ORIGINAL ARTICLE

Agronomic performance and chemical composition of different varieties of *Amaranthus caudatus*

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ABSTRACT

The cost of feed with sufficient nutrient content in monogastric animal industries is significantly high. It is therefore crucial to search for alternative and cost-effective feed resources that have optimal nutrient content and could be used as a supplement. In this endeavor, a field experiment was conducted to assess the agronomic performance and nutrient content of three local (white, dark, and red) and two improved (AC-NL and Madiira II) varieties of *Amaranthus caudatus* under field experiment in Dedo district, Jimma Zone, Oromia Regional State. The experiment followed a randomized complete block design, with each treatment replicated three times. Data were collected on phenological traits, seed and leaf yield, nutritive value, and mineral compositions. The findings showed that Madiira-II showed better agronomic performance in terms of number of leaves and branches per plant, plant height, and leaf yield compared to the other varieties. The local white variety had a higher mean seed yield per hectare than the others, while AC-NL and Madiira-II varieties had superior leaf biomass yield. Local white amaranths had significantly ($p< 0.05$) higher leaf and grain crude protein contents than the other varieties. AC-NL and Madiira-II varieties had lower crude fiber content. The local red variety had relatively higher calcium content, while the local dark variety had higher copper and iron content compared to the other varieties. In conclusion, even though all varieties of *A. caudatus* yielded sufficient nutrient content, the agronomic performance, mean seed yield per hectare, leaf biomass, crude protein, fiber, and mineral contents showed heterogeneity among the different varieties.

Keywords: Amaranths, Chemical composition, Yield, Mineral, Agronomic performance, Varieties.

INTRODUCTION

According to Cassidy et al. (2013) 36% of the global crop calories are used as animal feed, of which only one third being used as human food, due to the inherent metabolic inefficacy of animals to convert "feed" to "food. The use of human food as sole source of animal feed remains a major concern for global food security (Wilkinson and Lee, 2018). In the past decade, the amount of soybean meal used as animal feed worldwide was more than doubled (Rahnama and Safaeie, 2017). The need for plant sources of animal feed is expected to further increase at par with global dietary transition (Sun et al., 2022). These changes ultimately could have significant risks for climate breakdown (Clark et al., 2020).

The demand for nutrient rich animal food resources will push the animal production system to search for alternative and potential high-quality protein feed resources. Available literatures indicated that various efforts were made to find viable alternatives feed sources particularly for protein sources. These include feeding intact proteins, peptides, or free amino acids, identifying other possible replacement food sources, innovative and information technology methods to precision feeding, integrating food-waste into feedstock, or scaling novel, less land-intensive ingredients such as insects, algae, and single-cell proteins. Integrating more regenerative or agro- ecological practices into the cropland for monogastric feedstock are also another opportunity (Parisi et al., 2020). One such potential alternative is the use of underutilized cereals or legumes such as *Amaranthus caudatus*, a plant that goes by common names such as love-lies-bleeding, pendant amaranth, tassel flower, velvet flower, foxtail amaranth, and quilete.

Amaranth is annual, herbaceous plant belonging to the Amaranthacea family comprising of 65 genera and 900 species, the majority of which are native to Africa and Central and South America (Sarker and Oba 2020). The *Amaranthus* species of Central and South America emerged as a potential solution to global food security challenges (Gamel et al., 2006). The plant boasts exceptional nutritional and functional properties, thriving under harsh climates and poor soil conditions (Berger et al., 2003). It is impressive in protein, mineral, and fat content compared to common cereals (Mustafa et al., 2011). The amino acid and fatty acid profiles of the plant are rich in lysine and unsaturated fats (Mustafa et al., 2011). The agricultural advantages of amaranths, like short production cycles, drought resistance, and relatively high grain yields, has captured attention at the global level (Mekonnen et al., 2018), and redefined it as a promising crop for human nutrition and animal feed, due to the high nutritional value of both seeds and leaves (Rivelli et al., 2008), in terms of source of protein, fiber and bioactive ingredients (Chisoro and Nkukwana 2020). Therefore, Amaranth would be a good alternative to the problem of inadequate supply of quality forage during the dry season (Stallknecht and Schulz-Schaeffer, 1993).

