Hindawi
International Journal of Agronomy
Volume 2024, Article ID 3918033, 13 pages
https://doi.org/10.1155/2024/3918033

Research Article

Effect of Earthing-Up Frequency on Growth and Yield of Anchote (*Coccinia abyssinica*) Varieties at Gimbi District, Western Ethiopia

Habte Wakjira,[1] Weyessa Garedew,[2] Amsalu Nebiyu,[2] and Garome Shifaraw[3]

[1]*Irrigation Agronomist in West Welega Agricultural Office, Gimbi, Ethiopia*
[2]*Jimma University, College of Agriculture and Veterinary Medicine, Department of Horticulture and Plant Science, Jimma, Ethiopia*
[3]*Mettu University, Bedele Campus, Department of Plant Science, Bedele, Ethiopia*

Correspondence should be addressed to Garome Shifaraw; shifarawgarome@gmail.com

Received 9 August 2023; Revised 18 December 2023; Accepted 27 December 2023; Published 6 January 2024

Academic Editor: Maria Serrano

Anchote (*Coccinia abyssinica* (Lam.) Cogn) is a tuberous root crop native to Ethiopia. It is a good source of protein, carbohydrates, calcium, and iron. However, little attention has been given to the improvement of genetic and agronomic practices such as selection of variety, staking, weeding, fertilizer application, and earthing-up frequency. Thus, the attainable yield is below the potential. The experiment was arranged in a 3×5 factorial arranged in a randomized complete block design (RCBD) with three replications with the objective of determining the effect of earthing-up frequency on the growth and yield of anchote varieties. The interaction effect of earthing-up frequencies and varieties significantly affected anchote leaf number plant^{-1}, shoot dry weight plant^{-1}, unmarketable tuber weight ha^{-1}, vine diameter, shoot fresh weight plant^{-1}, tuber fresh weight plant^{-1}, marketable tuber weight ha^{-1}, and total tuber yield ha^{-1}. Total tuber yield ha^{-1} was perfectly correlated with tuber fresh weight plant^{-1} ($r = 1$), and all parameters were significantly correlated with tuber dry matter plant^{-1}, and tuber dry matter plant^{-1} was positively and significantly correlated with total tuber yield ha^{-1} ($r = 0.46$). Consequently, the highest total tuber yield was observed from earthing-up four times (26.94 t ha^{-1}) and three times (26.88 t ha^{-1}) with Desta 01, while the lowest was observed from the control with Acc405 (15.11). The highest economical tuber yield was obtained from three times earthing-up frequency (26.878 t ha^{-1}, 25.50 t ha^{-1}, and 23.92 t ha^{-1} for Desta 01, Acc405, and Acc173), and the lowest was observed from the control (22.83 t ha^{-1}, 15.11 t ha^{-1}, and 21.11 t ha^{-1} for Desta 01, Acc405, and Acc173), respectively. Therefore, for the study area, it is better to apply three times earthing-up frequencies (35 days, 49 days, and 63 days from planting date for once, twice, and three times earthing-up, respectively) with Desta 01 variety followed by Acc405. Since the experiment was conducted using irrigation, it is suggested to be repeated under rainfed conditions to draw a definite conclusion.

1. Introduction

Anchote (*Coccinia abyssinica* (Lam.) Cogn.) is a short life cycle plant known by trailing vine belonging to the cucurbitaceous family. In Ethiopia, the cultivation of anchote is limited to the western and south-western parts of Ethiopia such as Wollega, Kaffa, Sidama Jimma, and Illubabor [1, 2]. Anchote is produced for its tuberous root though its young immature leaves are also used as food in some areas [3]. It is used as a cultural, social, and economic crop for the community of anchote-producing area [4]. It is important as food and forage for people and livestock, respectively [4]. Anchote dish is known for its cultural food in the western region of the Oromo people, such as the celebration of the Ethiopian Meskel holiday (the finding of True Cross) and other holidays. Food prepared from anchote is the first to be served in the town and rural communities of the western regions of Ethiopia [5]. The food from anchote is also mixed with different green pepper paste, which is named "*kochkocha*" and ghee, and eaten with different bread, made of teff, maize, and wheat. Anchote dish is considered a unique and cultural food, which specifies western regions of Ethiopia. However, its expansion to other different parts of the county is very limited [2]. This could be because of low agricultural productivity, overdependence on some cereal crops, limited research coverage, and little attention given to this crop at a national level; which brings the absence of information on suitable planting time, lack of planting materials, shortage of released varieties, lack of awareness on production and utilization could be considered as a bottleneck for its good distribution [2].

Little attention has been given to anchote research and development [2]. Consequently, there is only one variety so far developed and released by Debre Zeit Agricultural Research Center [6]. Due to this problem, it is widely known that poor agronomic practices and traditional selection practices are being followed by farmers to have anchote types of desired quantity and quality, such as larger tuber size [2]. In Ethiopia, no study has been conducted on anchote earthing-up frequency. Therefore, in the study area, farmers usually apply to earth up to their anchote crop only once. Besides, they use landraces, which are very low in production and productivity.

Anchote has the potential to produce a tuber yield of 20–30 t ha^{-1} under farmer's conditions [7] and from 73 t ha^{-1} to 76.45 t ha^{-1} under research stations [2, 8]. However, the average yield of anchote in the Gimbi district is 14.35 t ha^{-1}, while 10–15 t ha^{-1} for western Oromia zones [9]. Among other factors, this yield gap of anchote is partially attributed to the low frequency of earthing-up [10] because adequate earthing-up results in plants having a larger area of root volume to gain enough water and nutrients for tuber development, which needs for photosynthesis [10, 11]. Besides, earthing-up minimizes the soil temperature, which is used to facilitate tuber growth and formation [10, 12]. Earthing-up also protects the tuber from insect damage by barring the tuber in the soil [13]. Hence, it needs to optimize and ensure the earthing-up frequency of anchote through research, since in anchote crop production, earthing-up is critical in that it creates a favorable condition for tuber growth and development.

Anchote has a high return for the farmers. However, most farmers are failing to achieve high yields partly because they do not adequately earth-up their anchote crop [10]. Anchote has a relatively short growing period, which means that it is one of the acceptable alternative crops to withstand the population pressure in developing countries like Ethiopia to minimize hunger because anchote is known to withstand draught and can substitute other food crops. Besides, within a single year, it can be produced more than once. When farmers do not adequately earth-up their anchote crop, the reward or advantage of anchote production cycle is shortly meaningless, as it will not bring away the good consequences in line with [10] who confirmed that the earthing-up frequency was carried out in order to increase yield in case of potato [14]. Besides, the positive effect of earthing-up of any level of sweet potato on marketable tuber was significantly higher than no earthing-up. Western Ethiopia is one of the high rainfall receiving areas and known for different root and tuber crop cultivation, specifically anchote, which is highly coupled with the life of the community in the area [2, 5]. Thus, anchote is a potential crop produced on nearly 3,000 ha, 743 ha, and 29 ha of land in the West Wollega Zone, Gimbi district, and weraseyo peasant association [7], and Gimbi district has a high potential for anchote production [2, 3 15]. Though anchote is produced on large coverage of land and too interlinked with the life of people in Gimbi district, their existing practice of its production is very poor, and in other anchote-producing areas, the crop has been grown under poor agronomic practices, particularly earthing-up frequency [2, 3, 15]. Consequently, their reward is too low as compared to the potential yield as stated for all regions of the anchote-producing area [2, 3, 10, 15]. Therefore, the overall objective of this study was to assess the growth and root yield response of anchote varieties to the earthing-up frequency at Gimbi district, western Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area. The study was carried out in Weraseyo peasant association, in Gimbi district, western Ethiopia and located 5 km from Gimbi district which is located 441 km from Addis Ababa. The site is found between Gimbi town in South West, Lalo Choli peasant association in the North, Choli Mikael peasant association in the West, and Lelisa Sarity in the east direction. Geographically, it is located between 9°10′ N latitude and 35°44′ E longitude while its altitude range is 1824 to 1872 m a.s.l (Figure 1). Besides, from personal observation, the soil of the study site has sandy (40%), clay (30%), and silt (30%); the soil is clay loam, which is good for most crops.

