Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.6, No.3, 2016

Effects of Various Rooting Media on Survival and Growth of Tea (Camellia sinensis L.) Stem Cuttings at Jimma

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Abstract
Study on the effect of different soil media types on tea stem cutting was conducted inside shade house nursery at Jimma agricultural research center with the objective to identify appropriate soil media for better survival, growth and field establishment of tea seedlings regenerated from stem cutting. Single nodal tea stem cuttings with one leaf were used from the healthy bushes 11/56 tea clone and raised in different soil media type during the 2010 and 2014 crop season. The soil media was prepared from topsoil, subsoil, sand, farm yard manure and decomposed coffee husk as solely and with various volume of soil mixture filled in polythen tube. The experiment was repeated to collect a more comprehensive data that support or confirm the former result. The subsoil (1/3 top part) + {topsoil + sand + farm yard manure (2/3 bottom part) at 2:1:1 ratio}, subsoil (1/3 top part) + topsoil (2/3 bottom part) and subsoil (1/3 top part) + {topsoil + decomposed coffee husk (2/3 bottom part) at 2:1 ratio} and subsoil alone gave higher survival rate, root length, root dry weight and shoot dry weight. Based on soil laboratory result the pH of best performing media ranged between 4.5 and 5.5. Therefore for Jimma and areas having similar conditions subsoil alone, subsoil (1/3 top part) + topsoil (2/3 bottom part), subsoil (1/3 top part) + {topsoil + sand + farm yard manure (2/3 bottom part) at 2:1:1 ratio} and subsoil (1/3 top part) + {topsoil + decomposed coffee husk (2/3 bottom part) at 2:1 ratio} are recommendable rotting media options for successful rooting survival, establishment and growth of tea seedlings.
Keywords: rooting media, subsoil, sand, topsoil, farm yard manure, decomposed coffee husk

Introduction

Tea (*Camellia sinensis L.*) can propagate either by seed or vegetative means by using stem cuttings. Propagation by seed is a traditional method of raising tea plants and it shows a wide range of variation in growth behavior, vigor, morphological characters, yield potential and leaf quality among others. The extent of variability in seed tea was shown by Wellensik (1934) in Indonesia, Tubbs (1939) in north east India. Contrarily, vegetative propagation from selected tea bushes greatly improved the opportunity of rapid multiplication of tea plants with high attributes for yield and quality. Banerjee (1992) reported that vegetatively propagated plants produced a higher yield and showed a uniform stands of tea. It is also more economical and time saving method of propagation. Hamid *et al.* (1991) reported the period around September/October as the most suitable time for raising of tea cutting under plastic tent in the tea growing areas of Pakistan. Harler (1966) held the same observation and stated that cutting in north east India in mid-September and early October. It has been reported that rooting success of stem cuttings is dependent on factors such as position of the cuttings on the shoot (Hansen, 1988) rooting medium used (Jawanda *et al*, 1997); Hartman *et al*.,1997), season when the cutting were made (Leaky 1983) as well as physical and environmental factors (Loach 1992; Wilson 1993).

Tea plant needs adequate supply of nutrient for its nourishment, growth, development and build- up of organic tissue from different organic and inorganic soil type for vigorous growth of tea cutting in the nursery. In addition to these growth of tea cuttings largely depends on the soil texture (the proportion of sand, silt and clay) of the soil media. Loamy soil containing sufficient fine particles (clay and silt) to hold up water together with sand to facilitate excess water to drain out are suitable for nurseries.

Successful propagation of cuttings requires a suitable medium in which the cuttings root and grow. The choice of an appropriate propagation medium depends on the species, cutting type, season and cost and availability of the medium (Green, 1964). As soils in most tea growing regions are so variable, a precise prescription is not possible and much depends on the type and history of the local soil. The rooting medium for the best results, therefore, depends on the type of soil used and its chemical property, mainly PH. For instance, it is reported that in Australia, a mixture of sub-soil, composted pine-bark and sand has proved to be suitable for good rooting and growth of green tea cuttings (Angela, 1999), where as in India, cattle manure thoroughly mixed with soil and rock phosphate is used as planting medium for tea propagation (Barbora *et al*., 1996). In general, it is believed that red soils are better than black soils. In East Africa and Malawi a layered profile with sub soil on top of surface soil was found to give the best results in total growth and in the former rooting of stem cuttings (Green, 1964). The sub-soil to be used in the nursery should be friable, free draining, free from grits and low in organic matter. Soil with high clay content may lead to impeded drainage which in turn may cause water logging in sleeves. When such a clayey soil dries up it cracks, breaks the tea roots and becomes difficult to re-wet. Generally, the ideal sub-soil for rooting should have a pH value of between 4.5 and 5.5. Above pH 5.5, the cuttings are likely to have large callus without roots (Visser's, 1959).

