Influence of potting media types and weights on emergence and shoot growth of avocado (*Persea americana* Mill.) seedlings

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Abstract — Introduction. In Ethiopia, avocado is cultivated in many traditional homesteads. For the nurseries, there is a need for standardized formulas for potting media constituting locally available sowing media. **Materials and methods**. Our study was undertaken at the Jimma Agricultural Research Center (Ethiopia) to evaluate the effect of different media types and weights on the emergence and the seedling shoot growth of avocado trees. The study focused on addition of various proportions of locally available organic sources (farmyard manure and coffee pulp) and sand to topsoil. Eight media mixes were prepared. Those media mixes were combined at three media weights [(1.5, 2.5 and 3.5) kg] and studied with a factorial block design completely randomized with four replications. The data on mean days to emergence (Mde) and shoot growth were destructively collected from four sample plants per plot at 30-day intervals (duration) starting from 30 days after emergence (Dae) up to 180 Dae (six months after emergence). An analysis of variance was done at each sampling. **Results and discussion**. Avocado seeds took about 70 Mde. The different media types significantly influenced the total fresh and dry weight of the seedlings. Plant height, fresh and dry weight and shoot diameters were highly and significantly affected by media type and weight interactions. MT_6 (topsoil 3 vol. + farmyard manure 2 vol.) gave a significantly higher total dry weight than MT_1 (topsoil 4 vol. + sand 1 vol.) and MT_8 (topsoil). Media weights affected all shoot growth characters. As the media weight increased, most shoot growth characters increased. All growth characters were highly influenced by the growth duration, and by the medium weight and growth duration interactions. **Conclusion**. At the initial growth stages, the dry matter increase was similar on all media weights up to 60 Dae; as the seedlings developed, the effect of higher weights was clearly seen, showing the importance of using larger medium containers for optimizing growth, which is due to the contribution of a larger supply of nutrients and no restriction on root growth. Based on this study, the seedling growth was stabilized between (90 and 120) Dae and responded well to additional nutrients and media weight as growth advanced in the nursery.

Ethiopia / *Persea americana* / plant propagation / growing media / growth / agronomic characters

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Influence de différents types et poids de substrats en pot sur l'émergence et la croissance de plantules d'avocatier (*Persea americana* Mill).

Résumé — Introduction. En Ethiopie, l'avocatier est cultivé dans de nombreuses fermes traditionnelles. Il apparaît nécessaire de déterminer des formules de composition standard pour des milieux de culture en pot, constitués à partir d'éléments localement disponibles en pépinière. **Matériel et méthodes**. Notre étude a été entreprise au centre de recherche agricole de Jimma (Ethiopie) pour évaluer l'effet de différents types et poids de substrats sur l'émergence et la croissance de plantules d'avocatiers. L'étude a porté sur différents milieux de culture issus de la combinaison, en proportions diverses, de terre végétale et de sable avec des sources organiques (fumier et pulpe de café) localement disponibles. Huit milieux composites ont été préparés. Ces milieux composites ont été combinés à l'utilisation de trois quantités différentes de substrats [(1,5, 2,5 et 3,5) kg] et étudiés selon un dispositif en blocs factoriels en randomisation totale et quatre répétitions. Les données portant sur le nombre de jours moyens jusqu'à émergence et sur la croissance des tiges ont été collectées à partir de 30 jours après l'émergence des plantules (Jae), tous les 30 jours et jusqu'à 180 Jae (six mois après émergence), par l'analyse destructive de quatre plants témoins par parcelle élémentaire. Une analyse de variance a été faite lors de chaque échantillonnage. **Résultats et discussion**. Les graines d'avocatier ont germé en 70 jours environ. Les différents types de substrat ont influencé de manière significative le poids frais et sec des jeunes plantes. La hauteur de la plante, le poids frais et sec, et le diamètre des tiges ont été fortement et sensiblement affectés par l'interaction entre le type de mélange et la quantité de milieu utilisés. Le milieu MT_6 (3 vol. de terre végétale + 2 vol. d'engrais) a donné des plantules ayant un poids sec total significativement plus élevé que MT_1 (4 vol. de terre végétale + 1 vol. de sable) et MT_8 (terre végétale). Les différentes quantités de milieux de culture utilisés ont affecté tous les caractères de croissance de la tige. La plupart de ces caractères de croissance ont augmenté dans le même sens que l'augmentation du volume de substrat dans les containers de culture. Tous les caractères de croissance ont été fortement influencés par l'âge des plants, la quantité de substrat et les interactions entre mélanges utilisés et temps de croissance. **Conclusion**. En début de croissance et jusqu'à 60 Jae, l'augmentation de matière sèche a été la même quelle que soit la quantité de milieu utilisée. Ensuite, au fur et à mesure du développement de la plantule, l'effet de l'utilisation de plus gros volumes de milieux a été mis en évidence, d'où l'importance d'utiliser de plus grands récipients pour optimiser la croissance des plants liée à la contribution d'un plus grand apport nutritionnel et à la libre croissance des racines. Dans notre étude, la croissance des jeunes plantes s'est stabilisée entre (90 à 120) Jae et a bien répondu à l'addition de sources de matières organiques et à la présence d'une quantité maximale (3,5 kg) de milieux.