2.2. Experimental Material. Three varieties of anchote were obtained from the Debre Zeit Agricultural Research Center and used in this study. Two of them (Acc405 and Acc173) were in the pipeline to be released. The released variety, Desta 01, which yields an average yield of 32 t ha^{-1}, matures at 120 days, and creamy fresh root color has been used for the study. The descriptions of the three varieties are shown in Table 1.

2.3. Treatments and Experimental Design. Five levels of earthing-up frequency are no earthing-up, earthing-up once, earthing-up twice, earthing-up three times, and earthing-up four times and tree varieties of anchote (Desta 01, Acc405, and Acc173 were used as treatments combination). The experiment was arranged in a 3×5 factorial arrangement in a randomized complete block design (RCBD) with three replications. The plot sizes were fixed at two meters long and two meters wide, and each plot had five rows with 10 plants in each and with row spacing of 40 cm. There was a 20 cm distance between the plants, and the plots were 0.6 m apart from each other and 1 m between replications. The total numbers of plots were 45. Three seeds per hill were sown and finally thinned into one seedling per hill after complete emergence. Seeds were sown on well-prepared five rows per

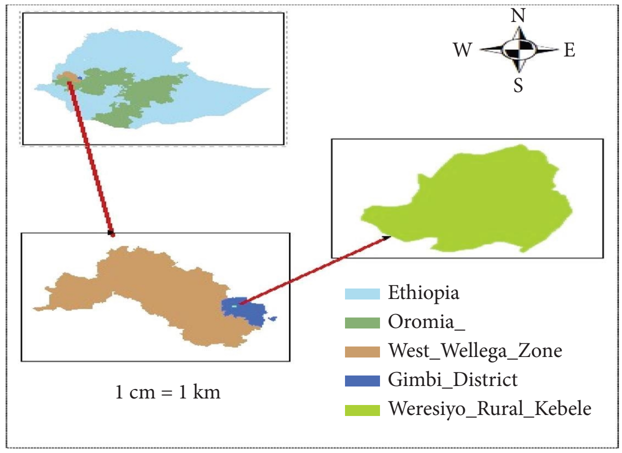

Figure 1: Map of the study area.

Table 1: Information about the three anchote genotypes/varieties.

Accession no.	Collection area and other information					
	Zone	Woreda	Kebele	Longitude	Latitude	Altitude m.a.s
405/09	East Wollega	Gudeya Bila	Walane Limu	9°21′00.44″N	37°01′54.05″	2338
173/09	West Wollega	Gimbi	Didisa Bikilal	9°16′33.28″N	35°44′54.60″	1886
Desta 01	Illu ababor	Ale	Sotelo	8°26′32.00″N	36°11′01.82″	1952

Source: Desta Fikadu, 2021, personal communication.

bed at a 5 cm depth in the soil directly on the bed [8]. Data were recorded from 15 randomly taken plants (from the three middle rows of the five rows per plot) in line with the experiment conducted on sweet potatoes [16] and cucurbit species [17].

2.4. Experimental Procedure

2.4.1. Land Preparation and Sowing. The land was plowed by oxen. Fine seedbeds were prepared and used for the ease of seed planting [15]. Then, planting blocks and plots were opened using a hoe, which was used for the row marker. The rows were straightened using a plastic thin rope line and sharp wood. This operation was followed by the pegging of three blocks with fifteen plots. Local wooden pegs have marked all plots [15]. The sowing of anchote seed was carried out on 07 December 2020. Though there is no seeding rate recommendation, there were 125,000 seedlings ha^{-1} [8]. This seed was covered by a thin thickness of soil to be sown at a shallow depth and spaced at 20 cm within the row. The rows were spaced 40 cm from each other. Three seeds were placed at each planting station. The sown seeds were then covered completely with soil with care not to heap too much soil above but to minimize seed emergency barriers.

2.4.2. Fertilizer Application. The recommended rate of N and P is 46 kg ha^{-1} and 20 kg ha^{-1}, respectively, but P in NPS-blended fertilizer is in the form of P_2O_5 (19% N: 38% P_2O_5: 7% S graded). Therefore, 45.8 kg ha^{-1} P in the form of P_2O_5 was used [7]. Consequently, based on this recommendation, 120.53 kg ha^{-1} and 50.21 kg ha^{-1} of NPS and Urea were applied, respectively. The fertilizer was applied in the band; this means that the application was 2.17 kg and 0.91 kg per total 45 plots for NPS and UREA, respectively. Then, 0.048 kg and 0.02 kg of NPS and urea were applied for each plot, but urea was applied by split application, i.e., 0.61 kg (2/3 of the total recommendation) was applied at planting.

2.4.3. Earthing Up. The earthing up was carried out starting 15 days after the complete emergence of plants [18] even though anchote can be germinated 9 days after planting [2]. However, in line with Mengesha et al. [8], the complete emergence occurred after 20 days while the rest of the three levels were carried out at every two weeks intervals from each other: 49 days, 63 days, and 77 days from the complete emergence date. This was carried out according to the experimental protocol of up to five treatments, which required that some plots were earthed-up once, some twice, some three times, and some four times while in some plots, earthing up was not carried out [10]. The different levels of earthing-up frequency could be implemented to evaluate appropriate earthing-up levels for the growth and root yield of anchote varieties. The practice of earthing up was carried out to improve growth and yield parameters as earthing up lowered the soil temperature and protected the tuber from sunlight. However, in line with Sakadzo et al. [19], the earthing-up operation was ended three weeks before flowering to minimize economic loss. Therefore, a ridge of a uniform height was prepared at each earthing up to keep other factors constant.

2.5. Agronomic Practices. The first weeding was carried out after three weeks from the date of the emergency [10] because plants compete for nutrients, light, and water at the initial stage is comparatively higher that of other growth stages [20]; however, the rest weeding operations were carried out simultaneously at every earthing-up operation to clean up the field. Appropriate field sanitation and other agronomic practices such as watering schedules, staking, and weeding were wisely managed to minimize the occurrence of diseases and pests. However, no insecticide, fungicide, or nematocide was applied, since there are no serious diseases or pest problems.

2.6. Data Collected. Different treatments were harvested at different times (110 days to 139 days from the planting date according to varieties and experimental protocol) when more than 90% of the plants showed physiological maturity. Harvested yield from each plot was gathered separately to allow parameters to be measured. The tubers were harvested manually by digging with hoes, and care was taken to separate the tubers produced by each crop. All samples on a plot were harvested, packed, and labeled separately for ease of identification. Therefore, data were collected on phenological traits, growth traits, and yield and yield components of the crop.

2.6.1. Phenological Traits. Days to 50% flowering was recorded as the number of days from planting when 50% of plants in each plot produced flowers (15, 16, 17, 21]. *Days to physiological maturity* recorded from plants in the plots, as the number of days from planting when 90% of leaves turned yellow [21].

2.6.2. Growth Traits. Plant height was measured by tape meter at maturity, but before harvesting from the 15 sampled plants and taken from the base of the plant to the top of the shoot by using a graduating tape meter, and the mean was used for data analysis. *Vine internodes length (cm)* was measured by a graduated ruler at maturity, but before harvesting of the plant by taking the representative part or the middle portion of vines from 15 sampled plants, and the mean was taken for data analysis. *Vine diameter (mm)* was measured at maturity, but before harvesting, and taken at 12 cm above the ground or middle part of the vine from 15 sampled plants. It was measured by a caliper meter and calculated for each plant.