In Ethiopia, amaranth cultivation is concentrated in the humid regions of Oromiya, Benashangule Gumuz, and Gambella, with the Benchi Maji area serving as a major hub. Three varieties (white, red, and black) are widely grown in four Woredas (districts) of Benchi Maji Zone (Mekonnen et al., 2018). The crop is cultivated and harvested three times annually, either as a sole crop or intercropped with maize or sorghum, with minimal water requirement. Despite being amaranth thrives best in certain Ethiopian regions, there is limited information about its cultivation and nutritive value at mid-altitudes. Hence, the present study was conducted to evaluate the agronomic performance and chemical composition of the leaves and seeds of different varieties of amaranth in the mid-altitude of southwestern Ethiopia.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted at Bilo Kebele Farmers Training Centers (FTC), Dedo district, Jimma Zone of Oromia Regional State from May to August 2022 under field condition. The experimental site is situated at latitudes between 7°13' and 7°39' north and longitudes between 36°43' and 37°12' east, with an altitude of 2115 meters above sea level. The mean annual daily minimum and maximum temperature for the area is 15 and 24^0 C respectively. The mean annual rainfall varies between 1,200 and 1,700 mm. The rainfall is bimodal, with main and short seasons occur between June to September and January to April, respectively. The soil of the site is well-drained clay to silt clay with pH of 5.4 Dedo District Agriculture and Natural Resource Management Office (DDANRMO, 2021).

Land Preparation

After selecting the experimental site, all unwanted threshes, grasses, and weeds were cleared before ploughing. The experimental field was ploughed two times to create a fine field, followed by manual harrowing using a hoe and rack to break down clods to enhance the easy germination of the seeds.

Experimental Design and Treatments

The experiment was carried out using a randomized complete block design with three replications per treatment. Each plot had a size of 12 m^2 (2m wide × 6 m long) and consisted of four rows. Rows were arranged at 0.40 m (inter) × 0.25 m (intra) spacing as prescribed by Bongase et al. (2019). To minimize edge effects, the distance between the replications was the same as that of the row length. The local seeds (white, dark, and red) were obtained from Guraferda wereda of Bench Maji Zone, while AC-NL and Madiira-IIseeds were obtained from Melkassa Agriculture Research Center.

The seeds were sown in the first week of May 2022 at the onset of the main rainy season. The seeds were mixed with sand at a 1:10 ratio and sown in seed beds. The assigned plots were fertilized following the recommendation of Bongase et al. (2019) and consists of NPSB blended fertilizer (19% N, 38%P_2O_5, %S and 0.1%B) at planting at a rate of 100 kg /ha at time of planting and Urea was applied at the rate of 50 kg /ha after establishment. Plant density at harvest was 24 plants per raw; correction to the desired density was done manually when the plants were 10 cm high. Weed control was carried out by inter-row cultivation and manual eradication. Seed and leaf yield determination was carried out on the two middle rows from an area of 6 m^2.

Agronomic Data

Data on growth variables (plant height, number of tillers per plant, number of leaves per plant and Leaf length) were determined at harvesting time using six plants randomly sampled from the two middle rows of each plot. Plant height was determined by measuring the height of the main shoot of each sampled plant from its base to its last leaf using a measuring tape. The numbers of tillers and leaves per plant were determined by counting the number of visible tillers and leaves of each of the six sampled plants. Leaf length was determined by measuring the length of each leaf of the six sampled plants from the base to the tip of the leaf and the mean was calculated for each plant. Leaf area: The length and width multiplied by a constant (6.6) of the four (4) tagged plants in each experimental unit was used to obtain this parameter, the mean was calculated and recorded. L x W x 6.6 = LA (Saeed et al. , 2012).

Seed harvesting was carried out manually by shaking inflorescences. Yield and seed moisture were determined after the harvest. Seed yields were expressed at the 13% moisture level. Biomass yield of the forages per plot was evaluated at harvest. Samples were collected from inner two rows of each replication and harvested at height of 5cm stubble aboveground. The harvested green forage of each plot was weighed using a top loading field balance. The fresh forage sub sample was measured from the inner rows of each plot, weighed and chopped into small pieces using sickle (2.5 cm), labeled and kept in separate perforated bags for chemical composition analyses.