Éthiopie / *Persea americana* / multiplication des plantes / substrat de culture / croissance / caractère agronomique

1. Introduction

Avocado, *Persea americana* Mill., is a native of Central America, from where it spread to other regions of the world. Its high nutritional value makes it a valuable source of food [1]. The first small-scale avocado orchard in Ethiopia was established around 1930 [2]. Currently, it is cultivated in the Sidamo, Gedeo, Borena, Jimma, Illu-Ababor, Kafficho, Sheka, Bench-Maji and West Wellega zones [3]. Avocado seedlings are generally raised by sowing seeds in polyethylene containers filled with sowing media, which, however, vary greatly from country to country [4]. The traditional potting media contain a large proportion of organic matter [5]. Coffee pulp is one of the important organic materials available in coffee-growing areas of Ethiopia. It supplies a high amount of K, high available P, a high [C/N] ratio and other nutrients [6]. Similarly, farmyard manure is another organic source that contains K and other nutrients [5]. Potting medium may be considered from two entirely different physical and chemical aspects [7] and can be evaluated by plant performance. Seedlings grown in large containers were found to be better than those grown in smaller containers. Thus, adapting the container size to the growth habit of avocado seedlings was the focus of the present study. Hence, our work aimed at determining the effect of potting media types and weights on the emergence and shoot growth of avocado seedlings.

Table I.
Composition (volume / volume) of eight medium types used to study the influence of potting media on emergence and shoot growth of *Persea americana* seedlings.

Medium type	Top soil	Sand	Coffee pulp	Farmyard manure
MT_1	4	1	–	–
MT_2	4	–	1	–
MT_3	4	–	–	1
MT_4	3	–	2	–
MT_5	3	1	1	–
MT_6	3	–	–	2
MT_7	3	1	–	1
MT_8	5	–	–	–

2. Materials and methods

The experiment was conducted at the Jimma Agricultural Research Center (JARC) located at lat. 7° 33' N, long. 36° 57' E and at an altitude of 1753 m above sea level. Jimma has a mean maximal temperature of 26.2 °C and minimal temperature of 11.4 °C with annual rainfall of 1593 mm. The experiment was laid out in a factorial randomized complete block design with four replications. Eight media mixtures were prepared from four locally available media ingredients: topsoil (Ts), river-deposited sand (S), farmyard manure (Fmy) and decayed coffee pulp (Cp), a well-decomposed medium obtained by production of wet processed coffee (*table I*). Three weights of medium were experienced for each medium type : small weight (W_1: 1.5 kg), intermediate weight (W_2: 2.5 kg) and large weight (W_3: 3.5 kg). The mixtures were transferred to polyethylene bags of respective sizes.

Seeds of weight ranging from (80 to 100) g were obtained from fruits of West Indian race trees of *Persea americana* growing at the research center. For each medium type, 45 seeds were sown immediately after extraction at one 5 cm-depth-buried seed per polyethylene bag. The determination of the physicochemical characteristics of the individual components before mixing, and those of the mixes, were carried out at JARC focusing on macronutrient status. Medium pH was determined using a pH-meter on a mixture of a [1 vol. soil / 2.5 vol. distilled water] ratio after the suspension was stirred for 30 min using an automatic stirrer. The exchange capacity (EC) was measured with an EC-meter in a mixture of a [one part potting medium / two parts water] ratio; cation exchange capacity (CEC) and exchangeable bases (Na, K, Ca and Mg) were determined as described by Okalebo *et al.* [8]. The field capacity was measured at 1/3 bar and the permanent wilting point at 15 bar. The total nitrogen was determined by the modified Kjeldahl method. The organic carbon was determined by the Walkley and Black digestion procedure [9]. From the respective organic carbon and total nitrogen values, the carbon to nitrogen ratio was calculated using the formula [C/N] of a given medium. The available P was determined [10] under partial shading. The emerging seedlings were counted and recorded at daily intervals starting from the first day of emergence until the germination process was completed. The mean number of days to emergence (Mde) of each plot was computed with the procedure of Maguire [11]:

$$\text{Mde} = \frac{\sum(nt)}{\sum n}$$

where n is the number of newly emerged seeds at time t and t the number of days from sowing.

The data on Mde, plant height, shoot diameter, total fresh weight, total dry weight, shoot dry weight, numbers of true leaves and leaf area were collected at monthly intervals starting from 30 Dae and continuing up to 6 months after emergence (180 Dae). Thus, there were six growth samplings during the study.

Four seedlings per plot were randomly sampled for measurements. Leaf area (cm^2) was determined following conventional procedures in accordance with the procedures outlined by Ajayi [12]. Estimated leaf area, assessed by k × W × L, was derived from the actual leaf area, where k is a leaf area constant; W, the leaf width, and L, the leaf length. The average k of all sample leaves was 0.5713, which was uniformly adopted throughout the study.

Analyses of variance were done using MSTAT-C software at each of the six growth samplings for all the shoot growth characters. For each character, variance homogeneity tests were done using a chi-squared (χ^2) test across the sampling stages [13]. For heterogeneity of error variance, the data were transformed using a logarithmic transformation, and pooled analyses of variance based on the transformed data were done [14]. Mean separations were done using LSD (Least Significant Differences) at $p < 0.01$ and $p < 0.05$ for media weight and DMRT (Duncan's Multiple Range Test) at the $p < 0.01$ and $p < 0.05$ levels for media type and growth duration (H) wherever treatments were significant.

