.THE EFFECT OF DIFFERENT NITROGEN LEVELS ON THE GROWTH AND DEVELOPMENT ON GRAIN AMARANTH(*Amaranthus cruentus L)*

BY

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Abstract

Vegetable *Amaranth* (*A. cruentus*) is a promising C4 crop for semi- arid regions due to its nutritive value, medicinal property and ornamental for beautifying gardens . It is widely grown in the tropics and is one of the most important leafy vegetables in the lowlands of Africa, South America and Asia. Little knowledge is known on its Nitrogen requirement, that is why this experiment was conducted to fill in that gap. A field study was conducted in Nyanga which is a high rainfall area receiving over 1000 mm/ annum. The vegetable was sown in the cropping season of 2014/15 to determine the effect of different nitrogen fertilizer levels on (0, 50, 100, 150kg/ha and 200 kg/ha on the growth and yield parameters which were, days to 50 % flowering, dry weight (kg/ha), seed yield (kg/ha) and fresh leaf weight (kg/ha). There was significant difference ($p<0.05$) on the effects of N fertilizer levels on fresh leaf yield of vegetable *Amaranthus cruentus* with the highest yield obtained at 150 and 200 kg/ha N. Mean yield of 33562 kg/ha and 58359 kg/ha and the least 12060kg/ha obtained at 0 kg/ha. There was significant difference ($p<0.05$) on the effects of N fertilizer levels on dry weight. The highest dry weight of 32573 kg/ha and 45102 kg/ ha was achieved between 150 and 200 kg/ha N respectively and the least dry weight of 12621 kg/ ha was obtained at 50 kg/ ha N. The highest seed yield of 2300 kg/ha and 3500 kg/ ha N was also attained at 150 and 200 kg/ ha N respectively. The least seed yield being obtained at 0 kg/ha with seed yield of 292 kg/ha. There was no significant difference on days to 50% flowering due to different rates on N. From this study it can be concluded that *Amaranthus cruentus* performed well at 200 kg/ha N as it gave the highest yield in terms of fresh leaf weight. Thus farmers can use 200 kg/ha N to maximise yield.

Declaration

I hereby declare that this dissertation has been the result of my own original efforts and investigations, and such work has not been presented elsewhere for any degree. All additional sources of information have been acknowledged by means of references.

MASVANHISE BESSY CHRISTINA R13595M

Signed: …………………………….

Date…../……../2015

Certification of Thesis Work

I, the undersigned, certify that Masvanhise Bessy Christina, a candidate for the Bachelor of Science General Degree in Natural Resources Management has presented this dissertation with the title:

THE EFFECT OF DIFFERENT NITROGEN LEVELS ON THE GROWTH AND DEVELOPMENT ON GRAIN AMARANTH (*Amaranthus cruentus)*

That the dissertation is acceptable in form and content, that satisfactory knowledge of the field covered by the dissertation was demonstrated by the candidate through oral examination held on / /2015.

SUPERVISOR: Mr T. Madanzi

SIGNATURE: …………………………

Dedication

To my Husband Peter, My brother Patrick and Terrence, My Mother Margaret, My sisters Bester, Betty, Belinda and Brenda, My children Tafara, Tapiwa, Taonga, Yoyo, Naman and Gigi and my In laws Heskel and Tabani. God bless you!!

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CHAPTER 1

1.1 Introduction and Justification

In Africa traditional leafy vegetables are a useful source of nutrients and vitamins for rural population, as many nutritional studies have shown (Munzava, Daring, Guarino and Chweya, 1982). The indigenous vegetables like *Amaranth* therefore contribute immensely to the human health and livestock feed and hence the need to promote its cultivation and utilization. Vegetable *Amaranth* (*Amaranthus* spp) is widely grown in the tropics and is one of the most important leafy vegetables in the lowlands of Africa, South America and Asia, (Schippers, 2000). *Amaranth* is the collective name for the domesticated species of the genus *Amaranthus*, which has approximately 60 species (BOSTID, 1984) It is an annual, fast growing plant, and is easily cultivated in gardens and fields. The vegetable when taken regularly can reduce trouble of constipation, (Dey, 2000). *Amaranth* is a rich source of calcium, iron, and vitamins A and C which is vital to cater for nutritional component of people which helps to reduce malnutrition cases (Palada and Chang, 2003). The grains also compliment other cereal crops like maize when it is pound for thick porridge and starch while the leaves are used as vegetables. The indigenous vegetables like *Amaranthus cruentus* have been known to prove to be vital for consumption in most rural communities in Africa, (Mposi, 1998). Studies carried out in Buhera showed that the nutritional contribution of Amaranth to the community is very high (Muchiwetu, Kasimuhuru, Benhura, Chiparura, Amina, Francis and Rarawira, 2009). The grain has 12-17 % protein while the leaf has more lysine and more methionine than soybean meal. The grain is high in fibre and low unsaturated fats, factors which contribute to its use in healthy foods market (Putman, Oplinger, Doll, and Schulte, 1989). Based on the nutritive value of amaranth, the vegetable has the potential benefits of feeding programmes, as well as their promotion as part of a composite diet for the vulnerable groups (Muchiwetu et al., 2009).