Chemical Analysis

The nutritional content of leaves and seed samples were determined according to AOAC (2000). Dry Matter (DM), Crude Protein (CP), Ether Extract (EE), Total Ash and Nitrogen Free Extracts (NFE) contents were determined according to (AOAC, 2000). Macro mineral and trace elements sample digestions were undertaken using a closed-vessel microwave digestion system. Blank samples containing the same reagents were run using the same procedure as the samples and standards. Calcium, magnesium, manganese, zinc, iron, sodium, potassium, copper, sulphur and phosphorus concentrations were determined according to AOAC (2012) after cooling involving inductively coupled plasma spectroscopy.

Data Analysis

All data were analyzed following statistical procedures of SAS version 9.3 and subjected to Analysis of variance (ANOVA) using general linear model (GLM) whenever treatment effects were significant, the means were separated using the Tukey Multiple Range Test at 5% level of significance.

RESULTS AND DISCUSSION

Agronomic Performance

Days at 50% flowering and 90% maturity

The results of days at 50% flowering and at 90% maturity are presented in Fig. 1. According to Figure 1, there was significant difference ($P<0.05$) among the amaranths varieties in mean days at 50% flowering. The overall mean day at 50% flowering for all varieties was 74.07 days. The dark variety blossomed significantly ($P<0.05$) earlier (72.27 days) than that of the white variety (75.37 days). On the contrary, there was no significant difference ($p>0.05$) between the dark and the other varieties in mean days at 50% flowering. Notably, the white *Amaranthus* variety attained 50% flowering later than other varieties. To reach 50%, different *A. caudatus* in the current study took longer time compared to the previous finding (60.74 days) reported by Li et al. (2022) for amaranth accessions of nine species. Additionally, Nazeer et al. (2020); Srivastava and Mahavidyalaya (2015) reported the lower value compared to our finding.

The dark variety matured earlier than the others, followed by Madiira-II and Red variety. The white and AC-NL varieties matured later than the others. The time taken for full seed setting of varieties used in the present study exceeded 76.8 days reported by Bongase et al. (2019) but in agreement with 113 days reported by Nazeer et al. (2020). The variations in days at 90% maturity and seed setting could be attributed to varietal differences, agronomic practices and environmental factors. Late-maturing varieties might possess a longer grain filling period, explaining potential for higher seed yields.

Plant height

The results of plant height of the experimental varieties are presented in Table 1. The results showed that there was significant difference in mean plant height ($P<0.05$) among the varieties. Among the tested varieties, AC-NL had significantly ($P<0.05$) the tallest plant height (137.3 cm), followed by Madiira II (132.53 cm), while, Red variety had significantly ($P<0.05$) the shortest height of 92.90 cm. Statistical analysis revealed a significant height difference ($p<0.05$) between AC-NL and the white, dark, Red, and Madiira -II varieties but no significant difference in mean plant height between AC-NL and Madiira -II , and between the dark and white varieties ($p>0.05$). The result of the current study suggests potential genetic similarities within these particular groups. The average plant height observed in this study (170.21 cm) was higher than the mean of 112.43 cm for various amaranth species reported by Bongase et al. (2019) However, the result of this study was in contrast to those of (Rahnama and Safaeie, 2017) and (Jacques et al. 2021) who documented considerably taller average plant heights (402.8 cm) for *Amaranthus hypochondriacus* L. and 229.84 cm for *Amaranthus cruentus*.

