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Full Length Research Paper

Yield and nutrient concentration of Anchote [*Coccinia abyssinica* (Lam.) Cogn.] affected by harvesting dates and in-situ storage

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Anchote is an indigenous root crop that is commonly produced by Oromo Nation in Ethiopia. Its production extension to the Southern Nations Nationalities Peoples (SNNP) Regional State may be useful in contributing to food security in the region. Traditionally, farmers use in-situ stored Anchote tuber with the hypothesis of nutrient concentrateon increase over time. Thus, we tested farmers' hypothesis through investigating yield and nutrient concentration of Anchote as affected by harvesting dates and in-situ storage (at 4, 7, 10, 13 and16th months) at Hawassa College of Agriculture Research Farm. Extending the harvesting dates and in-situ storage from 4 to 7th month significantly increased fresh and dry tuber yield by an average of 450%. The results confirmed that delayed harvesting dates and in-situ storage improved Anchote tuber nutrient concentrations, largely Ca and Fe. Remarkably, Anchote leaf and tuber tissues exhibited higher crude protein and nutrient contents than anticipated values for most root and tuber crops. Nutrient analyses revealed that Anchote tuber contains 19 g N, 122.6 g K, 7.4 g P, 5.1 g Ca and 316 mg Fe kg^{-1} of dry weight, suggesting that Anchote can contribute more nutrients than equal amount of vegetables and root crops. The results indicated that Anchote could be a healthy food crop that has enormous potential to fill food security gap besides providing essential mineral elements both in its tuber and leaf parts.

Key words: Anchote, harvesting dates and in-situ storage, nutrient concentration, yield.

INTRODUCTION

Anchote [(*Coccinia abyssinica* (Lam.) Cogn.] is one of the indigenous root and tuber crops widely produced in south and southwestern parts of Ethiopia (PGRC/E, 1988). According to Fufa and Urga (1997) anchote is specfically widely cultivated and used in Jimma, Illu- Abba Bora and Wallaga areas of the Oromia Regional State. It is a subsistence crop commonly produced to fill food security gaps during the hunger months (June to September). The production of Anchote has strong cultural ties with Oromo Nation, since it is used as cultural food during the finding of true cross locally called "Meskel Festival". According to Abera and Gudeta (2007), Anchote has enormous genetic diversity, as it is indigenous and long-stayed in the production systems. Unlike many other crops, Anchote can be grown with minimal inputs and is able to produce reasonable yields in conditions of low soil fertility, acidic soils or drought and in intercropping with cereals. It is a co-staple crop during the hunger months in certain pocket areas of western Ethiopia. Despite this fact, Anchote has been historically given low attention in terms of research and production.

Anchote belongs to the family Cucurbitaceae, which are fruit bearing plants. However, it is the only tuber-bearing crop in the genus Coccinia and family Cucurbitaceous. Anchote has been grown over a wide range of environments (1300-2800 m asl.), with sporadic distribution (Getahun, 1973). It occurs in many parts of Ethiopia including the western, southern and northern parts (Edward, 1991). This wild and cultivated tuberous cucurbit is regarded as medicinal as well as an important dietary item in south and south western Ethiopia. The tuber is eaten while the fruit is not (http://cc.msnscache.com/cache.aspx). Anchote can withstand dry conditions and produce food for the poor smallholder farmers when other crops fail to grow.

Anchote is commonly propagated by botanical seed. Usually farmers sow Anchote seed in April or May and harvest in July or August. Anchote harvesting date often depends on farmers' wealth condition. In times of staple food crops depletion from store, farmers forced to harvest Anchote as early as possible. It is interesting to note that early harvest may result in low yield and poor quality produce. Anchote produces one root per plant, which is usually harvested after 4-5 months of planting when the leaves turn yellow (Hora, 1995; Abera, 1997). Remarkably, Anchote has special merits in that the tubers can be maintained on the farm (stored in soils) for considerable number of months after attained harvestable maturity. Its stem is herbaceous vine like cucurbits with tendrils. The vine of Anchote can grow on average of up to 2 m length, and thus usually requires staking for quality seed production. Anchote produces heart shaped leaf, oval shape fruit and flat smooth whitish seed in the fruit (Abera and Gudeta, 2007).