The indigenous vegetable has been underutilized and neglected by most indigenous farmers despite its richness in nutrients (Mnzava et al., 1982). This is mainly due to lack of knowledge on production of the vegetable. The cost of fertilizer has also gone beyond the reach of many farmers to the extent that they priorities it for other major cash crops. Studies of the impact of diverse fertilizer regimes are especially relevant to agriculture practiced by the poor in developing countries where fertilization of crops is likely to be less organized and more improvised in terms of the timing of applications and the type of fertilizer used (Turan and Sevimli, (2000). Small scale farmers in developing countries can ill afford chemical fertilizers so they often either use manure or plant without fertilization. Also information on the effect of mineral fertilizer and cattle manure on the yield and quality of vegetable *Amaranth* is very scanty (Turan and Sevimli, 2000). FAO, (2007) also pointed out that the Kobe Framework recommends that promotion interventions of indigenous vegetables like *Amaranth* should consider the process from production to consumption. Inorganic fertilizers are most preferable since they supply nutrients quickly (Singh, 2004). It has been noted that *Amaranth* responds differently to different Nitrogen rates (Elbehri, 1993). The production of indigenous vegetables like *A. cruentus* still remains very low in spite of it being abundant in the wild state as a weed. *A. cruentus* remains underutilized due to various constraints related to production, processing, distribution and marketing as well as nutrient information. There are no significant studies that have been done in Zimbabwe on fertilizer rates especially nitrogen rates on Amaranth under rain fed conditions. There are problems of shortage of Nitrogen fertilizer in Zimbabwe and thus the need to find optimum rates to promote production of *Amaranth* as it can be grown in areas where there is a shortage of fertilizer in Zimbabwe.

To grow this vegetable efficiently, it is important to know the effect of fertilization on its yield because nitrogen has been found to be the most limiting factor (Elbehri, Putman and Schmitt, 1993). The studies carried out by Makus and Hettiarachchy , (1999) on effect of nitrogen source and rate on vegetable Amaranth leaf blade mineral nutrients, pigments and oxalates proved nitrogen sources resulted in greater plant height and yield. This also becomes part of this study to find out the effects of different nitrogen rates on amaranth under rain fed conditions. The vegetable responds differently to different nitrogen rates (Elbehri, 1993). According to Mposi (1998), *Amaranthus* requires nitrogen of 112-135 kg per hectare. The typical growth duration of *Amaranth* in Onyango et al (2008) on the influence of manure and diammonium phosphate (DAP) mineral fertilizer on germination, leaf nitrogen content, nitrate accumulation and yield of vegetable amaranth (*Amaranthus hypochondriacus*) in Kenya, the highest yield was recorded in plots receiving 40 kg N ha^{-1} from DAP at eight weeks after planting. Singh and Whitehead, (1996) noted that higher rates (45, 90 and 135 kg N ha^{-1}) have been successfully used to increase the production of vegetable *Amaranth*.

In Zimbabwe Amaranth grows in wild state with little or no attention at all. This study will contribute significantly to the production and utilization of Amaranth which has remained a reserve for rural folk despite the fact that it is essential in the sustenance of a balanced diet in rural areas (FAO, 2002). The main aim of this study was to determine the effect of different Nitrogen levels on Amaranth production.

1.2 Aim

To determine the effects of different Nitrogen level on growth and yield of (*A cruentus*) measuring plant fresh weight and dry matter, days to 50% flowering, vegetable fresh weight (kg/ha) and seed yield (kg/ha)

1.2.1 Main objective

To investigate the effects of different Nitrogen levels on growth and yield potential of *A. cruentus.*

1.3 Specific objectives

1. To determine the effects of different nitrogen levels on dry matter accumulation and days to 50 % flowering of *A. cruentus*.
2. To investigate the effects of fresh vegetable leaf yield of *A. cruentus.*
3. To determine the effects of different Nitrogen levels on seed yield of *A. cruentus.*

1.4 Hypotheses

1. H_0: Different Nitrogen levels do not significantly affect growth and development of *Amaranth* in terms of dry weight and vegetable leaf yield (kg/ha).
2. H_0: Nitrogen levels do not significantly affect growth and development of Amaranth in terms of seed yield (kg/ha).
3. H_0: Days to 50 % flowering is not significantly affected by different Nitrogen levels.

CHAPTER 2

2.0 Literature Review

2.1 Origin and Distribution

Amaranth originated in America and is one of the oldest food crops in the world, with evidence of its cultivation reaching back as far as 6700 BC. *Amaranth* consists of 60-70 species, several of which are cultivated as leaf vegetables, grains or ornamental plants, while others are weeds. At present, *Amaranth* is extensively grown as a green, leafy vegetable in many temperate and Tropical regions. Meanwhile, *Amaranth* had spread around the world and had become established for food use (the grain or leaves) in places such as Africa, India, Nepal and Zimbabwe. other types create employment opportunities through leafy vegetables, cereals, ornamentals landscape. (Trucco and Tranel, 2011)

2.2 Plant characteristics

African indigenous vegetables have a pivotal role in the success of the world health organisation's initiative on promoting fruits and vegetable consumption (Fransca and Pablo, 2007). *Amaranth* is bushy, erect, branched annual herb which can grow up to 1 m. with thick stalks, similar to native weedy species. Predominantly self-pollinated, plant flowers are purple, red, pink, orange, or green. The stems are tinged reddish, erect, occasionally ascending, branched, with linear marks on the surface, and hairless to moderately pubescent with multicellular hairs. Leaves are simple, broadly tapering at the end to ovate or rhombic in shape with the lower surface hairless or sparsely covered with hair along the margins and veins. The flowers are Yellowish green, reddish, or purple, in auxiliary and terminal spikes, both sexes mixed throughout the spikes, bracts and bracteoles deltate-ovate, tipped with a long, pale brown to reddish awn; lanceolate or oblong, apex acute, often awn-tipped, sometimes the apex of female flowers blunt, only the midrib green; stigmas are 2 to 3. Fruit is small in size and dark red, brown or black in colour. Seeds are black, sometimes shiny, compressed, 0, 8 to 1, 3 mm long, faintly reticulate near the margins. The plants are indeterminate, but tend to have a dominate seed head with fewer side branches than weedy amaranths. Many amaranths are sensitive to day length, which is useful in developing varieties (Shroyer, Stegmeier and Mikesell, Shroyer, 1990).

