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Morphological Characteristics of *Amaranthus cruentus* and *Amaranthus tricolor* as Influenced by Integration of Organic and Inorganic Fertilizers in Kiambu County, Kenya

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Authors' contributions

This work was carried out in collaboration between all authors. Author KT designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors TW and PGOJ managed the analyses of the study. Author PGOJ managed the literature searches. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

A field experiment was conducted to evaluate the effect of organic and inorganic fertilisers application on growth parameters of two amaranth varieties. Fifty-four treatments were evaluated as factorial combinations of organic manure applied at 16.9 t/ha, inorganic NPK fertiliser at 500 kg/ha, zero fertiliser (control treatment) and two amaranth varieties *(A. tricolor* and *A. cruentus varieties*). The treatments were fitted into in a randomised complete block design (RCBD) replicated three times. *A. cruentus* recorded the highest leaf area of 1415 cm^2 in the second from 248 cm^2 in season one. *A. tricolor* in the second season recorded 700 cm^2 from 387 cm^2 at the same treatment of 16.9 t/h+ 500 kg/ha. The number of leaves was highly significant at $p≤0.01$ in the second season but was significant at $p≤0.05$ in the first season while sole organic manure was applied at 16.9t/ha*, A. tricolor* variety had 17.56 number of leaves in season two from 14.56 in season one at 16.9 t/h, in *A. tricolor* the number of leaves in reduced from 17.06 to 14.06 in season one when 500 kg/ha of NPK 17-17-

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17- was applied. The longest shoot of 43 cm in the second season from 22 cm in the first season was in *A. tricolor* at the rate of 16.9 t/ha + 500 kg/ha in season two. In *A. cruentus* the shoot length increased to 34.7 cm from 31.1 cm in season one when sole organic manure was applied at 16.9 t/ha. The root length was highly significant at $p \le 0.01$ in the first season but was significant at $p \le 0.05$ in the second season *A. tricolor* had 16.58cm and *A. cruentus* having 17.39 cm in season one at control, in season two at control, the root length was 18.73 cm in *A. cruentus* and 18.94 cm in *A. tricolor*. Root length reduced from 18.23 cm in season one to 12.86 in season two in *A. cruentus* when 16.9 t/ha of organic quail manure was applied. The root dry weight in *A. tricolor* recorded 2.392 g from 1.177 g at 8.45 t/h+500 kg/ha, at 16.9 t/h+500 kg/ha in season one, *A. cruentus* had 0.625 g which increased to 2.468 g but *A. tricolor* increased to 2.328 g from 0.72 g.

Keywords: Amaranthus; organic manure; NPK 17-17-17; morphological.

1. INTRODUCTION

In this modern age, individuals are becoming more and more aware of the effect, that inorganic crop production has adverse effects on the environment. Hence they are taking significant measures to mitigate these environmental effects. Manure is an environmentally safe way to ensure enrichment of the soil with nutrients required for crops production [1]. In many agricultural systems, management of the nutrient system is very crucial and there ought to be a balance between the import as well as the export of nutrients within the system [2]. Manure plays a positive role in the nutrient balance as it ensures minimal loss of nutrients in the system. It is also an important way of nutrient cycling since the large fraction of nutrient from the manure is taken up by crops [3].

1.1 Origin, Habit, Distribution and Environmental Requirements for Growth of Amaranth

Amaranth is the collective name for the genus Amaranthus. Amaranthus is one of the oldest food crops in the world having been cultivated from early as 6000 years in Mexico [4]. Amaranthus dates back over 8,000 years during the Mayan civilisation in South and Central America. They observed that Amaranthus was a staple food for Aztecs and was deeply incorporated into Aztecs religious ceremonies [5]. In 1500, Amaranthus plant was prohibited in Spain due to unknown reasons and continued to grow in Spain as a wildflower; used in making "Alegria", a confectionary of honey mixed with popped Amaranthus. It has received considerable attention in many countries due to its high nutritional value and therefore as an essential source of food in grain or vegetable form [4].

Amaranthus species produce edible leaves in two weeks and therefore makes it one of the most productive vegetable crops in the world [6]. Amaranthus is one of the most adaptable and cheap vegetables to produce [7]. Its adaptability to environmental conditions makes it a perfect plant to establish for food security purposes in Africa. The Crop is drought tolerant and matures in 45-75 days [8]. Amaranths are tall plants measuring 0.5 to 2 m and moderately branched from their main stems. Amaranth grain type forms large loose panicles at the tips of the stems. Vegetable types form flowers and seeds along the stems. Root morphology, growth, development and distribution in the soil, as well as responses to the availability of nutrients and water have been barely investigated in amaranth [9]. Observations show that Amaranth root system without competition develops rapidly, reaching nearly its maximum extent (2.4 m depth and 1.8 m spread). The stem of Amaranths normally measures from 0.5 to 3.5 m in height depending on species, genotype and growth conditions, but mainly on plant density [9]. Amaranth leaves develop into various shapes; the key being elliptic, rhombic, ovate, lanceolate or rhombic-ovate, with acute, obtuse or acuminate leaf tips, of green, red or silver colour. Because of anthocyanin (amaranthine) colouration, entirely red plants and plants with reddish or silver spots on the leaves also exist [10]. Inflorescence can be of various colours: yellow, green, purple, orange, pink, violet, brown and two-coloured inflorescence [10]. Amaranth is a monoecious plant. The first flower in each glomerulus is staminate (male) while the following are all pistillate (female). The crop is mainly anemophilous, up to 90% pollination occurs on the same crop, but in some genotypes and circumstances, the rate of cross-pollination can increase up to 30%.

1.2 Nutritive Significance of Amaranth

Amaranths are some of the traditional vegetative plants known for having highly nutritious components for animal and human consumption. Nutritional value of the Amaranths varies with species [11]. Mnikeni et al. [12] reported that Amaranthus cooked grains contained equivalent of 8.8% to 19.5% protein and is also high in lysine and sulphur-containing amino acids not common in plants. fibre content in the Amaranth seeds is three times that of wheat and its iron content is five times more than wheat [13], oil from the Amaranth seeds (5 to 10%) is predominantly unsaturated and is high in linoleic acid and rich in squalene [14]. Amaranth grain consists of 6 to 10% of oil, which is higher than most other cereals. Amaranth oil contains approximately 77% polyunsaturated fatty acids which are mostly within the grain [15]. Amaranth oil has been found to be predominantly unsaturated oil; high in linoleic acid necessary for human nutrition. oil extracted from *Amaranthus cruentus* contained around 19% palmitic acid, 3.4% stearic acid, 34% oleic acid,33% linoleic acid while docosaenoic acid (C22: 1) was present at the level of 9% [16]. The ratio of saturated to unsaturated fatty acids was approximately 1:3. The lipid fraction is unique due to such high biologically active compounds, such as: squalene (up to 8%), tocopherols (to 2%), phospholipids (to 10%), and phytosterols (to 2%).

2. THE EXPERIMENTAL SITE

2.1 The Experimental Design

The study was carried at Kenyatta university main campus Department of Agricultural Science and Technology farm. The county has an altitude of 1520-1760 m above sea level. The area has minimum temperatures of 12°C and maximum of 24.6°C. The rainfall range was aggregate 1100 mm with a bimodal distribution during the 2015 year. The long rains were experienced between March to May and the short rains between Octobers to December. The area has dark reddish brown to dark brown loam which is an alisols type with low pH of 3-4.5, low levels of nutrients with aluminium and manganese toxicities.