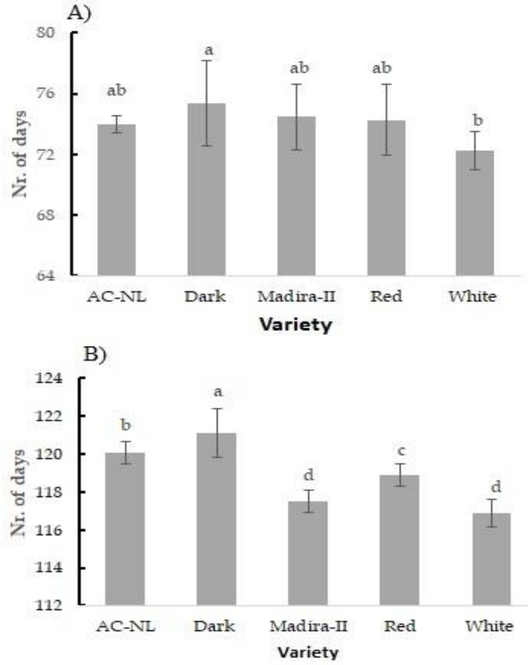

Figure 1. The mean number of days (mean ± SE) required for 50% flowering (A) and 90% maturity (B) across different varieties of *A. caudatus*

Number of leaves per plants

The results revealed that there was significant difference ($p<0.05$) in the number of leaves per plant among the five varieties studied (Table 1). Madiira-II variety had the largest number of leaves per plant, followed by AC-NL variety. On the contrary, the red and dark varieties had less number of leaves per plant. Statistically, Madiira-II variety had significantly ($p<0.05$) higher number of leaves per plant than the dark, white, and Red varieties. However, there was no significant difference between AC-NL and Madiira-II varieties, and between the dark and white varieties. In agreement with the current result, Bongase et al. (2019) reported that Madiira-II variety produced the highest number of leaves per plants among the other varieties of *A. caudatus.* The same author reported comparable mean number of leaves per plant (220.9) from different amarathus varieties, which is in agreement with the current findings. Contrary to the current result, less number of leaves (123) per plant was reported by Dinssa et al. (2015) from different amaranths varieties. The discrepancy between the results might be due to varietal, agro climatic condition, harvesting stage, soil fertility and agronomic management. Highest leaves numbers per plant are an indicator of higher nutritional value of the variety as leaves are better in protein and micro-nutrients content compared to different plant parts.

Number of branches per plant

There was significant variation between the varieties in number of branches per plant ($p<0.05$). Among the evaluated varieties, Red variety had significantly lower ($p<0.05$) mean number of branches than the other varieties. However, there was no significant difference ($p>0.05$) among the AC-NL, white, dark, and Madiira-II varieties. The AC-NL variety had the highest average number of branches per plant (16.60), followed by the dark and Madiira-II varieties with average values of 15.63 and 15.53 branches per plant, respectively. The overall average number of branches per plant in this study was 15.09, which was lower than the mean of 19.95 reported by Bongase et al. (2019). The observed difference in the mean number of branches per plant might be attributable to various factors, such as variations in environment, cultivation practices, harvest time, and plant genotype. The differences in varietal characteristics among the studied *Amaranthus caudatus* could also contribute to the observed variation, as reported by Bongase et al. (2019) for different amaranth species.

Leaf area

As shown in Table1, the average leaf area of the five different *Amaranthus caudatus* varieties evaluated in this study was 39.35 cm^2. The current recorded mean leaf area is broader - than the value reported by Srivastava and Mahavidyalaya (2015) for *Amaranthus tricolor,* which was 32.88 cm^2. The *Amaranthus caudatus* dark variety had a significantly wider leaf area (54.27 cm^2) compared to the other four varieties. On the contrary, Red variety had the smallest mean leaf area of 29.07cm^2. Genetic differences between *Amaranthus* varieties and intra-spacing could influence the leaf area per plant. And also species, environmental conditions, and soil properties could also contribute to these variations (Srivastava and Mahavidyalaya, 2015; Bongase et al., 2019).