2.2.1 Climate and Soil Requirements

Amaranth seed requires high light and temperature to break dormancy. It highly tolerate arid environments. *Amaranth* seeds need soil temperatures of between 18 °C and 25 °C to germinate and an air temperature above25 °C (Grubben, 2004) for optimum growth. Moisture stress, poor nutrients, lower temperatures and shorter days will induce flowering with a subsequent reduction in leaf yield. Frost damage is not of effect to *Amaranth* as the crop is planted with the onset of rains, just like maize it flowers in April after planted in November. The vegetable prefers well drained fertile soils in a sunny position (Ken, 2010).

2.2.1 Role of traditional vegetable

Leaf *Amaranth* is an indigenous vegetable used as a steamed vegetable in soups and stews. The grain has some protein (12 % to 17 %) and is high in lysine, an amino acid that is low in other grain crops like wheat, maize and millets. The grain is ground into flour. It is prepared as porridge. The seed is used to make soft popcorns. *Amaranth* is high in fibre and low in saturated fats. *A. cruentus'* stem is used in blending curry powders. Leaves are cooked as spinach. Seed can be germinated into nutritious sprouts. Seeds can also be eaten as cereal. It is an exceptionally rich source of calcium, iron and vitamin C, a very rich source of potassium, vitamin A and riboflavin, a rich source of niacin and an above-average source of protein. The ground floor is used in making breads, noodles, pancakes, cereals. The leaves stem and head are high in protein (15 to 24 % on a dry-matter basis). Grain *amaranth*, have 24 % crude protein and 79% in vitro digestible dry matter. Vegetable amaranths, has (80 % moisture). In areas where corn silage yields are low owing to moisture limitations, grain amaranth may become a suitable silage alternative. There are many species of *amaranth* in cultivation. Other types create employment opportunities through leafy vegetables, cereals, ornamentals landscape. (Trucco and Tranel, 2011)

A. cruentus is a tall, fast-growing herbaceous annual herb topped with greenish- yellowish flowers. The plant can grow up to more than three metres high. It is a c4 plant that does well under very hot temperatures. *Amaranthus cruentus* is the most commonly grown species in countries like Sierra Leone. It has medicinal properties that are of paramount important to both young and adult people. Its properties in high protein content help in marginal and impoverished rural/ communal areas as it corrects for malnutrition.

African indigenous vegetables have a pivotal role in the success of the world Health Organisation's initiative on promoting fruits and vegetable consumption (Fransca and Pablo, 2007). Cooked leaves provides Vitamin A, Vitamin C and Foliate, they complement for vitamins such as thiamine, niacin and riboflavin and the dietary mineral including Calcium, Iron, Magnesium, Phosphorus, Zinc, copper and Manganese.

Amaranthus species, sequester carbon dioxide in the stratosphere, mesosphere, thermosphere and alto sphere to attain clean atmosphere. It is part of flora that beautify the environment which is a natural amenity to attract foreign currency for current generation and posterity.

2.3.2 Production Trends of *A. cruentus*

In southern Africa indigenous vegetables are still considered valuable since imperial time. The leaves of all *Amaranthus* species are edible and many appear regularly in the diets of several societies. (Grubben 1976; Lackom 1991). Manicaland province in Zimbabwe is the highest consumer of indigenous weeds like *Amaranthus* and spider plant- Black jack. Indigenous vegetables are sold in rural and in urban markets during rainy season. Due to awareness, improved cultivars is commercially available. In urban centres it is becoming increasingly popular with demand frequently surpassing supply. Dried indigenous vegetables improve cross border trade as peanut butter and dried vegetables are sold to neighbouring countries like Botswana, Mozambique and Zambia.

2.3.3 Choice of Variety

Choice and preference depends on taste and preference among different tribes. *Amaranthus* consist of 60-70 species. Some species are used in land- scaping, wedding gardens, around hotels, vegetables, and seed production used in confectionary for production of flour, corn flecks and popcorns. Therefore choice of variety is influenced by individual preference for leaf color and taste (Palada and Sigh, 2003). In Africa most variety used as leaf vegetable is *Amaranthus cruentus* and *A. hybridas* while *A. spinosus* is a thorn weed. *A. tricolor* is dominant in the South and Southeast Asia. *Amaranthus dubias* is mostly found in the Caribbean Region.

Agronomic Practices

2.3.3.1 Seed Bed Preparation

Like other vegetable seeds, *Amaranths* seed is a small seed that requires fine tilth for easier of germination. Soils with a wetness factor should be avoided as good aeration is a prerequisite for resumption of metabolic activity. Soils with shallow depth should be avoided as they prolong wetness period if heavy rains are received which will lead to lodging, wet feet and result of death. Boulder and rock out crop areas need to be avoided as they hinder germination. Crusting or t-factor soils have a capping effect that will cement the soil thereby killing all the germinating seeds. Acidic and Alkaline soils should be avoided as they render nutrients unavailable to the seedlings. Primary tillage using a disc plough is followed by secondary tillage using spike toothed harrow to break the clods.