In Ethiopia however, one of the main tea production constraints is lack of appropriate media types for enhanced rooting of tea stem cutting, growth and establishment. Therefore the objective of the present study was to identify appropriate soil media type for successful rooting, survival, growth and establishment of tea under Jimma conditions.

Materials and Methods

The study was conducted in south-western Ethiopia, at Jimma Agricultural Research Centre (JARC) located at (7° 3'N latitude and 36°0'E) longitude. It is situated within the Tepid to cool humid highlands agro-ecological zone of the country at an altitude of 1753 meters above sea level. The site receives high amount of rainfall with a long-term mean total of 1573.6 mm per annum, which is distributed into 166 days. The driest months usually last between November and February. The mean maximum and minimum air temperatures are 26.3 and 11.6 °C, respectively (Anthene *et al*., 2006).

Tea nursery experiment was conducted with the objective to determine appropriate media types for better survival, growth and establishment of tea clones at Jimma Research Centre between 2010 and 2014 crop seasons. A randomized complete block design (RCBD) with three replications was used. A tea clone known as 11/56 was used for the trial where sixteen pots per plot were used in the first round evaluation. The following 21 media treatments namely: (1). topsoil (TS), (2) sand (S), (3) decomposed coffee husk (DCH), (4) farm yard manure (FYM), (5) subsoil (SS) (6) TS + S at 2:1 ratio, (7) TS + DCH at 2:1 ratio, (8) TS + FYM at 2:1 ratio, (9), TS + S + DCH at 2:1:1 ratio, (10) TS + S + FYM at 2:1:1 ratio, (11) TS + DCH + FYM at 2:1:1 ratio, (12) SS (1/3 top part) + TS (2/3 bottom part), (13) SS (1/3 top part) + S (2/3 bottom part), (14) SS (1/3 top part) + DCH (2/3 bottom part), (15) SS (1/3 top part) + FYM (2/3 bottom part) (16) SS (1/3 top part) + {TS + S (2/3 bottom part) at 2:1 ratio}, (17) SS (1/3 top part) + {TS + DCH (2/3 bottom part) at 2:1 ratio}, (18) SS (1/3 top part) + {TS + FYM (2/3 bottom part) at 2:1 ratio}, (19) SS (1/3 top part) + {TS + S + DCH (2/3 bottom part) at 2:1:1 ratio}, (20) SS (1/3 top part) + {TS + S + DCH (2/3 bottom part) at 2:1:1 ratio} and (21) SS (1/3 top part) + {TS + DCH + FYM (2/3bottom part) at 2:1:1 ratio}in the first round experiment. However, only eighteen treatments were used in the second round experiment excluding sand, decomposed coffee husk, farmyard manure from the rest of the treatments. In general among 21 treatments described above the following ten treatments namely (1) decomposed coffee husk, (2) sand, (3) farm yard manure, (4) TS + DCH + FYM at 2:1:1 ratio (5) SS(1/3top part) + FYM(2/3 bottom part, (6) TS+ DCH at 2:1, (7) TS + FYM at 2:1, (8) TS + S + DCH at 2:1:1, (9) TS + S + FYM at 2:1:1 ratio, and (10) SS(1/3top part) + DCH (2/3 bottom part) showed inferior or poor performance and thus excluded from statistical analysis. Each media type was tested for its physical and chemical properties including PH before planting of tea stem cuttings of 11/56 clone. The stem cuttings used as planting material was obtained from mother tea trees that have been allowed to grow for about six months after pruning. Single node cuttings with a leaf were taken immediately above a leaf and auxiliary bud by discarding two or three internodes from the top and bottom of the stem. All cultural practices (watering, weeding, and hardening off among others) were applied uniformly as the research recommendation (Melaku,2008).

The following parameters namely: rate of rooting (in days), per cent rooting (recorded at two to three months after planting), percent survival rate (recorded at mid of fifth month of planting), seedling vigor- (visual scoring from one to five), stem girth (measured in cm at the base of the plant (5cm from the ground), number of lateral branches, length of lateral branches, plant height (cm), number of nodes on the main stem, number of nodes on lateral branches, leaf number, leaf length, width, shoot fresh weight, shoot dry weight, root fresh weight, root dry weight, total leaf area, soil moisture content (using the formula indicated below), pH, bulk density, Nitrogen, phosphorus and potassium (NPK) contents of soil media, organic matter content, soil texture rooting media.

