Effect of rooting media and number of nodes on growth and leaf yield of chaya (Cnidoscolus aconitifolius McVaugh) at Dire Dawa, Eastern Ethiopia

Fantahun Yesuf¹*, Wassu Mohammed³ and Kebede Woldetsadik¹

Abstract: Chaya known as spinach tree, rich in vitamins and minerals, can grow under drought, low soil fertility conditions and tolerant to insect pest and could be used to tackle malnutrition problem in eastern Ethiopia. Thus, the first step is to establish the propagation and field establishment method. This experiment was conducted to assess the effect of rooting media, and the number of nodes and on rooting, seedling establishment and early growth of chaya at Dire Dawa in 2018 cropping season. The experiment was conducted to evaluate three rooting media (top soil, 3:2 top soil: FYM: 3:1 top soil: FYM) and cuttings with 1, 2 and 3 nodes in factorial combination in completely randomized design with three replications. Rooting media (RM) significantly influenced all growth parameters of seedlings and number of node (NoN) on cuttings significantly influenced most of the traits. Rooting media and number of nodes interacted to influence number of roots, fresh and dry weight of re-growth shoot. The highest number of roots (10.53) was registered from chaya stem cuttings with three nodes grown on rooting media filled with 3:2 top soils: FYM. Cuttings grown on 3:2 top soils: FYM media had significantly tallest re-growth stem height and highest number of leaves followed by cuttings grown on 3:1 top soil: FYM media.

Subjects: Agriculture; Horticulture; Agriculture and Food; Soil Sciences; Agronomy

ABOUT THE AUTHOR

Fantahun Yesuf is a Horticulturist at School of Plant Sciences, Haramaya University, Ethiopia and currently serving as lecturer and researcher. His key research areas are on vegetable crops improvement, agronomic practices and management of Tropical and Temperate fruits crops. Wassu Mohammed (PhD) is an associate professor of Plant Breeding and Genetics at School of Plant Science, Haramaya University, Ethiopia and a vegetable and coffee crops researcher. Kebede Woldetsadik is a professor of Horticulture at school of plant science, Haramaya University, Ethiopia and his key research areas are on vegetable and fruit crops. Currently he is Vice President for Enterprise Development and Community Engagement of Haramaya University.

PUBLIC INTEREST STATEMENT

Chaya is known as spinach tree and has been given the name “famine plant” due to its potential to grow under drought low soil fertility conditions, and tolerant to insect pest. It is a fast-growing perennial shrub that produces attractive, large, and dark green leaves that has two to three folds of nutrition than any vegetable. Predominantly, chaya is propagated through vegetative means mainly from stem cuttings collected from healthy and vigorous motherplant. This article described the recommended rooting media for rooting and seedling growth and best part of the plant to propagate by cuttings. Using chaya cuttings with more than one node and applying a mixture of 3:2 top soil: farmyard manure for propagation and seedling establishment is advisable for those who want to grow this plant for family consumption and commercial purposes.
Keywords: Rooting media; node number; chaya; growth; yield

1. Introduction
Chaya (Cnidoscolus aconitifolius McVaugh) belongs to the Euphorbiaceae family. It is a leafy green vegetable consisting of over 40 species. It is a fast-growing perennial shrub that produces lots of attractive, large, and dark green leaves. It is widely cultivated in Mexico and Central America, often planted in hedges and home gardens. The plant shows great adaptability to milder climates and can be found growing in northern latitudes, under dryer environments and in different soils (González-Laredo et al., 2003). Chaya is known as spinach tree and has been given the name “famine plant” due to its potential to grow under drought, low soil fertility conditions, tolerant to insect pest. The crop is tolerant to heavy rain and drought, grows in most soils except acidic soils, cold sensitive but may recover, propagated from stem cuttings, slow until established then fast and become large shrub. Chaya is also an attractive landscape shrub/tree that can quickly supply shade (Kisida & Gardener, 2012).

Population is undernourished. The prevalence of anemia is 56.8% and it is the public health problem in eastern Ethiopia (Addis & Mohamed, 2014). About a quarter of school children suffer from anemia and their educational potential is likely to be affected especially for those with moderate and severe anemia (Mesfin et al., 2015). In Ethiopia, chaya is not known in the food chain though the crop has been introduced before 35 years by one individual (personal communication). Chaya tree is propagated via woody stem cuttings that are 15-30 cm long in well-draining soil. The spiraling roots of the seedlings should be trimmed so they are growing downward and the planting hole needs to be deep enough so they hang the roots vertically.

Chaya lacks recommended media for rooting and seedling growth and best part of the plant used for cuttings to propagate. Predominantly, chaya is propagated through vegetative means mainly from stem cuttings collected from healthy and vigorous mother plant. Experiences are lacking about the number of nodes to be retained per cutting and ideal rooting media for rooting and seedling growth of chaya.

However, the success of the spinach tree (chaya) establishment, the time required to the first harvest of edible leaves and leaf yield of the tree at early establishment period depends on the propagation methods and type of seedlings used for planting, the planting holes and the suitability of the area where the seedlings are transplanted, and the management of seedlings after transplanting for good establishment. Haramaya University has been conducting an experiment to identify the suitable seedling growing methods for the propagation of chaya in eastern Ethiopia, but the effects of the seedling growing methods on field establishment of the crop has not yet been evaluated. The time required to harvest of first edible leaves and leaf yield potential of the established seedlings is not known. Thus, the objective was initiated to assess effect of rooting media and number of nodes on rooting, seedling establishment and early growth of chaya.