Traditionally, in Anchote birth place, Wollega, people use over stayed (over matured) Anchote tuber when they face a problem of bone-fracture and when women give birth, due to the fact that anchote is suposed to contain high Ca and Fe (Abera and Gudeta, 2007; Yambo and Feyissa, 2013). In other words, the local people believe that Anchote has medicinal value in healing many maladies. The idea behind the use of soil stored or ratoon (locally called "guboo") anchote tuber is that the nutrient concentration of the tuberous root will increase over time, however, there has been limited study conducted to verify this assumption. Anchote is claimed to be a good source of minerals and protein, besides carbohydrate (Getahun, 1973). It was also reported that anchote juice can be used to treat gonorrhea, tuberculosis and cancer. Anchote's saponin content was pointed out as active ingredient for its medicinal use in this case (Getahun, 1969).

In modern crop production systems, the object is to maximize growth rates, yield and product quality through genetic and agronomic manipulation. Nonetheless, except few preliminary agronomic studies (spacing and fertilizer rates) undertaken at Bako Agricultural Research Center, there has been limited research conducted on Anchote agronomy (Abera, 1997; Abera and Gudeta, 2007). In contrast, Anchote farmers, especially women, have been carrying out Anchote husbandry since antiquity. Therefore, this study was initiated to evaluate the effect of harvesting dates and in-situ storage on yield and nutritive value of Anchote at College of Agriculture Farm, Hawassa University, southern Ethiopia.

MATERIALS AND METHODS

Description of the study site

The study was conducted at Hawassa University's College of Agriculture Research and Farm Center (RFC), under rain fed and supplemental irrigation conditions. The College is situated at Hawassa, which is a capital city of Southern Nations, Nationalities Peoples Regional State in Ethiopia. Geographically it is located at 7°3' N and 38°28' E at elevations of 1708 m a.s.l. The study site receives long term annual rainfall of 952 mm year^{-1} and average annual temperature of 19.4 °C. The rainfall distribution has two phases: large amount of rain that extends from June to September and small amount of rain during March to May (short rainy season). The soil of Hawassa is broadly classified as Andosol, which is developed from volcanic ash parent material during tertiary and quaternary periods (Abebe, 1998). In general Adosol is supposed to be a fertile soil as it is a young soil formed by volcanic or a soil with possibility of renewal by volcano. The surface soil of Hawassa contained 22.4 g kg^{-1} OM, 13.0 g kg^{-1} total C, 12.6 g kg^{-1} organic C, 0.92 g kg^{-1} total N, and 67 mg kg^{-1} available P, a pH of 7.23 and loam in texture (Abera *et al*., 2013a).

Land preparation and field experiment set up

Land was manually dug, pulverized and fine seedbed was prepared. Seed of Anchote (local variety) brought from Ambo was planted to elucidate the effect of harvesting dates and in-situ storage at three month interval (4, 7, 10, 13, and 16th months). The plot area used was 2.5 m long row, which consisted of 5 rows and 11 plants per row and a total of 55 plants per plot (2.5 x 2.2 m). Two Anchote seeds were planted per hole and later weaker seedlings were thinned out. Average germination of Anchote seed was noted to be about 75% under laboratory condition and is presumed to be lower under field condition. The seeds were planted at spacing of 50 x 20 cm between rows and plants, respectively. A path of 0.5 m between plots and 1 m between blocks were maintained to provide appropriate agronomic management. Fertilizers, 20 kg P ha^{-1} in the form of DAP and 46 kg N ha^{-1} in the form of urea were applied (Abera and Gudeta, 2007), while other management practices were adhered to as required. Sufficient irrigation water was provided manually to avoid soil and seed wash off.

Data collection and recoding

Important agronomic data: stand count, above ground fresh and dry biomass, fresh and dry weights of tuber, roots, leaves, and vine with petiole were collected at different harvesting date and in-situ storage after planting.

The first harvesting date and in-situ storage was made on May 20, 2007 (4^{th} month after planting, Treatment 1), the second harvesting date and in-situ storage was August 20, 2007 (7^{th} month after planting, Treatment 2), the 3^{rd} harvesting date and in-situ storage was November 20, 2007 (10^{th} month after planting, Treatment 3), the 4^{th} harvesting date and in-situ storage was February 22, 2008 (13^{th} month after planting, Treatment 4) and the 5^{th} harvesting date and in-situ storage was May 20, 2008 (16^{th} months after planting, Treatment 5). All the plant parts were analysed for their nutrient concentration except that of the last harvesting date (16^{th} month after planting).