% Water holding capacity of media = (Wet weight - Dry weight)/ Wet weight x100

Results and Discussions

I. Destructive and non-destructive parameters studied in 2010 crop season

In the first round experiment, significantly highest percent survival of stem cutting, plant height and number of node on main stem were observed among media treatments. Consequently, subsoil, subsoil (1/3top part) + {topsoil + sand + decomposed coffee husk (2/3bottom part) at 2:1:1 ratio} and subsoil (1/3 top part) + {topsoil + sand + farm yard manure (2/3bottom part) at 2:1:1 ratio} resulted in high percent survival rate, plant height and number of nodes on main stem (Table 1). This is perhaps due to adequate supply of plant nutrients and better soil chemical properties (Table 10), suitable for better survival, growth and establishment of tea stem cuttings. In similar study it was indicated that the rooting medium for the best results, depends on the type of soil used and its chemical property, mainly pH. For instance, it was reported that in Australia, a mixture of subsoil, composted pine-bark and sand has proved to be suitable for good rooting and growth of green tea cuttings (Angela, 1999). Tea data on stem girth and root length recorded during the first round of the experiment is presented in (Table 2).

In this regard significant variations among treatments were observed for both stem girth and root length of tea seedlings. Accordingly, highest (3.86 mm) mean tea stem girth was obtained from tea seedlings grown on subsoil (1/3 top part) + {topsoil + sand (2/3 bottom part) at 2:1 ratio}. The highest value of stem girth was not statistically different from most of the treatments, except topsoil + sand at 2:1 ratio of media treatment (Table 2). Among treatments highest (25.7 cm) mean root length was recorded from seedlings grown on subsoil (1/3 top part) + sand (2/3bottom part) though the variation was statistically insignificant from most of the treatments except topsoil + sand at 2:1 ratio. This might be due to poor chemical and physical properties of the rooting media mainly fertility status, (Table 10). Similarly study under taken in India showed that cattle manure thoroughly mixed with soil and rock phosphate is recommended as planting media for tea propagation (Barbora and Baruah, 1996).

Data on destructive shoot and root fresh and dry weight of the first round experiment is presented in (Table 3). Significant variation in shoot fresh weight was detected among the treatments. However, variation in shoot dry weight among treatments was not significant. Highest (17.78 gram per plant) of shoot fresh weight was obtained from tea seedlings grown on subsoil (1/3 top part) + {topsoil + sand + farm yard manure (2/3 bottom part) at 2:1:1}ratio thought variation with most of the treatments was insignificant except subsoil (1/3 top part) + {topsoil + farm yard manure (2/3 bottom part) at 2:1} and subsoil (1/3 top part) + {topsoil + farm yard manure + decomposed coffee husk (2/3 bottom part) at 2:1:1} ratio. Furthermore significantly highest (7.38 gram per plant) root fresh was obtained from subsoil (1/3 top part) + {topsoil + sand + farm yard manure (2/3 bottom part) at 2:1:1} ratio pursued by subsoil (1/3top part) + {topsoil + farm yard manure (2/3 bottom part) at 2:1} ratio with mean value of 6.45 gram per plant (Table 3). Significant variation in root dry weight was also observed among media treatments. Accordingly, subsoil resulted in highest (2.24 gram per plant) root dry weight pursued by subsoil (1/3 top part) + {topsoil + sand (2/3 bottom part) at 2:1 ratio} with mean value of 2.07 gram per plant (Table 3). The results of the present study suggested that since soils in most tea growing areas are variable, a precise recommendation of suitable media is not possible at a wider range of agro-ecology as it depends on the type and history of the local soil conditions. The high root dry weight of subsoil treatment in the current study might be due to low soil pH which favored the hormonal balance of tea rooting and growth.