Table 1. Comparison of some growth parameters of five *A. caudatus* varieties

Variety	PH (cm)	NL	NB	LA (cm)
AC-NL	137.30^{a}	195.83^{ba}	16.60^{a}	35.32^{c}
Dark	109.73^{b}	168.87^{b}	15.63^{a}	54.27^{a}
Madiira-II	132.53^{a}	211.67^{a}	15.53^{a}	34.06^{cd}
Red	92.90^{c}	105.43^{c}	12.40^{b}	29.07^{d}
White	105.47^{b}	169.27^{b}	15.30^{a}	44.02^{b}
SEM	4.12	12.13	0.68	1.89
p-value	<0.0001	0.0021	<0.0001	<0.0001

PH: Plant height: NL: Number of leaf; NB: Number of branches; LA: Leaf area.Values within a column with different superscript letters are significantly different ($p<0.05$)

Leaf Yield

The results of the current study indicated that mean total leaf and fresh and dry forage yield showed significant differences ($P<0.05$) among the five varieties (table 2). The AC-NL variety had significantly higher fresh biomass and dry matter yield per hectare, followed by Madiira-II . The lowest leaf yield both in fresh biomass and dry matter yield were recorded from red amaranth when copared to the other varieties. Contrary to the findings of the current study, Alemu et al. (2018) observed that Madiira-II was superior in terms of leaf yield, followed by AC-NL. It has been reported that fresh leaves yield of amaranth may vary from 10 to 70 t /ha (Svirskis, 2003). The mean fresh leaves yield obtained from the current study was lower than the findings of the previous studies. On the other side, the results of the current study was comparable with that obtained by Mbwambo et al. (2015), who reported that fresh leaves yield range from 12 to 21 t/ha from amaranth varieties. The higher fresh leaves yield reported in the earlier study may be explained by differences in harvesting methods, time and genotypes evaluated. In the present study, differences among the different variety in leaf yields indicate their differences as dual purpose or grain amaranths.

Table 2. Fresh biomass and dry matter yield of *A. caudate* leaves harvested at maturity

Variety	Fresh biomass ton/ha	Dry matter ton/ha
AC-NL	16.35 ^{a}	4.84 ^{a}
Dark	7.66 ^{d}	2.08 ^{c}
Madiira-II	11.48 ^{b}	3.55 ^{b}
White	9.51 ^{c}	2.64 ^{c}
Red	6.88 ^{d}	1.93 ^{d}
SEM	0.37	0.17
p-values	<0.0000	<0.0000

Values within a column with different letters are significantly different (p<0.05)

Grain Yield

The results of grain yield of amaranth varieties are presented in figure 2. The results indicated that, there was significant difference (p<0.05) in grain yield among the *A. caudatus* varieties studied. The white *Amaranthus* had a significantly higher (P<0.05) seed yield per hectare, followed by the dark variety. On the contrary, the Madiira-II variety had the lowest seed yield. Grain yields are extremely variable depending upon species and genotype, site, soil and weather conditions, growing season and agronomic practices. Grain yields within a range of 1000 to 3000 kg/ha have been obtained in the United States and in several countries of Northern Europe (Myers, 1998). Exceptionally high amaranths grain yield of 4500 - 5000kg /ha were reported from intensive cultivation in Argentina, China and Southern Italy (Wu et al., 2000; Lovelli et al., 2005).

Chemical Composition

Proximate composition of amaranth leaf

The results of the proximate composition of amaranths leaves are presented in Table 3. The results revealed that dry matter content of the leaves of the five amaranths genotypes ranged from 22.61 - 26.79%. These results were higher than the findings of Sarker and Oba (2020), who reported dry matter content within a range of 17–18%. The Crude protein (CP) content of the amaranth leaves showed considerable variations, ranging from 7.31 to 9.05%. Notably, ACNL and white amaranth had significantly higher protein content ranging from 7.31 to 9.05%. Notably, ACNL and white amaranth had significantly higher protein content compared to the other three varieties.

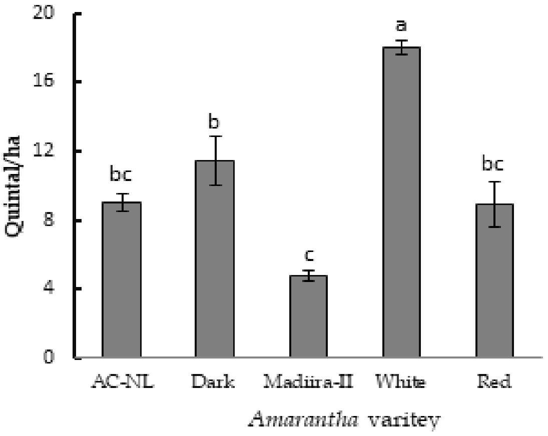

Figure 2. Grain yield of different *A. caudatus* varieties.

