Growth and Yield of *Amaranthus hybridus* L. subsp. *cruentus* (L.) Thell. Grown on Fields Treated with Different Levels of Urea and Compost

Nigist Bekele Ayalew

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3. Prof Fisseha Itanna (Advisor)	____________________	________________
4. Prof Ensermu Kelbessa (chair man)	____________________	________________

Growth and Yield of *Amaranthus cruentus* Grown on Fields Treated with Different Levels of Urea and Compost

Nigist Bekele Ayalew

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ABSTRACT

Grain amaranth (Amaranthus spp.) is a pseudo-cereal crop high in protein content and quality, which originally was domesticated in Latin America and whose favorable nutritional profile belie its potential to alleviate nutrition and food insecurity in developing countries. There is scanty information in Ethiopia on its fertility requirements for optimum growth and yield. A field experiment was conducted to evaluate the effect of different levels of urea (0, 50, 100, and 150 Kg/ha) and compost (0, 5, 10 and 15 t/ha) on the growth and yield of Amaranthus cruentus. The experiment was conducted during late January to mid-May 2013 at the Castle Vineyard and Winery Project site in Batu (Ziway) town of East Shewa. Treatments were laid out in a completely randomized block design and replicated four times. Data collected at two week interval were plant height, number of leaves, number of branches, leaf area and stem girth. Inflorescence height was measured at 12 weeks after sowing and grain yield was measured after harvesting. Data collected on the growth parameters and yields were subjected to analysis of variance (ANOVA). Significant treatment means were separated using Tukey test at $P<0.05$. The results showed that the applications of urea and compost significantly ($p<0.05$) influenced all growth parameters and yield of Amaranthus cruentus. The highest rates of compost (15 t/ha) and urea (150 Kg/ha) significantly increased the growth parameters and yield when compared to the control and have the highest mean values for all the parameters measured. The use of urea and compost is therefore essential in increasing Amaranthus cruentus yield. Since no significant difference was found at 10 t ha^{-1} and 15t$ha^{-1}$of compost 10 t ha^{-} compost and urea at the rate of 150 Kgha^{-1} is recommended.

Key words: compost, urea, yield

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CHAPTER ONE

1. INTRODUCTION

Amaranth is an old cultivated crop originating from Latin America. Amaranth is a vegetable crop and belongs to the genus *Amaranthus.* It is broad-leafed non-grass plant that produces significant amounts of edible cereal-like grains. Amaranth (family *Amaranthaceae)* is an underexploited plant with exceptional nutritive value (Downton, 1973). Many species of the genus Amaranthus are best known as opportunistic weeds which have a long history of use as leafy vegetables and are gathered as subsistence food in many parts of the world (Kauffman, 1992).

Amaranth is considered as underutilized crop and has, until recently, received little research attention. However, grain amaranth and many other *Amaranthus* species show tremendous potential for human consumption and other uses, and are particularly promising as a remedy for hunger and malnutrition in developing countries (NRC, 1984).

Grain amaranth has a short growing time. Harvesting of leaves normally starts just 4 weeks after planting while grains can be harvested at 60-90 days. The crop can be grown all year round and can be produced even on marginal soils. It requires 40-50% less moisture than maize and survives better than most crops under dry and hot conditions because of its extensive root system and use of C_4 photosynthesis mechanism (Stallknecht *et al*., 1993).

Grain amaranth stores very well once well dried and is not easily infested by pests (Myers, 1996). It therefore does not require pesticide treatments. Grain amaranth has potential to help address the problem of food insecurity, which has been aggravated by poor climatic conditions in recent years. It can also help to provide all year round income for small holder farmers. Its content of high quality protein and micronutrients, often lacking in diets of the resource poor populations, makes it a good commodity for fighting malnutrition and nutritional deficiencies among the poor.

Amaranthus cruentus is an important vegetable in human diet as a source of nutrients such as vitamin, minerals, sugar, protein and fiber needed for healthy body growth and sustenance (Bailey, 1992). The young leaves and stems are boiled as greens (NRC, 1984). It is grown as soup vegetable or for boiled salad greens (Adeyemi et al., 1987). The nutrient values of amaranthus per 100% edible portion (leaves) as water 85 ml, calorie 48, protein 5 g, fat 0.7 g, carbohydrates 5 g, fibre 1.5 g, calcium 250 mg, iron 4 mg, B-carotene equivalent 1800 mg, thiamine 0.1 mg, riboflavin 0.3 mg, niacine 1.5 mg and ascorbic acid 100 mg (Tindall, 1975).

Amaranth seed is high in protein (15-18%) and contains respectable amounts of lysine and methionine, two essential amino acids that are not frequently found in other grains. Lysine plays a vital role in the treatment and prevention of a disease known as *osteoporosis* that makes bones prone to fracture (Pisarikova et al., 2005).

It is high in fiber and contains calcium, iron, potassium, phosphorus, nitrogen and vitamins A and C. The fiber content of amaranth is three times that of wheat and its iron content, five times more than wheat. It contains two times more calcium than milk. This leafy vegetable is also high in micronutrients. Using amaranth in combination with wheat, corn or brown rice results in a complete protein as high in food value as fish, red meat or poultry (Teutonico and Knorr, 1985).

Amaranth is one of the few plants whose leaves are eaten as a vegetable while the seeds are used in the same way as cereals and there is no distinct separation between the vegetable and grain type since the leaves of young grain type plants can be eaten by humans and livestock. Vegetable amaranth species are utilized for food in different parts of the World. Grain amaranth can be used as seeds or flour to make products such as cookies, cakes, pancakes, bread muffins, crackers, pasta and other bakery products (Teutonico and Knorr, 1985).

This plant is valued for chemical composition of seed that does not contain gluten which is a protein complex responsible for the elastic texture of dough and found in cereal grains like wheat,barley and rye. A gluten-free diet is the only medically accepted treatment for celiac disease (Crevel et al., 2006).

As a result production of amaranth with high yield will highly improve nutrition. But the fertility of the soil where it can be grown should be considered. The better the soil is fertile the better the yield of amaranth.

Amaranth is a crop that can grow on poorer soils, it can withstand drought and heat, early maturing, hardly attacked by pests, widely adaptable and above all nutritious and high yielding In southwestern Nigeria, under dry condition, seed yields from 1 to 6.7 tones/ha and Green material of up to 70 tones are harvestable (Olaniyi, 2007). Thus a promising future crop with potential to contribute to a substantial increase in food production due to large amount of biomass produced in a short period of time.

Although *Amaranthus* is known to be a relatively drought resistant crop, insufficient water reduces yield (Palada and Chang, 2003). When planted directly; *Amaranthus* seeds require well moistened soil to germinate. Even when transplanted as seedlings, water is required for establishment (NRC, 1984; Palada and Chang, 2003). After seedlings have established well, *Amaranthus* usually performs well even under limited water conditions. This is because most species are able to maintain high Relative Water Content (RWC) through factors such as stomatal conductance, maintenance of leaf area and biochemical factors such as enzyme function, photosynthesis and respiration (Spreeth *et al*., 2004).

Amaranthus is also known to be a low management crop that can grow in poor soils but studies have shown that its yields could be improved by application of fertilizers (Palada and Chang, 2003). Myers (1998) and Schippers (2000) reported that like any other crop, *Amaranthus* responds well to good soil fertility and organic matter.

Some of the problems encountered by amaranth growers include decreasing soil fertility and quantity of compost required for optimum crop productivity (Lucas and Ojeifo, 1985; Adeyemi *et al*., 1987).

To increase the availability of high quality amaranth there is a need to use organic fertilizers such as manure and compost which are the most available or can be found in large quantities in local areas. There are few reported works on this vegetable particularly with respect to its response to such agronomic practices as planting/transplanting date, spacing, population (Manga *et al*., 2004), pest attack (Bruce and Philippe, 2008; Bano *et al*., 1987) and nutritive value (Lucas and Ojeifo, 1985; Andrasofszky *et al*., 1998). However information on fertilizer application is scanty.

This study therefore focused at assessing the effectiveness of locally available organic fertilizers and urea. The study was conducted on the growth and yield of amaranth by growing on fields treated with different levels of compost and urea.

1.1 STATEMENT OF THE PROBLEM

Unlike food insecurity, hunger and poverty which are old problems, high food price is a new crisis with anecdotal evidence emerging from all developing regions about its effects on people. High food prices have serious implications for food and nutrition security, and macroeconomic stability of any nation. Except clothing and shelter as the basic necessities of life, food remains the most vital item in the hierarchy of need because of its centrality to human existence. Lack of access to food influences food intake and consequently impacts the health and nutritional status of households. Food and nutrition security are the fundamental challenges to human welfare and economic growth. Attending the nutritional needs of people is an equally important aspect of improving health and survival. Action should be taken to solve this problem.

I believe that this problem can be solved by growing crops that have high nutritional value. And Amaranth is one of these crops. Therefore we need to grow or cultivate amaranth with high yield potential by using fertilizers. Therefore to increase the yield and availability of high quality amaranth throughout the year there is a need to use fertilizers like urea and compost.

1.2 Objectives of the study

1.2.1 The main objective of this study is:

→To compare the growth performance and yield of *Amaranthus cruentus* on fields treated with different levels of compost and urea.