II. Destructive and non-destructive parameters studied in 2014 crop season

Data on non-destructive growth parameters of second round experiment is presented in (Table 4 and 5). Significant percent seedling survival rate was observed among the treatments. Accordingly highest (83.33%) survival rate was noted from tea stem cuttings raised on subsoil (1/3 top part) + topsoil (2/3 bottom part) followed by subsoil alone and subsoil (1/3 top part) + {topsoil + sand (2/3 bottom part) at 2:1} ratio with respective mean values of 77.08 and 70.83 percent survival rate (Table 4). Same media treatments gave significantly highest values of seedling vigor and number of node on main stem (Table 4). Data on plant height, number of leaf and stem girth in (Table 5) and significant variations were observed among treatments for each non destructive growth parameters studied. Accordingly, highest (24.7 cm) mean plant height was recorded from subsoil (1/3top part) + {topsoil + sand (2/3 bottom part) at 2:1} ratio followed by subsoil with mean value of 24.6 cm. Similarly highest (9) number of leaves was recorded from seedlings grown on subsoil (1/3top part) + {topsoil + farmyard manure + decomposed coffee husk (2/3 bottom part) at 2:1:1 ratio pursued by subsoil (1/3top part) + {topsoil + decomposed coffee husk (2/3 bottom part) at 2:1 } and subsoil (1/3top part) + {topsoil + sand (2/3 bottom part) at 2:1:1} and subsoil alone with equal mean value of 8 leaves per plant. On the other hand highest (3.7 mm) stem girth was detected from seedlings raised on subsoil (1/3top part) + topsoil (2/3 bottom part) followed by subsoil (1/3top part) + {topsoil + farmyard manure + decomposed coffee husk (2/3 bottom part) at 2:1:1 ratio} with mean value of 3.6 mm (Table 5). Table 6 presents leaf and stem fresh and dry weight of tea seedlings. Significant variations in leaf fresh and dry weight were noted among media treatments. Consequently highest (7.29 gram per plant) leaf fresh weight was obtained from tea seedlings grown on topsoil, pursued by subsoil (1/3top part) + {topsoil + sand (2/3 bottom part) at 2:1} ratio 6.49 gram per plant (Table 6). Leaf dry weight also showed significant difference among treatments. Top soil alone and subsoil (1/3top part) + topsoil (2/3 bottom part) at gave 2.28 and 2.15 gm/plant respectively. In addition, highest (4.82, 4.76, 4.74 gram per plant of stem fresh weight were recorded from tea seedlings grown on topsoil, subsoil (1/3top part) + {topsoil + sand (2/3 bottom part) at 2:1} ratio and subsoil (1/3top part) + topsoil (2/3 bottom part) respectively (Table 6). Mean number of fibrous root and root length and volume of tea seedling in the second round experiment are presented in (Table 7). Significant variation was observed among treatments for each parameter studied. Accordingly, highest (5 number of fibrous root) was recorded from seedlings grown on topsoil followed by subsoil (1/3top part) + {topsoil + sand (2/3 bottom part) at 2:1} and subsoil (1/3 top part) + {topsoil + farm yard manure (2/3 bottom part) at 2:1} ratios with equal mean value of 4 fibrous roots. On the other hand high (26.00 cm) mean root length was observed under subsoil rooting media, pursued by subsoil (1/3top part) + {topsoil + sand + decomposed coffee husk (2/3 bottom part) at 2:1:1 ratio} with mean value of 24.33 cm (Table 7). The highest root length recorded under subsoil media treatment is strongly associated with its low soil pH

(Table 10) that enhanced the hormonal balance for successful root proliferation and growth root of tea cuttings.

Fresh and dry weight of shoot and root of tea seedlings is presented in Table 8. Significance difference in shoot and root fresh and dry weight was observed among treatments. Accordingly, topsoil gave highest (18.17 gram per plant) of shoot fresh weight followed by subsoil (1/3top part) + {topsoil + farm yard manure + decomposed coffee husk (2/3 bottom part) at 2:1:1} ratio with mean value of 17.60 gram per plant. Dry weight was also highest though the difference was not statistically significant with most of the treatments except subsoil (1/3top part) + {topsoil + farm yard manure (2/3 bottom part) at 2:1} and topsoil + sand at 2:1 at ratios. Highest (7.65) gram per plant of root fresh weight was obtained from seedlings grown on subsoil (1/3top part) + topsoil + sand + decomposed coffee husk (2/3 bottom part) at 2:1:1} ratio but root dry weight was highest (2.60) gram per plant for tea plant grown on subsoil (1/3 top part) + sand (2/3 bottom part) media type (Table 8). This might be due to better soil physical and chemical attributes. It is indicated that soil media which have more acidic property gave higher survival rate and excellent rooting efficiency on tea stem cutting .Where as soil which have less acidic property could not perform well in most destructive and nondestructive attributes of tea seedlings studied in each round of the trail. Similarly study conducted in India indicated that cattle manure thoroughly mixed with soil and rock phosphate is recommended as planting medium for tea propagation (Barbora and Baruah, 1996). In studies undertaken in east Africa and Malawi a layered profile with subsoil on top of surface soil was found to give the best results in total growth and best rooting of stem cuttings (Green, 1964). This result is also agreed with our current findings. Generally result of the present study suggest that for better growth of tea stem cutting under nursery condition using the following media options namely subsoil alone, subsoil (1/3 top part) + topsoil (2/3 bottom part), subsoil (1/3 top part) + {topsoil + sand + farm yard manure (2/3 bottom part) at 2:1:1 ratio}, and subsoil (1/3 top part) + {topsoil decomposed coffee husk (2/3 bottom part) at 2:1 ratio} filled in polythene bag of 22 cm height and 10 cm diameter seems preferable for successful survival, establishment and growth of tea seedlings.