The CP content of amaranth leaves observed in present study was higher than the findings of Nicodemas (2013), who reported that amaranth leaves had 3.37–4.42% CP. It can be inferred that the protein content of the leaves from all varieties in this study could serve as a viable alternative protein source for poultry. The ether extract (EE) content of the leaves of amaranth varieties varied between 1.34 and 2.11%. White and dark amaranth recorded significantly higher EE% than the other three verities. The Ash content of the leaves of the varieties ranged between 35.03 and 35.41%, without exhibiting significant variations among the amaranth genotypes. These results are in agreement with that of Sarker and Oba (2020).

The current study revealed that there was a significant difference (p<0.05) in CF and NFE content the leaves among the five amaranth genotypes The CF and NFE content ranged from 11.5 to 26.22 and 29.72 to 42.95% respectively. White amaranth leaves had significantly higher CF and lower NFE content, whereas ACNL and Madiira-II had significantly higher NFE and lower CF content. These results are higher than that of Arendt and Zannini (2013), who stated that dietary fiber in amaranth ranged between 9.8 and 14.5%, depending on the variety.

Table 3. Proximate composition (% DM) of five *A. caudatus* varieties leaves harvested at maturity

VARITEY	DM %	CP%	EE%	CF%	Ash%	NFE%
AC-NL	28.66	9.05^{a}	1.34^{b}	11.5^{b}	35.18	42.93^{a}
Dark	26.98	7.93^{b}	2.13^{a}	24.17^{a}	35.03	30.75^{c}
Madiira-II	29.01	8.02^{b}	1.65^{b}	12.35^{b}	35.41	42.95^{a}
White	27.69	9.03^{a}	2.11^{a}	26.22^{a}	35.58	29.72^{c}
Red	27.97	7.31^{b}	1.63^{b}	22.3^{a}	35.32	33.29^{b}
SEM	1.77	1.89	0.02	4.12	0.55	2.12
P value	0.4803	<0.0001	0.3712	<0.0001	0.1402	<0.0001

Means within a column followed by different lower case letter are significantly different (p<0.05)

Proximate composition of amaranth grains

The results of the chemical composition of amaranths grains studied are presented in Table 4. There was no statistically significant (P>0.05) variation among the varieties in mean dry matter (92-93%) content. These results are in line with that of Singhal RS and Kulkarni PR. (1988), who reported a dry matter content of 89.77% from different amaranth grains. There was no statistically significant difference in mean total ash content of the grains among the five varieties, with the values ranged from 2.99-3.30% DM, which was consistent with the findings of Mekonnen et al. (2018).

The white variety of amaranth grain had significantly higher CP content (p<0.05) than that of red and dark varieties, but similar with Madiira-II and AC-NL varieties. The mean CP content of amaranth grain observed in this study was similar to that of Lopez et al. (2001), who reported a range of 14-15% crude protein. According to the results of the current study, the crude protein content of amaranth grains exceeded that of the common cereal grains such as corn and rice (8-12%). On the contrary, the crude protein content of amaranths grains is relatively lower than that of legume grains which contain about 28-36% crude proteins (Koehler and Wieser, 2013).

In this study, the EE content of amaranth grains ranged from 4.5- 8.4%, with the white varieties displaying significantly higher levels than the others. Temesgen and Bultosa (2017) reported a crude fat content ranging between 7.0 and 7.5%. The fat content in amaranth grains varies depending on the species ranging from 2- 10% (Muyonga et al., 2008; Caselato-Sousa et. al., 2012). According to the results of the current study, the white amaranth grains are found to have higher fat content. No significant difference was observed between the varieties in CF and NFE contents of grains. The crude fiber content recorded from the current study was comparable with Cai et al. (2004) and Emire and Arega (2012). The proximate composition of *A. caudatus* varieties is variable primarily due to the effect of variety (Mérida-López et al., 2023).