Table 1. Anchote tuber, above ground biomass and root yield as affected by harvesting dates and in-situ storage (months) at Hawassa, southern Ethiopia.

HD & in-situ situ storage	FAB (t ha^{-1})	DAB (t ha^{-1})	FTY (t ha^{-1})	DTY (t ha^{-1})	ATW (g)	FRY (kg ha^{-1})	DRY (kg ha^{-1})
4 months	66.7A	8.2A	3.5C	0.72C	90B	363.6B	0.26B
7 months	4.2D	0.5A	19.2A	3.96A	334A	1121.2A	0.50A
10 months	3.5D	0.7A	17.6AB	3.65A	313A	1064.3B	0.27B
13 months	7.9A	1.7B	15.5B	2.69B	309A	539.4B	0.24B
16 months	13.0B	2.1B	15.9B	2.76B	267A	600.0B	0.30B
Prob.	0.0001	0.0001	0.0001	0.0001	0.0001	0.023	0.0001

Key: HD = harvesting dates, FAB = fresh above ground biomass, DAB = dry above ground biomass, FTY = fresh tuber yield, DTY = dry tuber yield, ATW = average tuber weight, FRY = fresh root yield, DRY = dry root yield and NDF = neutral detergent fiber.

Table 2. Anchote leaf nutrient concentrations as affected by harvesting date and in-situ storage at Hawassa, southern Ethiopia.

HD & in-situ situ storage	N%	CP%	P%	K%	Ca%	Fe (ppm)	OM (%)	Ash (%)	NDF (%)
4 months	2.4A	14.9AB	0.78AB	2.8	0.74B	311.8B	82.5	17.5	-
7 months	2.6A	16.0A	0.62B	4.6	1.29A	1929.3A	80.8	19.2	52.8
10 months	2.7A	16.9A	1.01A	4.6	1.30A	385.2B	84.4	15.6	47.6
13 months	1.9B	12.4B	0.85AB	4.2	0.80B	204.4B	86.7	13.3	50.5
Prob.	0.02	0.05	0.03	0.15	0.002	0.002	0.08	0.08	0.41

Key: HD = harvesting dates, N = nitrogen, CP = crude protein, P = phosphorus, K = potassium, Ca = calcium, Fe = iron, OM = organic matter and NDF = neutral detergent fiber.

Nutrient analyses of Anchote plant tissues

The different plant parts (vine + petiole, leaf, tuber and roots) of Anchote sub-samples were collected, dried at 70 °C for 24 hours and finely ground using a Thomas–Wiley Laboratory Mill Model 4 (http://www.thomassci.com) to pass a 1-mm size sieve labor Mill (Abera et al., 2013b). The plant tissues nutrient contents analyses were performed for N, P, K, Ca, Fe, DM, Ash and neutral detergent fiber (NDF) contents at International Livestock Research Institute (ILRI) Laboratory Service, Addis Ababa. Total N was determined by the Dumas method (Bremner and Mulvaney, 1982), whereas extractable P was determined by Olsen's method (Olsen and Sommers, 1982). Potaiisum (K), and calcium (Ca), were determined by atomic absorption spectrophotometer. Iron (Fe) was determined by flame atomic absorption. The nutrient analyses for all parameters were followed standard procedures.

Statistical analyses

To elucidate the effect of harvesting dates and in-situ storage on tuberous root yield, above ground biomass yield, and nutrient concentrations, the data were subjected to Analyses of Variance using the GLM Model MINITAB Statistical Software for Windows Release 14 (Minitab, State College, Pa.). Means found different were declared according to Tukey's honestly significant difference test at P ≤ 0.05.

