in this study were recorded in sawdust media. These results are associated to the lowest bulk density (0.23 g/cm^3), good aeration and high amount of manganese (142.3 mg kg^{-1}) in sawdust. According to Fagge et al. (2011), length and weight of roots in most cases are related to the type of rooting media. A well aerated medium enhances greater root penetration and favours metabolic activities for root initiation, which leads to formation of longer roots and high root growth rate (Gopale and Zunjarrao, 2011). Similar findings have also been reported in juvenile stem cuttings of *Buchholzia coriacea* when propagated in saw dust and top soil against river sand (Akinyele, 2010). Adugna et al. (2015) also reported significant root length of four nodal stem cuttings of vanilla using fine sand media with low bulk density.

CONCLUSION AND RECOMMENDATIONS

The objective of this study was to determine appropriate growth media for improving rooting of stem cutting of improved hybrid coffee varieties. Findings show that red soil media can increase rooting percentage of hybrid coffee varieties by 23.3% compared to the top forest soil + sand media at 2:1 (control) and by 13.7, 20.4, and 297.4% compared to sawdust, rice husk and peat moss media, respectively. Moreover, red soil media increases the number of roots per stem cuttings by 100.5% compared to the control and by 18.6 and 108.9% in comparison to the rice husk and peat moss media, respectively. This is the first study in which red soil media

is reported to improve rooting of hybrid coffee varieties in Tanzania. It is recommended that red soil should be used as best rooting media for mass multiplication of hybrid coffee varieties. Further studies are required to improve further the chemical and physical properties of red soil.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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