2. Materials and methods

2.1. Description of the study area
The experiment was conducted at the research site of Haramaya University at Dire Dawa (Tony farm) during the period from September to December 2018. The research Station is located at 09° 6’N and 41° 8’E longitude in the eastern part of Ethiopia. The altitude of the station is 1116 m above sea level and the mean annual temperature ranges from mean minimum 19 to mean maximum 31.5°C. The temperature is generally high with the monthly mean maximum temperature ranges from 28.1°C (December) and to 34.6°C (June). Dire Dawa enjoys bimodal type of rainfall with April as a peak for the scanty rainfall and July for the heavy rains. The
mean annual rain fall in the study area is 550 mm (Levoyageur Weather: Djibouti, 2012). The soil is classified as Eutric Regosol and the field has a gentle slope (3–8%). The soil has an average pH (H₂O 1:2.5) of 8.54 and organic matter content of 1.94% at (0–15 cm) and 1.84% at (15–30 cm) soil depth.

2.2. Description of experimental materials, treatments and design
In this study, the experimental materials stem cuttings of chaya; farmyard manure, and top soil were used. Well decomposed farmyard manure was collected from Haramaya University dairy farm and stem cuttings of chaya were collected from Dire Dawa research site (Toni farm). The woody cuttings were taken from the semi hardwood of a stem leaving extreme bottom and tip portions of the shoot. The cuttings were prepared to different nodes (one, two and three). Leaves were removed from cuttings and hardened under shade for two days to heal the wounds.

The cuttings were planted in September 15, 2018 in black polyethylene bags (plastic pots) having 12 cm diameter × 22 cm length size as suggested by Sengel et al. (2012) and gently firmed down till the surface just about 5 cm below the container’s top edge. The pot volume was adequate in size to provide enough rooting space and nutrients for the plants over the whole study duration (Addis & Mohamed, 2014). The polythene bags were filled with well-prepared soil (top soil only, 3:1 top soil: well decomposed FYM and 3:2 top soil: well decomposed FYM). The experiment consisted of three different node numbers of chaya cuttings and three level of soil media. It was laid out in 3 × 3 factorial combinations in Completely Randomized Design (CRD) with three replications. There were a total of 9 treatment combinations and 27 plots altogether in the experiment. Treatments were assigned to the experimental plots randomly. Samples were taken from 5 randomly selected seedlings from each plot that had 23 seedlings each.

2.3. Experimental procedures
After field preparation, well decomposed farmyard manure and top soilfilled up to polyethylene bags as required one month before planting to decompose the organic matter so as to release plant nutrients and thereby available for plant development. The semi-hard wood cuttings with different node numbers were prepared by slight cut below nodes to 45° angle and planted in polyethylene bag containers on different soil media depending on the number of nodes in each cutting treatment. The cuttings were kept moist but not overwatered to protect rotting. The seedlings were received water at field capacity during planting and every three days for one month until the seedlings established in the field. After one month of fully establishment, the seedlings irrigated every week at field capacity. The other recommended agronomic practices done to all treatments equally.

2.4. Soil and farmyard manure analysis
In order to determine the physical and chemical properties of the soil three representative soil samples were taken using auger from the depth of 0 to 30 cm before planting and application of any type of fertilizer (Table 1). The samples were mixed, after which about 1 kg of a single composite soil sample were prepared. The sample was taken to the Haramaya University soil testing laboratory and tested for total nitrogen, soil pH, organic carbon, available phosphorus, potassium, Cation Exchange Capacity (CEC) and texture analysis. Soil pH was measured in 1:2.5 soil water ratios using an electrodes pH meter. Organic carbon content of the soil was determined by Walkley and Black method (Walkley and Black, 1934). Available P was estimated following the standard procedure of Olsen et al. (1954). Total nitrogen was estimated by the Kjeldahl method.

The farmyard manure was collected from Haramaya University dairy farm which is a mixture of animal dung and urine that mixed together. The fine particle of the manure was separated using sieve and taken to Haramaya University soil laboratory to analyze the chemical properties of the samples. The laboratory results for selected chemical properties of farmyard manure indicated that the sample had pH of 8.67 which was strongly alkaline. The FYM contained a total nitrogen
**Table 1. Chemical and physical properties of the experimental plots of soil prior to planting**

| Soil physical Property       | Result   | Rating  | References               |
|------------------------------|----------|---------|--------------------------|
| Total Nitrogen (%)           | 0.24     | Moderate| Tadese (1991)            |
| Available Phosphorus (mg/kg) | 20.12    | Moderate| Olsen et al. (1954)      |
| Organic carbon (%)           | 2.73     | High    | Tadese (1991)            |

| Soil texture                  |          |         |                          |
| Clay (%)                      | 24       |         |                          |
| Silt (%)                      | 26       |         |                          |
| Sand (%)                      | 50       |         |                          |