III. Media Water Holding Capacity

Water holding capacity of a soil determined mostly by soil texture and organic matter content of the soil was also determined in media treatments (Table 9). As evidenced in this study possessing an intermediate water holding capacity of the soil media gave better rooting efficiency and maximum dry matter production. Treatments with lower water holding capacity easily dried out and cannot supply ample soil moisture for longer period of time the cuttings. Furthermore, if the water holding capacity of the media is high and beyond the need of the cutting, it causes dumping off and makes unavailability of nutrients for growth and development of the cuttings.

Conclusions and Recommendations

Tea cuttings planted in subsoil showed the best rooting response followed by subsoil (1/3 top part) + topsoil (1/3 bottom part), subsoil (1/3 top part) + {topsoil + sand + farm yard manure (2/3 bottom part) at 2:1:1 ratio} and subsoil (1/3 top part) + {topsoil + decomposed coffee husk (2/3 bottom part) at 2:1 ratio} in that order. However, use of subsoil alone resulted in reduced vegetative growth (shoot and root biomass production) at the latter growth stage of rooted plants and need to be ameliorated with organic and inorganic fertilizer sources. The subsoil (1/3 top part) + {topsoil + sand + farm yard manure (2/3 bottom part) at 2:1:1 ratio}, subsoil (1/3top part) + topsoil (2/3 bottom part) and subsoil (1/3 top part) + {topsoil + decomposed coffee husk (2/3 bottom part) at 2:1 ratio} and subsoil alone gave higher survival rate, root length, root dry matter and shoot dry matter. Generally results of this study indicated that for developing tea stem cutting under nursery condition different media options can be used. Therefore for Jimma and areas having similar conditions subsoil alone, subsoil (1/3 top part) + topsoil (2/3 bottom part), subsoil (1/3 top part) + {topsoil + sand + farm yard manure (2/3 bottom part) at 2:1:1 ratio} and subsoil (1/3 top part) + {topsoil + decomposed coffee husk (2/3 bottom part) at 2:1 ratio} are recommendable rotting media options for successful rooting survival, establishment and growth of tea seedlings.

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Table 1. Percent survival rate, plant height and number of node on main stem of tea seedlings as influenced by rooting media treatments in 2010 crop season at Jimma.

Treatments	PSR	PH (cm)	NNMS
Top soil (TS)	47.92b	21.40c	6bc
Sub –soil (SS)	87.50a	28.33abc	9ab
TS+ (S) at 2:1	54.17ab	17.80abc	6bc
SS(1/3top part)+TS(2/3 bottom part)	70.83ab	22.27abc	8abc
SS(1/3top part)+S(2/3 bottom part)	72.92ab	28.27ab	8abc
SS(1/3top part)+{TS+S(2/3 bottom part) at 2:1}	70.83ab	30.67ab	9ab
SS(1/3top part)+{TS+DCH(2/3 bottom part) at 2:1}	75.00ab	30.67ab	10a
SS(1/3top part)+{TS+FYM(2/3 bottom part) at 2:1}	70.83ab	29.05ab	10a
SS(1/3top part)+{TS+S+DCH(2/3 bottom part) at 2:1:1}	87.50a	32.73a	10a
SS(1/3top part)+{TS+S+FYM(2/3 bottom part) at 2:1:1}	85.42a	30.73ab	10a
SS(1/3top part)+{TS+FYM+DCH(2/3 bottom part) at 2:1:1}	72.92ab	27.20abc	8abc
C.V %	27.57	23.69	21.28
LSD(0.05)	33.96	10.97	3.13

PSR= Percent survival rate, PH= plant height and NNMS = number of node on main stem; means followed by same letter(s) in column are not significantly different at p ≤ 0.05 probability level.