Number of leaves per plant was counted from each sampled plant and divided by the total number of 15 sampled plants. Leaf *length (cm)* was recorded after flowering, but before the full maturity stage by measuring the length of the leaves in cm; which was taken from the middle parts of the plant by selecting 15 leaves at random from every 15 plants from the plot and then, mean was taken. After flowering but before reaching complete maturity, the breadth of the leaves (measured leaf width (cm)) was measured from the central sections of the plant by randomly picking 15 leaves from each of the 15 plants in the plot. The mean of the measurements was then obtained for analysis. This was done after flowering but before the full maturity stage. Shoot fresh weight per plant (kg): to calculate the shoot fresh weight for a specific plant, the weight of all the leaves, branches, and stems from 15 tested plants in each plot were weighed, and the result was divided by the total number of 15 sampled plants. Shoot dry weight per plant (kg) was obtained after drying the samples taken for determination of the shoot fresh weight in the open sun for seven days, and then, oven-dried was applied at 105°C until a constant weight of 10% was attained for 24 hrs.

2.6.3. Yield and Yield Components. Tuber fresh weight per plant (kg): all treatments were harvested and weighed separately by digital balance. The average weight of fresh tubers per plant was determined by dividing the initial tubers weight of 15 sampled plants per plot soon after harvest by the plant population within a sample of a single plot or divided by the number of 15 plants. Tuber dry matter content per plant (%): anchote tubers, which were harvested for fresh tuber weight per plant, were chopped into pieces. Then, the tuber fresh weights were placed in paper bags and dried at 105°C for 24 hours to a constant weight. Then, the dry matter content was calculated as the weight of 15 sampled tubers after drying in kg divided by the initial weight of 15 sampled tubers in kg times 100.

Marketable tuber weight per hectare (t ha^{-1}): anchote tubers, which were graded according to their free of blemishes, pest damage, and size of >100 g, were regarded as marketable as in the case of sweat potato [8]. So, the weight of marketable tubers per hectare was determined by weighing the weight of tubers from the whole three middle rows from each plot in kg and converting it to the weight of total marketable tuber weight in each plot. Finally, the marketable tuber weight was recorded for a single plot and converted to marketable tuber weight per hectare. Unmarketable tuber weight per hectare (t ha^{-1}) was measured in kg from the total storage root yield which was affected, damaged, and undersized (<100 g) as in the case of sweat potato [22] from whole three middle rows from each plot and calculated for each plot. Finally, the unmarketable tuber weight recorded for a single plot is converted to unmarketable tuber weight per hectare. Total tuber yield per hectare (t ha^{-1}): the total yield per hectare was determined by the mean fresh weight of the tuber per plant multiplied by the plant population per hectare.

2.7. Cost-Benefit Analysis to Determine the Appropriate Earthing-Up Frequency in Anchote Production. Cost-benefit analysis of the different levels of earthing-up frequency was carried out using a partial farm budget; total weeding and earthing-up costs were compared with net benefit [23, 24]. Therefore, it was estimated based on the formula developed by CIMMYT [25]. Gross unadjusted tuber yield (kg ha^{-1}) was the average yield of marketable tuber weight ha^{-1}. Adjusted tuber yield (kg ha^{-1}): the average yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield of farmers. Gross income/benefit (ETB ha^{-1}) was computed by multiplying the field/farm gate price that farmers receive for the crop when they sell it as adjusted yield. Total cost (ETB ha^{-1}) was the cost of labor for weeding and earthing up whereas other costs such as harvesting, land preparation, inputs, sawing, and transportation costs were assumed to remain the same or are insignificant among treatments. Net benefit (ETB ha^{-1}) was calculated by subtracting the total costs from gross income/benefits. The marginal rate of return (%) was calculated by dividing the change in net benefit by the change in cost time 100.

2.8. Data Analysis. First, data were checked for normality and meeting all ANOVA assumptions. The first step was verifying that the data met all ANOVA assumptions and were normal. Subsequently, the SAS statistical program with 9.3 version (SAS 9.3 version, 2014) was used to perform correlation and analysis of variance (ANOVA) [26]. The least significant difference (LSD) was used to separate the mean values of the treatments with a significance level of 5%. Eventually, the economical yield was analyzed by using Microsoft Office Excel to determine the recommended earthing up frequency for the study area.

$$\text{Model: } Y_{\text{ij}(k)} = \mu + R_i + E_j + V_k + \text{EV}_{\text{ik}} + \acute{\varepsilon}_{\text{ijk}}, \tag{1}$$

where $Y_{\text{ij}(k)}$ = the mean value of the response variables of the i^{th} earthing up at j^{th} variety in k^{th} blocks, μ = overall mean, E_j = earthing-up effect, V_k = variety effect, EV_{ik} = interaction effect, R_i = block effect, and $\acute{\varepsilon}_{\text{ijk}}$ = random error term.

3. Results and Discussion

3.1. Phonological Traits

3.1.1. Days to 50% Flowering. The analysis of variance indicated that the main effect of earthing-up frequency ($p < 0.01$) and varieties ($p < 0.01$) had a highly significant effect on days to 50% flowering. However, the interaction effect of earthing-up frequencies and varieties did not significantly affect day to 50% flowering. For earthing-up frequency, the maximum days to 50% flowering were obtained from four (91.81 days) and three (91.77 days) times earthing up, and the lowest (80.77 days) was obtained from no earthing-up (control) frequency (Table 2). This could be because adequate earthing-up frequency can facilitate vegetative growth. On the contrary, the absence of earthing up creates stress on the plant because of lack of aeration and enough moisture thereby, resulted in high production of ethylene hormone, which facilitates the reproductive stage, particularly early flowering. This result is in line with the work of Getachew et al. [27], who stated that the lack of aeration and mechanical barrier of soil colloids can affect plant growth and bring early flowering to plants. For variety, the longest day to 50% flowering was recorded from Desta 01 (88.29 days) while the shortest was recorded from Acc173 (85.76 days) and Acc405 (86.13 days) (Table 2). The study of Sadik et al. [21] which suggests that a variety of factors, including genetic and environment influence how early potatoes flower, is supported by this result, which may be the result of the environment's ability to vary for different kinds.

Table 2: Effect of earthing-up frequencies and varieties on the day to 50% flowering and days to physiological maturity of anchote at Gimbi district, western Ethiopia in 2020/2021.

Treatment	Level of trts	50% FD (days)	DFM (days)
Earthing-up frequency	Control	80.77^{d}	114.65^{d}
	Once	83.00^{c}	118.78^{c}
	Twice	86.25^{b}	120.57^{b}
	Three times	91.77^{a}	129.30^{a}
	Four times	91.81^{a}	129.84^{a}
LSD (0.05)		1.89	1.22
p value		0.0001	0.0001
Varieties	Desta 01	88.29^{a}	123.36^{a}
	Acc405	86.13^{b}	122.58^{b}
	Acc173	85.76^{b}	121.95^{b}
LSD (0.05)		**1.47**	**0.9452**
CV (%)		**2.26**	**1.03**

Means followed by the same letter across columns are not significantly different at $p = 0.05$; 50% FD = day to 50% flowering; DFM = day to physiological maturity; control = without earthing up. LSD = least significance difference and CV = coefficient of variation.