2.3.3.2 Planting

Sowing can be done by hand**,** depth 1.5 cm**,** in raw spacing 15-45 cm apart**,** Plant population 3000-4000 plants per hectare**.** Sowing usually begins in November when rain fed, but commence in the month of May if irrigation in form of sprinkler, flood and drip is used. Seeds are either broad cast, sown in rows or sown on well prepared seed beds. For effective germination, the seed is mixed with sand at a rate of 1g seed per 100 g sand. The seed is weak during germination, therefore require covering with fine sand to avoid cementing if soils cap.

Planting stations are measured using Pythagoras theorem which result in dug holes having a uniform pattern uniform diagonal, vertical and horizontal. Open furrow can be done using a small hoe at a depth of 2 mm.

2.3.4 Water Requirements

Amaranth has a high rate of photosynthesis and excellent water use efficiency at high temperatures and radiation intensity which render rapid growth and high water consumption. The Indigenous vegetable uses six (6 mm) per day which is highly achieved as the crop has high canopy cover which act as mulch to suppress weed and become correct measure of moisture conservation. Besides rain fed irrigation, Amaranth can do well under sprinkler and flood irrigation, provided it is planted on raised beds to avoid wet fit caused by fungal diseases.

2.3.5 Weeding

Weed pests in *Amaranth* production account for between 20-70 % losses in crop yield. (Khan et al. , 2004). Weeds mainly affect A. cruentus during the critical weed crop competition period which range between 27 and 50 days. (Srivastava et al. , 2003). If weeds compete with the desired crop, etiolating result as the crop try to compete for nutrients, sunlight and moisture. Weeds harvest nitrogen, phosphorus and potassium causing yellowish on the desired crop during the first 50 days. (Nyanhete, 2005).

2.3.6 Insect Pest and Disease Control

Leaf miners, Cutworm, Aphids, Leaf roller, Beetles and Flea are major pests of *A. cruentus*. The most problematic being Cutworm *(Agrotis spp*). The dull grey caterpillar with a smooth skin feeds at night severing *A. cruentus* vegetable just below soil level. It encircle the plant with its body and cuts through the stem. One cutworm cuts several *Amaranth* plants in one night. The problem is severe at during germination up to three weeks. Aphids, leaf minor, beetles and flea are not of significance important. Leaf roller falls under Lepidoptera family also favour succulent leaves of *Amaranthus cruentus*. Control spray with Malathion.

Control

Integrated weed management was practised starting with least expensive. Cultural practises, deep ploughing and clean cultivation of the land six weeks before planting was done to remove the weeds on which female cutworms lay eggs will reduce. Chlorpyrifos as a bait was used to control cutworm.

2.3.7 Harvesting

Amaranths is ready for harvest in 20–45 days after planting or sowing depending on variety and plant type (Palada et al, 2003). Like other traditional African leafy vegetables, amaranths grow quickly and thus can be harvested relatively soon after sowing (6–8 weeks) (Chweya and Eyzaguirre, 1999). Plants may be harvested once or several times. Once-over harvesting is adapted for short maturing and quick growing varieties such as *A. tricolor*. Whole plants are pulled from soil with roots, washed and tied in bundles. With multiple harvests, young leaves and tender shoots are picked at 2–3 week intervals. Eventually, the plants begin to flower and develop fewer leaves. Frequent harvesting of leaves and shoots delays the onset of flowering and thus prolongs the harvest period (Palada et al., 2003). *Amaranth* and other leafy vegetables have large surface-to-volume ratio and lose water rapidly. To reduce water loss, harvest during the cooler time of day, such as early morning or late afternoon. Picking the leaves stimulates growth (Moss 1988). The seed is ready for harvesting around March-April.

2.3.8 Yield

Vegetable yield has been reported to reach as high as 60 tonnes per hectare. Elbehri et al (1993) obtained yield response with Nitrogen application of 180 kg/ ha and yield increased from 1094 kg/ ha without N application 1428 kg/ ha with N applied at 190 kg/ ha.

2.3.9 Nutritional Benefits

Lysine is an essential amino acid a human body cannot make. This protein that is very expensive when derived from meat, milk, and fish can be cheaply derived from *A. cruentus* a very cheap vegetable which can be grown under rain fed conditions with both organic and inorganic fertilizers. Protein has a high content of sulphur containing amino acids that is methionine, lysine and systeine (Grubben, 2004). Protein a major component required by body, is cheaply derived from *Amaranhus* species, which make this essential nutrient accessed by a poor resource farmer in a rural set up. The grain has 12 to 17 % protein and is high in lysine, an essential amino acid in which cereal crops are low (Putnam, Oplinger, Doll, and Schulte, 1989).

2.4 Uses

A. cruentus had manifold medicinal uses, in cleansing intestines, diuretic properties, remineralisation, and ant-diarrheal and anti-anaemic. It can be grown as a pot herbs Saver,(1959) Dried *Amaranth* is ground and prepared in peanut butter to produce a relish dish saved with Sadza in Zimbabwe. *A. cruentus* can be used as fodder to feed livestock. It can be used to make silage fed to dairy cattle. In Ghana the water from macerated *A.cruentus* plants is used as a wash to treat pains and limbs. The seeds are used as cereal Oke, (1983). Senegalese use boiled roots as a laxative for infants. In Gabon heated leaves of *A. cruentus* were used on tumours. Sudanese burn *A. cruentus* plant to produce ash that is used as a wound dress. Essential amino acid found in *A. cruentus* give it the properties to polymerise, novel based properties, chirality's (Four different groups attached to the central carbon). Amino acids derived from *A.cruentus* function in synthesis of amino acids and Nitrogen containing compounds neurotransmitters, nucleotides, and nitrogenous bases. These amino acids can be converted into energy if the body is exhausted of lipid and carbohydrates.