Table 2. Root length and stem girth of tea seedlings as affected by rooting media in 2010 crop season

Treatments	Girth (mm)	RL (cm)
Top soil (TS)	2.95abcde	15.8ab
Sub –soil (SS)	2.99abcde	25.1ab
TS + (S) at 2:1	2.17cde	14.3b
SS(1/3top part)+TS(2/3 bottom part)	3.14abcde	20.9ab
SS(1/3top part)+S(2/3 bottom part)	3.42abcd	25.7a
SS(1/3top part)+{TS+S (2/3 bottom part) at 2:1}	3.86ab	24.4ab
SS(1/3top part)+{TS+ DCH(2/3 bottom part) at 2:1}	3.30abcde	20.9ab
SS(1/3top part)+{TS+FYM(2/3 bottom part) at 2:1}	3.81abc	19.0ab
SS(1/3top part)+{TS+S+DCH(2/3 bottom part) at 2:1:1}	3.45abcd	23.1ab
SS(1/3top part)+{TS+S+FYM(2/3 bottom part) at 2:1:1}	3.81abc	21.8a
SS(1/3top part)+{TS+FYM+DCH(2/3 bottom part) at 2:1:1}	2.77abcd	19.3ab
C.V %	32.12	30.98
LSD (0.05)	1.66	11.05

Where RL= root length and means followed by same letter(s) in column are not significantly different at p≤0.05 probability level.

Table 3. Shoot and root fresh and dry weight of tea as influenced by rooting media treatments during 2010 crop season

Treatments	SFW (g/pl)	SDW (g/pl)	RFW (g/pl)	RDW (g/pl)
Top soil (TS)	12.67ab	3.93	4.63abc	1.15ab
Subsoil (SS)	9.13ab	2.83	4.98abc	2.24a
TS+ (S) at 2:1	8.87ab	4.58	2.93c	1.33ab
SS(1/3top part)+TS(2/3 bottom part)	8.84ab	4.13	5.18abc	1.45ab
SS(1/3top part)+S(2/3 bottom part)	8.60ab	2.33	4.53abc	1.60ab
SS(1/3top part)+{TS+S(2/3 bottom part) at 2:1}	11.00ab	4.87	5.73abc	2.07ab
SS(1/3top part)+{TS+ DCH(2/3 bottom part) at 2:1}	11.50ab	4.43	3.40bc	1.77ab
SS(1/3top part)+{TS+FYM(2/3 bottom part) at 2:1}	6.40b	4.88	6.45ab	1.95ab
SS(1/3top part)+{TS+S+DCH(2/3 bottom part) at 2:1:1}	15.47ab	4.53	5.53abc	0.87b
SS(1/3top part)+{TS+S+FYM(2/3 bottom part) at 2:1:1}	17.78a	5.49	7.38a	2.00ab
SS(1/3top part)+{TS+FYM+DCH(2/3 bottom part) at 2:1:1}	7.60b	4.20	3.87bc	1.53ab
CV (%	50. 66	46.77	37.10	44.97
LSD(0.05)	9.25	NS	3.14	1.22

Where SFW=shoot fresh weight and shoot dry weight, RFW= root fresh weight, RDW= Root dry weight, and means followed by same letter(s) in column are not significantly different at p≤0.05 probability level.

Table 4. Percent survival rate, seedling vigor, number of node on main stem and stem as affected by rooting media in 2014 crop season

Treatment	PSR	SV (1-5)	NNMS
Top soil (TS)	27.08g	3bc	7b
Sub –soil (SS)	77.08a	5a	9a
TS+ (S) at 2:1	39.58efg	4ab	6b
SS(1/3top part)+TS(2/3 bottom part)	83.33a	5a	8ab
SS(1/3top part)+S(2/3 bottom part)	22.92g	2c	4b
SS(1/3top part)+{TS+S(2/3 bottom part) at 2:1}	70.83ab	5a	7ab
SS(1/3top part)+{TS+DCH(2/3 bottom part) at 2:1}	66.67abc	4abc	8ab
SS(1/3top part)+{TS+FYM(2/3 bottom part) at 2:1}	43.75efg	3bc	6ab
SS(1/3top part)+{TS+S+DCH(2/3 bottom part) at 2:1:1}	54.17cde	4ab	7ab
SS(1/3top part)+{TS+S+FYM(2/3 bottom part) at 2:1:1}	56.25bcde	5a	12a
SS(1/3top part)+{TS+FYM+DCH(2/3 bottom part) at 2:1:1}	47.92de	4ab	8b
CV (%)	23.44	26.83	39.0
LSD(0.05)	21.40	1.79	5.02

Where PSR = percent survival rate, SV= seedling vigor and, NNMS-=number of node on main stem; means followed by same letter(s) in column are not significantly different at p≤0.05 probability level.