| Soil textural class           | Sandy loam|         |                          |
| EC                           | 22.1      |         |                          |

| Available potassium (cmol\(\text{c}\)kg\(^{-1}\)) | 9.814 | High   | Hazelton and Murphy (2007) |
| EC                           | 8.38   | Strongly alkaline | Hazelton and Murphy (2007) |
| CEC (cmol\(\text{c}\)kg\(^{-1}\))               | 14.94  | Moderate| Hazelton and Murphy (2007) |

| Parameters Farmyard Manure (PYM) |          |         |                          |
| pH                            | 8.67     |         | Murphy (1968).            |
| Available phosphorous         | 47.12 mg/kg|        |                          |
| Total nitrogen (%)            | 0.454    |         | Tadese (1991)            |
| Organic carbon (%)            | 5.265    |         | Tadese (1991)            |
| CEC (cmol\(\text{c}\)kg\(^{-1}\))               | 16.99    |         | London, 1991             |

CEC = Cation Exchange Capacity, ppm = parts per million, and cmol\(\text{c}\) (+)/kg = cent moles of charge per kilogram of exchanger.
content of 0.454%, available phosphorus content of 47.12 mg kg\(^{-1}\), organic carbon 5.265%, and CEC of 16.99 meq kg soil\(^{-1}\). The data of these chemical properties were determined in a laboratory.

2.5. Data collected

The description of data collection and measurements for each treatment is presented in subsequent sub-titles as follows.

Re-growth stem height (cm): The heights of re-growth stem(s) from five sample seedlings were measured and the average was calculated for each treatment at the time of transplanting.

Number of leaves: Numbers of leaves produced in each plot were counted from five sample seedlings at four months after planting and the average was calculated for each treatment.

Number of roots: The numbers of roots produced from sample seedlings were counted and the average number of roots per seedling for each treatment was calculated after 4 months of planting.

Number of roots: The numbers of roots produced from sample seedlings were counted and the average number of roots per seedling for each treatment was calculated after 4 months of planting.

Fresh weight of leaves (g): The fresh weights of leaves from sample seedlings were measured and the average weight of leaves per seedling for each treatment will be calculated after 4 months of planting.

Total re-growth of above ground fresh weight (g): The weight of stem(s) and leaves were measured after detaching of stem(s) and leaves from sample seedlings at 4 months of planting.

Fresh weight of roots (g): The fresh weights of roots from five randomly selected samples were measured and the average weight of root weight was calculated after 4 months of planting.

Dry weight of leaves (g): The re-growth stem(s) and leaves separated from sample seedlings of each treatment were kept in oven at 78°C for 72 h and the weight of dry leaves was measured.

Total above ground re-growth dry weight (g): The dry weight of stem(s) and leaves separated from sample seedlings were kept in an oven at 78°C for 72 h and the sum of the stem(s) and leaves dry weight were registered as total above ground re-growth/shoots dry weight.

Dry weight of roots (g): The roots of five sample seedlings from each treatment were detached and kept in oven at 78°C for 72 h and the weight of dry roots was measured.

Shoot to root dry weight ratio: was obtained after dividing the total above ground re-growth dry weight (stem(s) and leaves) from sample seedlings by total dry weight of roots for each treatment.

Relative growth rate (g g\(^{-1}\) day\(^{-1}\)): The relative growth rate expresses the dry weight increase in four months of cuttings planting in relation to initial weight as a modified compound interest equation was employed as indicated below. The dry weight of the stem was taken before planting the cutting from each treatment and it was considered as initial weight.

\[ RGR = \frac{(\log_e W_2 - \log_e W_1)}{(t_2 - t_1)} \]

Where: RGR = Relative Growth Rate, \(W_1\) = dry weight of sample cuttings, \(W_2\) = dry weight of sample cuttings and re-growth/shoots, \(t_1\) = day of cuttings planting and \(t_2\) = day of cuttings maintained after planting for re-growth (four months).
2.6. Data analysis
The soil data was subjected to descriptive analysis while the data collected from field experiment were subjected to analysis of variance as per the design (Gomez and Gomez, 1984) using SAS software. Data registered as percentage were subjected to appropriate data transformation before analysis of variance conducted. The mean values were compared for data that exhibited significant mean squares using the least significant difference (LSD) at 5%.

3. Results and discussion

3.1. Re-growth initiation of cuttings

3.1.1. Interaction effect of media and number of nodes on number of roots
Rooting media interacted with number of nodes to influence significantly number of roots on cuttings. In addition, the main factors, rooting media and number of nodes had significant effect on number of roots (see Appendix Table A). The highest number of roots (10.53) was registered from chaya stem cuttings with three nodes grown on rooting media filled with 3:2 top soils: FYM, however, it had non-significant difference from cuttings with 2 and 1 nodes grown on same media. The lowest number of roots (5.367) observed in stem cuttings with one node grown on media having top soil only (See Table 2). It was observed that the number of roots increased with increase in node number of cuttings. The two and three nodes cuttings grown at 3:2 top soils: FYM media also had higher number of roots than similar cuttings with same number of nodes grown in top soil media though non-significant differences was observed among the treatments combination. This showed that the combination of cuttings with higher number of nodes with media containing higher rate of FYM seems better to increase the number of roots in chaya cuttings.