2.2 The Experimental Design and Treatment

An experiment was carried out in a 2×3×3 factorial arrangement in a randomised complete block design (RCBD) with three replications (Table 1). There were three factors: quail manure, NPK fertilizer and two amaranth varieties *A. cruentus* and *A. tricolor* (Table 2). The quail manure levels were 0, 8.45 t/ha and 16.9 t/ha. The NPK levels were 0, 250 kg/ha and 500 kg/ha.

2.3 Treatment Combination between the Two Varieties, NPK and Quail Manure Rates

The fertilisers were two, organic quail manure and organic NPK (17-17-17) each was applied at three levels. The organic manure levels were 0,8.45 t/h, and 16.9 t/h whereas the inorganic manure rates were 0,250 kg/h and 500 kg/h. Each level of organic manure was combined with each level of inorganic mineral fertiliser.

2.4 Management of the Experiment/ Agronomic Practices

Land preparation was done one month before sowing by first clearing the land. It was mechanically ploughed and levelled to create a suitable tilth. The plot units were slightly raised about 25-30 cm high to ensure that inter plot spacing was maintained. The two varieties were sowed in a seed nursery well prepared due to their small size and seeds were mixed with soil at a ratio of about one to ten (1.10) to ensure even distribution of seed. Sowing of the seeds was done in November and transplanting was carried out in December 2014. Sowing was carried out in drills measuring 30 cm apart. The seedlings were transplanted to the individual experimental site by the use of a garden trowel at an inter-row spacing of 30 cm and intra spacing of 10 cm apart from a plant population of 100 plants per sub-plots. Routine field maintenance practices, e.g. weeding were carried out by uprooting the weeds and diseases were controlled by rouging, field hygiene and maintenance of the correct plant population was done.

2.5 Sampling Procedure of Plants

A simple random procedure was used, where a plant in the plot had an equal chance of being selected. Growth parameters such as leaf area, number of nodes and auxiliary buds were taken from the plots with quail treatment, NPK and from the unfertilized plots. Twenty two plants were randomly picked from the rows at the centre of the plots, plants from the edges were avoided

Table 1. Treatment combination between the two varieties, NPK and quail manure rates

Levels of NPK				
	500 kg/ha	0 , 500	8.45, 500	16.9 , 500
	250kg/ha	0, 250	8.45, 250	16.9 , 250
	0kg/ha	0, 0	8.45 , 0	16.9, 0
		0 t/ha	8.45 t/ha	16.9t/ha
	Levels of Quail Manure			

Table 2. Symbols for treatment combinations

Treatment number	Variety	Quail manure	NPK rate	Symbol
1	V1	0	500	V1Q0N2
2	V1	8.45	500	V1Q1N2
3	V1	16.9	500	V1Q2N2
4	V1	0	250	V1Q0N1
5	V1	8.45	250	V1Q1N1
6	V1	16.9	250	V1Q2N1
7	V1	0	0	V1Q0N0
8	V1	8.45	0	VIQ1N0
9	V1	16.9	0	V1Q2N0
10	V2	0	500	V2Q0N2
11	V2	8.45	500	V2Q1N2
12	V2	16.9	500	V2Q2N2
13	V2	0	250	V2Q0N1
14	V2	8.45	250	V2Q1N1
15	V2	16.9	250	V2Q2N1
16	V2	0	0	V2Q0N0
17	V2	8.45	0	V2Q1N0
18	V2	16.9	0	V2Q2N0

KEY: V1 =Variety A. cruentus, V2= Variety A. tricolor, Q0=0 t/ha, Q1=8.45 t/ha, Q2=16.9t/ha, N0=0 kg/ha, N1= 250 kg/ha, N2=500 kg/ha

due to reduced competition. This was carried out from the first week of germination to 6th week during maturity.

2.6 Analyses

The number of the leaves, auxiliary buds and nodes were taken from the middle parts of the plants and the average taken. Number of leaves, mean leaf area per plant, plant height, and stalk diameter were taken. The plant height was measured from root tip to shoot tip for both varieties*, A. tricolar* and *A. cruentus* using a tape measure. Stalk diameter was measured using a caliper rule. Leaf Area Index (LAI) for the two varieties was computed using mean leaf area per plant divided by ground area per plant [17] .Harvested leaves from *A. tricolar* and *A. cruentus* were weighed using digital sensitive balance and calculated and converted to the number of leaves per square meter and converted in tonnes per hectare.

2.7 Leaf Growth Rate

Determination of leaf area Index (LA1) was carried out on sampled plants. The length of the first, middle and last leaf was measured and their averages used for calculation of leaf area Index. The relationship LA1=LxWxNx0.72/A where L = Length of leaves, W = Width of leaves N= Number of leaves per plant A = Area covered per plant and 0.72=constant for the determination of leaf area index [18].

3. RESULTS AND DISCUSSION

3.1 Data Analyses

To determine significant differences among treatments analyses of variance (ANOVA) was done using SAS computer software and least significant (LSD) at 5% was used for mean separation.

3.2 Effect of Quail Manure and NPK on the Growth, Development and Yield of Two Amaranth

The results showed that varieties were significantly different ($P \leq 0.05$) during the first season for leaf area, number of leaves and shoot length while non-significant differences ($P \leq 0.05$)

were observed on the root length, shoot dry weight.

ANOVA reviewed that NPK rates showed significant differences (P≤0.05) during the first season for leaf area, number of leaves, shoot length, root length, shoot dry weight during the first season.ANOVA reviewed that quail manure rates were significant differences (P≤0.05) during the first season for the leaf area, number of leaves, shoot length, root length, shoot dry weight and root dry weight while other variables were not significantly different (P≤0.05).

Significant interactions (P≤0.05) were observed between the Variety and NPK rates levels on the root length in the first season but non-significant differences (P≥0.05) were observed on the number of leaves, root dry weight, shoot dry weight, shoot length, leaf area.

Significant interactions (P≤0.05) were observed between variety and quail manure rates on the number of leaves and shoot dry weight during the first season however non-significant differences (P≥0.05) were observed on the leaf area, shoot length, root length, root dry weight.

Significant interactions (P≤0.05) were observed between NPK and quail manure rates on the root length during the first season while non-significant differences (P≥0.05) were observed on the leaf area, number of leaves, shoot length, root dry weight.

Significant interactions (P≤0.05) were observed between Variety, NPK and quail manure rates which is a second order interaction on the shoot dry weight during the first season while non-significant differences (P≥0.05) were observed on the leaf area, number of leaves, root length, shoot length, root dry weight.

Anova reviewed that varieties were significantly (P≤0.05) different for leaf area, number of leaves, shoot length, root length and shoot dry weight however root dry weight.

Anova reviewed NPK rate were significantly (P≤0.05) different for leaf area, number of leaves, shoot length, root length, shoot dry weight, root dry weight.

Anova reviewed that quail rate were significantly (P≤0.05) different for number of leaves, shoot length, root length however leaf area, shoot dry weight, root dry weight.

Results reviewed that interaction between variety and NPK were significantly (P≤0.05) different for root length however leaf area, number of leaves, shoot length, shoot dry weight, root dry weight, were not significantly (P≤0.05) different.