1.2.2 The Specific Objectives of this study are:

- To determine the effect of different rates of urea and compost on the vegetative growth of *Amaranthus cruentus.*
- To determine the appropriate fertilizer rates for the attainment of maximum yield of *Amaranthus cruentus.*

CHAPTER TWO

2. LITERATURE REVIEW

2.1 About the family Amaranthaceae

The family *Amaranthaceae* has more than 80 species of which about 60 are considered weedy and about 50 are consumed as pot-herbs or leafy vegetables worldwide (Olufaji, 1989; Janick, 1997). Schippers (2000) noted that all species found in Africa are grown for their leaves. Some varieties were introduced from America for grain production but this is not very popular in Africa. Three principal species considered for grain production are *A. hypochondriaachus*, *A. cruentus* and *A. caudatus* (NRC, 1984).

There is no distinct separation between vegetable and grain type species since even the leaves of young grain type plants can be eaten as leafy vegetables. The most popular leafy species are *A. hypochondriacus*, *A. tricolor*, *A. hybridus*, and *A. blitum* (Jansen van Rensburg *et al.*, 2004; NRC, 1984) and the most frequently cultivated species in Asia is *A.tricolor* but is hardly ever seen in Africa (Schippers, 2000). *Amaranthus* species have been separated into four principal groups: cultivated (improved species or cultivars), wild and weedy (growing in the field), racial (based on geographic morphological patterns) and landrace or accession (populations from specific locations) (Stallknecht and Schulz-Schaeffer, 1993). In South Africa various *Amaranthus* species are widely distributed, except in the more arid south western areas (Jansen van Rensburg, 2004; Van Zyl *et al*., 2002).

2.2 Growth habit

The genus Amaranthus is a widely distributed, short-lived herb occurring in temperate and tropical regions which produce large seed heads of edible seeds. Amaranth is a bushy plant that grows 5 to 7 feet, with broad leaves and a showy flower head of small, red or magenta, clover like flowers which are profuse, and constitute the plants exquisite, feathery plumes. The seed heads resemble corn tassels, but are somewhat bushier. They are quite striking as well. The seeds are tiny lens shaped, and are a pale-white, golden, pink, red or dark-brown colored (Kauffman and Weber, 1990). The seeds although barely bigger than a tef seed (0.9 – 1.0 mm in diameter) occur in massive numbers to a plant. Depending on species, amaranth leaves vary in shape, size and color (green, red, purple). Its stem, sometimes branched, is terminated by branched inflorescence (panicle). Inflorescence is usually indeterminate, a mode of inflorescence in which the flowers all arise from axillary buds, the terminal bud going on to grow and sometimes continuing the stem indefinitely (Harris and Harris, 1994) and reaches different lengths. Basic unit in inflorescence is called glomerulus containing female, male or both types of flowerets (Grubben, 1976).

2.3 Distribution of amaranth

Although grain amaranth is native to the Americas, currently many countries of Asia and Africa grow amaranth as grain and vegetable crop. For example, a dark seeded strain of *A. cruentus* is commonly cultivated as a vegetable in West Africa (Grubben, 1976). In Kenya, milled amaranth flour is added to maize-based gruel (Kauffman, 1992). In Ethiopia, little is known about the grain amaranth. The cultivation and usage has generally been limited to western and south western parts of the country (Siegenthaler, 1990). In these localities, the grain amaranth is toasted and popped, ground into flour to produce porridge (local traditional diet) or boiled for gruel, a fermented thin porridge known as *borde.* Amaranth seeds are fermented to make alcoholic beverages, e.g. beer (‘tella’) in Ethiopia. Ground seeds are mixed with tef to prepare (‘injera’). Harvest residues are used for feeding livestock and for thatching (Siegenthaler, 1990).

2.4 Yields of amaranth

Amaranth grain yields reported in the literature exhibit a large degree of variability depending on such factors as soil chemical and physical properties, climate, planting density, planting time, variety, and level of fertilization. Although most studies containing data on amaranth grain yield do not include information on soil chemical and physical properties, a study in the Kisumu District of western Kenya near Lake Victoria demonstrated yields of 50 kg ha $^{-1}$ with a cattle manure application rate of 0.5 ton/ ha; 110 kg/ ha at 1 ton/ ha; 250 kg/ ha at 2 ton/ ha; and 1500 kg/ ha at 3 ton/ ha (Stallknecht and Schulz-Schaeffer, 1993).

Another Kenyan study by Gupta et al. (1992) in assessing the impact of variety, date of planting, days to maturity, season ('long' or 'short' rains), planting density, and fertilization on amaranth grain yields at four locations found amaranth grain yields ranging from 70.7 to 714.0 kg ha^{-1} at a planting density of 66, 666 plants ha^{-1} (70 cm between rows, 20 cm within rows). In this experiment, synthetic fertilizer was applied at rates of 21 kg N ha^{-1} and 53 kg P_2O_5 ha^{-1}. Medium-maturing varieties in this study, with maturity dates similar to the "cream" and "golden" varieties in Uganda, tended to have higher yields compared to early- and late-maturing varieties under standardized conditions at Kabete, where yields ranged from 290 kg /ha to 1020 kg/ ha for early-maturing varieties.

In the study conducted by Olaniyi (2007) in southwest Nigeria, amaranth yields were generally low. Depending on year and variety, grain yields from the study ranged from 400 to 1500 kg ha^{-1}. In the US, amaranth grain yields typically range from 700 kg/ ha to 1700 kg/ ha, while higher yields have been achieved internationally. Grain amaranth breeding programs in Latin America have achieved yields of 7200 kg/ ha and 4600 kg/ ha for certain varieties in Peru and Mexico, respectively (Brenner *et al.*, 2000).

2.5 Application of urea

Sustainable crop production requires judicial use of inputs such as fertilizers. The use of inorganic fertilizers has drastically declined following the energy crisis, which has immensely affected most of the developing countries (Hauck, 1981). Urea is one of the synthetic organic fertilizers containing 46% of nitrogen. It is readily soluble and leachable when it is first applied to the soil but when it changes to ammonium it is held by clay and humus in the adsorbed forms that is readily available to plants. It can be applied to sod crops, winter wheat or other small grains. This application, however, should be made during cool seasons.

During warm periods (60 degrees °F or above), urea in contact with vegetative material will tend to give off ammonia. If urea must be applied on grass pastures in the summer, apply when there is a high probability of rainfall. If properly applied, urea and fertilizers containing urea are excellent sources of nitrogen for crop production. Under favorable temperature and moisture conditions urea hydrolyses to ammonium carbonate and then to nitrate within less than a week. The synthesis of ammonium carbonate is dependent on the influence of enzymes produced by numerous soil microorganisms (Anon, 2006).

2.6 Fertility requirement

Although *Amaranthus* is known to be a low management crop that can grow in poor soils, studies have shown that yield is improved by fertilizer (Palada and Chang, 2003). Myers (1998) and Schippers (2000) reported that *Amaranthus* responds well to good soil fertility and organic matter. Although Mhlontlo *et al*. (2007) reported that sheep kraal manure rates as low as 2.5 t/ha produced significant increases in the fresh and dry matter yields of mono-cropped *Amaranthus*, information on fertility requirements of both grain and vegetable *Amaranthus* is scanty (Elbehri *et al*., 1993).

Elbehri *et al.* (1993) noted that application of N-P-K fertilizer (at recommended rates) and irrigation during *Amaranthus* production could increase grain yield from 700 kg/ ha to 3000 kg/ ha. Increased yields due to fertilizer application were observed by Spreeth *et al.* (2004) at the University of Zululand, South Africa who applied 250 kg/ ha of 2: 3:2 compound fertilizer. According to Stalknecht and Schultz-Schaeffer (1993) a general suggested fertilization guide for *Amaranthus* is 112 to 135 kg/ ha of total available N, with a soil test of 15 to 30 ppm P and 80 to 120 ppm K. Studies conducted by Schippers (2000) indicated that the crop needs high potassium levels and best results were obtained with 400 kg ha^{-1} of compound fertilizer 10-10-20 (N-P-K). Plants grown with poultry manure had better yields when compared to those grown with kraal manure (Spreeth *et al*., 2004).

There are a number of studies examining the effects of fertilization on grain amaranth yield and protein content (Bressani et al., 1987; Elbehri et al., 1993; Myers, 1998; Olaniyi, 2007). Most studies found a significantly positive correlation between increasing fertilizer application, typically N, and yield with applications of up to 90 kg N/ ha (Myers, 1998).

Myers (1998) observed the effect of N-fertilizer on *Amaranthus* species grain yield, yield components and growth and development investigated in three Missouri environments with 5-levels of N-fertilizer and 3 cultivars. Averaged across cultivars and environments, N fertilizer act and top rate of 180 kg/ ha produced a yield increase of 42% relative to plots receiving no fertilizer. Although amaranth yield is responsive to N-application, high rates of N fertilizer can negatively affect grain harvest in terms of excessive plant height, increased lodging and delayed crop maturity.

Optimum nutrient amounts reported for maximum amaranth growth by different researchers are substantially different. Apart from the use of inorganic fertilizers, the level of organic compost in the soil is very essential in promoting crop growth. The complementary use of organic compost and mineral fertilizer has been recommended for sustenance of long term cropping in the tropics (Palm et al., 1997). Akambi and Togun reported that optimum N and P uptake by amaranth was obtained when 30 t/ha compost was applied along with 30 kg N ha^{-1} fertilizer while the best K uptake was obtained with plants treated with 1.5 t ha^{-1} compost + 60 kg N ha^{-1}.

Another study conducted in Croatia by Pospisil *et al.* (2006) examined the effects of chemical N fertilizer on grain amaranth yield and protein content, finding a yield response in dry years, but no effect on protein content. On this basis, the authors concluded that organic production of grain amaranth was a possibility in soils where moisture is adequate for provision of plant available N. This shows how environmental conditions greatly affect plant density and soil fertility management on grain amaranth. It also shows that nitrogen is major nutrient affecting grain amaranth (Olaniyi, Adelasoye and Jegede, 2008).