2.5 Factors affecting amaranth production

According to research, organic production of grain *Amaranth* is possible in soils with adequate moisture for provision of plant available N. *Amaranth* seed is quite small and range from 0.7 to 0.9 g/ 1000 seeds, which lead to poor and non-uniform seedling establishment. (Brenner et al., Putnam, 1990). The problem of variability in plant height and seed head size make it difficult to harvest using combine harvester. High rainfall tropical areas have high problem of lodging that hinder cultural practices like Fertiliser application, chemical sprays, weeding and harvesting operations. The C:N ratio of compost and manure may be altered during transportation and storage, depending on whether the conditions are aerobic or anaerobic (Murwira et al., 1994). Manures with high NH_4^+,N content, such as poultry manure, maintain high levels of ammonia volatilization, which are purportedly between 9 and 44% (Nahm, 2005), displaying a strong inverse correlation between ammonia losses and C:N ratio (Murwira et al., 1994; Moore et al., 1995). Nitrogen losses through NH4+–N volatilization will increase C:N ratios and ultimately N availability, but these losses tend to be greatest under dry, windy climatic conditions which facilitate evaporation and volatilization (Moore et al., 1995). Similarly, most studies corroborate that poultry manure contains high levels of inorganic N as ammonium (NH4+–N) prior to handling and storage (Davis et al. 2002; Moore et al. 1995; Chae and Tabatabai, 1986). For cattle manure, ammonium levels are generally lower than for poultry manure; however, these values depend on the feeding regimen and, more specifically, whether the animals are beef or dairy cattle. Research conducted by Burger and Venterea (2007) indicated that, while NH4+–N content of manure from beef cattle may be as low as 5 mg kg-1, NH_4^+,N levels reported for dairy cows (64 mg kg-1) were higher than those found for turkeys (50 mg kg-1). Similarly, a study comparing N mineralization from various manures and composts by Gale et al. (2006) demonstrated levels ranging from 49.3 to 82.7 mg kg-1 for uncomposted broiler manure and 6.9 to 24.0 mg kg-1 for solid dairy manure. The same study corroborated lower quantities of solid dairy manure. Countries in developing countries use organic manure, but the challenges they face are of poor nitrogen levels which will lead to low *Amaranth* production.

Elevated price of Nitrogen fertilizers made other farmers to shun planting *Amaranth* vegetable. Lack of training on the importance of Nitrogen as the essential element of Amino acids, proteins and its role in photosynthesis, carbohydrate use and metabolic processes through various plant secondary compounds (Brady and Weill 1999) result in complete ignorance toward *A cruentus* farming.

Low of diminishing returns reveals that the more fertilisers are applied in excess, the yield will decline, and therefore effective farming is after soil analysis to avoid over application which will lead to ground water pollution.

Low production is also as a result of nutrient budget of Nitrogen, phosphorus and potassium in African soils. (Esilaba et al., 2005, and Smaling et al. (1997) Low soil fertility is the major constraint to sustainable development throughout sub Saharan Africa (SSA) (Nyombi et al., 2006)

2.6 Effects of Nitrogen on Amaranth

Nitrogen is an important component of proteins. Up to 65% of leaf protein occurs in the chloroplasts, 50% of which is RUBISCO. Nitrogen levels may become very low enough to impair photosynthesis through mobilisation and export of Nitrogen from leaves to other organs of the plant. In *Amaranthus cruentus* Nitrogen uptake is reduced after anthesis and Nitrogen is exported from leaves towards flowering to meet the demands of growing seeds, reducing net photosynthesis. Nitrogen is necessary for protein synthesis. *Amaranthus* is a C4 plant that require high nitrogen levels. If nutrients are in short supply they are translocated from older leaves to the younger leaves. Nitrogen, Manganese and iron are constituents of chlorophyll and if they are in short supply chlorophyll will not form and thus reduce carbon exchange rate (CER). Remobilization of nutrients to the sinks will lead to necrosis and chlorosis of lower leaves, which will predispose the plant to Necrotic fungi (blight and rotting fungi), which can survive on decaying and dead host tissue. Bacterial infections cause structural damages to chloroplasts. Toxins produced by bacteria inhibit photosynthesis.

CHAPTER 3

3.0 Materials and Methods

3.1Description of the study site

The study was conducted from 17/ November/2014 through to March 2015, In Nyanga South A, Ward 24, during the cropping season 2014/2015. The district lies in Natural Farming Region 1 and about 141 km from Harare. Nyanga lies between longitude and 32.74 and latitude 18.21 and 2000 m above sea level with an annual rainfall of 1000 mm and mean temperature of 18ºC

3.2 Experimental Design

The experimental was laid out at a Randomised Complete Block Design with five treatments (0, 50, 100, 150, 200 kg N/ha and replicated three times(Table 3.1.)