ANOVA reviewed that interaction between variety and quail manure rate were not significantly (P≤0.05) different for number of leaves however leaf area, shoot length, root length, shoot dry weight, root dry weight. The results reviewed that interaction between NPK rate and quail manure while non-significant differences (P≥0.05) were observed on leaf area, number of leaves, shoot length, root length, shoot dry weight, root dry weight. ANOVA reviewed that interaction between varieties, NPK rate and quail manure rate were significantly (P≤0.05) different for shoot dry weight however leaf area, number of leaves, shoot length, root length, root dry weight.

3.3 Effect of Organic and Inorganic Fertilizers on Plant Leaf Area

Significant differences (p≤0.05) between the treatments were observed on leaf area (Figs. 1 and 2), where the highest leaf area of 991 cm^2 in the second season was observed on the *A. tricolor* from 387 cm^2 in season one at an application of 16.9 t/h+ 500 kg/ha. in the second season, *A. cruentus* recorded the highest leaf area of 1415 cm^2 from 248 cm^2 in season one. *A. tricolor* in the second season recorded 700 cm^2 from 387 cm^2 at the same treatment of 16.9 t/h+ 500 kg/ha. The leaf area was 71 cm^2 in *A. cruentus* during the first season and 79 cm^2 in *A. tricolor* at the control during the first season season. The lowest leaf area was recorded in both varieties where no fertilizer was applied for both seasons in the second season. There were significant differences (p≤0.05) between NPK and quail manure fertilization at different rates (Figs. 1 and 2). The leaf area increased as the supply rate of NPK and quail manures increased in the interaction but at 16.9 t/ha+500 kg/ha the leaf area increased probably due to high amount of micro elements in the quail manure hence high growth rate, similar result as increased leaf area of lettuce and cabbage crops when chicken manure was used as organic fertilizer [19]. The highest leaf area was obtained when sole NPK was applied at 500 kg/ha of 45 cm^2 in *A. tricolor* in season one which reduced to 40 cm^2, NPK still had the highest leaf area 41.3 cm^2 at the same rate in *A. cruentus* also which reduced to 40 cm^2 (Tables 3 and 4). Therefore, increase in NPK brought about the leaf area increase. Changes in the number of leaves are bound to affect the overall performance of Amaranthus as the leaves serve as photosynthetic organ of the plant [12]. The leaf area was highly significant at p≤0.01. The highest was recorded at 16.9 t/ha in season one and two in the two varieties, in *A. tricolor* the leaf area increased to 32 cm^2 from 29 cm^2 in season one. The lowest leaf area was recorded at control in the two seasons, *A. cruentus* recording 20 cm^2 and *A. tricolor* recording 23 cm^2

3.4 Effect of Inorganic and Organic Fertilizers on Number of Leaves

Application of organic and NPK had significant effects (P≤0.05) on the number of leaves on the two amaranth varieties for both seasons (Fig. 3). The number of leaves that was recorded when 500 kg/ha + 16.9 t/ha was applied was 19.67 leaves, observed in *A. tricolar*, but *A. cruentus* variety had 20.67 at the same rate in the same second season (Fig. 3 II), but

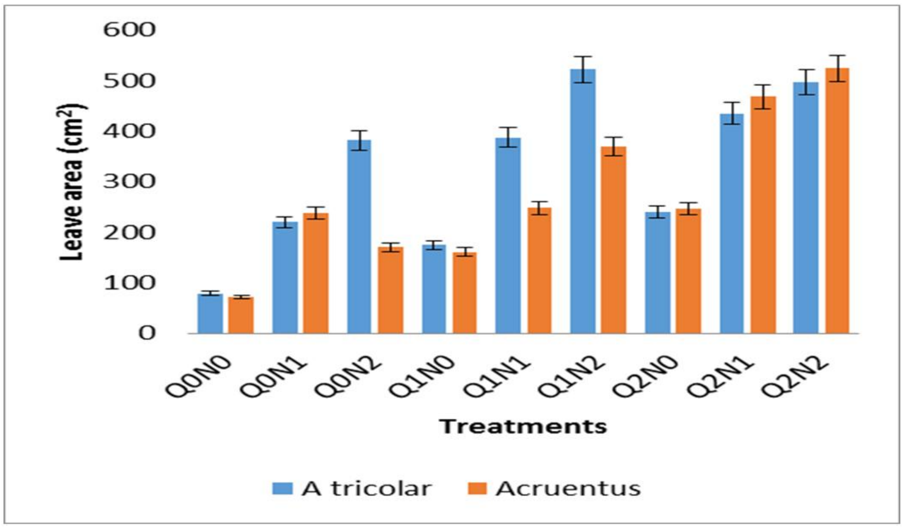

Fig. 1. The interaction effect of NPK rates and quail manure rates on leaf area in season one under the two amaranth varieties

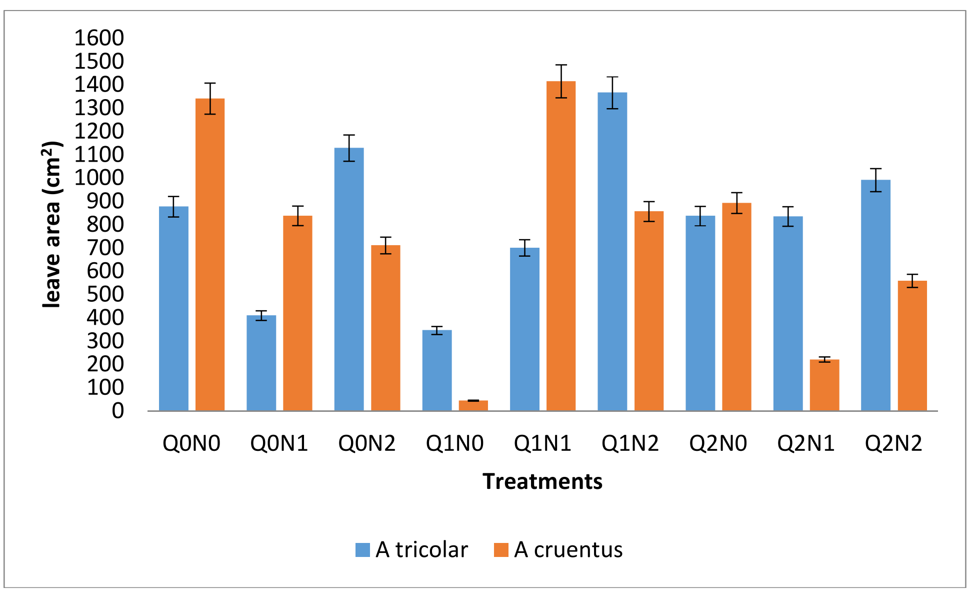

Fig. 2. The interaction effect of NPK rates and quail manure rates on leaf area in season two under the two amaranth varieties