This might be due to, richness of soil with nutrients that are necessary for basic plant nourishment that include nitrogen, phosphorous, potassium and micro nutrients. Animal manure has long been recognized as the most desirable organic fertilizer that improves soil fertility by adding both major and essential nutrients as well as soil organic matter which improve moisture and nutrient retention. This might be due to the fact that larger cuttings store more carbohydrates (Thoundjieu & Leakey, 1996) and root growth is dependent on carbohydrates reserves in the leaf and stem (Philipson, 1988).

| Table 2. Interaction effects of rooting media and number of nodes on number of roots of chayacuttings at Dire Dawa in 2018 |
|---------------------------------------------------------------|
| **Treatment** | **Parameter** | **Number of nodes on cutting** | **Number of roots** |
|----------------|---------------|--------------------------------|---------------------|
| Rooting Media  |               |                                |                     |
| Top soil only  |               | 1                              | 5.37<sup>cd</sup>   |
|                |               | 2                              | 6.93<sup>cd</sup>   |
|                |               | 3                              | 7.53<sup>bc</sup>   |
| 3:1 top soil: FYM |           | 1                              | 7.60<sup>bc</sup>   |
|                |               | 2                              | 7.87<sup>bc</sup>   |
|                |               | 3                              | 8.27<sup>bc</sup>   |
| 3:2 top soil: FYM |           | 1                              | 8.83<sup>ab</sup>   |
|                |               | 2                              | 9.00<sup>ab</sup>   |
|                |               | 3                              | 10.53<sup>a</sup>   |
| LSAD (5%)      |               |                                | 1.05                |

Means in a column followed by the same letter(s) had non-significant difference at 5% level of probability. LSD (5%) = least significant difference at P < 0.05, TS = top soil and FYM = farmyard manure.
3.1.2. Effects of rooting media and number of nodes on stem height and number of leaves

The result of analysis of variance revealed that rooting media and number of nodes had significant effect of re-growth on stem height and number of leaves. Rooting media and number of nodes did not interact to influence the two re-growth parameters (see Appendix Table A). Chaya cuttings grown on 3:2 top soils: FYM media had significantly tallest re-growth stem height and highest number of leaves followed by cuttings grown on 3:1 top soil: FYM media. Whereas chaya cuttings grown on top soil alone had significantly shortest re-growth stem height and lowest number of leaves (See Table 3). Increment of plant height might be due to the fact that FYM provide major elements in addition to retention of soil moisture available to the cuttings at the early stage of plant growth and development.

This finding is related to Irshad et al. (2014) who noted that maximum plant height observed in planting media having garden soil and FYM. Osaigbovo et al. (2010) suggested that potting medium with top soil and cow dung in ratio of 2:1 produced the best seedling attributes in terms of plant height. Awan et al. (2003) worked on response of olive hardwood cuttings to different growth media for propagation observed that the media with considerably higher organic matter content gave maximum number of leaves due to availability and release of essential nutrients which initiated early root development. Chaya cuttings with three nodes produced significantly tallest re-growth stem height and highest number of leaves. There-growth stem height of cuttings with three nodes was higher by about 26 and 11% than cuttings with one and two nodes, respectively. The number of leaves produced on cuttings with three nodes was also higher by about 26 and 12% than cuttings with one and two nodes, respectively (Table 3). This might be due to the longer cutting that had more carbohydrates accumulation which helps in early growth of the seedlings as compared to shorter cuttings (Tchoundjeu & Leakey, 1996).

3.2. Re-growth fresh and dry weight of seedlings

3.2.1. Effect of media and number of nodes on fresh and dry weight of leaves and roots

The results of analysis of variance revealed that rooting media and number of node had highly significant effect on fresh and dry weight of leaves as well as on fresh and dry weight of roots of chaya plants. The two factors did not interact to influence the three parameters (See Appendix Table A). Chaya cuttings grown on 3:2 top soils: FYM media had significantly highest fresh and dry weight of leaves and also highest fresh and dry weight of roots followed by cuttings grown on 3:1 top soils: FYM media. The dry weight of leaves registered from cuttings grown on 3:2 top soils: FYM

| Table 3. Effects of rooting media and number nodes on stem height and number of leaves of Chaya cuttings at Dire Dawa in 2018 |
|-------------------------------------------------|----------------|----------------|
| **Treatments**                                  | **Re-growth stem height (cm)** | **Number of leaves** |
| Top soil                                        | 12.39 c         | 26.00 c         |
| 3:1 TS:FYM                                     | 27.32 b         | 32.24 b         |
| 3:2 TS:FYM                                     | 39.06 a         | 37.73 a         |
| LSD (5%)                                       | 2.426           | 4.328           |
| **Number of nodes on cuttings**                 |                 |                 |
| 1                                              | 23.10 c         | 28.34 b         |
| 2                                              | 26.36 b         | 31.91 ab        |
| 3                                              | 29.30 a         | 35.72 a         |
| LSD (5%)                                       | 2.426           | 4.328           |

Means in a column followed by the same letter(s) had non-significant difference at 5% level of probability. LSD (5%) = least significant difference at P < 0.05, TS = top soil and FYM = farmyard manure.
had non-significant difference with cuttings grown on 3:1 top soils: FYM media whereas chaya cuttings grown on top soil alone had significantly minimum values of fresh and dry weight of leaves and roots (Table 4).