3. Results and discussions

3.1. Physicochemical components of the media

The physicochemical characteristics of the individual components and mixes were highly variable and much influenced by the nature of the organic amendments used (*tables II, III*).

The pH of the individual components and mixtures were from 7.77 for coffee pulp to less than 6 for the mixes MT_3 (topsoil 4 vol. + farmyard manure 1 vol.) and MT_1 (topsoil 4 vol. + sand 1 vol.). Since avocado seedling growth requires an optimum pH of 5.5 to 6.6 [7], all the media mixtures tested are suitable.

The sand recorded the lowest value for EC (0.125 $dS \cdot m^{-1}$), while the coffee pulp and farmyard manure recorded the highest ones with (1.77 and 1.66) $dS \cdot m^{-1}$, respectively (*table II*). In general, the mixes with the highest organic matter components (coffee pulp or farmyard manure) recorded the highest EC. Thus, the EC of MT_1 (topsoil 4 vol. + sand 1 vol.) was low in view of its high proportion of sand and its absence of organic constituents. A similar view is held by other authors [15].

In the different mixes, the cation exchange capacity (CEC) was influenced by the organic sources. In general, the value of CEC was observed to be the highest for the media with a high proportion of farmyard manure and coffee pulp (MT_5 and MT_6) (*table III*). The lowest values of CEC were recorded in mixtures with a high proportion of sand, which may be due to the fact that the CEC is affected by the nature and the amount of minerals and organic colloids present in the medium [15].

The base saturation percent of the media was also influenced by the organic sources, particularly by the farmyard manure (Fym), as can be seen for MT_6 (*table III*). This is due to a high amount of potassium and calcium present in Fym (*table II*). This may be significant if considering that the ease with which cations are absorbed by plants is related to the degree of base saturation [15].

Table II.
Physical and chemical characteristics of components for the individual media tested to study the best medium to use for sowing seeds of *Persea americana*.

Characteristics	Topsoil	Farmyard manure	Coffee pulp	Loamy sand
PH (H_2O)[1]	6.54	6.13	7.77	6.32
EC ($dS \cdot m^{-1}$)	0.286	1.659	1.771	0.125
Na ($mEq \cdot 100\ g^{-1}$)	0.94	2.36	4.87	0.55
K ($mEq \cdot 100\ g^{-1}$)	3.50	10.63	37.5	1.00
Ca ($mEq \cdot 100\ g^{-1}$)	6.19	15.52	9.53	4.74
Mg ($mEq \cdot 100\ g^{-1}$)	2.67	7.66	8.00	1.83
CEC[2] ($mEq \cdot 100\ g^{-1}$)	32.00	61.00	65.00	15.00
Base saturation (%)	41.56	59.29	92.15	4.13
Field capacity (1/3 bar)	36.99	66.58	–	14.76
Permanent wilting point (15 bar)	28.33	48.75	–	10.50
Total nitrogen (%)	0.34	1.4	1.9	–
Organic carbon (%)	2.00	4.13	11.70	–
[Carbon/nitrogen] ratio	5.882	2.95	6.1578	–
Available P ($\mu g \cdot g^{-1}$)	9.80	253.80	265.50	–

[1] pH was measured on a mixture of [1 vol. soil / 2.5 vol. distilled water] ratio.
[2] CEC: Cation Exchange Capacity.

The exchangeable bases K, Ca and Mg were very high in organic sources and in their corresponding mixtures as compared with those that did not contain organic sources (*table II*). Organic sources influenced exchangeable bases, as revealed by MT_5 and MT_6. High K content ($18\ mEq \cdot 100\ g^{-1}$ of soil) was obtained when mixtures were formed with Fym. The Ca content was also increased in MT_6 with Fym as compared with MT_8 .

The field capacity of topsoil (MT_8) was around 37% before mixing. The highest total nitrogen content was recorded for mixtures with the highest proportions of organic matter, while the mixtures with the highest proportions of sand recorded the lowest total N percent. In the present case, the media MT_2, MT_3, MT_4, MT_5, MT_6 and MT_7 might supply the organic matter requirements to sustain satisfactory seedling growth. That is also sustained by the high values of organic carbon recorded for those media types compared with that of MT_1, which contained a high proportion of sand. This may be significant in view of the observation that the total N content of the organic substance being added to the soil is a factor to be considered when predicting effects on N release [15].

The coffee pulp (Cp) alone recorded a high organic carbon content (11.70%), followed by the farmyard manure (4.13%) (*table II*). As expected, the mixtures with Cp and Fym recorded the highest organic carbon percent (*table III*). The highest [C/N] ratio was recorded for MT_4 (topsoil 4 vol. + farmyard manure 1 vol.), followed by MT_1 (topsoil 4 vol. + sand 1 vol.), while the ratio was the least in MT_6 (topsoil 3 vol. + farmyard manure 2 vol.). The available P content of the topsoil was very low ($9.80\ \mu g \cdot 100\ g^{-1}$ of soil), while it was high in coffee pulp ($265.5\ \mu g \cdot 100\ g^{-1}$ of soil) and farmyard manure ($253.80\ \mu g \cdot 100\ g^{-1}$ of soil). All media mixtures containing Fym

Table III.
Physical and chemical characteristics of media mixes (*table I*) tested to study the best medium to use for sowing seeds of *Persea americana*.