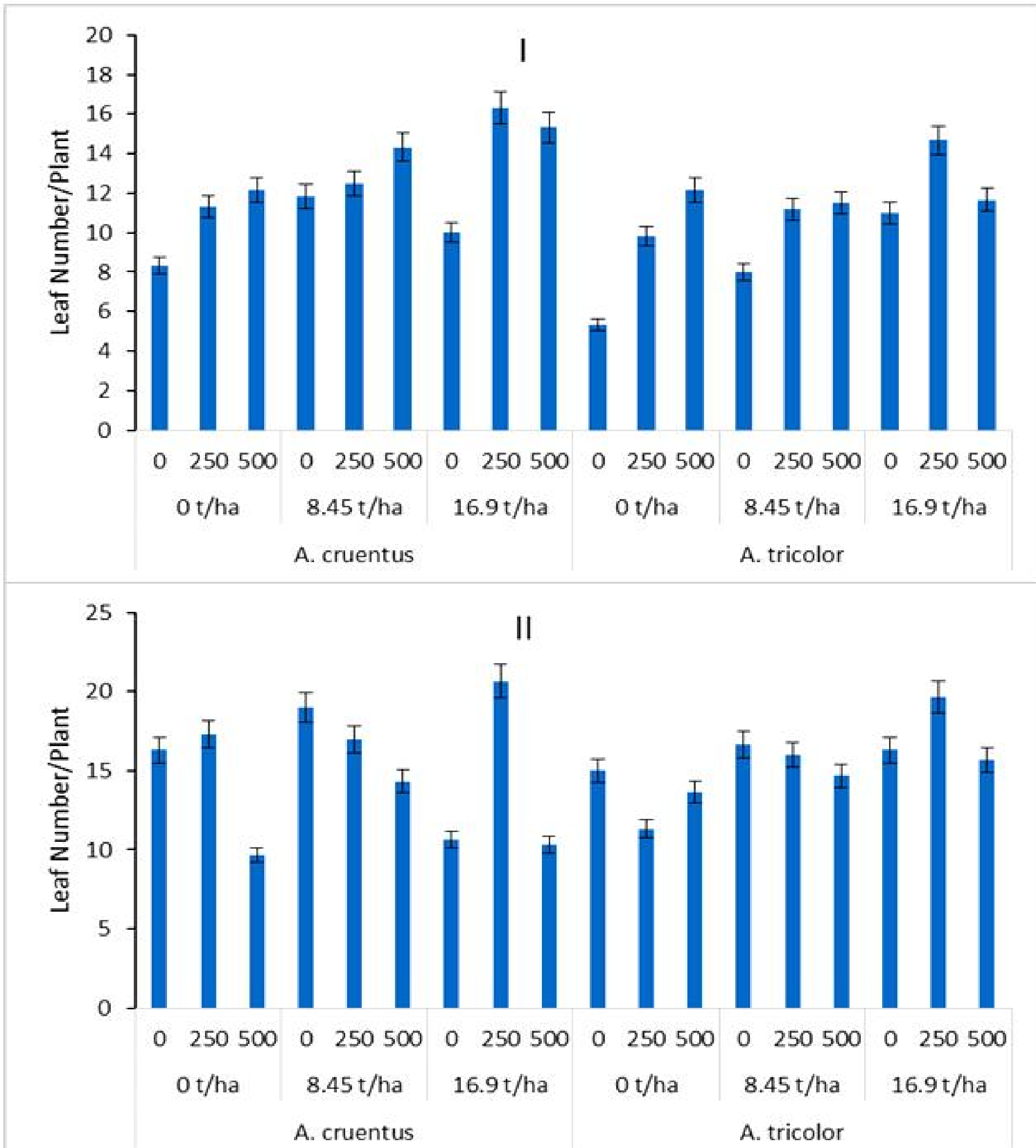

Fig. 3. The interaction effect of NPK rate, quail manure rates and variety on number of leaves per plant during season one (I) and season two (II)

significantly (P≤0.05), the lowest number observed on the controls with a minimum of 5.33 in *A. tricolar* in season one. The number of leaves in the first season was 17 in *A. cruentus* were significantly higher than in *A. tricolor* which recorded 15 at 500 kg/ha + 16.9 t/ha. *A. cruentus* had 22 leaves the highest in the second season. Plants that were fertilized with NPK fertilizer at 500 kg/ha, *A. tricolar* had 17.06 and *A. cruentus* had 12.86 in the first season, in the second season *A. cruentus* and *A. tricolor* recorded 15.86 and 14.06 respectively at the same rate of 500 kg/ha. The number of leaves in *A. tricolor* increased from 14.56 to 17.56 in the second season in the plants that were treated with quail manure from 13.7 to 17.56 in *A. cruentus* at 16.9 t/ha organic manure contain high amount of micro nutrients that increase the rate of leaves formation [19], at 500 kg/ha the number of leaves further reduced to 14.06 from 17.06 in *A. tricolor* (Table 3). Contrary to the plants that were fertilized with quail manure whose leaves increased (Tables 1 and 2). The number of leaves was highly significant at p≤0.01 in the second season but was significant at p≤0.05 in the first season while sole organic manure was applied. The highest while sole Quail manure was applied was recorded at 16.9 t/ha, in *A. tricolor* variety of 17.56 in season two from 14.56 in season one, in *A. tricolor* the number of leaves increased to 32 from 29 in season one.the lowest leaf area was recorded at control in the two seasons, *A. cruentus* recording 7.86 in season two and *A. tricolor* recording 9.56 in the first season

3.5 Shoot Length

Application of quail manure and NPK significantly (P≤0.05) influenced the shoot length of the amaranth varieties (Figs. 4 and 5). As the rate of NPK increased so did the shoot length, the longest shoot 43 cm from 22 cm in the first season in *A. tricolor* was realized at the rate of 16.9 t/ha + 500 kg/ha rate of NPK in season two (Fig. 5), *A. cruentus* at the same application increased to 30 cm in the second season from 28 cm. The shortest shoots were observed on the controls where they recorded less than 10 cm for each, *A. cruentus* in the first season had 9cm while *A. tricolor* had 8cm. The highest level of sole NPK (500 kg/ha) exhibited the tallest plants (33.5 cm) in *A. cruentus* and the shortest plants were under the control with 15 cm in season 2 in the same variety (Table 3). Similar results were reported that increased Amaranthus plant height at higher nitrogen application rate [20]. The highest level was recorded in the *A. tricolor* species 32.7 cm of when organic manure was applied at 16.9 t/ha and the control had 20.9 cm, (Table 4). *A. cruentus* in the control had the lowest height of 20.8 cm and 34.7 cm when 16.9 t/ha was applied in season two. Sole NPK application at 500 kg/ha in *A. cruentus* in season two had 30.5 cm and the control had the shortest shoot length in season two of 15 cm in *A. tricolor*, the highest shoot length was 33.5 in season two. *A. cruentus* shoot length obtained in season one at control had shorter shoot length having a length of 9.5 cm as it rely on the native soil fertility which has deficient in nutrients compared to season two shoot length. The positive performance of NPK+ quail manure on the growth response of *A. tricolar* and *A. cruentus* may be due to the balanced nutrients they contained [21]. The mean shoot length was directly related to the quantity of NPK and quail manure supplied to maize [22]. The shoot length was significant at p≤0.05 in the two seasons while sole organic manure was applied. The highest while sole Quail manure was applied was recorded at 16.9t/ha in season two, *A. tricolor* variety had 32.7 cm in season two from 31.9 cm in season one, in *A. cruentus* the shoot length increased to 34.7 cm from 31.1 cm in season one. The lowest leaf area was recorded at control in the two seasons, *A. cruentus* recording 20.9 cm in season one and *A. tricolor* recording 20.9 cm in the first season.