Lucas (1988) recommended application of 50-100 kg N, 20-60 kg P_2O_5 and 40-60 kg K_2O ha^{-1} after two weeks of planting. Babatola and Olaniyi (1999) revealed that 120 kg and 160 kg N ha^{-1} have the best yield of *Amaranthus caudatus*. Vegetable cropping systems require a greater degree of management and utilize a large N input than most agronomic cropping systems. Soil fertility management for grain amaranth is environmentally dependent, with more nitrogen required in areas with higher rain fall (Stallknecht and Schulz-Schafter, 1993).

On evaluation of nitrogen fertilization rates between 0 and 180 kg ha^{-1} in Missouri, by Myers in 1998, grain amaranth yields increased with nitrogen fertilization up to 90 kg, while Elbehri *et al.* (1993), in Minnesota obtained yield response with nitrogen fertilization up to 180 kgha^{-1}, with no response to phosphorus and potassium. Yields increased from 1094 kg ha^{-1} with nitrogen application to 1428 kg ha^{-1} with nitrogen applied at 180 Kg ha^{-1}. Therefore most studies examining the effects of fertilization on grain amaranth yield (Bressani *et al.*, 1987; Elbehri *et al.*, 1993; Myers, 1998; Olaniyi, 2007) have shown a significantly positive correlation flanked by increasing fertilizer application, typically N, and yield of grain amaranth.

The N needed for the growth of a crop will vary depending on the N status of the soil and potential for mineralization. Therefore, optimum N amount reported for maximum amaranth growth by different researchers are substantially different. The reported range varies from 50-200 kg N ha^{-1} (Keskar *et al.* 1981; Subhan 1989; Ramachandra and Thimmaraju 1983). All studies agree that supplemental N is required for optimum amaranth yield. However, few of these studies did not explore organic soil amendments as a nutrient source, nor did they test amaranth responses in nutrient-poor soils. Additionally, most studies did not report initial plant available nutrient levels prior to fertilizer application. Notable exceptions include Apaza-Gutierrez *et al.* (2002), who tested yield response of *A.caudatus* and *A. hypochondriacus* to application of dried organic sheep manure (7.5 and 15 ton ha^{-1}) in Bolivian soils with moderate levels of organic matter and low levels of NPK (values not reported). Both species showed a linear yield response to organic and chemical fertilizers and a quadratic response to a mixture of the two. Yield response to fertilization by chemical fertilizer was 29% greater than for the manure treatment.

2.7 Benefits of adding compost to soils

In many parts of the developing world commercial fertilizers are often beyond the reach of poor farmers in terms of availability and affordability. Consequently, alternative soil fertility maintenance techniques need to be evolved in order to meet up with food need of the teeming populace. One of such technique is the use of both animal and crop residue compost (Olaniyi et al., 2008).

Composting is a biological process of aerobic decomposition, which degrades labile organic matter to carbon dioxide, water vapor, ammonia, inorganic nutrients and a stable organic material containing humic like substances (Senesi, 1989).

It is an organic matter source with a unique ability to improve the chemical, physical, and biological characteristics of soils. It improves water retention in sandy soils and promotes soil structure in clay soils by increasing the stability of soil aggregates. Adding compost to soil increases soil fertility and cation exchange capacity and can reduce fertilizer requirements up to 50%. Soil becomes microbially active and more suppressive to soil-borne and foliar pathogens. Enhanced microbial activity also accelerates the breakdown of pesticides and other synthetic organic compounds (Akanbi et al., 2002).

The presence of organic matter in the soil is fundamental in maintaining the soil fertility and decreasing nutrient losses. Organic matter continues to enhance soil fertility, soil structure and water storage capacity. Organic matter retains plant nutrients and thus prevents the fertilizer from being washed away (Senesi, 1989).

The compost adds air space to the soil, and incorporating it alleviates compacted conditions. Adding compost increases the moisture holding capacity of sandy soils, reducing drought damage to plants. When added to heavy clay soils, compost improves drainage and aeration.

However, adding compost cannot solve drainage problems that result from poor surface contours or subsurface conditions. Such problems often must be solved by beaming or installing drainage tiles. All of these changes create a better environment for root growth. Adding compost increases the ability of the soil to hold and release essential nutrients. The activity of earthworms and soil microorganisms beneficial to plant growth is also promoted. Other benefits include improved seed emergence and water infiltration as a result of reduced soil crusting (Agboola and Sobulo, 1981).

Amending soils with compost may also reduce the incidence of damping off disease and root rots. The micro floras present in compost compete with disease microbes for the sugars and nutrients secreted from plant roots, preventing these pathogens from growing and keeping them inactive. Over time, yearly additions of compost will create desirable soil structure, making the soil much easier to work. To improve the physical properties of the soil, 1 to 2 inches of well-decomposed compost are incorporated into the top 6 to 8 inches of soil (Hauck, 1981).

Information on the optimum compost required for growing amaranths on degraded soils are scanty in literature. Over and above this, nutrient availability uptake efficiency and quality of grains produced by crop varies according to efficiency of the applied materials to release the bound nutrient as reported by Agboola and Sobulo (1981) and Akanbi *et al.* (2006).

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CHAPTER THREE

3. Study Area

The experiment was carried out at Castle Vineyard and Winery Project site during the dry season (late January – mid May 2013). The project is located in Adami Tulu- Jido Kombolcha Wereda of East Shewa Zone in Oromia Regional State. Adami Tulu Jido Kombolcha Wereda is found in East Shewa Zone of Oromia Region at $7^{0}37$- $8^{0}04$ latitude north and $38^{0}32$ – $39^{0}04$ longitude east. The average elevation above sea level of the Wereda is between 1500 to 2300 meters. The Wereda is bound by Dugda Wereda in the north, Arsi Nagale in the south, Arsi Zone in the east.

The project specific location is south of Batu (Ziway) town nearly at a distance of 3km along the eastern side of the Addis Ababa – Hawassa road. It is bound by Addis Ababa – Hawassa road in the west, in the east it is bound by Bulbula River which starts from Ziway lake and flows south ward and ends up in Abijata lake. Lake Ziway lies in the north east of the project site about 3 km upstream of the Project.

The availability of Bulbula River adjacent to the project area creates a conducive situation and opportunity to get abundant water supply for the farm. The project gets its water supply for the farm from this river by pumping the water using electrical pumps.

3.1 Climate

The primary climatic data was obtained from meteorological station. The major meteorological parameters analyzed are rainfall and temperature (minimum and maximum). The record on rainfall data shows that the area has uni-modal rainfall type. The heavy rain begins in the area during June and lasts until beginning of September. The mean total annual rain fall in the area based on the record is 647.5mm. The highest temperature is in March (29.4 ^{0}C), and the lowest temperature is in December (11.5 ^{0}C) (Figure 1).

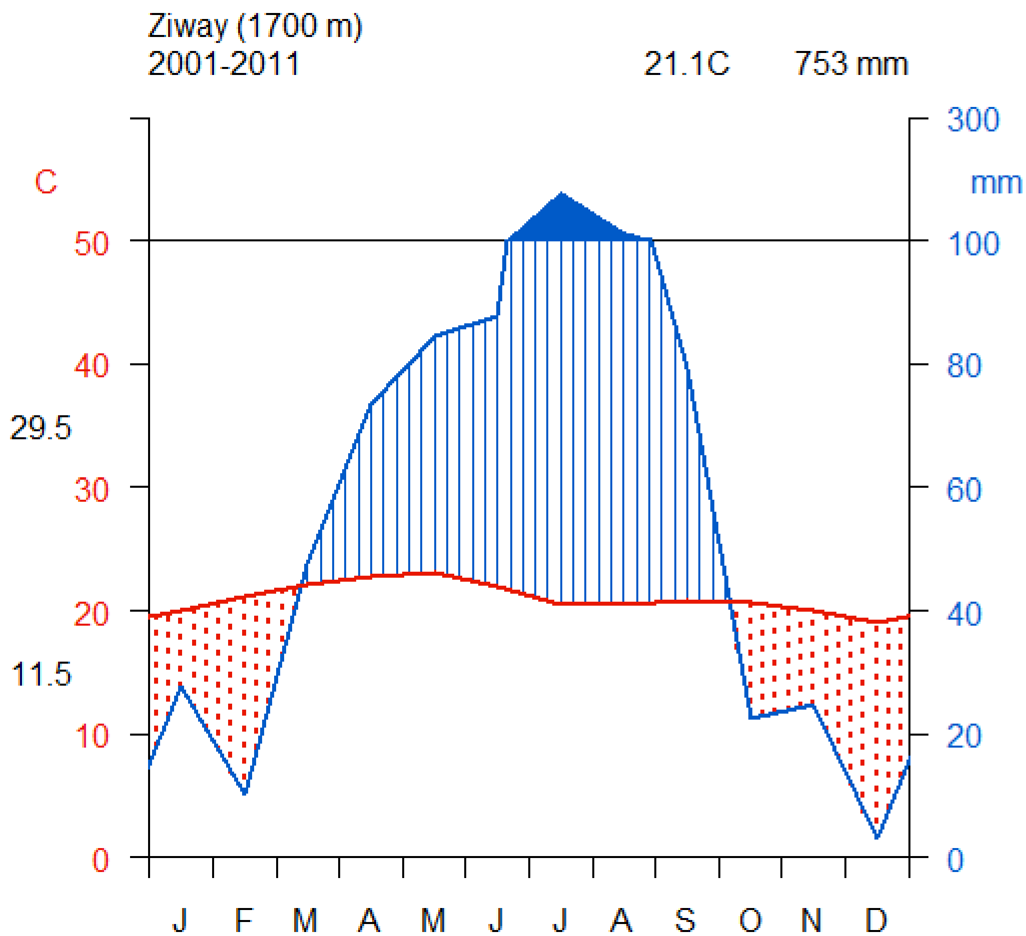

Figure 1 Monthly Mean Minimum, Mean Maximum Temperature *(C^0)* and Rainfall(mm)