3.1.2. Days to Physiological Maturity. Both main effects of earthing-up frequency ($p < 0.01$) and varieties ($p < 0.01$) had significant effects on days to physiological maturity. However, their interaction effect had no significant ($p < 0.05$) effect on days to physiological maturity. This is in line with the work of Gutema (2016), who confirmed that the interaction effect of earthing up and tuber form of potato had no significant effect on the days to physiological maturity of potato. For earthing-up frequency, the highest days to physiological maturity were recorded from four times (129.84 days) and three times (129.30 days) earthing up, while the least days to physiological maturity were obtained from control (114.65 days) (Table 2). The reason for this may be because soil with no earthing up lacked enough moisture and was exposed to high temperatures, consequently probing the plant for the production of ethylene hormone which is the main cause of aging. This supports the finding of Getachew et al. [27], who stated that stress could affect plant growth and bring early maturity to the plant whereas adding the soil to the plant could facilitate the mobilization of nutrients and regulate adequate temperature and moisture thereby prolonging vegetative growth over reproductive growth. This result supports the finding of Getachew et al. [27], who reported that earthing up at 15 days after the complete emergence of the potato enhances vegetative growth that extends days to physiological maturity. For variety, the highest (123.36 days) days to physiological maturity were obtained from Desta 01, and the lowest (121.95 and 122.58 days) were recorded from Acc173 and Acc405, respectively (Table 2). This variance may result from genetic variability; variations in the plant's vegetative growth validate the findings of Sadik et al. [21], who found that environmental and genetic factors regulate the number of days potatoes take to reach physiological maturity.

3.2. Growth Traits

3.2.1. Plant Height. The interaction effect of earthing-up frequency and variety and the main effect of variety had no significant ($p > 0.05$ and 0.202, respectively) effect on plant height. However, the main effect of earthing-up frequency ($p < 0.01$) was highly significantly influenced plant height of anchote (Table 3). The longest plant height was obtained from earthing up four times (237.19 cm) and three times (235.04 cm), while the shortest was obtained from control (174.86 cm) (Table 3). This could be because adding soil to the plant is adding nutrients and moisture for the plant and is utilized by plants for their growth and development, specifically plant height. This agrees with the finding of Fitsum et al. [12], who indicated that the highest plant height was recorded from potatoes earthed up. Similarly, the authors of [28] reported that earthing up significantly affected the height of the onion plant, measured on different days after planting.

3.2.2. Vine Internode Length. The interaction effect of earthing-up frequency and variety and the main effect of variety did not significantly ($p > 0.05$ and 0.1473, respectively) affect the vine internode length of anchote. However, the earthing-up frequency had a highly significant effect ($p < 0.01$) on anchote vine internode length. The highest vine internode length was obtained from four times (7.88 cm) and three times (7.85 cm) earthing up while the lowest was obtained from the control treatment (5.0822 cm) (Table 3). This result might be as the results of the different varieties of anchote vine internode length were influenced by a change in soil condition because of added soil to the anchote. The authors of [8] stated that the variability in internode length among accessions of anchote could be due to genetic differences and/or environmental effects.

3.2.3. Leaf Length. The interaction effect of earthing-up frequency and variety did not significantly affect ($p > 0.05$) the leaf length of anchote. However, the two main effects ($p < 0.01$) had a highly significant effect on the leaf length of anchote. The longest leaf length was observed from earthing up four times (9.72 cm) and earthing up three times (9.71 cm), while the shortest leaf length was observed from no earthing up (7.46 cm) (Table 4). This might be because the active growth stage of the plant was improved by the soil porosity, aeration, better root growth, and penetration for nutrient absorption thereby increasing leaf length for the requirement of metabolic activities. This result agrees with that of Getachew et al. [27], who stated that the largest leaf area was obtained from potato earthing up after a complete plant emergency coincided with the increased plant growth and development that ultimately increased the leaf area of potato. In the case of variety, the longest leaf length was obtained from Desta 01 (8.64 cm) and Acc405 (8.51), and the shortest was observed from Acc173 (8.32 cm) (Table 4). This result may be due to the genetically unique characteristics of different varieties. The results are consistent with the finding of Mengesha et al. [8], who reported that the presence of genetic variability among accessions evaluated and that the accessions interact with the environment resulting in a differential genotypic response.

Table 3: Effect of earthing-up frequencies and varieties on plant height and vine internodes length of anchote at Gimbi district, western Ethiopia in 2020/2021.

Treatment	Level of trts	PH (cm)	VIL (cm)
Earthing-up frequency	Control	174.86^{d}	5.08^{c}
	Once	187.88^{c}	5.89^{b}
	Twice	210.80^{b}	5.98^{b}
	Three times	235.04^{a}	7.85^{a}
	Four times	237.19^{a}	7.88^{a}
LSD (0.05)		3.89	0.3299
p value		0.0001	0.0001
Varieties	Desta 01	207.75	6.40
	Acc405	209.26	6.55
	Acc173	210.45	6.55
LSD (0.05)		NS	NS
CV (%)		**1.93**	**5.29**

Means followed by the same letter across the column are not significantly different at $p = 0.05$; PH = plant height; VIL = vine internode length; control = without earthing up. LSD = least significance difference and CV = coefficient of variation.

Table 4: Effect of earthing-up frequencies and varieties on leaf length and leaf width of anchote at Gimbi district, western Ethiopia in 2020/2021.

Trts	Level of trts	LL (cm)	LW (cm)
Earthing-up frequency	Control	7.46^{d}	9.24^{d}
	Once	7.66^{c}	9.43^{cb}
	Twice	7.89^{b}	9.69^{b}
	Three times	9.71^{a}	10.26^{a}
	Four times	9.72^{a}	10.29^{a}
LSLD (0.05)		0.1466	0.4025
p value		0.0001	0.0001
Varieties	Desta 01	8.64^{a}	9.97^{a}
	Acc405	8.51^{a}	9.91^{a}
	Acc173	8.32^{b}	9.46^{b}
LSD (0.05)		**0.1136**	**0.3118**
CV (%)		**1.79**	**4.26**

Means followed by the same letter across columns are not significantly different at $p = 0.05$, LL = leaf length, LW = leaf width, and control = without earthing up. LSD = least significance difference and CV = coefficient of variation.

3.2.4. Leaf Width. The interaction effect of earthing-up frequency and variety did not significantly affect the leaf width of anchote. However, the main effects of earthing up ($p < 0.01$) and variety ($p < 0.01$) had a highly significant effect on the leaf width of anchote. The widest leaf width was observed from earthing up four times (10.29 cm) and earthing up three times (10.26 cm) while the narrowest leaf width was observed from no earthing up (9.24 cm) (Table 4). This might be because the active growth stage of the plant is improved by the soil porosity, aeration, better root growth, and penetration for nutrient absorption thereby increasing leaf width for the requirement of metabolic activities. This result agrees with that of Getachew et al. [27], who reported that the largest leaf area was obtained from potato earthing up after complete plant emergence, which coincided with the increased plant growth and development that ultimately increased the leaf area of potato.

For variety, the widest leaf width was obtained from Desta 01 (9.97 cm) and Acc405 (9.91 cm) while the narrowest was observed from Acc173 (9.46 cm) (Table 4). This result may be due to genetic differences among the varieties under study. The result agrees with the finding of Mengesha et al. [8], who reported that the presence of genetic variability among accessions evaluated and that the accessions interact with the environment resulting in a differential genotypic response.

3.2.5. Vine Diameter. The interaction effect of earthing-up frequency and variety had a significant effect ($p < 0.05$) on the vine diameter of anchote. The analysis showed that the highest vine diameter was obtained from four times (6.82 mm) and three times (6.80 mm) earthing up with anchote variety Desta 01, while the lowest was recorded from no earthing up with variety Acc173 (3.94 mm) (Table 5). This result might be because earthing-up contributed to controlling weeds and increased root penetration that enabled the plant to absorb enough nutrients and water thereby increasing the vine diameter of anchote. This is in line with the finding of Getachew et al. [27] who reported that the earthing-up enabled potatoes to absorb more nutrients and Gebremedhin et al. [29] who also indicated that one-time earthing up increased growth parameters and yield components of potatoes as compared to no earthing up.

3.2.6. Leaf Number per Plant. The interaction effect of earthing-up frequency and variety had a highly significant effect ($p < 0.01$) on the leaf length of anchote. The highest leaf numbers per plant were obtained from earthing up four times (35.36 leaves) and three times (35.18 leaves) with Acc173. The lowest leaf numbers per plant were observed from no earthing up with Desta 01 (17.82 leaves) and Acc405 variety (18.11 leaves) (Table 5). This result is in line with the finding of Ali et al. [28], who indicated that the number of leaves per plant was observed to vary significantly between earthing up and none earthing up in the case of onion.