Characteristic	MT_1	MT_2	MT_3	MT_4	MT_5	MT_6	MT_7	MT8
PH (H_2O)[1]	5.80	6.48	5.60	6.32	6.83	6.10	6.52	6.54
EC ($dS \cdot m^{-1}$)	0.175	0.35	0.35	0.17	0.37	0.56	0.34	0.29
Na ($mEq \cdot 100\ g^{-1}$)	0.78	1.65	1.10	1.25	2.04	1.41	1.49	0.94
K ($mEq \cdot 100\ g^{-1}$)	2.38	7.50	4.00	4.50	10.00	18.00	5.63	3.50
Ca ($mEq \cdot 100\ g^{-1}$)	5.89	7.78	6.44	6.064	7.39	10.78	5.94	6.19
Mg ($mEq \cdot 100\ g^{-1}$)	2.50	3.00	2.17	2.67	3.83	3.57	2.67	2.67
CEC[2] ($mEq \cdot 100\ g^{-1}$)	25.60	35.00	36.00	29.40	41.00	41.6	26.0	32.00
Base saturation (%)	45.00	55.14	38.08	51.22	56.73	81.05	60.5	41.56
Field capacity (1/3 bar)	29.30	46.34	40.33	36.72	47.04	44.38	30.44	36.99
Permanent wilting point (15 bar)	21.99	30.41	30.74	23.43	32.57	34.82	23.17	28.33
Total nitrogen (%)	0.17	0.48	0.45	0.18	0.55	0.76	0.46	0.34
Organic carbon (%)	1.03	2.40	2.20	1.80	2.61	2.00	1.802	2.00
[Carbon/nitrogen] ratio	6.06	5.00	4.88	10.00	4.745	2.63	3.91	5.88
Available P ($\mu g \cdot g^{-1}$)	2.59	28.0	59.15	62.30	29.8	126.00	18.60	9.80

[1] pH was measured on a mixture of a [1 vol. soil / 2.5 vol. distilled water] ratio.
[2] CEC: Cation Exchange Capacity.

and Cp had higher available P than media without any externally-added organic sources, such as MT_1 and MT_8.

3.2. Mean number of days to emergence

Most viable seeds of avocado germinated in 1 month at optimum growing conditions including a night-day temperature ranging from (24 to 30) °C; however, cooler temperatures greatly retarded all growth characteristics [16]. Our data showed a mean delayed day number for emergence that may be attributed to the low temperatures experienced during fruit ripening and sowing. This is in agreement with other findings [17] which reported that chilled seeds germinated more slowly and unevenly.

A highly significant interaction was observed between the media types and media weights on the mean day number for emergence (Mde) (*table IV*). The Mde for MT_1, MT_2, MT_3, MT_6 and MT_8 was the shortest with seeds sowed in 2.5 kg of medium (W_2), while the Mde for MT_4, MT_5, and MT_7 was the shortest for seeds in 1.5 kg of medium (W_1). Different medium weights had a highly significant effect on the Mde (*table V*). The emergence of seedlings grown in containers with 3.5 kg of medium (W_3) was significantly late compared with those on W_1 and W_2 (*table V*). This may be attributed to the effect of the container size on the rooting medium temperature [18], which occurred as container weight increased because of an increased distance to the container wall. Similarly, the media types also had a significant effect on the mean number of days to emergence. A significantly shorter Mde was recorded on media MT_1, MT_2, MT_4, and MT_8. (*table VI*) This may be due to the presence of organic

Table IV.
Analyses of variance for the parameter "mean number of days to emergence" for avocado seedlings grown in different media types and weights.

Source of variations	Degree of freedom	Mean square
Replication	3	6.678
Weight (W)	2	336.712 **
Medium type (MT)	7	84.246 **
W × MT	14	76.208 **
Error	69	12.656
Coefficient of variation (%)	–	5.11

** Significance at the $p < 0.01$ level of probability.

Table V.
Main effects of media weight on the mean days to emergence (means of four replications) for avocado seedlings.

Medium weight (kg)	Mean days to emergence
1.5	67.778
2.5	67.825
3.5	73.420
Mean	69.674
Least Significant Difference at $p < 1\%$	2.356

Table VI.
Main effects of media types on the mean days to emergence (means of four replications) for avocado seedlings.

Medium type (vol. / vol.)	Mean days to emergence
Topsoil 4 / sand 1	65.497 c
Topsoil 4 / coffee pulp 1	68.972 bc
Topsoil 4 / farmyard 1	70.844 ab
Topsoil 3 / coffee pulp 2	67.737 bc
Topsoil 3 / sand 1 / coffee pulp 1	71.143 ab
Topsoil 3 / farmyard 2	74.391 a
Topsoil 3 / sand 1 / farmyard 1	70.278 ab
Topsoil	68.532 bc
Mean	69.674
DMRT[1] at $p < 1\%$	3.848

[1] DMRT: Duncan's Multiple Range Test.
Figures followed by the same letter within the column are not significantly different at prescribed levels of significance.

matter which could create an open soil structure and increase the water-holding capacity of the media [15].