3.2 MATERIALS AND METHODS

3.2.1 Experimental Design and Treatments

The experimental design was a completely randomized block design with four replicates. Each block had a size of 4mx4m. The experimental field was cleared, ploughed, harrowed and divided into plots. Prior to planting, four soil samples were randomly collected within the depths of 0-15 cm using a hand auger. Each soil sample was separately labeled and air-dried and crushed to pass through a 2mm sieve and taken to the laboratory for physical and chemical analysis to determine their nutrient level prior to application of compost and urea. In the laboratory, each Soil sample was analyzed for pH, in 1:2 (soil: water) suspension using a pH meter, total nitrogen with the micro-kjeldahl method (Bremner and Keeney, 1966), and exchangeable bases (K^+, Ca^{2+}, Mg^{2+} and Na^+) after extraction with 1N NH OAC (pH 7). K^+ in the filtered extract was determined with a flame photometer, whereas Ca^{2+}, Na^+, and Mg^{2+} were determined with an atomic absorption spectrophotometer (AAS). Available phosphorus (Bray-1-P) was determined by colorimeter using the method of Bray and Kurtz (1945) and organic carbon was determined using the Walkley and Black procedure as described by Nelson and Sommers (1982).

Samples of the mature compost made from cattle manure and house wastes like food processing wastes were taken for laboratory analyses in order to determine their nutrient composition. Before analysis, the compost samples were air dried and ground to pass through a 2 mm sieve. The samples were then analyzed for pH, total N, total P, organic carbon and exchangeable bases (K^+, Ca^{2+}, Mg^{2+} and Na^+) in the laboratory using standard methods (IITA, 1982).

Compost at 0, 5, 10 and 15 t ha^{-1} and urea at 0, 50, 100 and 150 Kg ha^{-1} were carefully weighed and applied into the experimental plots. The urea amount assigned to a plot was applied in split application; half of each level of fertilizer was applied before planting and the other half applied six weeks after sowing.

The seed was found from CISO (Community Initiative Support Organization) which is found in Hawassa. Preirrigation was done before sowing and the seeds were sown in rows of 80 cm apart, at 50 cm interval within rows. Drill planting method was used. Shallow furrows of about 3 cm were made and seeds spread thinly along the furrows. After sowing it was covered with grass and watering was done every three days for three weeks since adequate watering is necessary for the seedlings to emerge. After the seedlings emerged well, watering was done only once a week for three weeks. To attain the desired plant population densities, plants were hand-thinned in the third week at a spacing interval of 50cm. To reduce weed competition for growth factors, and create pest and disease free environment, hand pulling of weeds was done regularly and it was carried out three times.

3.2.2 Data collection

The seed was sown on 26/01/2013 and data collection on growth and yield of *Amaranthus cruentus* began four weeks after sowing at two week intervals. Height, stem girth, number of leaves, leaf area, number of branches, inflorescence height and the total grain yield of the crop was measured and evaluated. The plant parameters were taken from any 4 randomly selected plants per plot for measurements. Plant height was taken from the ground to the top of the flower head using a meter ruler. Stem girth was taken at 12cm above the ground. Number of leaves and branches were recorded by counting. Leaf area was measured using graph paper. A graph paper, 1mm x 1mm graduated was taken. The leaf traced on the graph paper, the leaf removed then the whole squares occupied by the leaf counted. The number of squares counted is the surface area of one side of leaf. Mean inflorescence height was determined by measuring the top flower heads of the randomly selected plants using a meter ruler. Harvesting was done on 04/05/2013. Grain yield for the different treatments was established by hand threshing of dried inflorescences in sacks in order to prevent grain loss. Winnowing was performed to remove any dirty and immature seeds to obtain clean seeds. Seed yield was recorded by weighing the seeds in an electric weighing balance.

3.3 Data analysis

Data collected on the growth parameters and yield subjected to analysis of variance (ANOVA). Significant treatment means were separated using Tukey test at P<0.05.

CHAPTER FOUR

4. RESULTS

The data recorded on soil chemical and physical characters are given in Table 1. Based on the results of the analysis, the soil is sandy loam in texture and it is alkaline in nature. The soil is good in exchangeable cations but low in its nitrogen and organic carbon. Therefore the site requires soil amendments with nitrogen fertilizer and fertilizers which are rich in organic carbon.

Table 1 Data of Some Selected Soil Chemical and Physical Characteristics

Chemical characteristics	
parameter	Result
pH	8.2
Orgn.C	1.4%
Total N	0.2%
Ca	13.7 $cmolKg^{-1}$
Mg	1.9 $cmolKg^{-1}$
K	4.0 $cmolKg^{-1}$
Na	0.8 $cmolKg^{-1}$
CEC	18.7 $cmolKg^{-1}$
Avail.P	41.8 $mgkg^{-1}$
Avail.K	4.0 $mgkg^{-1}$

Physical characteristics	
sand	75%
silt	13%
clay	12%
Texture class	Sandy loam

The data recorded on the chemical characters of compost are given in Table 2.Based on the results of the analysis the compost is high in its organic carbon and nitrogen and it is slightly acidic.

Table 2 Chemical Composition of the Compost

Parameter	Result
pH	5.24
Orgn.C	19.72%
Total N	2.12%
Ca	2.86 $cmolKg^{-1}$
Mg	1.23 $cmolKg^{-1}$
K	2.96 $cmolKg^{-1}$
Na	0.89 $cmolKg^{-1}$
Avail.P	18.7 $cmolKg^{-1}$

4.1 Plant height

The results showed that plant height was observed to increase with plant age. The plant that received treatments of 150 Kg ha^{-1} urea produced the highest plant height of 26.5, 64.5, 110.6, 171.6, 198.5 cm at 4, 6, 8, 10 and 12 weeks after sowing. The least average plant height of 14.4, 2.73, 119.1 and 148.6 cm at 4, 6, 8, 10 and 12 weeks after sowing were produced by *Amaranthus hybridus* subsp. *cruentus* that received no fertilizer(Figure 2 a). There was no significant difference between the height of *Amaranthus hybridus* subsp. *cruentus* treated with the applied levels of urea and that of the control (without urea) (Appendix 2).

Plant height also increased with increased compost levels (Fig 2b). The result revealed that *Amaranthus hybridus* subsp. *cruentus* treated with the highest compost level of 15 t/ha attained the highest plant height of 26.5, 60, 102, 168 and 191cm which was not significantly different from 10 t/ha and those that receive no compost treatment produced the least average plant height of 14, 38.2, 73, 119.1 and 148.6 cm at 4, 6, 8, 10 and 12 weeks after sowing. The height of *Amaranthus hybridus* subsp. *cruentus* treated with both 15 t/ha and 10 t/ha showed significant difference from the height of *Amaranthus hybridus* subsp. *cruentus* treated with no compost (Appendix 2).

Fig 2(a)

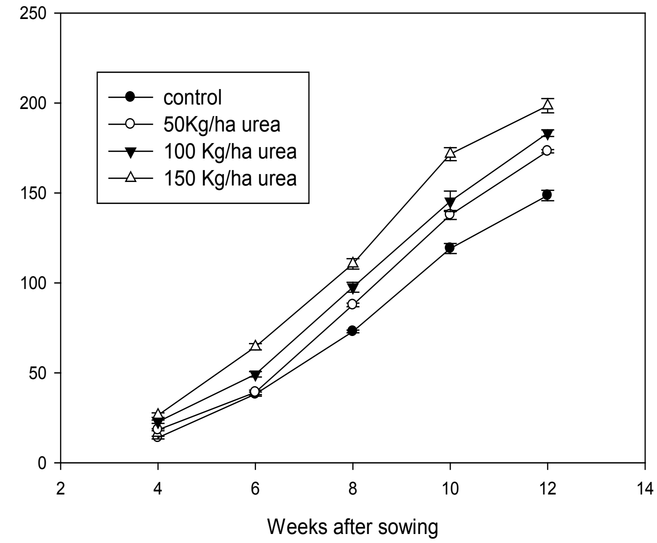

Fig.2(b)

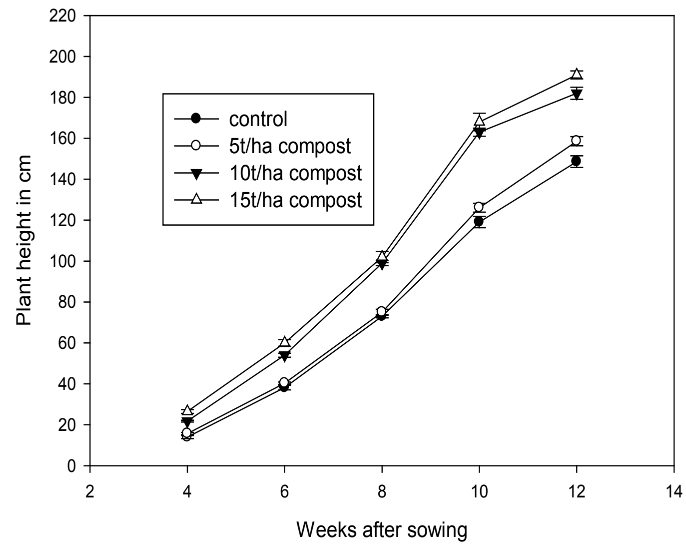

Figure 2(a) the height of *Amaranthus hybridus* subsp.*cruentus* At different levels of urea from 4-12 weeks after sowing

Figure 2(b) the height of *amaranthus hybridus* subsp.*cruentus* at different leves of compost from 4-12 weeks after sowing

4.2 Leaf area

Amaranthus hybridus subsp. *cruentus* treated with the various levels of urea (0, 50, 100 and 150 Kg/ha) showed an increase in leaf area but no significant difference was found. At 4 and 6 weeks after sowing leaf area was low but the leaf area increased rapidly at 8, 10 and 12 weeks after sowing. The plants that received treatments of 150 Kg ha^{-1} urea produced the highest leaf area of 62.3, 97.9, 183.8, 358.7, 367.5 cm^2 and least average leaf areas of 22.2, 49.8, 131.3, 215.0 and 216.1 cm^2 at 4, 6, 8, 10 and 12 weeks after sowing were produced by *Amaranthus hybridus* subsp. *cruentus* that received no fertilizer (Figure 3a).