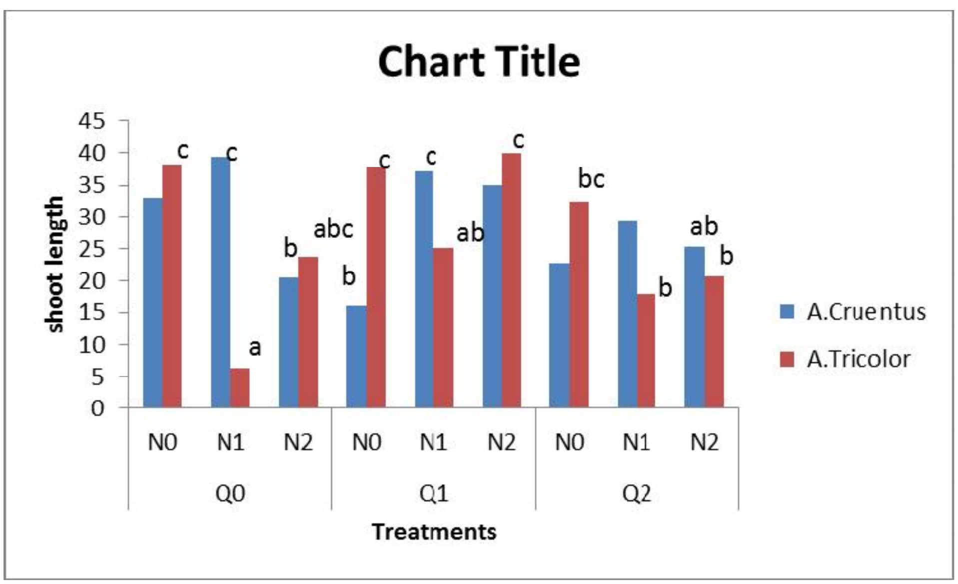

Fig. 4. The interaction effect of NPK rates and quail manure rates on shoot length in season one under the two amaranth varieties

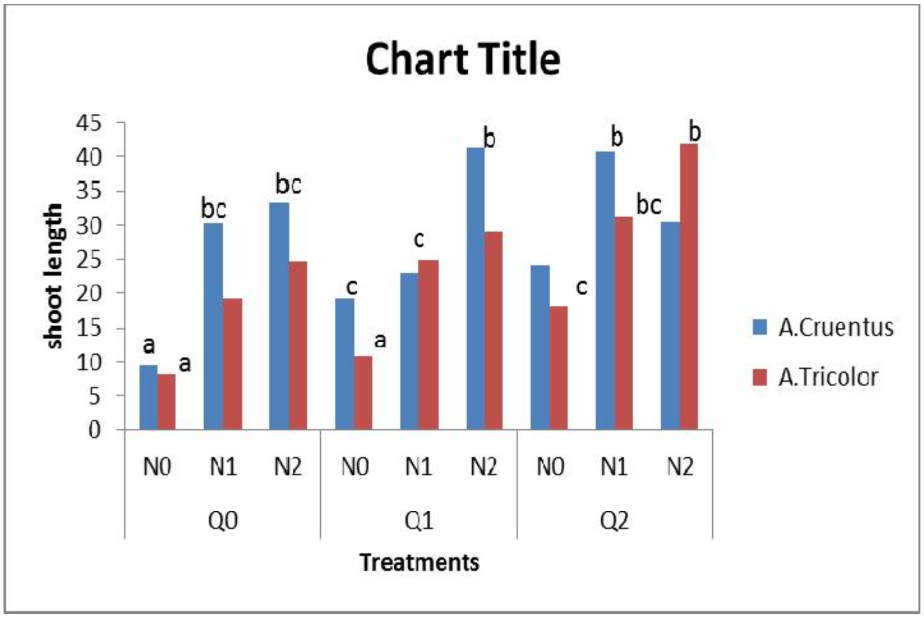

Fig. 5. The interaction effect of NPK rates and quail manure rates on shoot lenth in season two under the two amaranth varieties

3.6 Root Length

There were significant differences (p≤0.05) in *A. tricolar* and *A. cruentus* on the root length as influenced by the treatments (Tables 1, 2, 3 and 4). The root length was significantly enhanced due to increased supply rate of NPK and quail manures. In season one the value of root length was relatively higher than in season two as in season two the majority of the nutrients were available in the soil from the previous NPK and quail manure application. Similar results were reported by Watson who observed that maximum root growth and rooting depth of barley crop was higher in treatments that did not received organic and inorganic fertilizer relative to where manure was applied [18]. The root length in season one (Tables 3 and 4 when NPK was applied was high in comparison with season two, the longest length was at the control where *A. tricolar* had 16.58 cm and *A. cruentus* having 17.39 was cm in season one, in season two at control the root length was 18.73 in *A. cruentus* and 18.94 in *A. tricolor*. root length reduced from 18.23 cm in season one to 12.86 in *A. cruentus* in season when 16.9 t/ha of organic quail manure was applied, and in *A. tricolar* the root length further reduced to 11.81 cm when 16.9 t/ha was applied (Table 1). The results therefore suggest that the observed response was largely due to decreased availability of macro and micro elements in season one since quail manure nutrients are dissipated slowly unlike in the inorganic fertilize [17]. Significant differences (p≤0.05) were observed between the treatments for both seasons. In this case, there was a significant difference (p≤0.005) in *A. tricolar* and *A. cruentus* root length obtained from the treatment. The root length in season two was significantly (P≤0.05) reduced due to increase the supply rate of NPK and quail manures. In season one the value of root length at was relative higher than in season two, this is because in season two the majority of the nutrients were available in the soil from the previous NPK and quail manure application. The intergration of organic at 16.9 t/ha+250 kg/ha had the 21.1 cm which reduced to 14.33 cm in the second season. *A. tricolor* reduced the length from 17 cm to 9 cm in the second season. *A. cruentus* in season one at 16.9 t/h with no NPK fertilizer had 17.3 cm which reduced to 14.33 cm in the second season in comparison with *A. tricolor* that recorded 9.33 cm from 16.33 cm.

3.7 Root Dry Weight

There were significant differences (P≤0.05) on quail manure (Tables 1 and 2) and NPK rates on the root dry weight (Table 3 and 4). It was observed that more root dry matter yield was obtained in where quail manure and NPK were previously applied. Different rates of quail manure and NPK had different influence on root weight. NPK application at different rate influences the root dry weight [23,24]. *A. tricolor* had the highest root dry weight of 2.2grammes at 8.45 t/ha+250 kg/ha of NPK of NPK in season one, followed by *A. cruentus* having 2.1 grams at 8.45 t/ha+250 kg/ha of NPK in season two. The root dry weight in season two increased further where the plants were treated with quail manure (Table 2) *A. tricolor* had a mass of 1.9 g whereas *A. cruentus* had a mass of 1.86 g in comparison with those that were treated with the NPK rates (Tables 3 and 4), the inorganic treated plants in the second season showed reduced dry weight in comparison with season