Table 3.1:- Experimental Treatments

Treatment Number	Amount of Ammonium Nitrate in Treatment (kg/ha)
1	0
2	150
3	50
4	200
5	150

3.2 Management of non-experimental variables

The study was established on land that had never been cultivated before. The land being virgin, labour was employed to dig out grass, Primary tillage followed by disking and levelling was done before pegging of plots. The plot area was 17.5 m x9 m to give a net area of 157.5 $m^{2.}$ The pathway distance was 0.5 m. Each block was divided into five equal plots which were 3 x 3.5 = 10.5 m^2 with spacing of 0.4 m and 0.4 m, respectively. The seeds were sown on 17/11/14. For good seed spacing during planting, seed was mixed with fine sand. Planting depth was 1.0 cm deep. Thinning was done three weeks after planting, to reduce population and competition for water, nutrient and nutrient. Thinning is done to avoid etiolating and the fact that *A. cruentus* is a weak emerger, thinning renders vigour. The experiment was rain fed, with no supplementary irrigation. Weeding was done with a hoe uniformly throughout the experiment plot in a day. First fertilizer application was done three weeks after planting, with the main source of N being Ammonium Nitrate (34 % N).

3.3 Data collection

First vegetable harvest commence 15 weeks after planting, harvesting can be earlier than that if the farmer is uprooting the whole plant. Fresh side shoots can be harvestable on a daily basis, but an interval of weekly harvesting of side shoots leaving leaves for photosynthesis was done. The data were recorded on 66 plants in each replication for vegetable weight in (kg/ha). On dry matter the weight was measured in (kg/ha). A digital and manual scale was used. On days to 50 % flowering , days were physically counted. On seed, yield was measured in (kg/ha).

3.4 Data Analysis

An Analysis of Variance was carried out as per harvest time on the parameters of growth in terms of fresh leaf weight (kg), Fresh and dry weight (kg), seed yield (kg) and days to 50 % flowering using the Genstat 14th Version. Fisher's least significant difference (LSD) test was used to identify significant differences among treatment means (P<0.05).

CHAPTER 4

RESULTS

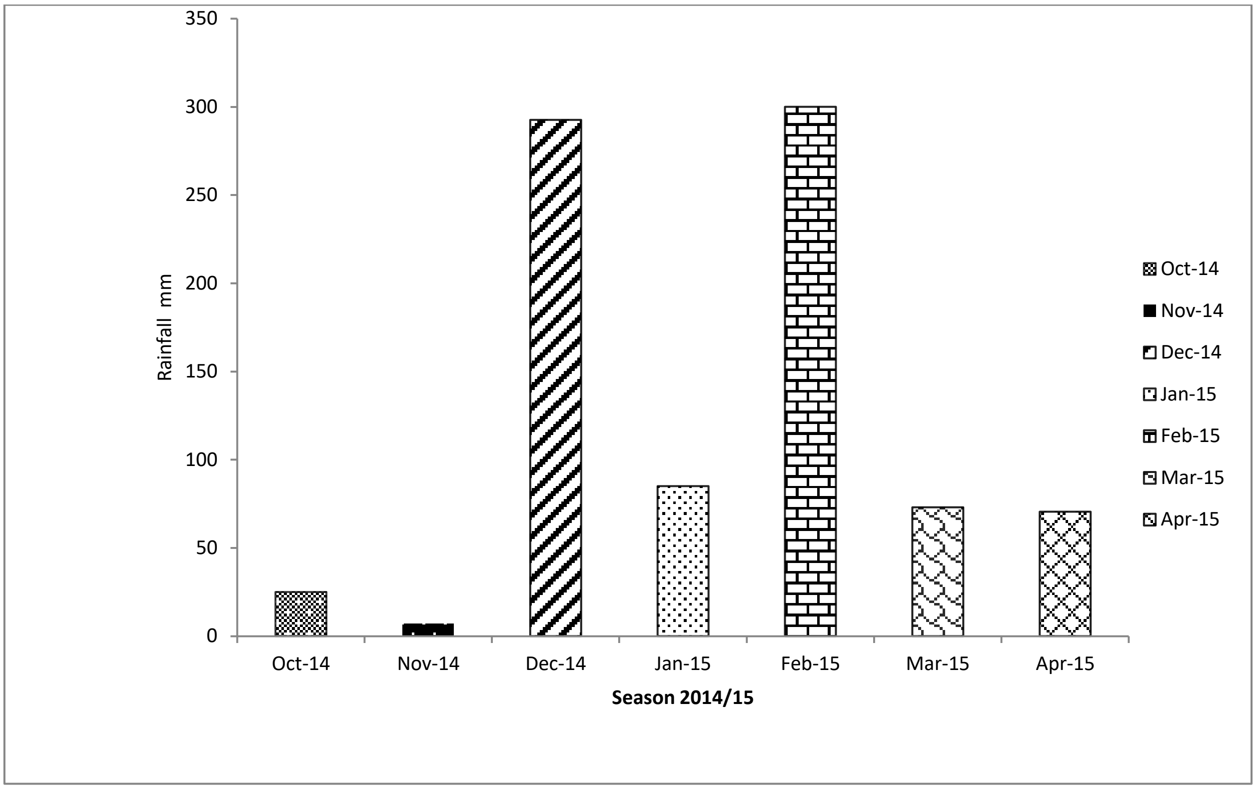

Fig 4.0 Rainfall for 2014/2015 season.

Rainfall was evenly distributed during the trial project, with highest rainfall received in the month of December and January which gives *A. cruentus* a long time of vegetable harvest.

4.1 Effects of nitrogen levels on the growth and yield of *A. cruentus*

4.1.1 Effects of different nitrogen levels on fresh leaf weight (kg/ha)

There was an interaction ($p<0.05$) between leaf vegetable yield and different Nitrogen fertilizer levels. Highest vegetables yield were obtained at 200 kg/ ha with a mean of 58359 kg/ha which is statistically different to the control and other treatments. The lowest vegetable weight was obtained at 50 kg/ ha with a mean of 23670 kg/ha, though it is significantly different from the control.