Amaranthus hybridus subsp. *cruentus* treated with the various levels of compost (0, 5, 10 and 15 t/ha), showed an increase in leaf area but no significant difference was found. The plants that received treatments of 15 tha^{-1} compost produced the highest leaf area of 50.6, 83.8, 162.3, 307.4 and 308.5 cm^2 and the least average leaf areas of 22.2, 49.8, 131.3, 215.0 and 216.1 cm^2 at 4, 6, 8, 10 and 12 weeks after sowing were produced by *Amaranthus hybridus* subsp. *cruentus* that received no compost (Figure 3b).

Fig.3(a)

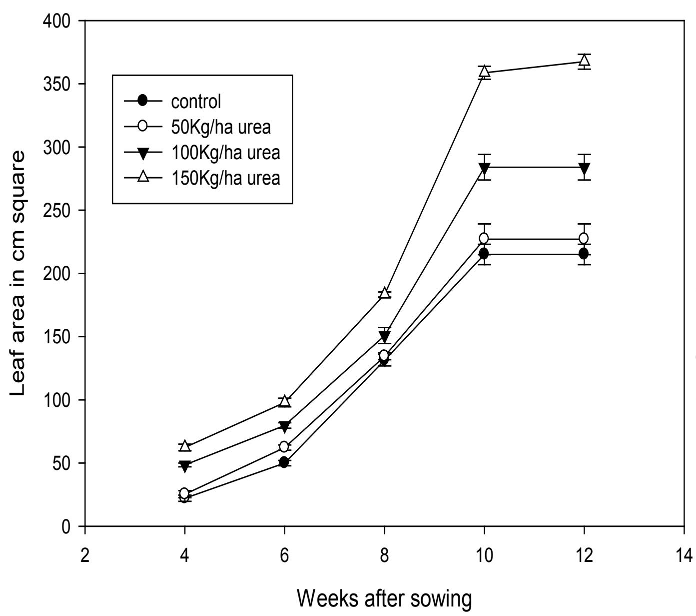

Figure 3(a) Leaf Area of Amaranthus hybridus subsp.*cruentus* At different levels of urea from 4-12 weeks after sowing

Fig.3(b)

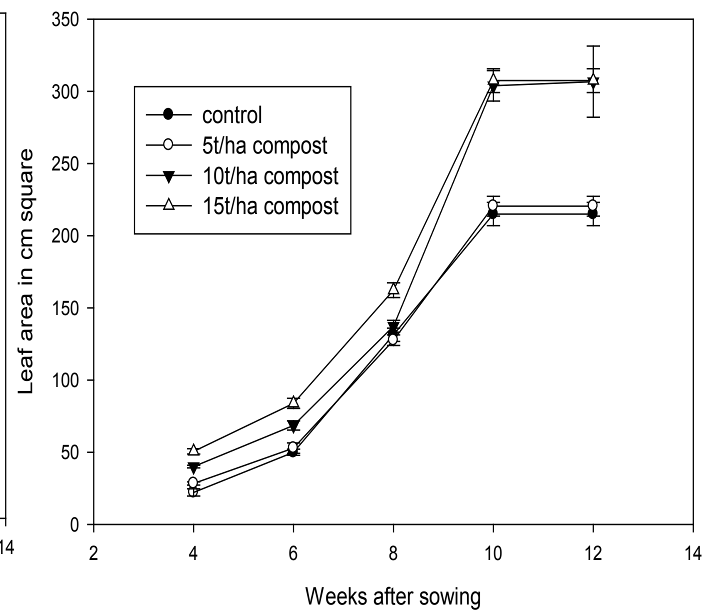

Figure 3(b) Leaf Area of *amaranthus hybridus* subsp.*cruentus* at different leves of compost from 4-12 weeks after sowing.

4.3 Number of Leaves

The average leaf number of *Amaranthus hybridus* subsp. *cruentus* treated with the various levels of urea (0, 50, 100, and 150 Kg/ha) increased with increased urea levels (Figure 4a).But no significant difference was found between the average leaf number of *Amaranthus hybridus* subsp. *cruentus* treated with those levels of urea.

The results showed that at 4, 6 and 8 weeks after sowing leaf number was low but leaf number increased rapidly at 8 weeks after sowing. This is because the plants bear many branches with a number of leaves after 8 weeks. The plant that received treatments of 150 Kg ha^{-1} urea produced the highest number of leaves of 24, 33, 49, 346 and 356. The least average leaf number of 12, 19, 27, 160, and 167 per plant at at 4, 6, 8, 10 and 12 weeks after sowing were produced by *Amaranthus hybridus* subsp. *cruentus* that received no fertilizer.

The average leaf number of *Amaranthus hybridus* subsp. *cruentus* treated with the various levels of compost (0, 5, 10 and 15 t/ha), increased with increased compost levels (Figure 4b).But no significant difference was found between the average leaf number of *Amaranthus hybridus* subsp. *cruentus* treated with those levels of compost. The plant that received treatments of 15 t ha^{-1} compost produced the highest number of leaves leaf number of 17, 27, 34 and 312, 316 per plant at 4, 6, 8 and 10,and 12 weeks after sowing. The least average leaf number of 12, 19, 27, 160, and 167 per plant were produced by *Amaranthus hybridus* subsp. *cruentus* that received no compost.

Fig. 4(a)

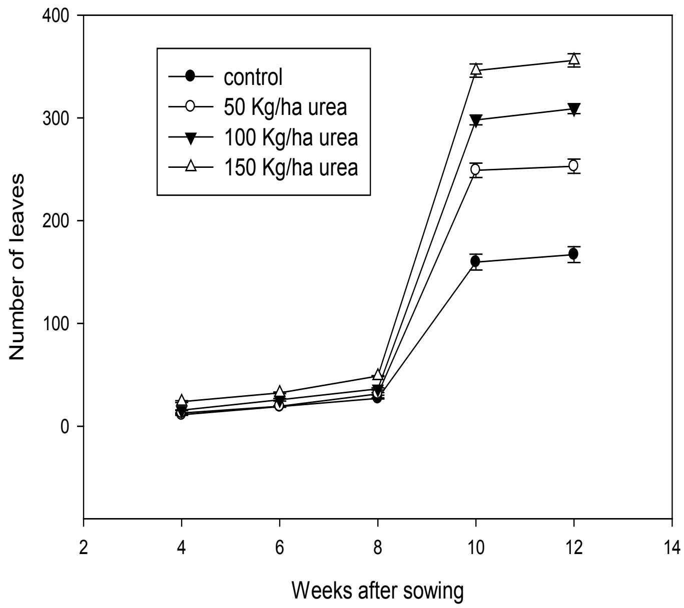

Fig.4(b)

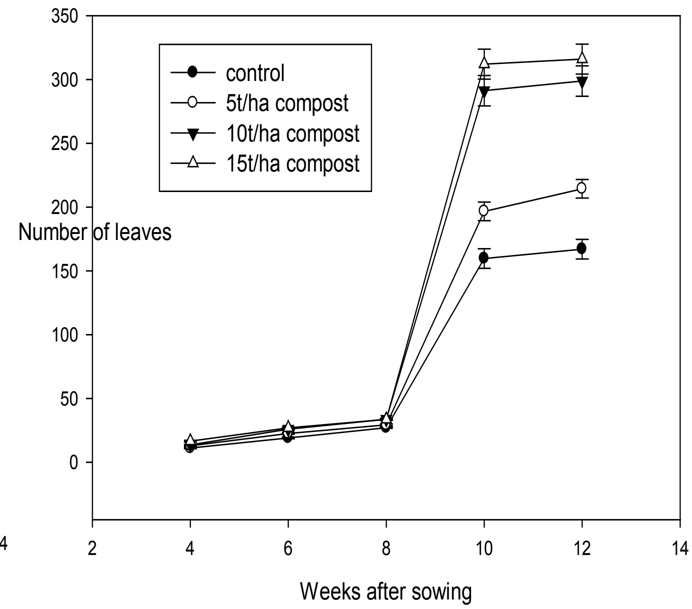

Figure 4(a) Leaf number of *Amaranthus hybridus* subsp.*cruentus* At different levels of urea from 4-12 weeks after sowing

Figure 4(b) Leaf number of *amaranthus hybridus* subsp.*cruentus* at different leves of compost from 4-12 weeks after sowing

4.4 Stem girth

Urea levels affected stem girth of *Amaranthus hybridus* subsp. *cruentus* in all the treatment groups from 8-12 weeks after sowing (Figure 5a). The plant that received treatment of 150 Kg ha^{-1} urea produced the largest stem girth of 8.1, 12.3, 17.2 and 17.6 cm at 4, 6, 8 and 10,and 12 weeks after sowing. The least average stem girth of 6.0, 8.6, 11.9 and 12.3 cm per plant were produced by *Amaranthus hybridus* subsp. *cruentus* that received no fertilizer.