3.2.7. Shoot Fresh Weight per Plant. The interaction effect of earthing-up frequency and variety had a significant effect ($p < 0.05$) on shoot fresh weight per plant of anchote. The highest shoot fresh weight per plant was recorded from four times earthing up with Acc173 (0.584 kg) and Acc405 (0.583 kg) and three times earthing up with Acc173 (0.57 kg) and Acc405 (0.58 kg) (Table 5). The lowest shoot fresh weight per plant (0.36 kg) was recorded from the control with Acc405. This result agrees with the finding of Fitsum et al. [12], who reported that the fresh shoot biomass of potatoes was significantly affected by earthing up whereas low fresh shoot biomass was recorded from the control. This may be because of more leaf number, leaf area, and lateral branches as the result of adequate nutrient and moisture absorption by their root that grew freely. Fitsum et al. [12] also supported this by showing that the more lateral branches and enlarged leaves, the higher the shoot biomass per potato plant as a result of earthing-up. In addition, the author of [2] indicated that the difference in ground coverage of anchote accessions could be due to the difference in soil conditions and varieties.

3.2.8. Shoot Dry Weight per Plant. The interaction effect of earthing-up frequency and variety had a significant effect ($p < 0.05$) on shoot dry weight per plant of anchote. The highest shoot dry weight per plant was recorded four times (0.06 kg) and three times (0.0609 kg) earthing up with Desta 01 (Table 5) while the lowest shoot dry weight per plant (0.04 kg) was obtained from the control with Acc173. This indicates that days to maturity were prolonged (up to 4 months) as a result of earthing up, and shoot dry weight increased though it declined after four months of harvesting as an increment of yield components. This agrees with the work of Abera and Haile [7], who indicated that anchote produced significantly higher fresh and dry above-ground biomass at the 4th month of harvesting date. However, it is also acknowledged that during the following harvesting dates, which are the seventh through the sixteenth month of in situ storage, the biomass of anchote, both fresh and dry, dramatically decreased [7].

3.3. Yield and Yield Components

3.3.1. Tuber Fresh Weight per Plant. The interaction effect of earthing-up frequency and variety had a significant effect ($p < 0.05$) on tuber fresh weight per plant of anchote. The highest tuber fresh weight per plant was obtained from earthing up four times with Desta 01 variety (0.216 kg) and earthing up three times with Desta 01 (0.215 kg) (Table 6), while the lowest was from control with Acc405 (0.121 kg) and control with Acc173 (0.169 kg). This might be because earthing up decreased the soil temperature, facilitated aeration and moisture, and improved root penetration that enabled to increase in tuber fresh weight. This is in agreement with the work of Chitsinde [10], who stated that adequate earthing up results in plants having a larger area of root volume, to gain enough water and nutrients for tuber development as compared to control, which has a limited area for water and nutrient extraction needed for photosynthesis. Therefore, due to favorable soil moisture, aeration, and availability of nutrients, there may greater number of leaves, thereby capturing enough sunlight that is used to facilitate tuber growth. This result agrees with the finding of [7], who stated that the greater the number of leaves in a field, the better the interception of sunlight, and the higher the tuberous root yield. In addition, the highest shoot fresh weight could be due to the genetic variability of anchote as also stated by Mwololo et al. [30], who reported that the weight difference of sweet potato varieties might have come from the genetic capability of the varieties.

Table 5: Interaction effect of earthing-up frequencies and varieties on vine diameter, leaf number per plant, shoot fresh weight per plant, and shoot dry weight per plant of anchote at Gimbi district, western Ethiopia in 2020/2021.

Treatments		VDPP (mm)	LNPP (No)	SFWPP (kg)	SDWPP (kg)
Earthing-up frequencies	Varieties				
Control	Desta 01	4.23^{f}	17.82^{g}	0.37^{def}	0.04^{fgh}
Once		5.12^{e}	20.3^{f}	0.43^{bcdef}	0.046^{de}
Twice		5.54^{d}	22.1^{e}	0.44^{bcdef}	0.05^{cd}
Three times		6.80^{a}	28.93^{c}	0.45^{bcd}	0.06^{a}
Four times		6.82^{a}	29.24^{bc}	0.45^{bcd}	0.0609^{a}
Control	Acc405	4.04^{gf}	18.11^{g}	0.36^{f}	0.04^{fgh}
Once		5.00^{e}	20.55^{f}	0.39^{cdef}	0.042^{ef}
Twice		5.38^{d}	22.20^{e}	0.44^{bcde}	0.044^{ef}
Three times		6.38^{b}	29.37^{cb}	0.57^{a}	0.055^{b}
Four times		6.40^{b}	29.91^{b}	0.583^{a}	0.0556^{b}
Control	Acc173	3.94^{g}	20.22^{f}	0.37^{ef}	0.038^{h}
Once		4.98^{e}	21.90^{e}	0.44^{bcde}	0.041^{fg}
Twice		5.08^{e}	23.62^{d}	0.47^{b}	0.0446^{ef}
Three times		6.14^{c}	35.18^{a}	0.58^{a}	0.05^{c}
Four times		6.20^{b}	35.36^{a}	0.584^{a}	0.051^{c}
LSD (0.5)		**0.2483**	**0.8844**	**0.0763**	**0.004**
CV (%)		**2.23**	**2.15**	**9.87**	**5.10**

Means followed by the same letter across columns are not significantly different at p = 0.05, VDPP = vine diameter per plant, LNPP = leaf number per plant control = without earthing up, SFWPP = shoot fresh weight per plant, and SDWPP = shoot dry matter content per plant. LSD = least significance difference and CV = coefficient of variation.

Table 6: Interaction effect of earthing-up frequencies and varieties on tuber fresh weight per plant and tuber dry matter content per plant of anchote at Gimbi district, western Ethiopia in 2020/2021.

Treatments		TFWPP (kg)	TDMCPP (%)
Earthing-up frequencies	Varieties		
Control	Desta 01	0.183^{bcd}	11.074^{cd}
Once		0.194^{abcd}	13.194^{c}
Twice		0.201^{abc}	19.593^{b}
Thrice		0.215^{a}	29.349^{a}
Four times		0.216^{a}	29.382^{a}
Control	Acc405	0.121^{d}	12.521^{cd}
Once		0.179^{bcd}	13.08^{c}
Twice		0.188^{bcd}	14.074^{c}
Three times		0.204^{abc}	21.999^{b}
Four times		0.205^{ab}	22.883^{b}
Control	Acc173	0.169^{d}	8.807^{f}
Once		0.178^{cd}	9.065^{f}
Twice		0.184^{bcd}	10.7^{ef}
Three times		0.191^{abcd}	20.321^{b}
Four times		0.192^{abcd}	20.748^{b}
LSD (0.5)		**0.0262**	**3.945**
CV (%)		**7.43**	**13.29**

Means followed by the same letter across columns are not significantly different at p = 0.05, TFWPP = tuber fresh weight per plant, TDWPP = tuber dry weight per plant, and control = without earthing up. LSD = least significance difference and CV = coefficient of variation.

3.3.2. Tuber Dry Matter Content per Plant. The interaction effect of earthing-up frequency and variety had a significant effect ($p < 0.05$) on tuber dry matter per plant of anchote. The highest tuber dry matter content per plant was obtained from earthing up four times with Desta 01 (29.382%) and earthing up three times with Desta 01 (29.349%) while the lowest was from control (8.807%) and earthing up once (9.065%) with Acc173 (Table 6). On the other hand, there was no significant difference between four times earthing-up frequency for Acc175 and three times earthing-up frequency for Acc405.