Table 5. Plant height, number of leaf and stem girth of tea cuttings as affected by rooting media in 2014 crop season

Treatment	PH (cm)	NL	girth (mm)
Top soil (TS)	23.33ab	6abcd	2.9ab
Sub –soil (SS)	24.6ab	8abc	3.3a
TS+ (S) at 2:1	13.40c	5cd	2.9ab
SS(1/3top part)+TS(2/3 bottom part)	22.5abc	8abc	3.7a
SS(1/3top part)+S(2/3 bottom part)	13.73c	4d	1.9b
SS(1/3top part)+{TS+S(2/3 bottom part) at 2:1}	24.70a	8abc	3.1a
SS(1/3top part)+{TS+DCH(2/3 bottom part) at 2:1}	22.60abc	8abc	3.2a
SS(1/3top part)+{TS+FYM(2/3 bottom part) at 2:1}	15.11bc	5cd	2.8ab
SS(1/3top part)+{TS+S+DCH(2/3 bottom part) at 2:1:1}	23.53ab	7abcd	3.5a
SS(1/3top part)+{TS+S+FYM(2/3 bottom part) at 2:1:1}	20.13abc	7abcd	3.4a
SS(1/3top part)+{TS+FYM+DCH(2/3 bottom part) at 2:1:1}	22.83abc	9a	3.6a
CV (%)	27.19	30.67	20.19
LSD(0.05)	9.53	3.57	10.69

Where PH= plant height and NL= number of leaf ; means followed by same letter(s) in column are not significantly different at p≤0.05
Probability levels

Table 6. Leaf and stem fresh and dry weight of tea seedlings as influenced by rooting media in 2014 crop season at Jimma

Treatment	LFW (g/pl)	LDW (g/pl)	SFW (g/pl)	SDW (g/pl)
Top soil (TS)	7.29a	2.28a	4.82a	1.95a
Sub –soil (SS)	4.94ab	1.69abc	3.64abc	1.42abc
TS+ (S) at 2:1	1.64b	0.52bc	0.93c	0.33c
SS(1/3top part) +TS(2/3 bottom part)	6.48ab	2.15a	4.74a	1.83a
SS(1/3top part) +S(2/3 bottom part)	5.34ab	1.67abc	3.68abc	1.35abc
SS(1/3top part) +{TS+S(2/3 bottom part) at 2:1}	6.49a	2.07a	4.76a	1.82a
SS(1/3top part) +{TS+ DCH(2/3 bottom part) at 2:1}	4.58ab	1.78abc	3.35abc	1.49abc
SS(1/3top part) +{TS+FYM(2/3 bottom part) at 2:1}	2.33ab	0.38c	1.18bc	0.43bc
SS(1/3top part) +{TS+S+DCH(2/3 bottom part) at 2:1:1}	6.01ab	1.99ab	4.33ab	1.58ab
SS(1/3top part) +{TS+S+FYM(2/3 bottom part) at 2:1:1}	5.80ab	1.96ab	4.12abc	1.56abc
SS(1/3top part) +{TS+FYM+DCH(2/3 bottom part) at 2:1:1}	5.51ab	1.95ab	3.92abc	1.56abc
CV (%)	57.31	52.06	52.56	51.89
LSD(0.05)	5.00	1.48	3.21	1.23

Where LFW= leaf fresh weight, LDW= leaf dry weight, SFW= stem fresh weight and SDW= stem dry weight; means followed by same letter in a column are not significantly different at (p≤0.05) probability level

Table 7. Number of fibrous root, root length and root volume of tea seedlings as influenced by rooting media in 2014 crop season at Jimma

Treatment	NFR	RL (cm)	RV (ml)
Top soil (TS)	5a	22.83ab	6.39a
Sub –soil (SS)	2ab	26.00a	4.81ab
TS+ (S) at 2:1	1b	7.11b	1.25b
SS(1/3top part)+TS(2/3 bottom part)	2ab	23.58ab	6.06a
SS(1/3top part)+S(2/3 bottom part)	1b	15.89ab	5.83ab
SS(1/3top part)+{TS+S(2/3 bottom part) at 2:1}	4ab	23.33ab	6.10a
SS(1/3top part)+{TS+DCH(2/3 bottom part) at 2:1}	2ab	18.67ab	5.00ab
SS(1/3top part)+{TS+FYM(2/3 bottom part) at 2:1}	4ab	7.67b	1.27b
SS(1/3top part)+{TS+S+DCH(2/3 bottom part) at 2:1:1}	3ab	24.33a	5.63ab
SS(1/3top part)+{TS+S+FYM(2/3 bottom part) at 2:1:1}	3ab	21.28ab	5.80ab
SS(1/3top part)+{TS+FYM+DCH(2/3 bottom part) at 2:1:1}	3ab	19.72ab	5.89ab
CV (%)	79.16	50.95	56.78
LSD(0.05)	3.52	16.6	4.75

NFR=Number of fibrous root, RL= root length and RV= root volume, means followed by same letter in a column are not significantly different at (p≤0.05) probability level.