Compost levels also affected stem girth of *Amaranthus hybridus* subsp. *cruentus* in all the treatment groups from 8-12 weeks after sowing (Figure 5b). The plant that received treatment of 15 t ha^{-1} compost produced the larger stem girth of 8, 11.4, 15.8 and 16.1cm per plant at 4, 6, 8, 10 and 12 weeks after sowing. The least average stem girth of 6.0, 8. 6, 11.9 and 12.3 cm per plant were produced by *Amaranthus hybridus* subsp. *cruentus* that received no compost.

Fig.5(a)

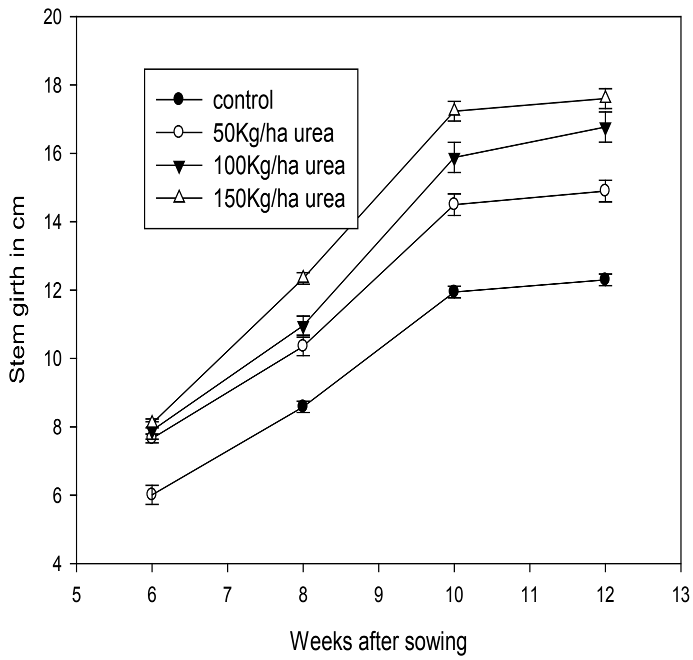

Fig.5(b)

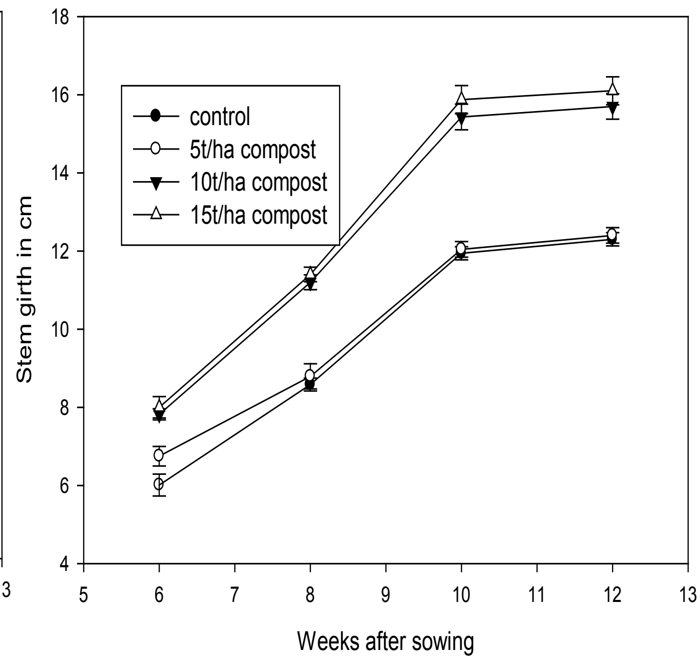

Figure 5(a) Stem girth of *Amaranthus hybridus* subsp.*cruentus* At different levels of urea from 6-12 weeks after sowing

Figure 5(b) Stem girth of *amaranthus hybridus* subsp.*cruentus* at different leves of compost from 6-12 weeks after sowing

4.5 Inflorescence height

Urea and compost levels affected inflorescence height of *Amaranthus hybridus* subsp. *cruentus.* Inflorescence length increased with increasing application rates of urea (Figure 6a). The result revealed that *Amaranthus hybridus* subsp. *cruentus* treated with the highest level of urea (150 kg/ ha) produced the tallest inflorescence height (82.3cm) and the shortest inflorescence height formed in the control (without urea) 76.0 cm.

Compost levels affected inflorescence height of *Amaranthus hybridus* subsp. *cruentus* (Figure 6b). Inflorescence height increased with increasing application rates of compost. *Amaranthus hybridus* subsp. *cruentus* treated with the highest compost level of 15 t/ha produced the tallest inflorescence height of (81.4cm). The shortest inflorescence height of 76.0 cm formed in the control (without compost).

Fig.6(a)

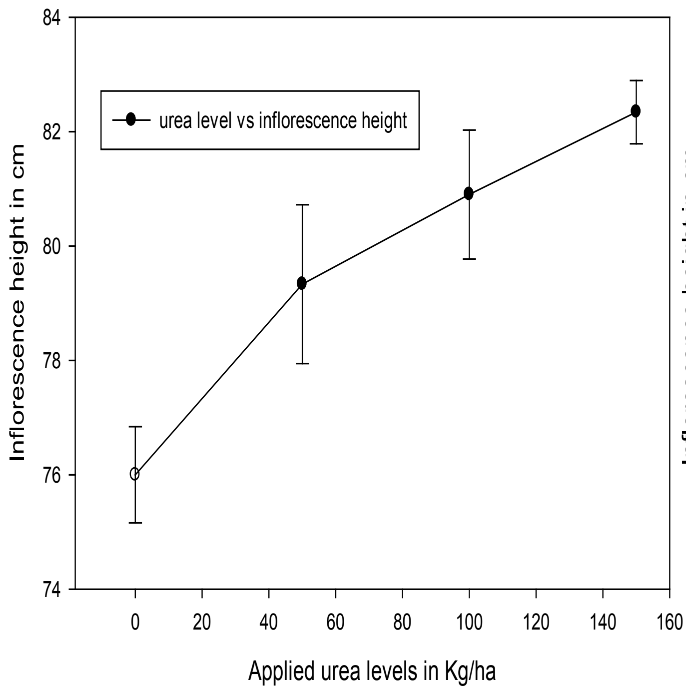

Figure 6(a) Inflorescence height of *Amaranthus hybridus* subsp.*cruentus* at different levels of Urea at 12 weeks after sowing.

Fig.6(b)

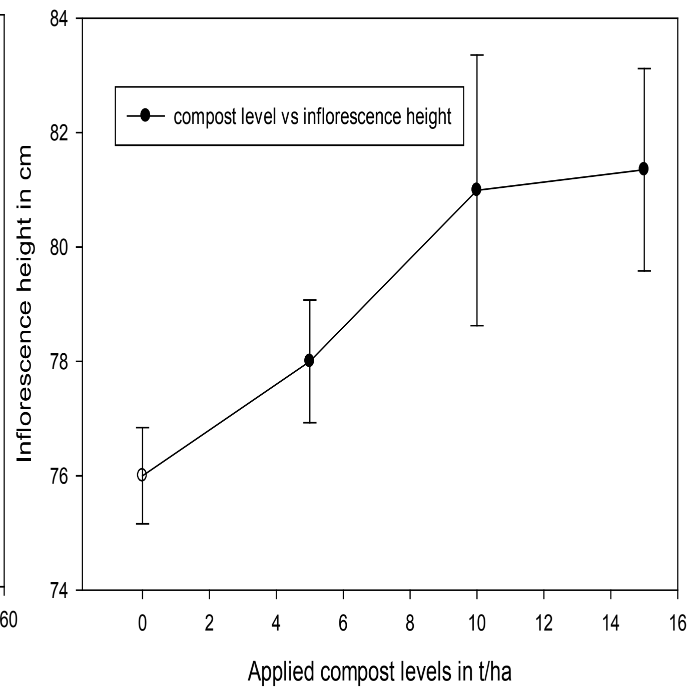

Figure 6(b) Inflorescence height of *Amaranthus hybridus* subsp.*cruentus* at different levels of Compost at 12 weeks after sowing.

4.6 Branch number

Amaranthus hybridus subsp. *cruentus* treated with the various levels of urea (0, 50, 100 and 150 Kg/ha) show an increase in branch number at increased levels of urea at 10 and 12 weeks after sowing (Figure 7b). The plant that received treatment of 150 Kg/ha urea produced the highest average number of branches of 25 at 12 weeks after sowing. The least average branch number of 18 per plant was produced by *Amaranthus hybridus* subsp. *cruentus* that received no fertilizer. The result showed that the higher the quantity of applied urea, the higher the number of branches produced per plant.

Compost levels also affected branch number of *Amaranthus hybridus* subsp. *cruentus* in all the treatment groups from 8-12 weeks after sowing (Figure 7b). The plant that received treatment of 15 t ha^{-1} compost produced the branch number of 23 at 12 weeks after sowing. The least average branch number of 18 per plant were produced by *Amaranthus hybridus* subsp. *cruentus* that received no compost. The result showed that the higher the quantity of compost applied, the higher the number of branches produced per plant.