Table 4. 1 Effects of different Nitrogen levels on fresh leaf weight (kg/ha)

Nitrogen Rate (kg N /ha)	**Total leaf vegetable yield (kg/ha)**
0	12060^{a}
50	23670^{b}
100	30686^{c}
150	33562^{c}
200	58359^{d}
Grand mean	31667
Significance	<.001
$L.S.D._{(o.o5)}$	4294.0
C.V.%	7.2

4.1.2 Days to 50% Flowering

There was no significant difference (p>0.05) between different Nitrogen levels on the days to 50 % flowering, except on treatment with 0 kg/ha which reached 50 % earlier.

4.2.1 Effects of different Nitrogen level of Amaranth in terms of seed yield (kg/ha)

There was significant difference (p<0.05) between different Nitrogen levels on seed yield. Highest seed weight were obtained at 200 kg/ha N with a yield of 3500 kg/ha, while the lowest was at 0 kg ha with 292 kg/sha.

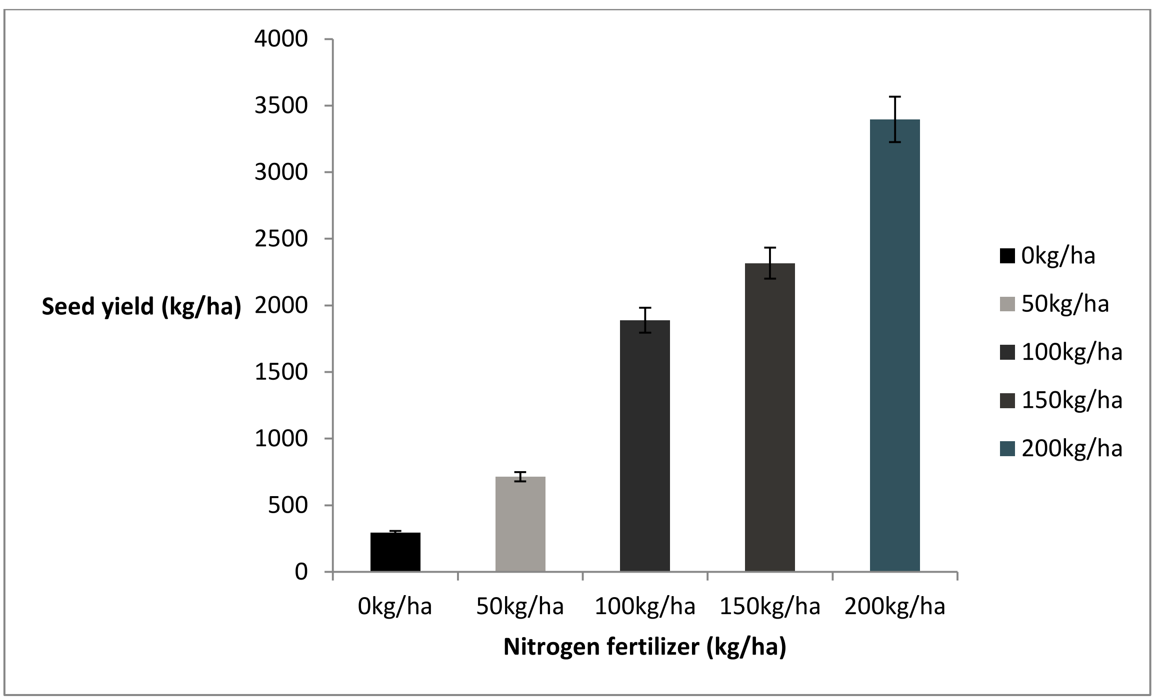

Figure 4. 1 Effects of different nitrogen levels on seed yield (kg/ha)

4.2.2 Effects of different Nitrogen levels on dry weight of leaves (kg/ha).

There was significant difference (P<0.05) by use of different Nitrogen levels. The highest dry weight was obtained on 200 kg ha N, with the mean of 45102 kg/ha, which is statistically different to the control and other means and the lowest among the treatments was obtained at 50 kg/ha with the mean of 18929 though it was significantly different to the control.

Table 4. 2 Effects of different nitrogen levels on dry weight (kg/ha).

Nitrogen Rate (kg N /ha)	**Total Dry Weight (kg/ha)**
0	12621[a]
50	18929[b]
100	24080[c]
150	32573[d]
200	45102[e]
Grand mean	26661
Significance	<.001
L.S.D.$_{(o.o5)}$	4378.0
C.V.%	8.7

CHAPTER 5

5.0 Discussion

5.1 Effect of Different Nitrogen levels on growth and yield of Amaranth in terms of fresh leaf weight (kg/ha)

The results of this study showed that there was significant effect ($p<0.05$) on Nitrogen fertilizer level on fresh weight. This was evidently shown by the fact that the highest values were observed in plants fertilised with 150 and 200 kg/ha N with mean yield of 33562 kg/ha and 58339 kg/ha respectively while the lowest was at 0 kg/ ha N with mean yield 0f 12060 kg/ha. This is also in line with the observation made by Elbehri et al (1993) who obtained yield response with Nitrogen application of 180 kg/ha and yields increased from 1094 kg/ha without N application to 1428 kg/ ha with N applied at 190 kg/ha. This shows that Nitrogen contributes greatly to yield increase as indicated by Ayadele (1998) in his study to compare two species of Amaranth that is *A. hybridas* and *A. hypochondriacs* in response to N fertilization. He used four rates of Nitrogen. The results showed that, number of leaves produces, fresh and dry weights of plants increased with the increased rate of Nitrogen application. Nitrogen contribute to growth and development of *Amaranth* crop. It is a component of amino acids, proteins, nucleotides, chlorophyll and coenzymes which is vital for growth which results in higher yield advantage as shown by this study.