The result showed that the tuber dry matter content was positively and significantly correlated with leaf width ($r = 0.71$), leaf length ($r = 0.87$), leaf number per plant ($r = 0.70$), shoot fresh weight per plant ($r = 0.48$), and shoot dry weight per plant ($r = 0.89$) (Table7). Zalalem et al. [31] reported that a positive and highly significant correlation was observed between above and underground biomass showing the presence of a close connection between them. This result revealed that as the result of earthing up, there was an increment of leaf width, leaf length, and leaf number, which increased the amount of solar radiation intercepted and more photo-assimilate produced, thereby adequate amount of carbohydrate to translocate to the tuber. This result agrees with the finding of Chitsinde [10], who stated that adequate earthing-up results in plants gaining enough water and nutrients for tuber development because of good photosynthesis in the case of potatoes. According to Zalalem et al. [31] , there was a possible increase in photo-assimilate production and translocation to the potato tuber due to the increased total leaf area, which also increased the amount of solar energy intercepted. Besides, tuber in aerated soil accumulated more dry matter content which supports the finding of [32, 33], who stated that the aerated plant had more dry matter due to the root improvement in the case of sweet potato.

The result also showed that the evaluation of any crop by its limiting factors and any additional value is due to varieties, which agrees with the work of [34], who indicated that different dry matter contents are observed even within the same varieties [35, 36] and also stated that the wider

Table 7: Correlation coefficient of the 15 parameters of three anchote varieties grown at Gimbi district, western Ethiopia in 2020/2021.

	FD	DPM	PH	VL	VD	LNPP	LL	LW	SFW	SDW	TFW	TDMC	MTW	UMTW	Ytha
FD															
DPM	0.89***														
PH	0.87***	0.95***													
VL	0.84***	0.93***	0.94***												
VD	0.88***	0.95***	0.92***	0.89***											
LNPP	0.77***	0.89***	0.90***	0.91***	0.83***										
LL	0.86***	0.94***	0.90***	0.91***	0.92***	0.89***									
LW	0.59***	0.69***	0.66***	0.64***	0.74***	0.47**	***								
SFW	0.52***	0.71***	0.77***	0.77***	0.66***	0.81***	0.69***	0.45**							
SDW	0.87***	0.91***	0.87***	0.82***	0.91***	0.72***	0.88***	0.74***	0.55***						
TFW	0.67***	0.61***	0.59***	0.56***	0.69***	0.47**	0.58***	0.45**	0.38*	0.62***					
TDMC	0.84***	0.87***	0.80***	0.77***	0.87***	0.70***	0.87***	0.71***	0.48**	0.89***	0.46**				
MTW	0.83***	0.79***	0.77***	0.73***	0.86***	0.65***	0.77***	0.60***	0.50**	0.80***	0.96***	0.69***			
UMTW	−0.87***	−0.92***	−0.88***	−0.83***	−0.89***	−0.80***	−0.80***	−0.72***	−0.60***	−0.90***	−0.43**	−0.96***	−0.67***		
Ytha	0.67***	0.61***	0.59***	0.56***	0.69***	0.47**	0.58***	0.45**	0.38*	0.62***	1.0***	0.46**	0.96***	−0.43**	

where *, **, and *** are weak, moderate, and strongly (highly) significant, respectively. MTW t ha^{-1} = marketable tuber weight per hectare, UMTW t ha^{-1} = unmarketable tuber weight per hectare, Y t ha^{-1} = yield tone per hectare, SDWPP = shoot dry weight per plant, TFWPP = tuber fresh weight per plant, TDWPP = tuber dry weight per plant, VDPP = vine diameter per plant, LNPP = leaf number per plant and SFWPP = shoot fresh weight per plant, FD = day to 50% flowering, DPM = days to physiological maturity, PH = plant height, VIL = vine internode length, LL = leaf length, and LW = leaf width.

variability in the root of sweet potato varieties is also in agreement with the root traits diversity exhibited in dry matter.

3.3.3. Marketable Tuber Weight per Hectare. The interaction effect of earthing-up frequency and variety had a highly significant effect ($p < 0.01$) on marketable tuber weight t ha^{-1} of anchote (Table 8). The highest marketable tuber t ha^{-1} was obtained from earthing up four times with Desta 01 (25.98 t ha^{-1}) and three times earthing up with Desta 01 (25.88 t ha^{-1}), while the lowest (11.38 t ha^{-1}) was from control with Acc405 (Table 8). The result showed that the earthing up increased the tuber in size and prevented it from being infected by insects because of a decrease in temperature, soil compaction, and exposure to sunlight. In addition, since dry matter content and marketable tuber were positively and significantly correlated (r = 0.69) (Table 7), it might be difficult to penetrate insects, and soil has physically buried the tuber, which enabled the tuber to be easily seen by insects. This result accepts the work of Getachew et al. [27], who indicated that proper ridging increases tuber yield, by creating favorable conditions for tuber initiation and development.

3.3.4. Unmarketable Tuber Weight per Hectare. The interaction effect of earthing-up frequency and variety had a significant effect ($p < 0.05$) on unmarketable tuber weight per plot of anchote. The highest unmarketable tuber weight per plot was obtained from control with Acc173 (4.59 t ha^{-1}), while the lowest was from earthing-up four times (0.96 t ha^{-1}) and three times (0.99 t ha^{-1}) with Desta 01(Table 8). Nevertheless, all earthing-up frequencies at four times and three times with their corresponding varieties were not statistically different. This may be because the anchote tuber with no earthing up could be undersized as a result of high temperature and low nutrient released as well as damaged by insects which agrees with the finding of Getachew et al. [27], who reported that poor earthing up around the plants could expose the tuber to sunlight, high temperature, diseases, and insect damage. In line with this, Chitsinde [10] also reported that when the temperature was increased to 25°C, the size of tubers formed by the plant also decreased, and this practice was common when the crop was not properly earthed up. In addition, genetic variability and genetic interaction with the environment also influenced unmarketable tuber yield which confirms the finding of Tafi et al. [37], who indicated the interaction of soil adding to bush and varieties influences yield components of sweat potato.

3.3.5. Total Tuber Yield per Hectare. The interaction effect of earthing-up frequency and variety had a significant effect ($p < 0.05$) on tuber yield per hectare of anchote. The highest tuber yield per hectare was obtained from earthing up four times (26.94 t) with Desta 01 and earthing up three times (26.88 t) with Desta 01, and the lowest (15.11 t) was obtained from control with Acc405 (Table 7). This might be because tuber yield was formed and increased as a result of low temperature and earthing up minimized tuber exposure to sunlight, damage by insects, and soil compaction collectively improved the total yield of the tuber. This agrees with the work of [38], who reported that tubers formed well when soil temperature was as low as 10°C to 12°C permitted tubers formation and development. This might be because, at a high temperature above the optimum, the rate of respiration is greater than the rate of photosynthesis, reduces the translocation of carbohydrates to the tuber, and increases the occurrences of diseases around the storage tuber [38] and also concluded that more earthing enables large tubers to be formed on the buried stems in the case of sweat potatoes. In addition, the wider variability in the root of sweet potato varieties is also in agreement with the root traits diversity exhibited in root yield variability, which confirms the work of germplasm collection from Tanzania [33, 35].

The correlation analysis also revealed that tuber yield t ha^{-1} was positively and perfectly correlated with tuber fresh weight per plant ($r = 1$). The total yield per hectare was also significantly correlated with days 50% to flowering ($r = 0.67$), days to physiological maturity ($r = 0.61$), plant height ($r = 0.59$), vine internode length ($r = 0.56$), vine diameter ($r = 0.69$), leaf number per plant ($r = 0.47$), leaf length (0.58), leaf width ($r = 0.45$), shoot fresh weight per plant ($r = 0.38$), shoot dry weight per plant ($r = 0.62$), tuber dry matter content per plant ($r = 0.46$), marketable tuber weight per hectare ($r = 0.96$), and unmarketable tuber weight per hectare ($r = -0.43$) (Table 7). This might be due to the improvement of the considered traits could result in an improvement in tuber yield. This confirms the finding of [39, 40], who stated that considerable emphasis should be given to yield and growth traits to increase root yield in anchote.