3.3. Influence on the plant growth characteristics

The variance homogeneity tests done across the growth stage samplings for each shoot growth character showed that, except for the shoot diameter, all other characters were heterogeneous (*table VII*).

3.3.1. Plant height

Highly significant interaction was observed between the media types and weights on the seedling height.

In all mixtures, seedlings grown in W_2 containers were superior in plant height compared with those grown in W_1 containers (*table VIII*), except when the media MT_5 and MT_6 were used. MT_5 recorded the seedlings with the highest height (*table IX*). Highly significant interaction was also observed between media weight and growth stages in plant height (*table X*). The plant height increased with the growth time extended. The plant height in W_1 containers was low up to H_3 (180 Dae), and half the height of seedlings grown in W_2 and W_3 containers. The vigorous avocado seedlings may attain a height of about 1 m, 3 months after emergence, while others less vigorous may require 6 months to reach that size under optimum growing conditions [19]. In our particular experiments, seedlings attained a mean of 1 m length at the sixth growth month (*table X*). However, it seems that the seedling height is not the best indicator of seedling growth because as shading increased, the seedling height increased with less increment in thickness because of competition for light and other resources.

3.3.2. Estimated total leaf area

A highly significant interaction was observed between media weight and growth stage in respect of estimated total leaf areas (*table VII*). The 2.5 kg containers (W_2) significantly recorded the highest leaf area. Besides, a seedling shoot has a green color and can photosynthesize before the true

Table VII.
Analysis of variance for shoot growth characters of avocado seedlings grown in different media types and weights, measured at monthly intervals of growth stages, based on transformed data (logarithmic transformation).

Source of variation	Degree of freedom	Mean square						
		Plant height (cm)	Leaf area (cm^2)	Total fresh weight (g)	Total dry weight (g)	Shoot diameter (cm)	Number of true leaves per seedling	Shoot dry weight (g)
Replication	3	0.161 **	0.169 ns	0.081 ns	0.049 *	0.040 ns	42.450 ns	0.090 **
Growth stage (H)	5	3.28 **	55.015 **	12.93 **	13.93 **	5.08 **	5384.96 **	14.52 **
Error	15	0.003	0.148	0.038	0.013	0.019	28.080	0.0170
Medium weight (W)	2	0.047 **	0.402 **	0.458 **	0.152 **	0.048 **	43.990 **	0.113 **
H × W	10	0.011 **	0.132 **	0.027 **	0.017 **	0.016 ns	8.400 ns	0.016 *
Medium type (MT)	7	0.012 **	0.010 ns	0.024 *	0.020 **	0.021 *	2.630 ns	0.018 *
H × MT	35	0.003 ns	0.022 ns	0.011 ns	0.006 ns	0.009 ns	9.470 ns	0.008
W × MT	14	0.009 **	0.051 ns	0.022**	0.015 **	0.023 **	13.780 ns	0.017 *
H × W × MT	70	0.004 ns	0.031 ns	0.008 ns	0.006 ns	0.009 ns	7.90 ns	0.007
Error	414	0.004	0.032	0.012	0.006	0.010	7.540	0.008
Coefficient of variation (%)	–	3.67	6.69	6.85	7.69	11.17	17.40	9.50

** Significance at the $p < 0.01$ level of probability; * significance at the $p < 0.05$ level of probability; ns = non-significant at the $p < 0.05$ level of probability.

Table VIII.
Main effects of medium weights on avocado seedling shoot growth characteristics. Means of eight media types, six growth stages and four replications.

Medium weight (kg)	Plant height (cm)	Estimated leaf area (cm^2)	Total fresh weight (g)	Total dry weight (g)	Shoot girth (cm)	Number of leaves per seedling	Shoot dry weight (g)
1.5	62.32 b	889.4 b	43.73 b	11.29 b	0.870 b	15.24 b	9.48 b
2.5	65.16 a	985.6 a	52.10 a	12.52 a	0.89a b	16.01 a	10.42 a
3.5	65.27 a	897.1 b	54.75 a	13.15 a	0.90 a	16.12 a	10.75 a
Mean	64.25	924.07	50.19	12.32	0.888	15.790	10.22
LSD[1] at $p < 1\%$	0.016	0.1636	0.028	0.0204	0.058	0.510	0.0236

[1] LSD: Least Significant Difference.
Means followed by the same letter within a column are not significantly different at prescribed level of significance (based on a transformed scale).

Table IX.
Main effects of media types (*table I*) on avocado seedling shoot growth characteristics. Means of three medium weights, six growth stages and four replications.