Fig. 7(a)

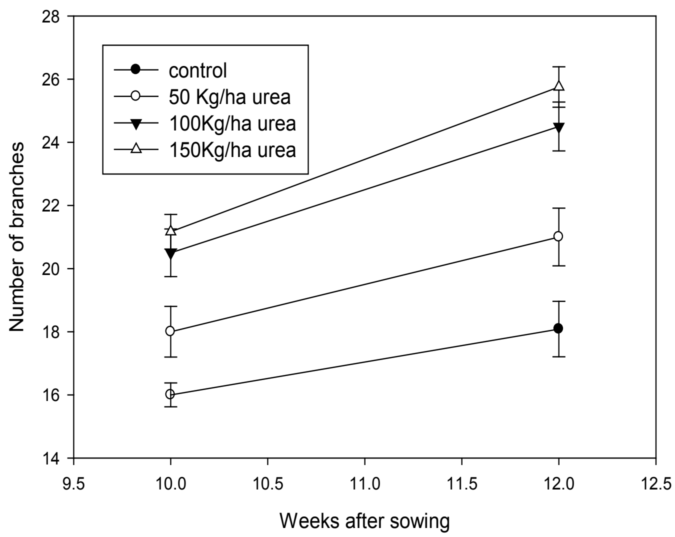

Fig. 7(b)

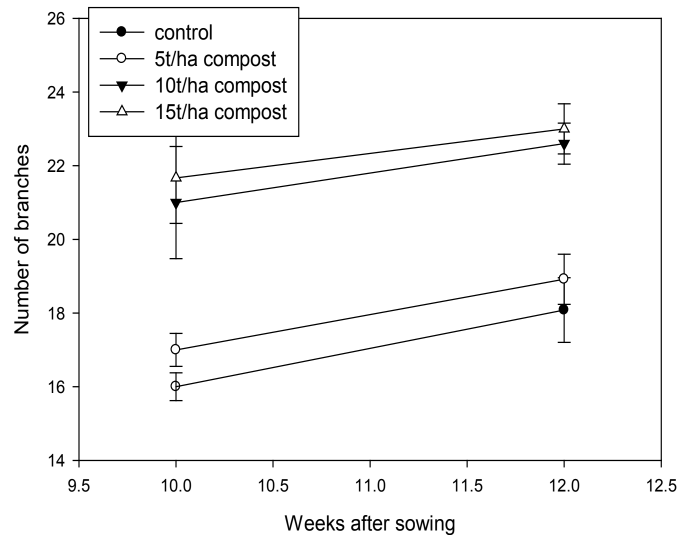

Figure 7(a) Leaf number of *Amaranthus hybridus* subsp.*cruentus* at different levels of urea at 10 and 12 weeks after sowing

Figure 7(b) Branch number of *amaranthus hybridus* subsp.*cruentus* at different leves of compost at 10 and 12 weeks after sowing

4.7 Grain Yield

The effect of different levels of urea on grain yield of *Amaranthus hybridus* subsp. *cruentus* was significant at $P<0.05$. The highest grain yield 3495.3 Kg $ha^{-1}$was obtained at the application of 150 Kg ha^{-1} urea and the lowest grain yield 1859.4 Kg ha^{-1} was obtained at zero fertilizer application, i.e. the control (Figure 8a). There were significant differences in grain yield of *Amaranthus hybridus* subsp. *cruentus* treated with all levels of urea (appendix 2).

The effect of different levels compost on grain yield of *Amaranthus hybridus* subsp. *cruentus* was also significant at $P<0.05$. The highest grain yield 3379.7 Kg $ha^{-1}$was obtained at the application rate of 15 t ha^{-1} compost and the lowest grain yield 1859.4 Kg ha^{-1} was obtained at the control (Figure 8b). There was significant difference between grain yield of *Amaranthus hybridus* subsp. *cruentus* treated with compost and the control. However there was no significant difference between grain yield of *Amaranthus hybridus* subsp. *cruentus* treated with 15 t/ha and 10 t/ha.

Fig.8(a)

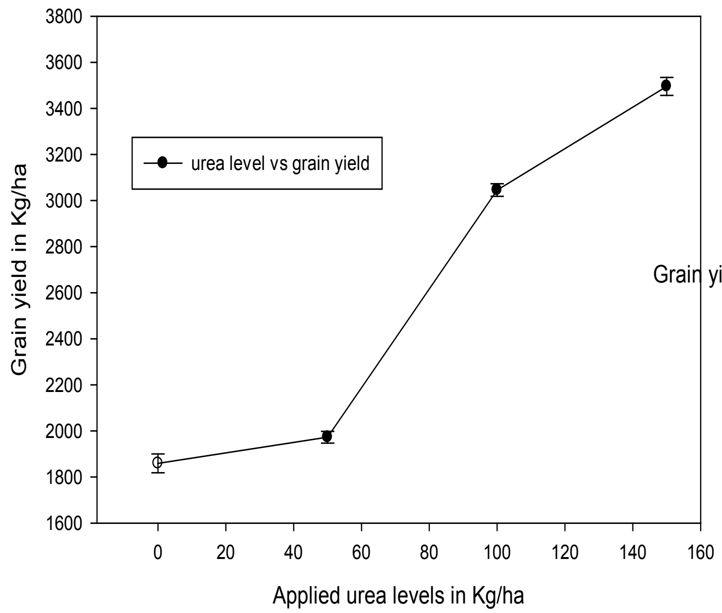

Fig.8(b)

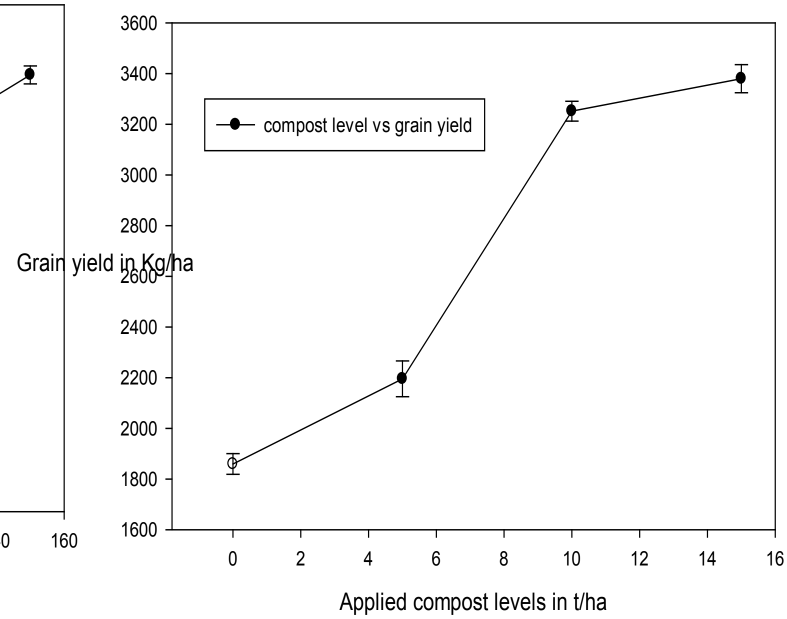

Figure 8(a) Grain yield of *Amaranthus hybridus* subsp.*cruentus* at different levels of urea.

Figure 8(b) Grain yield of *amaranthus hybridus* subsp.*cruentus* at different levels of compost.

4.8 Correlation among vegetative characteristics

In order to evaluate the correlation between characteristics following the application of different levels of urea and compost and also to assess the connection of these characteristics with the yield of *Amaranthus hybridus* subsp. *cruentus* all correlation coefficients between characteristics were investigated (appendix 1). There were significant positive correlations between all characteristics investigated. Also, significant positive correlations were obtained among yield with all characteristics. Therefore, yield increased with increasing characteristics such as plant height, leaf number, leaf area, branch number, stem girth and inflorescence height. According to the correlation coefficients, the yield of *Amaranthus hybridus* subsp. *cruentus* caused by an increase in branch number gave a higher correlation than other characteristics investigated. In contrast, the relationship between yield and stem girth was lower compared with other interactions.

CHAPTER FIVE

5. DISCUSSION

Application of both organic and inorganic fertilizers showed an increase in plant height from 4 weeks after sowing to 12 weeks after sowing or to plant harvesting. The highest level of urea (150 kg/ ha) produced the tallest plants (198.5cm) and the shortest plants were those of the control (without urea) 148.6 cm. Similar results were observed by Elbehri *et al*. (1993), who reported increased Amaranthus plant height at higher nitrogen application rate.

The highest level of compost (15 t/ ha) produced the tallest plants (191 cm) and the shortest plants were those of the control 148.6 cm. This finding agreed with earlier report of Tindall (1975) who reported that Amaranthus require soils with high organic content, and adequate mineral nutrients for the production of higher plant height. The positive influence of compost on the growth of the crop might be due to the release of the balanced nutrients contained in the organic nutrient.

The largest leaf area was produced by the plant that received treatments of maximum levels of urea (150 Kg/ha) and maximum levels of compost (15 t/ha) and the least was that of the control. The result showed that the higher the quantity of urea and compost applied, the higher the area of leaves produced per plant. Ammonium/urea based fertilizers tend to create lush or soft growth resulting in larger leaves and darker green plants (Anon, 2006).