3.4. Cost-Benefit Analysis for Appropriate Earthing-Up Frequency. The values of total income vary (309,054.26, 379,824.70, 412,304.54, 476,291.89, and 479,557.39 ETB (Ethiopian Birr) ha^{-1} for control, once, two times, three times, and four times earthing-up frequency, respectively) for different levels of earthing-up frequency, while the value of partial costs of anchote production calculated from control, and once and two times earthing-up frequencies were not different (180,000 Ethiopian Birr ha^{-1}) from each others. The current result showed that the highest total income was obtained from four times earthing-up frequency (479,557.39 ETB ha^{-1}) and the lowest was obtained from control (309,054.26 ETB ha^{-1}) whereas the highest total cost was obtained from four times earthing-up frequency (240,000 ETB ha^{-1}). However, the lowest total cost was recorded from control, once, two times, and three times (180,000 ETB ha^{-1}) earthing-up frequency. The highest net benefit was observed from three times earthing-up frequency (296,291.89 ETB ha^{-1}), while the lowest was recorded from the control treatment (129,054.26 ETB ha^{-1}). The above results might be due to differences in yield recorded by the different earthing-up frequency levels much resulting in the highest yield to its production cost which

Table 8: Interaction effect of earthing-up frequencies and varieties on MTW (t ha^{-1}), UMTY (t ha^{-1}), and Y (t ha^{-1}) of anchote at Gimbi district, western Ethiopia in 2020/2021.

Treatments: Earthing-up frequencies	Varieties	MTW t ha^{-1}	UMTW t ha^{-1}	Y t ha^{-1}
Control	Desta 01	18.45^{fg}	4.38^{ab}	22.83^{bcd}
Once		20.59^{cdef}	3.60^{c}	24.19^{abcd}
Twice		22.69^{bc}	2.45^{d}	25.13^{abc}
Three times		25.88^{a}	0.99^{e}	26.88^{a}
Four times		25.98^{a}	0.96^{e}	26.94^{a}
Control	Acc405	11.38^{h}	3.73^{bca}	15.11^{e}
Once		18.31^{fg}	4.08^{bc}	22.39^{bdc}
Twice		19.75^{def}	3.69^{bc}	23.44^{bcd}
Three times		23.55^{ab}	1.95^{d}	25.50^{abc}
Four times		23.88^{ab}	1.76^{d}	25.64^{ab}
Control	Acc173	16.52^{g}	4.59^{a}	21.11^{d}
Once		18.07^{fg}	4.21^{abc}	22.28^{cd}
Twice		19.41^{ef}	3.59^{c}	23.00^{bcd}
Three times		22.01^{bcde}	1.91^{d}	23.92^{abcd}
Four times		22.07^{bcd}	1.88^{d}	23.94^{abcd}
LSD (0.5)		**1.0462**	**0.2857**	**3.2705**
CV (%)		**6.73**	**13.77**	**7.43**

Means followed by the same letter across columns are not significantly different at $p = 0.05$, MTW t ha^{-1} = marketable tuber weight t ha^{-1}, UMTW t ha^{-1} = unmarketable tuber weight t ha^{-1}, and Y t ha^{-1} = yield tone per hectare.

confirms the work of Omovbude and Udensi [24], who stated that the differences in yield recorded by the different treatments mulch resulting in the highest yield.

4. Conclusion

Anchote is native to Ethiopia and is the only crop produced for its edible tuberous root from its family Cucurbitaceae. However, its distribution was limited to the western and south-western parts of Ethiopia, since the attempts made so far to improve the genetic and agronomic practice related to the management of the crop are very limited. Thus, the objective of this study was to evaluate the superior yielding variety and earthing-up frequency on anchote to improve the current anchote growth and root yield in the study area with the implementation of optimum earthing-up frequency on different anchote varieties.

Results of the current experiment revealed that the interaction effects of earthing-up frequency and varieties significantly affected anchote leaf number per plant, marketable tuber weight per hectare, shoot dry weight per plant, unmarketable tuber weight per hectare, vine diameter, shoot fresh weight per plant, tuber dry weight per plant, tuber fresh weight per plant, and tuber yield per hectare. The main effects of earthing-up frequencies and varieties significantly influenced days to 50% flowering, days to 50% flowering, leaf width, and leaf length. The maximum economical yield was obtained from three times earthing up (26.88 t ha^{-1}) with Desta 01 followed by three times earthing up with Acc405 (25.5 t ha^{-1}). In conclusion, for the study area, it is better to apply three times earthing-up frequency with Desta 01 variety followed by Acc405. To assure future food security, using the anchote crop will be an alternative opportunity. Thus, comparative attention should be given to this crop, to satisfy the food demand of the population. The experiment was conducted under irrigation conditions and at one location and season; therefore, it should be repeated under rainfed and at more locations and seasons to assess the further effect of earthing-up frequency on the growth and yield of anchote varieties and come up with a sound recommendation.

Data Availability

The data supporting the findings of this study are available upon request from the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] B. Endashaw, "Study on actual situation of medicinal plants in Ethiopia," *Japan Association for International Collaboration of Agriculture and Forestry*, vol. 2, pp. 1–9, 2007.

[2] D. Fekadu, "Phenotypic and nutritional characterization of anchote [coccinia abysinica (lam.) Cogn] accessions of Ethiopia," MSc. Thesis, Jimma University, Jimma, Ethiopia, 2011.

[3] G. Haki, "Phytochemical constituents in edible parts of anchote (*Coccinia abyssinica* (lam.)(Cogn.)) Accessions from Ethiopia," *Botswana Journal of Agriculture and Applied Sciences*, vol. 13, no. 1, pp. 1–9, 2019.

[4] B. S. Wayessa, "Anchote (*Coccinia abyssinica*): a tuber viewed as a relative of women in the Wollega region of southwestern Ethiopia," *Ethnoarchaeology*, vol. 10, no. 1, pp. 34–55, 2018.

[5] A. Parmar, B. A. Gebre, A. Legesse, Y. Demelash, K. Fladung, and O. Hensel, "Nutritional comparison of white and red *Coccinia abyssinica* (Lam.) Cong. accessions: an underutilized edible tuber of the Ethiopian highlands," *Foods*, vol. 6, no. 8, pp. 1–71, 2017.

[6] A. M. Bikila, Y. Tola, T. B. Esho, and S. F. Forsido, "Effect of predrying treatment and drying temperature on proximate composition, mineral contents, and thermophysical properties of anchote (*Coccinia abyssinica* (Lam.) Cogn.) flour," *Food Science and Nutrition*, vol. 8, no. 10, pp. 5532–5544, 2020.

[7] G. Abera and H. Guteta, "Response of anchote (*Coccinia abyssinica*) to organic and inorganic fertilizers rates and plant population density in western Oromia, Ethiopia," *East African Journal of Sciences*, vol. 1, no. 2, pp. 120–126, 2007.

[8] D. Mengesha, D. Belew, W. Gebreselas, and W. Sori, "Growth and yield performance of anchote [coccinia abyssinica (lam.) Cogn.] in response to contrasting environment," *Asian Journal of Plant Sciences*, vol. 11, no. 4, pp. 172–181, 2012.

[9] A. Gemeda, "Root and tuber crops as compliments to sustainable livelihood of the farm family in west Ethiopia," *AgriTopia*, vol. 15, no. 2/4, pp. 2-3, 2000.

[10] A. Chitsinde, *Effects of Frequency of Earthing up on the Yield of Irish Potato (Solanum tuberosum)*, (Doctoral dissertation, BUSE), Bindura University of Science Education, Bindura, Zimbabwe, 2018.

[11] C. Gutema, "Effect of earthing up frequencies and tuber seed form on yield and profitability of potato (*solanum tuberosum*) production in bale highlands," *Agricultural Research and Technology: Open Access Journal*, vol. 2, no. 4, pp. 96–101, 2016.