5.2 Effect of different Nitrogen levels on days to 50 % flowering

The time taken to reach 50 % flowering showed no significant difference at all as the range of flowering rate could not be linked to specific N fertilizer level. Plants that received lower N levels like 0 kg/ha N reached 50 % flowering earlier than those with higher rates. This was attributed to the contribution of inherent soil fertility which also supplied other nutrients like phosphorus, potassium, and micro nutrients to influence flowering.

5.3 Effect of different Nitrogen levels on seed yield kg/ha

There was a marked significant difference ($p<0.05$) on the effect of differing levels of nitrogen on the seed yield with the highest seed yield recorded on200 kg/ha which had 3390 kg/ha and of nitrogen in the soil. All vital processes in plants are associated with protein of which nitrogen is an essential constituent hence nitrogen occupies a conspicuous place in plant metabolism (Ali *et al.,* 2011). They went on to add that nitrogen application in the form of chemical fertilizer is essential in order to get more crop production. Application of nitrogenous fertilizer improves various crop parameters such as grain weight and grain yield (Warraich *et a*l., 2002; Ali *et al.*, 2011). The management of nitrogen, and other essential nutrients, is part of a balanced fertility programme. This can lead to increased efficiency and profitability for *Amaranth* growers because plants absorb N in the highest amounts of any essential nutrient since it is a C4 plant, Therefore N is needed in large quantities and must be in balance with other nutrients in order for the crop to achieve its maximum yield potential.

There is no other nutrient as important as nitrogen (N) to attain high yields of *Amaranth* with acceptable grain protein (Orloff *et.al,* 2012). As nitrogen is an essential constituent of structural and storage proteins, simple amino compounds, enzymes and chlorophyll, young leaves should be supplied with nitrogen until they reach maturity. Chlorophyll is associated with the production of simple sugars from carbon, hydrogen, and oxygen. High concentrations of chlorophyll combined with nitrogen utilize the sunlight as an energy source to carry out essential plant functions including nutrient uptake. The sugars produced play an important role in stimulating plant growth and development along with higher protein content in the grain. Chlorosis of the plant leaves which will start in the oldest leaves, and then proceed to develop on younger leaves if the deficiency continues in cases of nitrogen deficiency. Nitrogen deficient plants are typically shorter and or stunted and grow slower than plants with sufficient nitrogen. Nitrogen deficiency in *Amaranth* tends to reduce the amount of protein in the seed.

5.4 Effect of different Nitrogen levels on dry weight kg/ha

There was significant difference ($p<0.05$) between the Nitrogen levels on dry weight, with the highest dry weight attained at higher levels of 150 and 200 kg /ha N, with mean yield of 32573 kg/ha kg/ ha and 45102 kg/ha respectively while the lowest was at 0 kg/ ha with mean yield of 12621 kg/ha. This study were in accordance with the findings of Nyankanga et al. (2012) who, in a similar study, obtained the highest dry matter in grain *Amaranth* in Western Kenya with the application 100 kg N/ ha inorganic fertilizer, and a host of others who have also reported significant increase in plant dry matter accumulation per plant with corresponding increase in the fertility level up to a certain level (Kushwaha, 2001; Kalmani et al., 2002; Olaniyi and Ajibola, 2008).

CHAPTER 6

6.1 Conclusion

The results of this study showed that seed , leaf vegetable and dry weight can be obtained with higher N fertilizers of 200 kg/ ha. This gives a farmer high chances of maximising income from sale of fresh vegetable leaf at the same time meeting their nutritional needs. There was also effect on 50 % flowering and dry weight. It was therefore evident from this study that the optimum N level for high performance of *A. cruentus* is 200 kg/ha.

6.2 Recommendations

Based on the results from this research, 200 kg/ha N is recommended fertilizer to increase seed yield, fresh leaf vegetables and dry weight. However I would advise further research to be carried out on integrating organic and inorganic manure since Nyanga is a high rainfall area. Further research need to be carried out in different Natural regions on organoleptic taste and Nitrogen levels that suit *Amaranth* growth.

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APPENDICES

Appendix 1: Fresh Vegetable Weight

Analysis of Variance

Variate: Total_veg_yld_kg_ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	3.014E+07	1.507E+07	2.90	
Block.*Units* stratum					
Treat 4	3.496E+09	8.740E+08	168.04	<.001	
Residual	8	4.161E+07	5.201E+06		
Total 14	3.568E+09				

Appendix 2: Days to 50% Flowering

Analysis of Variance

Variate: Days_to_50%_flowering

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.000	0.000		
Block.*Units* stratum					
Treat 4	614.400	153.600			
Residual	8	0.000	0.000		
Total 14	614.400				

Appendix 3: Seed Yield

Analysis of Variance

Variate: Seed_Yield_Ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	757587.	378794.	9.19	
Block.*Units* stratum					
Treat 4	18743014.	4685753.	113.66	<.001	
Residual	8	329820.	41228.		
Total 14	19830421.				

Appendix 4: Destruction method to measure Dry Weight

Analysis of Variance

Variate: TOTAL_DMW

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	1.808E+07	9.040E+06	1.67	
Block.*Units* stratum					
Treat 4	1.916E+09	4.790E+08	88.59	<.001	
Residual	8	4.325E+07	5.407E+06		
Total 14	1.977E+09				