These results are supported by Baitilwakea et al. (2011) who reported that organic manures significantly increased both fresh and dry leafyields of Chinese cabbage and Amaranths. With the increase of concentration of animal manure, the growth parameters of cuttings were significantly increased. The response may largely be due to increased availability of N and P as well as micronutrients found in the FYM and better moisture retention and availability for uninterrupted growth. Phosphorus found in livestock manure is essential for strong root growth, increased physiological activity of roots to absorb nutrients and moisture which results in higher vegetative growth and, therefore, is critical to the plant's overall health and vitality (Kuepper, 2003; Ogendo et al., 2008; Iqbal et al., 2009).

The highest value of fresh and dry weight of leaves and roots were obtained from cuttings with threenode numbers. Chaya cuttings with two node numbers had non-significant difference from cutting grown with one node except in dry weight of roots. Cuttings with one node number had significantly lowest values of fresh weight of leaves, dry weight of leaves, fresh weight of roots and dry weight of roots from cuttings with three nodes. This may reveal that the longer cutting denotes longer roots due to more carbohydrate accumulation in the cuttings. Longer roots could have an ability of deeper penetration and therefore greater capacity in water and nutrient absorption leading to heavier root fresh weight.

3.2.2. Interaction effect of media and number of nodes on fresh and dry weight of re-growth shoots
The result of analysis of variance showed the interaction of rooting media and number of nodes had highly significant (p < 0.01) difference on fresh and dry weight re-growth of shoot. The main factor rooting media and number of nodes also influenced fresh and dry weight of re-growth shoot (See Appendix Table A). The maximum fresh weight of re-growth shoot (192.8 g) was obtained in rooting media filled with 3:2 top soils: FYM and cuttings with three numbers of nodes which was about 309% more than the lowest value (47.1 g) obtained from cuttings grown on top soil with one number of nodes. Similarly, the maximum dry weight of re-growth shoot (29.2 g) was recorded from rooting media filled with 3:2 top soils: FYM and three numbers of nodes. The lowest value was recorded from top soil only with one number of nodes (See Table 5).

Table 4. Effects of media and number of nodes on fresh and dry weight of leaves and roots of chaya cuttings at Dire Dawa in 2018

| Treatments | Growth parameters |
|------------|--------------------|
| Rooting media | fresh weight of leaves (g) | dry weight of leaves (g) | fresh weight of roots (g) | dry weight of roots (g) |
| Top soil | 15.40 c | 2.62 b | 3.99 c | 1.21 c |
| 3:1 TS: FYM | 22.48 a | 3.85 a | 6.87 a | 1.89 b |
| 3:2 TS: FYM | 25.15 a | 4.29 a | 9.98 a | 3.02 a |

Number of nodes

| Number of nodes | 1 | 2 | 3 | LSD (5%) |
|-----------------|---|---|---|----------|
|                | 18.62 b | 20.69 b | 23.92 a | 7.399 |
|                | 3.11 b | 3.53 b | 4.12 a | 0.4453 |
|                | 6.20 b | 6.94 ab | 7.71 a | 1.081 |
|                | 1.70 c | 2.07 b | 2.36 a | 0.244 |

Means in a column followed by the same letter(s) had non-significant difference at 5% level of probability. LSD (5%) = least significant difference at P < 0.05, TS = top soil only, FYM = farmyard manure.
This result may be due to the effect of the nutrients found in FYM at their suitable and adequate concentrations in promoting the vegetative growth and dry matter accumulation. Also, the stimulating effects of macro and micro nutrients may be due to activating apical meristems besides the protoplasm formation, division and elongation of meristems cells, enhancing the biosynthesis of proteins and carbohydrates, which together led to enhancing the growth (Madison et al., 1995). Thummanatsakun and Yampracha (2018) also reported that the fresh and dry weights of cassava responded to the different N and K rates. Cattle manure is rich in its nitrogen and other plant nutrients as a result it favors the growth and development of root system which reflects better vegetative growth, photosynthetic activity and dry matter accumulation (Abou El- Magd and Hoda, 2005).

Farmyard manure constitutes important mineral nutrients such as N, P, K, as well as micronutrients and provides decomposable organic matter thereby increasing soil aggregations which in turn improves physico-chemical conditions of the soil such as water holding capacity. In addition, the carbon content in the manure is utilized as food by soil microorganism, which increases microbial activity to convert unavailable plant nutrients to available forms through biological transformation (mineralization) (Balesh, 2005). This property of manure may have promoted chaya leaf and stem growth and expansion in this experiment. The result of this experiment clearly demonstrated that number of nodes per cutting and FYM had effect on the growth performance of chaya cuttings. The use of three nodes per cutting resulted to higher shoot and root weights than that of two nodes. This agrees with the findings of Gurnah (1974) for cassava plant. This better performance of three nodes per cutting could be as a result of production of more roots resulting from burying nodes in the growing medium as reported by Donkor (1971).