Table 8. Shoot fresh and dry weight and root fresh and dry weight of tea seedlings as influenced by rooting media in 2014 crop season at Jimma

Treatment	SFW (g/pl)	SDW (g/pl)	RFW (g/pl)	RDW (g/pl)
Top soil (TS)	18.17a	6.39a	7.55a	2.09a
Sub - soil (SS)	10.95abc	4.81ab	5.05ab	1.70ab
TS + (S) at 2:1	1.25c	1.25b	1.27b	0.40b
SS(1/3top part) +TS(2/3 bottom part)	15.18ab	6.06a	6.73ab	2.06ab
SS(1/3top part)+S(2/3 bottom part)	14.05ab	5.83ab	4.44ab	2.60a
SS(1/3top part)+{TS+S(2/3 bottom part) at 2:1}	15.45ab	6.10a	6.00ab	1.79ab
SS(1/3top part)+{TS+DCH(2/3 bottom part) at 2:1}	11.33abc	5.00ab	5.08ab	1.61b
SS(1/3top part)+{TS+FYM(2/3 bottom part) at 2:1}	5.75bc	1.27b	2.23ab	0.45ab
SS(1/3top part)+{TS+S+DCH(2/3 bottom part) at 2:1:1}	14.58ab	5.63ab	7.35a	1.92ab
SS(1/3top part)+{TS+S+FYM(2/3 bottom part) at 2:1:1}	12.70ab	5.80ab	7.65a	2.00ab
SS(1/3top part)+{TS+FYM+DCH(2/3 bottom part) at 2:1:1	17.60a	5.89ab	7.57a	2.06ab
CV (%)	53.69	56.78	58.69	69.41
LSD(0.05)	*11.39*	*4.75*	*5.54*	*2.00*

Where NFR= Number of fibrous root per plant, SFW=Shoot fresh weight, Shoot dry weight, means followed by same letter in a column are not
significantly different at (p≤0.05) probability level

Table 9. Water holding capacity of various tea rooting media treatments used for the study

Treatment	WWS (g/plot)	DWS (g/plot)	WHC (%)
Top soil (TS)	497.35	343.45	30.94
Sub-soil (SS)	457.95	336.55	26.51
TS + (S) at 2:1	494.3	379.55	23.21
SS(1/3top part)+TS(2/3 bottom part)	429.8	299.45	30.33
SS(1/3top part)+S(2/3 bottom part)	419.9	297.7	29.10
SS(1/3top part)+{TS+S(2/3 bottom part) at 2:1}	472.9	295.5	37.51
SS(1/3top part)+{TS+DCH(2/3 bottom part) at 2:1}	482.1	334.4	30.64
SS(1/3top part)+{TS+FYM(2/3 bottom part) at 2:1}	459.65	314.3	31.62
SS(1/3top part)+{TS+S+DCH(2/3 bottom part) at 2:1:1}	472.35	300.75	36.33
SS(1/3top part)+{TS+S+FYM(2/3 bottom part) at 2:1:1}	435.7	287.65	33.98
SS(1/3top part)+{TS+FYM+DCH(2/3 bottom part) at 2:1:1}	477.4	330.3	30.81

Table 10. Soil pH, organic carbon, organic matter and NPK content of soil media used for the study

Treatment	*pH (1:2.5)*	*P ppm (Bray II)*	*P ppm (Olsen)*	*% OC*	*% OM*	*% N*	*Available k (Meq K /100 gm)*
Top soil (TS)		2.29		2.87	4.95	0.29	1.28
Sub soil (SS)	4.65	0.74		0.90	1.54	0.05	0.26
Sand (S)	4.99		117.00	4.96	8.56	0.04	1.79
Farm yard manure (FYM)	6.55		70.50	12.79	22.06	0.84	24.30
Decomposed coffee husk (DCH)	7.3		*276.00*	5.99	10.33	*1.86*	*33.24*
TS + S at 2:1 ratio	7.11		178.50	3.99	6.88	0.11	1.15
TS + DCH at 2:1 ratio	5.7		84.00	6.67	11.51	0.33	7.16
TS+ FYM at 2:1 ratio	5.64		87.00	5.67	9.77	0.35	7.03
TS + S + DCH at 2:1:1 ratio	6.55		79.50	4.84	8.34	0.30	4.22
TS + S + FYM at 2:1:1 ratio	5.84		19.50	4.71	8.11	0.25	5.24
TS + DCH + FYM	6.7		13.50	7.65	13.20	0.57	8.31