Medium type	Plant height (cm)	Estimated leaf area (cm^2)	Total fresh weight (g)	Total dry weight (g)	Shoot girth (cm)	Number of true leaves per seedling	Shoot dry weight (g)
MT_1	62.53 b	913.57	46.20 b	11.47c	0.880 ab	15.46	9.59 bc
MT_2	62.09 b	887.76	50.00 a	12.47 abc	0.854 b	15.82	10.30 abc
MT_3	64.20 ab	930.71	48.97 b	12.13 abc	0.88 ab	15.72	10.13 abc
MT_4	63.58 ab	879.95	50.51 ab	12.61 ab	0.892 a	15.74	10.47 ab
MT_5	67.45 a	968.13	53.02 a	12.17 ab	0.890 a	15.78	10.11 abc
MT_6	64.03 ab	977.30	53.90 a	13.38 a	0.909 a	16.06	11.09 a
MT_7	66.02 ab	921.81	50.17 ab	12.42 abc	0.905 a	15.70	10.29 abc
MT_8	64.09 ab	913.33	49.37 b	11.90 bc	0.88 ab	16.02	9.51c
DMRT[1] at $p < 5\%$	–	ns	0.035	–	0.032	ns	0.043
at $p < 1\%$	0.0272	–	–	0.0334	–	–	–

[1] DMRT: Duncan's Multiple Range Test.
Means followed by the same letter within a column are not significantly different at prescribed level of significance (based on a transformed scale).

Table X.
Main effects of growth stages on avocado seedling shoot growth characteristics. Means of three medium weights, eight media types and four replications (Dae: days after emergence).

Growth stage (Dae)	Plant height (cm)	Estimated leaf area (cm^2)	Total fresh weight (g)	Total dry weight (g)	Shoot girth (cm)	Number of true leaves per seedling	Shoot dry weight (g)
H_1: 30	32.29 f	20.13 e	9.25 f	1.554 f	0.593 e	5.72 e	1.06 f
H_2: 60	45.37 e	374.6 d	23.61 e	4.94 e	0.698 d	9.39 d	3.91 e
H_3: 90	52.42 d	600.0 c	33.68 d	8.04 d	0.824 c	13.59 c	6.35 d
H_4: 120	67.92 c	1078. b	51.52 c	12.50 c	0.913 b	18.62 b	10.42 c
H_5: 150	86.91 b	1530.4 ab	83.01 b	21.24 b	1.129 a	23.39 a	18.38 b
H_6: 180	100.5 a	1940.9 a	100.09 a	25.65 a	1.19 a	24.01 a	21.26 a
DMRT at $p < 1\%$	1.754	0.1636	0.082	0.04849	0.058	0.254	0.0554

Means followed by the same letter within a column are not significantly different at prescribed level of significance (based on a transformed scale).

leaf emergence. The seedlings produced on average twelve scale leaves before they produced true leaves, which emerged very slowly. When there was crowding of seedlings, they tended to grow longer with broader leaves. Competition for space and for light was observed in the case of W_1 and W_2 containers as compared with W_3 containers due to the shade level; as the seedlings grew, the need for light was clearly observed. A lack of light is destructive for emerging avocado seedlings and it was very difficult to provide the optimum light requirement as the seedlings grew.

The 2.5 kg containers produced plants with significantly higher leaf areas than the 1.5 kg and 3.5 kg containers (*table VIII*). Growth stages indicated a highly significant variation of estimated leaf area, the highest being recorded at the H_6 stage (180 Dae) and the lowest at the H_1 stage (*table X*). This indicated that there was an increase in leaf area with advance in growth, irrespective of media types and weights. This was corroborated by other authors [5].

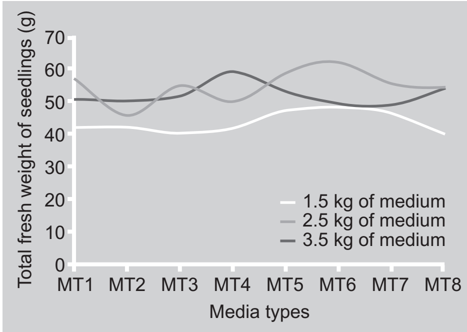

Figure 1.
Influence of media types (*table I*) and weights on the total fresh weight of avocado seedlings.

3.3.3. Total fresh weight

A highly significant interaction was observed between media types and weights in respect of the total fresh weight (*table VII*). Small containers (W_1) recorded lower total fresh weights in all media types while, at the same time, the larger medium containers gave higher total fresh weights (*figure 1*). This may be attributed to larger volumes of medium with relatively higher nutrient-supplying capacity. Similar results were obtained [20] where bananas grown on larger media weights gave higher fresh weights than those grown on smaller media weights.

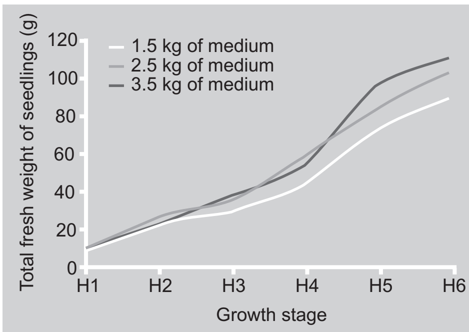

Figure 2.
The total fresh weight of avocado seedlings as influenced by the medium weights and growth stages [H1: 30 days after emergence (Dae), H2: 60 Dae, H3: 90 Dae, H4: 120 Dae, H5: 150 Dae, H6: 180 Dae].