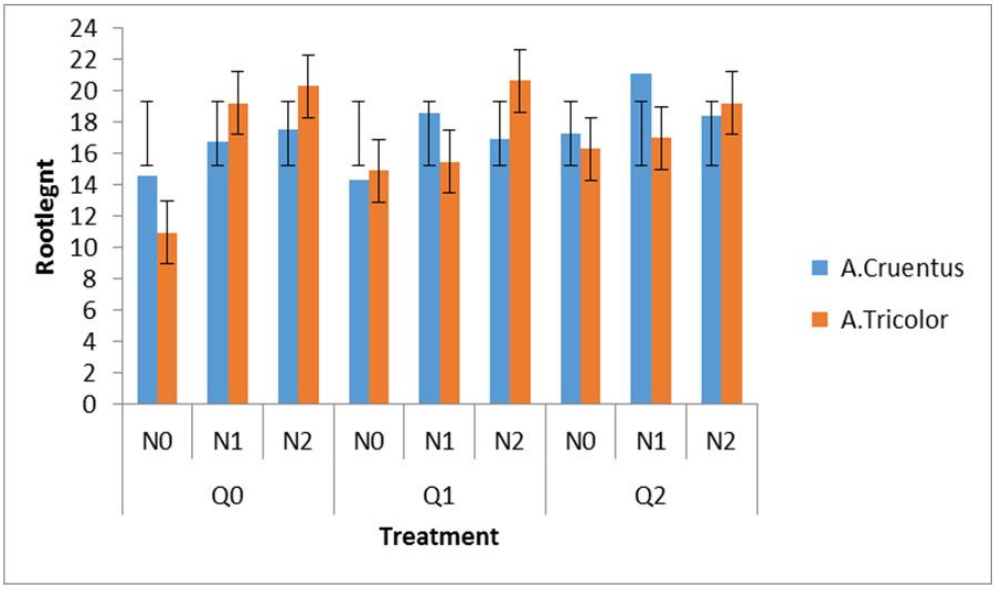

Fig. 6. The interaction effect of NPK rates and quail manure rates on leaf area in season one under the two amaranth varieties

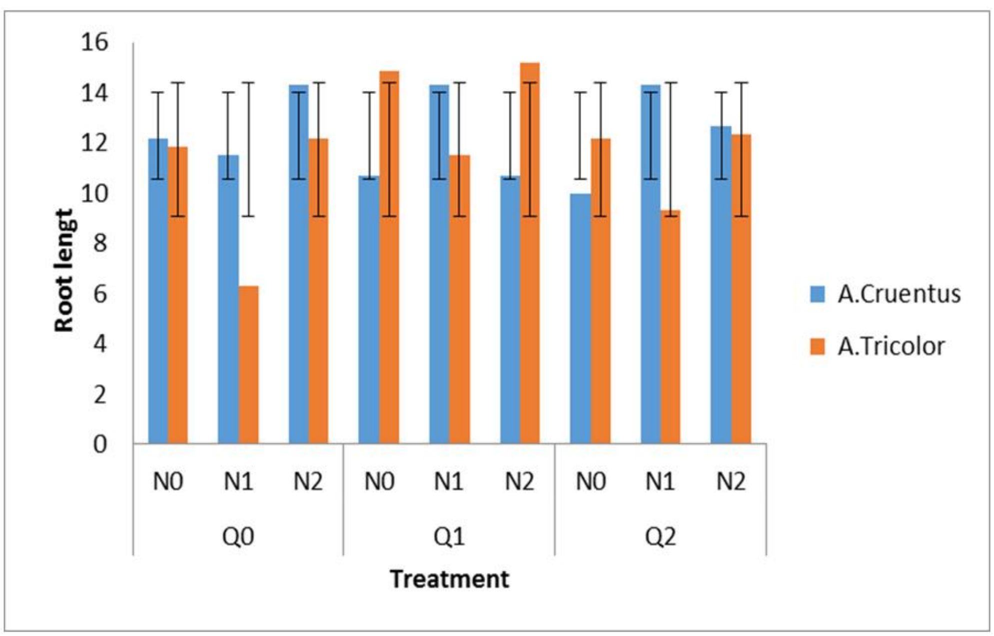

Fig. 7. The interaction effect of NPK rates and quail manure rates on leaf area in season one under the two amaranth varieties

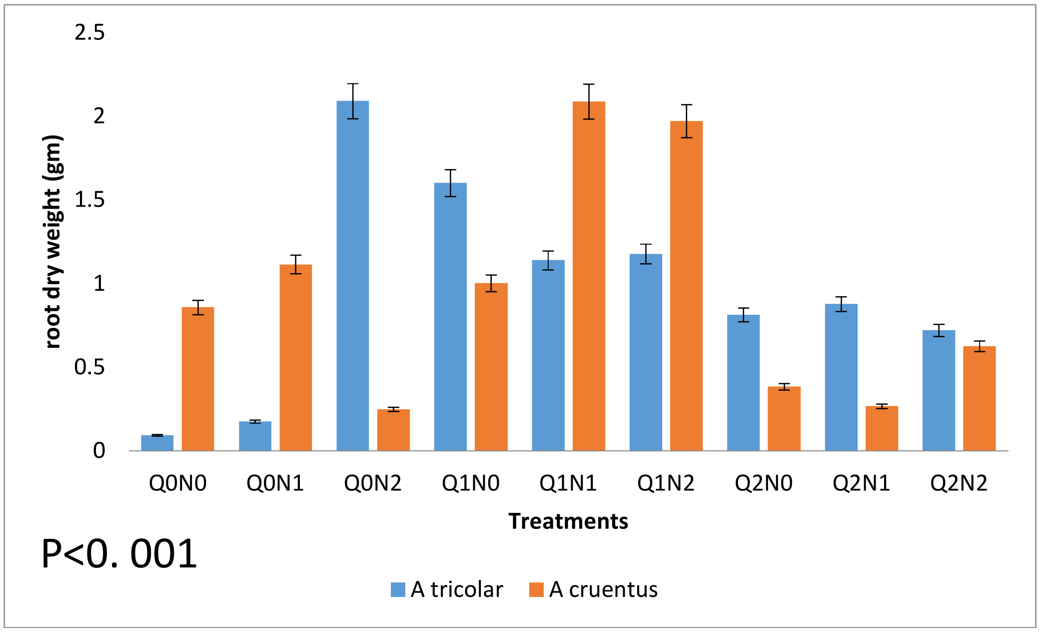

Fig. 8. The interaction effect of NPK rates and quail manure rates on leaf area in season one under the two amaranth varieties

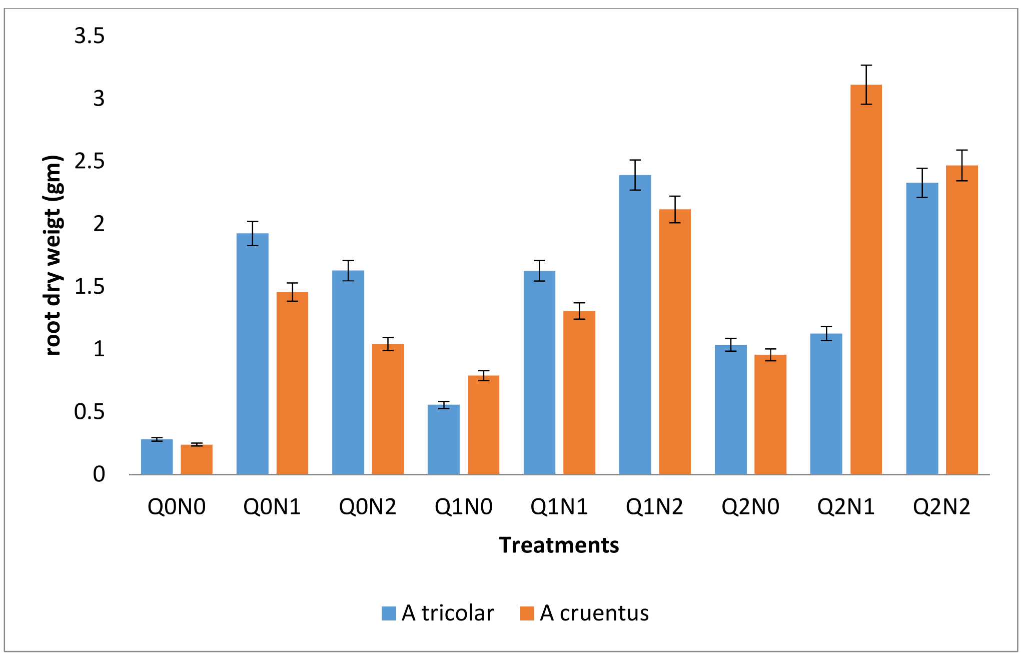

Fig. 9. The interaction effect of NPK rates and quail manure rates on leaf area in season two under the two amaranth varieties