### 3.3. Shoot to root dry weight ratio and relative growth rate

Shoot to root dry weight ratio and relative growth rate were significantly (P < 0.01) influenced by rooting media. Number of nodes and interaction of rooting media and number of nodes had non-significant effect on shoot to root dry weight ratio and relative growth rate of cuttings (See Appendix Table A). The highest value of shoot to root dry weight ratio (8.019) was higher by about 39% than the lowest value (5.764) obtained from cuttings grown at top soil media. The relative growth rate of chaya cuttings was significantly highest at media of 3:2 top soils: FYM while it was lowest at media containing only top soil. The cuttings grown on media of 3:2 top soils: FYM had higher relative growth rate by about 0.01111 and 0.02 g⁻¹day⁻¹ than cuttings grown on media of 3:1 top soils: FYM and top soil, respectively (See Table 6).

| Treatments | Parameters |
|------------|------------|
| Rooting media | Number of nodes | Fresh weight of shoot (g) | Dry weight of shoot (g) |
| Top soil | 1 | 47.1⁹ | 6.16 ⁹ |
| | 2 | 75.6⁹ | 8.58ef |
| | 3 | 97.6⁹ | 9.51⁹ |
| 3:1 TS: FYM | 1 | 76.6⁹ | 12.81⁹ |
| | 2 | 117.3⁹ | 14.38⁹ |
| | 3 | 120.5⁹ | 16.35⁹ |
| 3:2 TS: FYM | 1 | 105.9⁹ | 17.81⁹ |
| | 2 | 172.2⁹ | 20.87⁹ |
| | 3 | 192.8⁹ | 29.2⁹ |
| LSD (5%) | 16.08 | 3.389 |

Means in a column followed by the same letter(s) had non-significant difference at 5% level of probability. LSD (5%) = least significant difference at P < 0.05, TS = top soil only, FYM = farmyard manure.
Table 6. Effect of rooting media on shoot to root ratio and relative growth rate of chaya cuttings at Dire Dawa in 2018

| Shoot to root dry weight ratio | Relative growth rate (g g⁻¹ day⁻¹) |
|-------------------------------|-----------------------------------|
| Top soil only                 | 5.764 ²                          |
| 3:1 TS: FYM                   | 6.701ᵇ                         |
| 3:2 TS: FYM                   | 8.019ᵃ                         |
| LSD (5%)                      | 0.856                           |

Means in a column followed by the same letter(s) had non-significant difference at 5% level of probability. LSD (5%) = least significant difference at P < 0.05, TS = top soil only, FYM = farmyard manure.

The higher shoot to root dry weight ratio and growth rate were obtained from cuttings grown on media containing farmyard manure than growing media containing only top soil might be due to the additional supply of nutrients such as nitrogen, phosphorus and others from FYM. The increased shoot to root dry weight ratio of seedlings is associated with the increased growth rate due to the supply of nitrogen and micronutrients from the rooting media (Rufy et al., 1990). The nutrient supply and demand of root and shoot are inter-dependent due to their different functions of seedlings at a local environment (Siddique et al., 1990).

Root growth is closely related to physiological metabolism and dry matter accumulation in shoot (Siddique et al., 1990). An excessively low S/R indicates poor root growth, resulting in insufficient water and nutrients for shoot growth. An extremely high S/R may lead to root redundancy, which reduces shoot growth, yield, and water and nutrient use efficiencies (Zhang, 1995). Therefore, it is important to grow cuttings on proper growing media to attain balanced root and shoot growth and maximize dry matter accumulation and water and nutrient use efficiencies (Kahn & Schroeder, 1999; Tomar et al., 1997). Plants with a greater S/R usually have a relatively greater water and nutrient uptake capacity, higher yield stability, and greater drought resistance (Passioura, 1983).

4. Summary and conclusion

Chaya (Cnidoscolus aconitifolius McVaugh) is a fast-growing perennial shrub that produces lots of attractive, large, and dark green leaves. Chaya is known as spinach tree and has been given the name “famine plant” due to its potential to grow under drought, low soil fertility conditions, tolerant to insect pest. Chaya make good fodder for chickens and help to increase egg production and food for human being. Chaya out-performs most green leafy vegetables nutritionally thus, it has a great potential to improve deficits in population of developing countries as it is rich in protein, vitamin and mineral. It could be used to tackle malnutrition problem of the population in eastern Ethiopia in particular where sorghum is the major staple food and almost half of the population is undernourished.

In developing countries like Ethiopia vitamin A deficiency and anemia is a severe public health problem, affecting young children and mothers and reaching alarming levels especially in rural areas. About a quarter of school children suffer from anemia and their educational potential is likely to be affected especially for those with moderate and severe anemia in eastern Ethiopia. Realizing the problem, Haramaya University is conducting research to introduce chaya in the region which is rich in Vitamin A, Iron and Zinc. In Ethiopia, Chaya is not known in the food chain though the crop has been introduced before 35 years by one individual. The effort of Haramaya University is underway to introduce this crop in eastern Ethiopia considering the advantage of the crop to withstand drought, low soil fertility, fast growth, and its richness for many nutrients in which more than half of the population of the region is undernourished. However, the introduction of the crop could be successful if cultural practices such as the
propagation method(s), appropriate media are identified for success of field establishment and to attain potential yield of the crop.