The use of the MT_5 and MT_6 media mixes allowed us to obtain plants with significantly higher total fresh weights than the use of the MT_1, MT_3, and MT_8 media mixes (*table IX*). This may be largely attributed to the presence of organic sources in the media types, but the result with respect to MT_3 was not clear. This is in agreement with other findings [21]. Media weight and growth stages significantly interacted (*table VII*). At the initial stages, the growth was similar on all the media weights up to about 60 days after emergence. Then, growth stages brought significant variation in the total fresh weight. It was the highest (100 g) in the H_6 stage and the lowest (9.25 g) for the H_1 stage (*figure 2*). This may be attributed to increments in dry matter over the growth period. Similar views were expressed by others [22]. The growth trend in the 1.5 g medium container (W_1) was the least at latter growth stages where the influences of higher media weight containers were significant. As growth advanced, the effect of higher weights (2.5 kg and 3.5 kg) was clearly seen. After the H_4 stage, the growth in 3.5 kg containers was the maximum, and that in the 1.5 kg containers was the least, indicating the importance of using large media weights in the nursery to optimize seedling growth. This is in agreement with other authors [21].

3.3.4. Total dry weight of the seedlings

A highly significant interaction was observed between the medium type and weight for the seedling total dry weight (*table VII*). In all media types, except MT_6, the 1.5 kg container gave plants with the least total dry weight as compared with the other container sizes (similar to *figure 1*). In MT_2 and MT_7, the highest dry matter was obtained on the highest medium weight (3.5 kg) compared with the 2.5 kg container. The results agree with other findings [20] where, for banana plants grown in different root chambers, the dry weight of plant organs was generally greater for plants from large root chambers (medium weight) compared with those in small root chambers. In general, total dry weight increased with an increase in medium weight, as with total fresh weight. A significant maximum dry weight was obtained from seedlings grown in the highest media weights (2.5 kg and

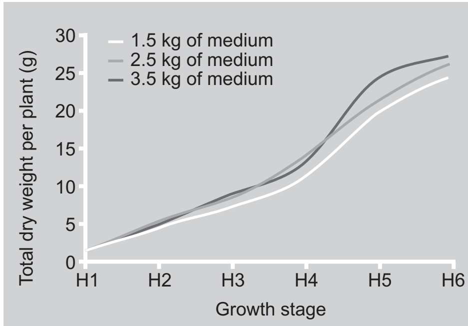

Figure 3.
The total dry weight of avocado seedlings as influenced by medium weights and growth stages [H1: 30 days after emergence (Dae), H2: 60 Dae, H3: 90 Dae, H4: 120 Dae, H5: 150 Dae, H6: 180 Dae].

3.5 kg). The growth stages brought about significant variation in total dry weight (*table X*).

Growth stage and media weight highly interacted on the total dry weight of the seedlings (*table VII*). As growth delayed, the total dry weight progressively increased, reaching a peak at H_6 (*figure 3*). In all the growth stages, plants grown in the 1.5 kg containers had the lowest dry weight whatever the medium. The (2.5 and 3.5) kg containers gave similar trends up to the H_4 stage. However, after that stage, the 3.5 kg containers significantly gave a maximum dry weight yield. This could be due to the contribution of a larger supply of nutrients and no restriction on the root expansion with the advance of growth stages [5, 20].

The different media types significantly influenced the total dry weight of the seedlings (*table VII*). MT_6 allowed us to obtain plants with the maximum dry weight. This medium has a high base saturation percentage due to a high amount of K and Ca and a narrow [C/N] ratio, indicating that the medium is biologically active with a high total nitrogen content (*table III*). MT_6 also has high available P as compared with the other media types. This may be attributed to more growth in dry matter [6]. Media that had an organic source were not significantly different in dry matter accumulation. Therefore, nurserymen need to adopt the addition of an organic source to the media for raising avocado seedlings. These observations are also similar to the findings of Gaillard and Godefroy [4] who reported that sowing media used in avocado nurseries vary greatly from country to country, usually consisting of materials that nurserymen can easily obtain locally.

3.3.5. Shoot girth

Interaction between medium type and weight was highly significant with regard to the shoot girth. Seedlings with the thickest shoot girth were recorded in 3.5 kg containers (*table VIII*), which indicated that larger medium weights are essential for promoting a better enlarging of the seedling shoot. That is an important factor of consideration in grafting. Media types significantly influenced the shoot girth; the highest values were recorded for the plants grown in MT4, MT_5, MT_6 and MT_7 (*table IX*). That may be attributed to the presence of a higher proportion of organic sources in the media. These observations agree with others [5].

3.3.6. Number of true leaves

The number of true leaves per seedling was significantly influenced by the growth stage and the medium weight but not by the medium type (*table VII*). Both the plants grown in the (2.5 and 3.5) kg containers gave a significantly higher number of true leaves than those grown in the 1.5 kg containers (*table VIII*). Thus, the leaf numbers tended to increase when the medium weight increased. That may be due to available nutrient sources in the largest medium weights [5]. As the growth stage advanced, the number of true leaves significantly increased. However, there were no significant variations between the H_5 and H_6 stages (*table X*). Each seedling produced on average about twelve scaly leaves before the growth stabilized when the true leaf emergence started. This indicates that, after the H_5 stage (150 days after emergence), the number of true leaves produced is stabilized.