[12] G. Fitsum, M. Gebremichael, and H. Gebremedhin, "Flower bud removal and earthing up time increased growth and tuber yield of potato at eastern tigray, Ethiopia," *Indonesian Journal of Agricultural Science*, vol. 20, no. 2, pp. 77–85, 2020.

[13] R. Bernik and F. Vučajnk, "The effect of cultivator/ridger type on the physical properties of ridge, power requirement and potato yield," *Irish Journal of Agricultural and Food Research*, vol. 47, pp. 53–67, 2008.

[14] A. M. Hassen Yassin, D. Fekadu, and S. Hussen, "Effect of flower bud removal on growth and yield of anchote root (coccinia abyssinica (lam.) Cogn.)Accessions at bishoftu," *Asian Journal of Plant Science and Research*, vol. 8, no. 4, pp. 18–23, 2013.

[15] M. E. Duresso, "Study on ethnobotany and phenotypic diversity in anchote (coccinia abyssinica (lam.) Cogn.) landraces in western Ethiopia," *International Journal of Agricultural Sciences*, vol. 8, no. 2, pp. 1402–1427, 2018.

[16] Z. Huaman, *Descriptors for sweet potato. Descripteurs pour la patete douce. Descriptores de la batata (No. C027. 041)*, International Board for Plant Genetic Resources (IBPGR), New Delhi, India, 1991.

[17] J. Casals, F. Casañas, and J. Simó, "Is it still necessary to continue to collect crop genetic resources in the Mediterranean area? A case study in Catalonia," *Economic Botany*, vol. 71, no. 4, pp. 330–341, 2017.

[18] B. C. Asogwa, J. C. Ihemeje, and J. A. C. Ezihe, "Technical and allocative efficiency analysis of Nigerian rural farmers: implication for poverty reduction," *Agricultural Journal*, vol. 6, no. 5, pp. 243–251, 2011.

[19] N. Sakadzo, F. Tafirenyika, and K. Makaza, "Effects of time of earthing-up on yield and yield parameters of Irish potato (*solanum tuberosum* (L.)) in zaka district, Zimbabwe," *Agricultural Science*, vol. 1, no. 1, p. 39, 2020.

[20] R. L. Zimdahl, *A History of weed Science in the United States*, Elsevier, Amsterdam, The Netherlands, 2010.

[21] E. Sadik, M. Hussien, and A. Tewodros, "Effects of seed tuber size on growth and yield performance of potato (*Solanum tuberosum* (L.)) varieties under field conditions," *African Journal of Agricultural Research*, vol. 13, no. 39, pp. 2077–2086, 2018.

[22] L. D. Gbaraneh and V. Wilson, "Effect of seedbed types and time of vine harvesting on shoot and tuber yield of sweat potato [*Ipomoe abatatas* (L.) lam.] in South-south, Nigeria," *Journal of Experimental Agriculture International*, vol. 43, no. 2, pp. 9–20, 2021.

[23] P. K. Mukherjee, S. Rahaman, S. K. Maity, and B. Sinha, "Weed management practices in potato (*Solanum tuberosum* (L.))," *Journal of Crop and Weed*, vol. 8, no. 1, pp. 178–180, 2012.

[24] S. Omovbude and E. U. Udensi, "Profitability of selected weed control methods in maize (Zea mays (L.)) in Nigeria," *Journal of Animal and Plant Sciences*, vol. 15, no. 1, pp. 2109–2117, 2012.

[25] Cimmyt Economics Program International Maize and Wheat Improvement Center, "From agronomic data to farmer recommendations: an economics training manual (No. 27)," 1988, https://scholar.google.com/scholar?cluster=15077715757906354752&hl=en&as_sdt=0.

[26] Sas Institute Inc, *Statistical Analysis System, Version 9.3*, SAS Institute Inc, Cary, North Carolina, USA, 2014.

[27] T. Getachew, D. Belew, and S. Tulu, "Combined effect of plant spacing and time of earthing up on tuber quality parameters of potato (*Solanum tuberosum* (L.)) at degem district, North showa zone of Oromia regional state," *Asian journal of crop science*, vol. 5, no. 1, pp. 24–32, 2012.

[28] M. K. Ali, M. N. Alam, M. A. B. Barkotulla, S. M. A. T. Khandaker, and P. W. Simon, "Effect of earthing up and level of irrigation on yield and quality seed production of onion," *Progressive Agriculture*, vol. 18, no. 2, pp. 81–91, 2014.

[29] W. Gebremedhin, G. Endale, and B. Lemaga, *Potato Variety Development. Root and Tuber Crops: The Untapped Resources*, Ethiopian Institute of Agricultural Research, Addis Abeba, Ethiopia, 2008.

[30] J. K. Mwololo, M. W. K. Mburu, and P. W. Muturi, "Performance of sweet potato varieties across environments in Kenya," *International Journal of Applied Agricultural Research*, vol. 2, pp. 1–11, 2012.

[31] A. Zalalem, T. Tekalign, and D. Nigusesie, "Response of potato (*Solanum tuberosum* (L.)) to different rates of nitrogen and phosphorus fertilization on vertisols at Debre Berhan, in central high lands of Ethiopia," *African Journal of Plant Science*, vol. 3, no. 2, pp. 016–024, 2009.

[32] S. H. Mobini, M. R. Ismail, and H. Aroiuee, "The impact of aeration on potato (*Solanum tuberosum* (L.)) minituber production under soilless conditions," *African Journal of Biotechnology*, vol. 14, no. 11, pp. 910–921, 2015.

[33] F. Tairo, E. Mneney, and A. Kullaya, "Morphological and agronomical characterization of sweet potato [*Ipomoea batatas* (L.) Lam.] Germplasm collection from Tanzania," *African Journal of Plant Science*, vol. 2, no. 8, pp. 077–085, 2008.

[34] T. Tekalign, "Processing quality of improved potato (*Solanum tuberosum* (L.)) cultivars as influenced by growing environment and blanching," *African Journal of Food Science*, vol. 5, no. 6, pp. 324–332, 2011.

[35] A. Elameen, A. Larsen, S. S. Klemsdal et al., "Phenotypic diversity of plant morphological and root descriptor traits within a sweet potato, (Ipomoea batatas (L.)Lam.), germplasm collection from Tanzania," *Genetic Resources and Crop Evolution*, vol. 58, no. 3, pp. 397–407, 2011.

[36] Dessie Fessiha Bitew, "Effect of inflorescence removal and time of earthing-up on growth, yield and quality of potato (solanum tuberosum l.) at jimma southwestern Ethiopia," 2017, https://core.ac.uk/download/pdf/234690008.pdf.
[37] M. Tafi, S. Siyadat, R. Radjabi, and M. Mojadam, "The effects of earthing up on the potato yield in Dezful (Khouzestan, Iran) weather condition," *Middle-East Journal of Scientific Research*, vol. 5, no. 5, pp. 392–396, 2010.
[38] H. Klikocka, "Effect of different soil tillage and weed-control methods in a potato field experiment on soil physical properties and the content of plant available micro-elements in the soil," *Landbauforschung Völkenrode*, vol. 50, no. 3/4, pp. 133–138, 2000.
[39] A. Tufa, N. Geleta, and H. Legesse, "Preliminary study for production of anchote (*Coccinia abyssinica* (lam.) Cogn.) in western part of Ethiopia," *Journal of Agriculture, Food and Natural Resources*, vol. 1, no. 1, pp. 16–20, 2017.
[40] B. Abeshu, "Effect of blended fertilizer (NPSB) and farmyard manure rates on yield and yield components of anchote [coccinia abyssinica (lam.) (Cogn.)] at jimma, south western Ethiopia," 2019, https://www.arcjournals.org/pdfs/ijrsb/v8-i9/3.pdf.