one, the lowest dry weight was 0.5 g shown in amaranth plant treated with NPK at 500 kg/ha. in season one *A. cruentus* variety at 8.45 t/h+500 kg/ha had 1.97 g which increased to 2.117 g at the same rate whereas *A. tricolor* recorded 2.392 g from 1.177 g at 8.45 t/h+500 kg/ha. At 16.9 t/h+500 kg/ha in season one, *A. cruentus* had 0.625 g which increased to 2.468 g but *A. tricolor* increased to 2.328 g from 0.72 g.

Table 3. The influence of interactions between variety and quail manure rates on leaf area, number of leaves, shoot length, root length and root dry weight during the first season

Variety	Quail Rate	Leaf area (cm2)	Leaf number	Shoot length (cm)	Root length (cm)	Root dry weight (g)
A. cruentus	0 t/ha	20c	9.86c	20.9c	16.58a	1.20c
	8.45 t/ha	27.4a	11.56b	24.7b	16.82a	1.56a
	16.9 t/ha	29.04a	13.7a	31.1a	18.23a	1.037
A. tricolor	0 t/ha	23b	9.56c	26.8b	11.39b	1.28c
	8.45 t/ha	28.8a	13.28a	31.9a	12.86b	1.39b
	16.9 t/ha	29a	14.56a	24.7b	11.81b	1.23c
	LSD	2.36	1.12	2.81	3.12	0.08
V×Q		*	*	*	**	**

Means in a same column followed by different letter (s) are significantly different at P<0.05
NS = Not significant.
** Significant at α=0.05*
*** Significant at α=0.01*

Table 4. The interaction influence of variety and quail manure rates on leaf area, number of leaves, shoot length, root length and root dry weight during the second season

Variety	Quail rate	Leaf area (cm2)	Leaf number	Shoot length (cm)	Root length (cm)	Root dry weight (g)
A. cruentus	0 t/ha	22c	7.86c	20.8d	14.73a	1.27c
	8.45 t/ha	28b	16.96a	26.9c	11.04b	1.85a
	16.9 t/ha	29.9ab	17.7a	34.7a	12.86b	1.86a
A. tricolor	0 t/ha	22c	10.56b	32ab	11.94b	1.24c
	8.45 t/ha	30a	17.28a	31.9b	11.20b	1.55b
	16.9 t/ha	32a	17.56a	32.7ab	12.89b	1.9a
	LSD	2.16	1.09	2.49	2.89	0.07
V×Q		**	**	*	*	*

Means in a same column followed by different letter (s) are significantly different at P<0.05
NS = Not significant.
** Significant at α=0.05** Significant at α=0.01*

Table 5. The interaction influence of variety and NPK rates on leaf area, number of leaves, shoot length, root length and root dry weight during the first season

Variety	NPK rate	Leaf area (cm2)	Leaf number	Shoot length (cm)	Root length (cm)	Root dry weight (g)
A. cruentus	0 kg/ha	24d	8.00c	15.0c	16.58a	1.28c
	250 kg/ha	34.6c	12.64b	28.2b	12.82b	1.84a
	500 kg/ha	41.3a	12.86b	33.5a	13.23b	0.83d
A. tricolor	0 kg/ha	21d	8.67c	10.0d	17.39a	1.25c
	250 kg/ha	37b	17.67a	25.9b	12.96b	1.55b
	500 kg/ha	45a	17.06a	27.5b	13.81b	1.91a
	LSD	6.89	3.58	2.91	3.11	0.06
V×N		**	*	**	*	*

Means in a same column followed by different letter (s) are significantly different at P<0.05
NS = Not significant.
** Significant at α=0.05*
*** Significant at α=0.01*

Table 6. The interaction influence of variety and NPK rates on leaf area, number of leaves, shoot length, root length and root dry weight during the second season

Variety	NPK rate	Leaf area (cm2)	Leaf number	Shoot length (cm)	Root length (cm)	Root dry weight (g)
A. cruentus	0 kg/ha	22c	9.00b	15.0d	18.73a	1.28b
	250 kg/ha	28b	12.64ab	27.2b	16.04a	1.60a
	500 kg/ha	35ab	15.86a	30.5a	17.86a	0.50c
A. tricolor	0 kg/ha	23c	9.67b	19.0c	18.94a	1.23b
	250 kg/ha	32b	15.67a	26.9b	11.22b	1.22b
	500 kg/ha	40a	14.06a	28.5ab	16.89a	0.57c
	LSD	7.11	3.18	2.34	2.81	0.43
V×N		**	*	*	*	*

Means in a same column followed by different letter (s) are significantly different at P<0.05; NS = Not significant.
** Significant at α=0.05; ** Significant at α=0.01*

4. CONCLUSION

Analyses of variance parameter showed significant differences at (P≤0.05) in the shoot length, root length, leaf area, root dry weight.

This study shows that the quail treatment crop recorded longer roots compared to the crop treated with NPK. There was an observable trend of the crop under quail manure to have thicker roots throughout the five weeks and it was concluded that the crop treated with quail manure recorded higher root fresh weights compared to the ones treated with NPK. Leaf number increased with increased application NPK fertiliser. This showed that Nitrogen promoted the vegetative growth of amaranth. *A. cruentus* produced a higher number of leaves, and hence the breeding of the two can be done to transfer the genes to *A. tricolor.* It may be advisable to grow amaranth with 500 kg/ha if the grower is targeting the leaves, but with integration of organic manure, the inorganic fertilizer is reduced to 250 kg/hac.