RESULTS AND DISCUSSION

Growth performance and yield of Anchote

Anchote is a new introduction to Hawassa area. Its growth performance appeared to be attractive, green and healthier at field condition. This good vegetative growth performance of Anchote depicted its successful adaptation to Hawassa area. Harvesting dates and in-situ storage significantly affected fresh above ground biomass and tuber yield of Anchote (Table 1). Anchote produced significantly higher fresh and dry above ground biomass at the 4th month of harvesting date and in-situ storage. Nevertheless, Anchote biomass was sharply declined during subsequent harvesting dates and in-situ storage. During 7th to 16th moth harvesting dates and in-situ storage fresh and dry above ground biomass of Anchote was declined on average by 833 and 556%, respectively (Table 1).

As compared to the 4th month harvesting date and in-situ storage, field vegetative growth performance of Anchote was noted to be very poor during subsequent harvesting date and in-situ storage. This was due to the fact that Anchote complete its vegetative life cycle and the haulms and the photosynthetic center of the plant, leaves were dried. During the 13th month harvesting date and in-situ storage, the vegetative growth of Anchote was started to regenerate and the biomass was relatively increased over the earlier harvesting date and in-situ storage (7th and 10th months).

Table 3. Anchote vine + leaf petiole concentrations as affected by harvesting date and in-situ storage at Hawassa, southern Ethiopia.

HD & in-situ situ storage	N%	CP%	P%	K%	Ca%	Fe (ppm)	OM (%)	Ash (%)	NDF (%)
4 months	4.6	28.4	0.81	3.9A	2.2B	293.6C	82.4A	17.6C	-
7 months	4.2	26.3	0.52	3.1AB	3.5A	2709.9A	72.7C	27.3A	40.4
10 months	4.2	26.4	0.84	2.6B	3.6A	1190.9B	76.4B	23.6B	33.9
13 months	3.7	22.9	0.73	2.6B	2.7B	958.5B	80.1A	19.9C	39.3
Prob.	0.07	0.07	0.50	0.006	0.009	0.0001	0.0001	0.0001	0.027

Key: HD = harvesting dates, N = nitrogen, CP = crude protein, P = phosphorus, K = potassium, Ca = calcium, Fe = iron, OM = organic matter and NDF = neutral detergent fiber.

Table 4. Anchote tuber nutrient concentrations as affected by harvesting date and in-situ storage at Hawassa, southern Ethiopia.

HD & in-situ situ storage	N%	CP%	P%	K%	Ca%	Fe (ppm)	OM (%)	Ash (%)	NDF (%)
4 months	1.5B	9.6B	0.74AB	1.41	0.44	219.2B	93.8B	6.2A	-
7 months	2.1A	13.4A	0.58B	1.32	0.51	382.8AB	95.0A	5.0B	58.3A
10 months	2.2A	13.8A	0.77AB	1.43	0.47	440.5A	93.8B	6.2A	56.6A
13 months	2.0A	12.3A	0.85A	1.53	0.60	401.8AB	93.0B	7.0A	33.7B
Prob.	0.001	0.002	0.023	0.423	0.278	0.049	0.005	0.006	0.005

Key: HD = harvesting dates, N = nitrogen, CP = crude protein, P = phosphorus, K = potassium, Ca = calcium, Fe = iron, OM = organic matter and NDF = neutral detergent fiber.

Table 5. Anchote root nutrient concentrations as affected by harvesting dates and in-situ storage at Hawassa, southern Ethiopia

HD & in-situ situ storage	N%	CP%	P%	K%	Ca%	Fe (ppm)	OM (%)	Ash (%)	NDF (%)
4 months	2.0	12.7	0.66AB	1.89	0.87	525B	91A	9B	-
7 months	2.7	16.9	0.49B	1.45	0.99	1689A	89B	11A	65A
10 months	2.9	17.8	0.91A	1.75	0.70	847B	90B	11A	54B
13 months	2.2	13.7	0.73AB	1.76	0.85	1494A	88B	12A	59AB
Prob.	0.05	0.05	0.001	0.696	0.156	0.0001	0.001	0.001	0.021

Key: HD = harvesting dates, N = nitrogen, CP = crude protein, P = phosphorus, K = potassium, Ca = calcium, Fe = iron, OM = organic matter and NDF = neutral detergent fiber.