The experiment was conducted during cropping season of 2018 at Dire Dawa, eastern Ethiopia to assess effect of rooting media and number of nodes on rooting, and seedling establishment. Treatments consisted 3 × 3 factorial combinations in which 3 levels of rooting media (top soil only, 3:1 top soil: FYM, 3:2 top soil: FYM), three levels of node numbers (cutting with 1, 2, 3 nodes) using completely randomized design for nursery experiment. The study revealed that the main effect of rooting media and node number significantly affected number of leaves, re-growth plant height, fresh and dry weight of leaves, fresh and dry weight of roots, shoot: root ratio and relative growth rate. The interaction of the two main factors significantly affected number of roots, fresh and dry weight of re-growth shoots.

Using cuttings with three node numbers and applying media 3:2 TS: FYM ratio resulted in the highest values of all parameters. In general, chaya cuttings on the nursery experiment responded well to rooting media containing top soil: FYM: and cutting length with three nodes. Therefore, it is advised to use a mixture of 3:2 top soils: FYM and cuttings with three nodes for growing planting materials in the study area.

Funding
This work was supported by the Ministry of Education, Ethiopia.

Author details
Fantahun Yesuf
E-mail: fantahun23@gmail.com
ORCID ID: http://orcid.org/0000-0003-4866-903X
Wassu Mohammed
E-mail: wassmoha@yahoo.com
Kebede Woldetsadik
E-mail: kwolede58@gmail.com

School of Plant Science, Haramaya University, Dire Dawa, Ethiopia.

Citation information
Cite this article as: Effect of rooting media and number of nodes on growth and leaf yield of chaya (Cnidoscolus aconitifolius McVaugh) at Dire Dawa, Eastern Ethiopia, Fantahun Yesuf, Wassu Mohammed & Kebede Woldetsadik, Cogent Food & Agriculture (2021), 7: 1914383.

References
Abou El-Magd, M.M., & Hoda, M. A. (2005). Relationships, growth, yield of broccoli with increasing N, P or K ratio in mixture of NPK fertilizers.
Addis, K., & Mohamed, A. (2004). Prevalence of anemia and associated factors among pregnant women in an urban area of eastern Ethiopia. Hindawi Publishing Corporation Anemia. Article ID 561567.
Awam, A. A., Iqbal, A. U., Rehman, M. J., & Idris, G. (2003). Response of olive hard wood cuttings to different growing media and basal injuries for propagation. Asian Journal of Plant Science, 2(2), 883–886. https://doi.org/10.3923/ajps.2003.883.886
Baitišköwea, M., De Bolle, S., Salomezb, J., Mrmečac, J. P., & De Neve, S. (2011). Effects of manure nitrogen on vegetables’ yield and nutrient efficiency in Tanzania. International Journal of Plant Production, 5(4), 417–430.
Boleš, T. (2005). Integrated plant nutrient management in crop production in the central Ethiopian highlands [Doctor of Philosophy (PhD)]. Norwegian University of Life Science.
Chandra Shaha, S., Kashem, M., & Osman, K. T. (2012). Effect of lime and farmyard manure on the concentration of cadmium in water spinach (Ipomoea aquatica). International Scholarly Research Notices. doi:10.5402/2012.719432.
Donkor, S. K. (1971). Investigation of the suitability of the best cuttings and methods of planting cassava [B.sc dissertation]. Kumasi University of Science and Technology.
Gomez, K. A., & Gomez, A. A. (1984). Statistical procedure for agricultural research. John Wiley and Sons.
Gonzalez-Laredo, R. F., Flores, M. E., Quintero-Ramos, M. J., & Karchesy, J. J. (2003). Flavonoid and cyanogenic contents of chaya (Spinach Tree). Plant Foods for Human Nutrition, 58(3), 1–8. https://doi.org/10.1023/B:QUAL.0000041142.48726.07
Gurnah, A. M. (1974). Effect of method of planting and type of cutting on the cuttings on yield components of cassava (Manihot esculenta Crantz) grown in the forest zone of Ghana. Journal of Agriculture Science, 7 (2), 103–108.
Hazelton, P. A., & Murphy, B. W. (2007). Interpreting soil test results (2nd ed.). CSIRO Publishing.
Iqbal, U., Wali, V. K., Kher, R., & Jamwal, M. (2009). Effect of FYM, urea and azotobacter on growth, yield and quality of strawberry. Notuloe Botaniceae Horti Agriculturici Cluj-Napoca, 37(1), 139–143.
Irshad, M., Rohman, R. A., Sajid, J., Khan, M., Ali, I., Razaq, S., & Sallahuddin, M. (2014). Influence of different planting dates and media on growth of Kiwi (Cv. Hayward) cuttings. Sarhad Journal of Agriculture, 30(6), 419–424.
Kahn, B. A., & Schroeder, J. L. (1999). Root characteristics and seed yields of cowpeas grown with and without added nitrogen fertilizer. Horticulture Science, 34(7), 1238–1239.
Kisidi, N., & Gardner, M. (2012). The curious case of chaya (Tree Spinach). The Manatee County Master Gardener Newsletter, 14(2).
Kuepper, G. (2003). Manures for organic crop production. Appropriate technology transfer for rural area (ATTRA). Fayetteville, AR. available at https://attra.org/attra-pub/PDF/manures. www.Attra.nctou.org.
London, J. R. (1991). Booker tropical soil manual: A handbook for soil survey and agricultural land evaluation in the tropics and sub-tropics. Longman Scientific and Technical.
Levoyageur Weather: Djibouti. (2012). Retrieved July 11, 2012, from http://en.wikipedia.org/wiki
Madison, F., Kelling, K., Massie, J., & Ward Good, J. (1995). Guidelines for applying manure to cropland and Pasture in Wisconsin. Extension bulletin, University of Wisconsin: Madison Extension.