3.3.7. Shoot dry weight

Media types and weights significantly interacted ($p < 0.05$) on the shoot dry weight (*table VII*). The overall effect of larger media weight was clearly seen, which may be related to the organic sources present in the media exerting a favorable influence on growth in dry matter accumulation through their chemical properties. That is corroborated by other findings [14, 20]. In our study, seedlings grown in different media types significantly influenced ($p < 0.05$) the shoot dry weight (*table VII*). Plants in MT_6 gave a significantly higher shoot dry weight than those on MT_8 and MT_1 (*table IX*). MT_1 and MT_8 were the media that lacked organic sources. Here again the importance of high proportions of organic sources in the growing medium for a better shoot dry matter accumulation was observed [21]. The largest media weights [(2.5 and 3.5) kg] significantly ($p < 0.01$) influenced the seedling shoot dry weight (*table VIII*). The increase in shoot dry weight was progressively high during the growth stages (*table X*), which may be attributed to the plant growth and the dry matter accumulation resulting from an increasing number of true leaves produced and their role in photosynthesis production [2].

4. Conclusion

At the initial growth stages, the dry matter increase was similar on all the media weights up to 60 days after emergence. As growth advanced, the effect of higher medium weights was clearly seen, indicating the importance of using larger containers to optimize the dry matter increase. As growth advanced, the total dry weight progressively increased, reaching a peak at the sixth month after emergence; after the fourth month, the largest containers (3.5 kg) gave the maximum dry weight due to the contribution of a larger supply of nutrients and no restriction on root growth. The overall effect of a larger medium weight was clearly seen, which may be related to the organic sources present in the media exerting a favorable influence on growth in dry matter accumulation through their physical and chemical properties. These results need to be confirmed to achieve fast and uniform growth of *Persea americana* seedlings.

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Influencia de diferentes tipos y pesos de sustratos en maceta sobre la emergencia y crecimiento de plántulas de aguacate (*Persea americana* Mill).

Resumen — **Introducción**. En Etiopía, se cultiva el aguacate en numerosos huertos tradicionales. Creemos que es necesario determinar fórmulas de composición estándar para medios de cultivo en maceta a partir de elementos disponibles en los viveros locales. **Material y métodos**. Nuestro estudio se realizó en el centro de investigación agrícola de Jimma (Etiopía) para evaluar el efecto de diferentes tipos y pesos de sustratos sobre la emergencia y el crecimiento de plántulas de aguacates. El estudio se refirió a distintos medios de cultivo procedentes de la combinación, en distintas proporciones, de tierra vegetal y arena con fuentes orgánicas (estiércol y pulpa de café) disponibles localmente. Se prepararon ocho medios compuestos. Dichos medios se combinaron utilizando tres cantidades distintas de sustrato [(1,5, 2,5 y 3,5) kg] y se estudiaron mediante un diseño de bloques factoriales totalmente aleatorio con cuatro repeticiones. Se tomaron los datos del promedio de días hasta la emergencia y, luego, los datos de crecimiento de tallos a partir de 30 días después de la emergencia (Dde) de las plántulas y cada 30 días y hasta los 180 Dde (6 meses después de la emergencia) mediante análisis destructivo de cuatro plantas testigo por parcela elemental. Se realizó un análisis de varianza en cada muestreo. **Resultados y discusión**. Las semillas de aguacate tardaron aproximadamente 70 días en germinar. Los distintos tipos de sustrato influyeron significativamente en el peso fresco y seco de las plántulas. La altura de la planta, el peso fresco y seco, y el diámetro de los tallos se vieron fuertemente y sensiblemente afectados por la interacción entre el tipo de mezcla y la cantidad de medio utilizados. El medio MT_6 (3 vol. de tierra vegetal + 2 vol. de fertilizante) proporcionó plántulas con un peso seco total significativamente más alto que MT_1 (4 vol. de tierra vegetal + 1 vol. de arena) y MT_8 (tierra vegetal). Las diferentes cantidades en los medios de cultivo utilizados afectaron a todos los caracteres de crecimiento del tallo. La mayoría de estos caracteres de crecimiento aumentó con el incremento del volumen de sustrato en las macetas. Todos los caracteres de crecimiento estuvieron muy influidos por la edad de las plantas, la cantidad de sustrato y las interacciones entre las mezclas empleadas y el tiempo de crecimiento. **Conclusión**. En la primera fase de crecimiento y hasta 60 Dde, el aumento de materia seca fue el mismo sin que influyera la cantidad de medio de cultivo empleada. A continuación, y a medida que la plántula se desarrollaba, se evidenció el efecto de la utilización de un mayor volumen del medio, de ahí la importancia de utilizar mayores recipientes para optimizar el crecimiento de las plantas vinculado a la contribución de un mayor aporte nutricional y al libre crecimiento de las raíces. En nuestro estudio, el crecimiento de las plantas jóvenes se estabilizó entre (90 a 120) Dde y respondió bien al aporte de materias orgánicas y a la presencia de una cantidad máxima (3,5 kg) de medio de cultivo.

Etiopía / *Persea americana* / propagación de plantas / substratos de cultivo / crecimiento / características agronómicas