The results showed that extending the harvesting dates and in-situ storage of Anchote from 4th to 7th month increased fresh and dry tuber yield by an average 450%, afterwards yield appears to decline (Table 1). Similar report revealed that late harvesting (7th month after sowing) of sugar beet varieties resulted in greater yield of root and sugar content than earlier harvesting dates (Al-Sayed et al., 2012). Delayed harvesting of Anchote from 4th to 7th month resulted in average tuber weight increase by 271.1%. This is perhaps the most important reason for tuber yield increase in the present study as often Anchote produce one tuberous root per plant. Average tuber weight of Anchote was found non-significantly different among 7th, 10th, 13th and 16th months harvesting dates and in-situ storage (Table 1). The current average tuber yield recorded was comparable with yam tuber yield that was reported from Nigeria (Law-Ogbomo and Emison, 2009). In overall, the tuber yield of Anchote recorded in the present study was 2.7 to 3.3 times higher than average national yield 5.8 t ha^{-1} (Personal communication) when harvested at 7th month. This reveals the importance of appropriate agronomic management intervention in improving crop productivity and product quality. Unlike other root and tuber crops, Anchote also produced sizeable amounts of root biomass that range from 364 to 1121 kg ha^{-1} depending on its harvesting dates. This biomass can also sequester large amount carbon into the soil besides it above ground biomass.

Anchote produces excessive above ground biomass, which may grow at the expense of tuber. Anchote vine usually grow longer beyond the set row width and determinately affect agronomic management activities. The excessive growth of Anchote vine may influence tuber yield and quality by affecting tuber size categories and dry matter production. The manipulation of growth of Anchote through different techniques may help to overcome the constraints.

Crude protein and dry matter production of Anchote

The nutritive quality indictors such as dry matter, nutrient concentrations and crude protein were significantly varied among harvesting dates and in-situ storage (Tables 1, 2, 3, 4, and 5). Strikingly, Anchote leaf and tuber tissues exhibited higher crude protein and nutrient concentrations than anticipated values for most root and tuber crops (Table 6). The results of the present study confirmed previous study that stated Anchote is a good source of protein, carbohydrate, calcium and iron (Getahun, 1973). Similarly, another study revealed that from a total of 100 g fresh weight, Anchote tuber consists of 74.93 g moisture, 3.25 g protein and 327 mg calcium (Fekadu, 2011). Anchote plant parts exhibited significant differences in terms of crude protein production (Tables Strikingly, Anchote leaf and tuber tissues exhibited higher crude protein and nutrient concentrations than anticipated values for most root and tuber crops and vegetables. The 2, 3, 4, and 5). The vine + leaf petiole produced on average the highest crude protein (26%), while tuber was produced the lowest crude protein (12.3%). Anchote tuber and leaf produced, on average 94 and 84% dry matter, respectively. This indicates that there is higher translocation of dry matter to the tuber of Anchote. Accordingly, ash contents of 6 and 16%, respectively for tuber root and leaf of Anchote were recorded.

Nutrient concentration of Anchote plant parts

Leaf tissue held 2-3 times higher N and K concentrations over Anchote tuber, while equivalent P nutrient contents exhibited in both leaf and tuber tissues. Calcium nutrient contents were 5-8 times higher in leaf tissue than in tuber. Also leaf tissue Fe nutrient concentration was on average 3.5 times higher than in tuber tissue (Tables 2 and 3). Nevertheless, vine + leaf petiole contains more nutrients than others (leaf, tuber and root), except phosphorus (Tables 2, 3, 4 and 5). During the optimum growth periods, 7th and 10th months the leaf K content was higher than P, reveals that Anchote's high demand for K than for P. The relatively high leaf K compared to P was reported with yam crop, becuase of the fact that K is usfusl to enhance translocation of assimilates to the tuber (Law-Ogbomo and Emison, 2009).

Anchote leaf and tuber N, P, K, Ca and Fe nutrient concentrations were found to be lower at 4th month harvesting and in-situ storage (Tables 2, 3 and 4). As the harvesting date and in-situ storage delayed the nutrient concentrations increased. In contrast, except Ca and Fe most of the nutrient concentrations of vine + leaf petiole were higher during the 4th month of harvesting and in-situ storage. This implies that vine + leaf petiole can be good index in Anchote nutrient status assessment for fertilizer recommendation.