Mesfin, F., Berhane, Y., & Worku, A. (2015). Anemia among primary school children in eastern Ethiopia. PLoS ONE, 10(4), e0123615. https://doi.org/10.1371/journal.pone.0123615

Ogendo, R. O., Isutsa, D. K., & Sigungu, D. O. (2008). Interaction of farmyard manure and plant population density effects on soil characteristics and productivity of mulched strawberry in a tropical climate. African Journal of Horticultural Science, 1, 100–115.

Olsen, S. R., Cole, C. V., Watanable, F. S., & Dean, L. A. (1954). Estimation of available phosphorus in soil by extraction with sodium bicarbonate (No. 939). USDA, Circular, 1–19.

Osaigbovo, A. U., Orhue, E. R., & Nwaogula, C. N. (2010). Effect of fish pond effluent on some soil chemical properties and vegetable growth of maize (Zea mays L.). Journal of Sustainable Agriculture and Environment, 12(2), 123–131.

Passioura, J. B. (1988). Root and drought resistance. Agriculture and Water Management, 7(1–3), 265–280. https://doi.org/10.1016/0378-3774(88)90089-6

Philipson, J. (1988). Root growth in Sitka spruce and Douglas-fir transplants: Dependence on the shoot and stored carbohydrates. Tree Physiology, 4(2), 101–108. https://doi.org/10.1093/treephys/4.2.101

Rufty, T. W., Mackown, C. T., & Israel, D. W. (1990). Phosphorus stress effects on assimilation of nitrate.

Plant Physiology, 94(1), 328–333. https://doi.org/10.1104/pp.94.1.328

Sengel, E., Isci, B., & Ahmet, A. (2012). Effects of different culture media on rooting in grafted grapevine. Ege University Ziraat Fakültesi Derg, 49(2), 143–148.

Siddique, K. H. M., Belford, R. K., & Tennant, D. (1990). Root: Shoot ratios of old and modern, tall and semi-dwarf wheat in a Mediterranean environment. Plant and Soil, 121(1), 89–98. https://doi.org/10.1007/BF00013101

Tadesse, T. (1991). Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa.

Tchoundjeu, Z., & Leakey, R. (1996). Vegetative propagation of African mahogany: Effects of auxin, node position, leaf area and cutting length. New Forest, 11(2), 125–136. https://doi.org/10.1007/BF00033408

Thummanatsakun, V., & Yamprach, S. (2018). Effects of interaction between nitrogen and potassium on the growth and yield of cassava. International Journal of Agricultural Technology, 14(7), 2137–2150.

Tomar, H. P. S., Dadiwal, K. S., & Singh, H. P. (1997). Root characteristics and moisture-use pattern of spring sunflower as influenced by irrigation, nitrogen and phosphorus. Journal of Agronomy, 42(3), 515–519.

Zhang, D. Y. (1995). Analysis of growth redundancy of crop root system in semi-arid area. Acta Botanica Boreali-Occidentalia Sinica, 15, 110–114.
Appendix

| Parameter                          | RM (2)  | NoN (2) | RM*NoN (4) | Error (16) | CV (%) |
|-----------------------------------|---------|---------|------------|------------|--------|
| Re-growth Stem height             | 1607.9**| 86.63** | 6.078      | 5.894      | 9.2    |
| Number of leaves                  | 310.18**| 122.52**| 4.80       | 18.76      | 13.5   |
| Number of roots                   | 18.24** | 3.94**  | 1.39*      | 0.36       | 7.6    |
| Fresh weight of leaves            | 228.27**| 68.91** | 5.77       | 5.76       | 11.4   |
| Fresh weight of re-growth shoot   | 16,032.26** | 8883.72** | 507.3**   | 86.33      | 8.3    |
| Fresh weight of root              | 80.68** | 5.12*   | 2.83       | 1.17       | 15.6   |
| Dry weight of re-growth shoot     | 479.43**| 85.65** | 19.18**    | 3.83       | 13.0   |
| Dry weight of leaves              | 6.78**  | 2.34**  | 0.15       | 0.19       | 12.4   |
| Dry weight of root                | 7.51**  | 0.97**  | 0.15       | 0.06       | 11.9   |
| Shoot to root dry weight ratio    | 11.5446**| 1.9465  | 1.6272     | 0.7329     | 12.5   |
| Relative growth rate              | 0.00090370** | 0.00002593 | 0.00001481 | 0.00001898 | 15.9   |

*and**, significant at P < 0.05 and at P < 0.01, respectively. Number in parenthesis indicates degree of freedom. RM = Rooting media, NoN = Number of nodes and CV (%) = coefficient of variation in percent.