Anova Tables

Leaf Area Season One

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	15801	7901	0.93	
REPLICATION.*Units* stratum					
VARIETY	1	34101	34101	4.01	0.053
NPKRATE	2	692112	346056	40.66	<.001
QUALMANURE	2	335148	167574	19.69	<.001
VARIETY.NPKRATE	2	31079	15540	1.83	0.177
VARIETY.QUALMANURE	2	37811	18905	2.22	0.124
NPKRATE.QUALMANURE	4	27777	6944	0.82	0.524
VARIETY.NPKRATE.QUALMANURE					
	4	31334	7833	0.92	0.463
Residual	34	289359	8511		
Total	53	1494522			

Leaf Area Season Two

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	204378	102189	2.66	
REPLICATION.*Units* stratum					
VARIETY	1	421173	421173	10.97	0.002
NPKRATE	2	671850	335925	8.75	<.001
QUALMANURE	2	229390	114695	2.99	0.064
VARIETY.NPKRATE	2	168481	84240	2.19	0.127
VARIETY.QUALMANURE	2	13293	6647	0.17	0.842

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
NPKRATE.QUALMANURE	4	188895	47224	1.23	0.317
VARIETY.NPKRATE.QUALMANURE					
	4	98333	24583	0.64	0.637
Residual	34	1305366	38393		
Total	53	3301160			

Number of Leaves Season One

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	7.259	3.63	2.34	
REPLICATION.*Units* stratum					
VARIETY	1	11.574	11.574	7.46	0.01
NPKRATE	2	39.704	19.852	12.8	<.001
QUALMANURE	2	22.259	11.13	7.17	0.003
VARIETY.NPKRATE	2	7.259	3.63	2.34	0.112
VARIETY.QUALMANURE	2	1.815	0.907	0.58	0.563
NPKRATE.QUALMANURE	4	8.963	2.241	1.44	0.241
VARIETY.NPKRATE.QUALMANURE					
	4	11.185	2.796	1.8	0.151
Residual	34	52.741	1.551		
Total	53	162.759			

Number of Leaves Season Two

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	4.0864	2.0432	2.11	
REPLICATION.*Units* stratum					
VARIETY	1	9.2366	9.2366	9.55	0.004
NPKRATE	2	63	31.5	32.58	<.001
QUALMANURE	2	61.1481	30.5741	31.62	<.001
VARIETY.NPKRATE	2	0.9424	0.4712	0.49	0.619
VARIETY.QUALMANURE	2	18.3498	9.1749	9.49	<.001
NPKRATE.QUALMANURE	4	9.9259	2.4815	2.57	0.056
VARIETY.NPKRATE.QUALMANURE					
	4	3.1934	0.7984	0.83	0.518
Residual	34	32.8765	0.967		
Total	53	202.7593			

Shoot Length Season One

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	9.794	4.897	1.11	
REPLICATION.*Units* stratum					
VARIETY	1	35.77	35.77	8.14	0.007
NPKRATE	2	334.585	167.292	38.05	<.001
QUALMANURE	2	173.496	86.748	19.73	<.001
VARIETY.NPKRATE	2	2.492	1.246	0.28	0.755
VARIETY.QUALMANURE	2	7.986	3.993	0.91	0.413
NPKRATE.QUALMANURE	4	29.769	7.442	1.69	0.174
VARIETY.NPKRATE.QUALMANURE					
	4	11.766	2.941	0.67	0.618
Residual	34	149.5	4.397		
Total	53	755.156			

Shoot Length Season Two

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	18.28	9.14	0.24	
REPLICATION.*Units* stratum					
VARIETY	1	301.99	301.99	7.77	0.009
NPKRATE	2	794.58	397.29	10.22	<.001
QUALMANURE	2	582.44	291.22	7.49	0.002
VARIETY.NPKRATE	2	70.96	35.48	0.91	0.411
VARIETY.QUALMANURE	2	24.5	12.25	0.32	0.732
NPKRATE.QUALMANURE	4	184.92	46.23	1.19	0.333
VARIETY.NPKRATE.QUALMANURE					
	4	177.51	44.38	1.14	0.354
Residual	34	1321.44	38.87		
Total	53	3476.62			

Root Length Season One

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	5.561	2.78	1.11	
REPLICATION.*Units* stratum					
VARIETY	1	2.187	2.187	0.87	0.358
NPKRATE	2	139.765	69.882	27.8	<.001
QUALMANURE	2	65.716	32.858	13.07	<.001
VARIETY.NPKRATE	2	12.919	6.46	2.57	0.091
VARIETY.QUALMANURE	2	13.416	6.708	2.67	0.084
NPKRATE.QUALMANURE	4	60.351	15.088	6	<.001
VARIETY.NPKRATE.QUALMANURE					
	4	14.705	3.676	1.46	0.235
Residual	34	85.469	2.514		
Total	53	400.089			

Root Length Season Two

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	19.511	9.756	2.04	
REPLICATION.*Units* stratum					
VARIETY	1	59.956	59.956	12.52	0.001
NPKRATE	2	134.646	67.323	14.06	<.001
QUALMANURE	2	39.155	19.577	4.09	0.026
VARIETY.NPKRATE	2	227.077	113.538	23.71	<.001
VARIETY.QUALMANURE	2	24.835	12.418	2.59	0.09
NPKRATE.QUALMANURE	4	40.363	10.091	2.11	0.101
VARIETY.NPKRATE.QUALMANURE					
	4	37.222	9.305	1.94	0.126
Residual	34	162.845	4.79		
Total	53	745.61			

Shoot Dry Weight Season One

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	0.1804	0.0902	1.56	
REPLICATION.*Units* stratum					
VARIETY	1	0.0155	0.0155	0.27	0.608
NPKRATE	2	1.52372	0.76186	13.14	<.001
QUALMANURE	2	0.75889	0.37945	6.54	0.004

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY.NPKRATE	2	0.15278	0.07639	1.32	0.281
VARIETY.QUALMANURE	2	0.71081	0.35541	6.13	0.005
NPKRATE.QUALMANURE	4	0.07912	0.01978	0.34	0.848
VARIETY.NPKRATE.QUALMANURE					
	4	0.63704	0.15926	2.75	0.044
Residual	34	1.97188	0.058		
Total	53	6.03015			

Shoot Dry Weight Season Two

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	16.894	8.447	3.45	
REPLICATION.*Units* stratum					
VARIETY	1	25.384	25.384	10.35	0.003
NPKRATE	2	100.677	50.338	20.53	<.001
QUALMANURE	2	1.962	0.981	0.4	0.673
VARIETY.NPKRATE	2	9.838	4.919	2.01	0.15
VARIETY.QUALMANURE	2	0.847	0.423	0.17	0.842
NPKRATE.QUALMANURE	4	18.846	4.711	1.92	0.129
VARIETY.NPKRATE.QUALMANURE					
	4	28.656	7.164	2.92	0.035
Residual	34	83.359	2.452		
Total	53	286.462			

Root Dry Weight Season One

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	1.5395	0.7697	2.35	
REPLICATION.*Units* stratum					
VARIETY	1	0.8513	0.8513	2.6	0.116
NPKRATE	2	5.8311	2.9156	8.9	<.001
QUALMANURE	2	4.8662	2.4331	7.43	0.002
VARIETY.NPKRATE	2	1.8684	0.9342	2.85	0.072
VARIETY.QUALMANURE	2	1.0182	0.5091	1.55	0.226
NPKRATE.QUALMANURE	4	1.374	0.3435	1.05	0.397
VARIETY.NPKRATE.QUALMANURE					
	4	0.6066	0.1517	0.46	0.762
Residual	34	11.1409	0.3277		
Total	53	29.0962			

Root Dry Weight Season Two

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	0.8651	0.4326	3.59	
REPLICATION.*Units* stratum					
VARIETY	1	0.0158	0.0158	0.13	0.719
NPKRATE	2	2.7988	1.3994	11.6	<.001
QUALMANURE	2	0.1663	0.0831	0.69	0.509
VARIETY.NPKRATE	2	0.0216	0.0108	0.09	0.914
VARIETY.QUALMANURE	2	0.2719	0.136	1.13	0.336
NPKRATE.QUALMANURE	4	0.5953	0.1488	1.23	0.315
VARIETY.NPKRATE.QUALMANURE					
	4	0.7742	0.1935	1.6	0.196
Residual	34	4.1018	0.1206		
Total	53	9.6109			

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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