The relationship of different nutrients with protein, organic matter and ash appears to be different for leaf and tuberous root plant parts of Anchote (Data not shown). The results exhibited that N and K uptake of Anchote leaf was positively and significantly correlated, they were negatively and non-significantly correlated in the tuberous root. Ca and Fe nutrient concentration were negatively and significantly correlated with OM production in the leaf, while ash was positively and significantly correlated (Data not shown).

Nutritional value of Anchote as compared to others

Nothing beats fiber when it comes to digestive health. Fiber helps to prevent colorectal cancer. The current study revealed that Anchote tuber contains large neutral detergent fiber (NDF) when harvested during 7th to 10th months after planting, albeit its nutritive value or digestive health needs further study.

nutrient concentrations in Anchote tuber are by far higher than that found in equal weight of potato (S*olanium tuberosum L.*), yam (*Dioscorea abyssinica)* and cassava

Table 6. Nutrient concentration (g kg^{-1}) of Anchote plant parts as compared to other edible vegetables and root and tuber crops.

Nutrient element	Leaf nutrient concentration			Tuber nutrient concentration		
	Cucumber	Swiss chard	Anchote	Yam	Potato	Anchote
N	56	-	41.8	13	1.5-2.2	19
K	45	25.5	30.5	-	20	123
P	9	-	7.3	-	2.4	7.4
Ca	24	7.8	30.0	0.45	0.78	5.1
Fe	3	0.29	1.29	0.15	0.075.2	0.316
Protein	284	323	260		15-20.2	96-138
Ash	176	176.2	221		11.08	50-70

Sources: Kołota, 2010; Law-Ogbomo and Emison, 2009, Montagnac et al., 2009.

(*Manihot esculenta* Crantz) tubers, Swiss chard and cucumber. Nutrient analysis revealed that Anchote tuber contains 19 g N, 122.6 g K, 7.4 g P, 5.1 g Ca and 316 mg Fe kg^{-1} of dry weight. This show that Anchote can contribute equal or more nutrients than equal amount of potato tuber and cassava roots, which contains (20.2 g N, 20 g K, 2.4 g P, 0.78 g Ca and 75.2 mg Fe) and (1.36 g N, 27 mg P, 3.9 g K, 16 mg Ca and 0. 27 mg Fe) kg^{-1} dry weight, respectively (Montagnac *et al*., 2009). Anchote tuber nutrient contents are also much higher than that of the indigenous root crop, *Dioscorea abyssinica,* which contains (13 g K, 0.45 g Ca and 0.15 g Fe) kg^{-1} dry weight. Likewise, Anchote leaf contains comparable amount of nutrients and ash with that of cucumber and swish chard leaf (Kołota, 2010; Law-Ogbomo and Emison, 2009). In overall, the results indicated that underutilized indigenous root crop, Anchote could be a healthy food crop with potential source of equal or even better mineral elements as compared to other exotic root and tuber crops.

In a nutshell, Anchote's genetic potential in yielding large above ground fresh and dry biomass production gives chance to consider it as alternative for livestock feed and organic fertilizer sources. In addition, the nutrient concentrations of Anchote biomass were found to be higher than most cereals residues and comparable with high quality legumes. Therefore, we suggest a detailed further study of decomposition and nutrient release of Anchote plant biomass. Additionally, it is also crucial to assess the palatability and digestibility of Anchote biomass as a livestock feed.

CONCLUSION

Ethiopia suffers huge food and nutritional security gaps. Diversification and improvement of under utilized and neglected crops have been considered as possible solution. Among them Anchote is an indigenous root crop that is commonly produced by Oromo Nation in Ethiopia. Anchote tuber yield and above ground biomass were significantly affected by harvesting and dates and in-situ storage. This showed that extending harvesting dates from the 4th to 7th month increased fresh and dry tuber yield by an average of 450%. Inversely, above ground biomass tremendously declined when harvesting dates and in-situ storage delayed from 4th to 7th month. Anchote appears to yield large biomass that can be used as an alternative sources of livestock feed and organic fertilizer. The present findings proved farmers' assumption that delaying Anchote harvesting dates and or in-situ storage improves nutritive value of Anchote (e.g. Ca and Fe concentration increased during later harvesting than early). Comparable to other root crops Anchote plant tuber and leaf contains valuable nutrient and hence should be promoted for greater consumption for human use to improve nutrition.

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