Table 4. Proximate composition (% DM) of different *A. caudatus* seed

Variety	Proximate composition					
	DM%	Ash%	CP%	EE%	CF%	NFE%
AC-NL	93.1	3.1	14.9^{ab}	5.8^{b}	3.8	71.5
Dark	93.1	3.5	15.4^{ab}	4.5^{b}	3.9	71.8
Madiira-II	92.8	3.2	14.8^{b}	5.6^{b}	4.8	71.6
White	93.2	3.5	16.1^{a}	8.4^{a}	4.5	67.5
Red	93.0	3.3	14.4^{b}	5.3^{b}	4.8	68.8
SEM	0.30	0.20	0.12	0.43	1.21	1.42
p-value	0.08062	0.0807	0.0308	<0.0001	0.0599	0.1440

Means within a column followed by different lower case letter are significantly different (p<0.05)

Mineral content of amaranth grains

The results of the mineral content of amaranths grains are presented in Table 4. The results obtained indicated that there was significant variation in the content of calcium, potassium, copper and iron (P ≤ 0.05) among the different varieties. The Red variety recorded the highest calcium content (310 mg/100 g), whereas the white variety had the lowest (109 mg/100 g). The AC-NL variety had the highest potassium content (630 gm/100 g), while the white variety had the lowest (450 mg/gm). The dark variety showed the highest copper content (8.12 mg/100 g), and the white variety showed the lowest (5.32 mg/100 g). Moreover, the AC-NL variety had the highest iron content (9.85 mg/100 gm), whereas the white variety had the lowest (4.67 mg/100 gm). However, there was no significant difference (P<0.05) in magnesium, sulfur, phosphorus, sodium, manganese, and zinc contents among the different varieties. Gamel et al. (2006) indicated that *A. caudatus* is an abundant source of iron (72–174 mg/L), calcium (1300–2850 mg/L), magnesium (2300–3360 mg/L), and zinc (36.2–40 mg/L). The results of this study concur with the diverse range of values in amaranths grains reported in previous literature (Alvarez-Jubete et al. 2009; Gamel et al.2006). However, the calcium, zinc, and iron levels obtained in this study were lower than that of the mean values reported in the aforementioned studies. It is possible that genetic factors contribute to variations in mineral composition. Environmental factors such as soil mineral availability during plant growth and seed development also play a significant role ((Rahnama and Safaeie, 2017).

Table 5. Mineral composition of *A. caudatus* grains on dry weight basis mg/kg

Variety	Mineral composition (mg/100 gm)									
	Ca	K	Mg	S	P	Na	Cu	Fe	Mn	Zn
AC-NL	210^{ab}	630^{a}	250	39.0	63.0	25.86	7.02 ^{ab}	9.84^{b}	4.59	3.59
Dark	222^{ab}	560^{ab}	222	40.0	64.1	25.56	8.12 ^{a}	9.95^{a}	4.63	3.89
Madiira-II	230^{ab}	600^{ab}	230	40.0	52.1	25.75	8.02^{a}	8.71^{c}	4.39	3.38
White	190^{b}	450^{b}	120	41.0	58.1	24.82	5.43^{b}	4.67^{e}	4.62	3.29
Red	250^{a}	570^{ab}	190	38.0	57.1	24.69	6.85^{ab}	6.68 ^{d}	4.51	2.98
SEM	40.2	90.1	20.2	8.5	6.7	10.4	1.02	2.53	0.58	0.78
p-value	0.0140	0.033	0.139	0.047	0.06	0.14	0.012	<0.0001	0.065	0.064

Means within a column followed by different lower case letter are significantly different ($p<0.05$)

CONCLUSION

From the findings of this study, it is concluded that agronomic performance, and chemical and mineral composition of *A. caudatus* were affected by its varieties. The 'white' variety exhibited relatively better performance in terms of grain yield and nutritional composition than the others. AC-NL and Madiira-II varieties were superior to the others in leaf yield. In addition the quantity of various minerals found in the five amaranth grain are ideal for monogastric nutrition. These results could serve as valuable information for farmers and scientists when selecting the optimal variety for cultivation aimed at enhancing the dietary value of this crucial crop.

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