Leaf number increased with increased application levels of urea (Fig 4a). This showed that N promoted the vegetative growth of amaranth. Nitrogen is an essential component of chlorophyll, protoplasm, protein and nucleic acid and its absence at appropriate levels could cause yellowing of leaves and stunting of plant growth (Bergman, 1992). The increase in height and number of leaves as N rates increased, reconfirmed the role of nitrogen in promoting vigorous vegetative growth in leafy vegetables (Tisdale and Nelson, 1990).

Leaf number also increased with increased levels of compost (Fig 4b).The result showed that the higher the quantity of urea and compost applied, the higher the number of leaves produced per plant. The increased in number of leaves under urea and compost application, reconfirmed the role of fertilizer in promoting vegetative growth in leafy vegetables (Tijani-Eniola *et al.*, 2000). Changes in the number of leaves are bound to affect the overall performance of the plant as the leaves serve as the organ of photosynthesis for the manufacture of assimilates. The number of leaves increased as urea and compost increased up to maximum level. The increase in number of leaves had been claimed to be directly influenced by N supply in fertilizer applied (Ehigiator, 1990).

(Gungula, 1999) reported that nutrient availability especially nitrogen (N) determined plant vegetative development. The consistent poor performance of non-fertilized plants and those planted with low nitrogen amendment revealed that when nutrients are available at adequate amounts plants tends to grow at their optimum potential. (Akanbi and Togun, 2002) reported significant reduction in plant growth parameters when soil is deficient in nutrient most especially nitrogen as they are often required for chlorophyll and protoplasm formation.

Stem girth and branch number increased with increased levels of urea and compost. The higher the quantity of urea and compost applied, the higher the stem girth and branch number of *Amaranthus hybridus* subsp. *cruentus.* The larger stem girth and branch number observed in the treated plots could mainly be attributed to increased availability of nutrients in soil and amaranth uptake of the applied nutrients which gave rise to increased stem girth which resulted in the retention of appreciable amount of assimilates in the stem for node and leaf production (Bano, 1987).

Urea and compost levels affected inflorescence height of *Amaranthus hybridus* subsp. *cruentus* Inflorescence length increased with increasing application of fertilizer rates.

Grain yield of *Amaranthus hybridus* subsp. *cruentus* significantly increased with increased levels of urea and compost.These results are in agreement with the findings of Elbehri et al. (1993), Myers (1998) and Bruce and Philip (2008) who reported a linear response of grain amaranth yield to N fertilization. The increase in grain yield as fertilizer application rates increased could have been due to increased plant growth, flowering and grain filling. This responsiveness of grain amaranth yield to nitrogen fertilization is also comparable to the findings of other researchers (Myers, 1996; Jefferson Institute, 1999; Bruce and Philipe, 2008).

As the major constitutive element of amino acids and proteins, nitrogen is an essential element in the biological functioning of all forms of life where in higher plants, nitrogen plays an integral role in photosynthesis, carbohydrate use, and metabolic processes through various plant secondary compounds. This accounts for the positive correlation between amaranth yields and nitrogen fertilizer application (Brady and Weil, 1999).

5.1 CONCLUSION

From this experiment, it was observed that addition of urea and compost on soil increased both vegetative growth and yield of *Amaranthus hybridus* subsp. *cruentus*. Results showed that all parameters measured increased with plant age. Application of both urea and compost levels increased all growth parameters and yield of *Amaranthus hybridus* subsp. *cruentus*. Hence, application of urea and compost were found to improve the growth and yield of grain amaranth. Application of 150 Kg ha^{-1} urea and 15 t ha^{-1} compost produced the higher grain yield of *Amaranthus cruentus*. However there was no significant difference between 15 tha^{-1} and 10 t ha^{-1} and therefore 150 Kg ha^{-1} urea and 10 t ha^{-1} compost recommended for farmers since, 10 t ha^{-1} is less bulky than 15 t ha^{-1} compost. Less bulkiness is an indication of lower transportation and labor cost.

5.2. RECOMENDATION

1.Production and utilization of grain Amaranth for improved nutrition should be promoted in ethiopia.

2.Grain amaranth production would be profitable with increased application of urea and compost.

3. 150 Kg ha^{-1} urea and 10 t ha^{-1} compost recommended for farmers. However, the projected compost rates of 10 tons/ha and 150 kg urea/ha may not be affordable by the small-scale farmers. This therefore calls for a follow-up study on an integrated approach to soil fertility management through a balanced use of chemical fertilizers and organic compost.

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APPENDIXE 1 Correlation among vegetative characteristics

Correlations

		Plant Height	Leaf area	Leaf number	Stem girth	Inflorescence height	Branch number	Grain yield
Plant Height	Pearson Correlation	1	.970(*)	.994(**)	.976(*)	.985(*)	.990(*)	.993(**)
	Sig. (2-tailed)		.030	.006	.024	.015	.010	.007
	N	4	4	4	4	4	4	4
Leaf area	Pearson Correlation	.970(*)	1	.968(*)	.997(**)	.959(*)	.994(**)	.988(*)
	Sig. (2-tailed)	.030		.032	.003	.041	.006	.012
	N	4	4	4	4	4	4	4
Leaf number	Pearson Correlation	.994(**)	.968(*)	1	.967(*)	.998(**)	.989(*)	.995(**)
	Sig. (2-tailed)	.006	.032		.033	.002	.011	.005
	N	4	4	4	4	4	4	4
Stem girth	Pearson Correlation	.976(*)	.997(**)	.967(*)	1	.953(*)	.993(**)	.987(*)
	Sig. (2-tailed)	.024	.003	.033		.047	.007	.013
	N	4	4	4	4	4	4	4
Inflorescence height	Pearson Correlation	.985(*)	.959(*)	.998(**)	.953(*)	1	.982(*)	.990(*)
	Sig. (2-tailed)	.015	.041	.002	.047		.018	.010
	N	4	4	4	4	4	4	4
Branch number	Pearson Correlation	.990(*)	.994(**)	.989(*)	.993(**)	.982(*)	1	.999(**)
	Sig. (2-tailed)	.010	.006	.011	.007	.018		.001
	N	4	4	4	4	4	4	4
Grain yield	Pearson Correlation	.993(**)	.988(*)	.995(**)	.987(*)	.990(*)	.999(**)	1
	Sig. (2-tailed)	.007	.012	.005	.013	.010	.001	
	N	4	4	4	4	4	4	4

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

APPENDIXE 2 ONEWAY ANOVA

Tukey HSD

(I) levels	(J) levels	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
		Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
leafau50	leafau0	8.50016	76.73154	1.000	-265.0881	282.0884
	leafau100	-34.20244	76.73154	1.000	-307.7907	239.3858
	leafau150	-78.73584	76.73154	1.000	-352.3241	194.8524
leafau100	leafau0	42.70260	76.73154	1.000	-230.8856	316.2908
	leafau50	34.20244	76.73154	1.000	-239.3858	307.7907
	leafau150	-44.53340	76.73154	1.000	-318.1216	229.0548
leafau150	leafau0	87.23600	76.73154	.999	-186.3522	360.8242
	leafau50	78.73584	76.73154	1.000	-194.8524	352.3241
	leafau100	44.53340	76.73154	1.000	-229.0548	318.1216
leafac5	leafac0	3.22066	76.73154	1.000	-270.3676	276.8089
	leafac10	-41.37332	76.73154	1.000	-314.9616	232.2149
	leafac15	-52.38334	76.73154	1.000	-325.9716	221.2049
leafac10	leafac0	44.59398	76.73154	1.000	-228.9943	318.1822
	leafac5	41.37332	76.73154	1.000	-232.2149	314.9616
	leafac15	-11.01002	76.73154	1.000	-284.5983	262.5782
leafnu50	leafnu0	36.34358	76.73154	1.000	-237.2447	309.9318
	leafnu100	-23.78974	76.73154	1.000	-297.3780	249.7985
	leafnu150	-48.28976	76.73154	1.000	-321.8780	225.2985
leafnu100	leafnu0	60.13332	76.73154	1.000	-213.4549	333.7216
	leafnu50	23.78974	76.73154	1.000	-249.7985	297.3780
	leafnu150	-24.50002	76.73154	1.000	-298.0883	249.0882
leafnu150	leafnu0	84.63334	76.73154	.999	-188.9549	358.2216
	leafnu50	48.28976	76.73154	1.000	-225.2985	321.8780
	leafnu100	24.50002	76.73154	1.000	-249.0882	298.0883
leafnc5	leafnc0	18.34332	76.73154	1.000	-255.2449	291.9316
	leafnc10	-37.50868	76.73154	1.000	-311.0969	236.0796
	leafnc15	-45.87334	76.73154	1.000	-319.4616	227.7149
leafnc10	leafnc0	55.85200	76.73154	1.000	-217.7362	329.4402
	leafnc5	37.50868	76.73154	1.000	-236.0796	311.0969
	leafnc15	-8.36466	76.73154	1.000	-281.9529	265.2236
leafnc15	leafnc0	64.21666	76.73154	1.000	-209.3716	337.8049
	leafnc5	45.87334	76.73154	1.000	-227.7149	319.4616
	leafnc10	8.36466	76.73154	1.000	-265.2236	281.9529
stemgu50	stemguo	2.42014	2.07153	.899	-4.2092	9.0495
	stemgu100	-2.34482	2.07153	.912	-8.9741	4.2845
	stemgu150	.43214	2.07153	1.000	-6.1972	7.0615
stemgu100	Stemgu0	4.76496	2.07153	.283	-1.8644	11.3943
	stemgu50	2.34482	2.07153	.912	-4.2845	8.9741
	stemgu150	2.77696	2.07153	.827	-3.8524	9.4063
stemgu150	Stemgu0	1.98800	2.07153	.958	-4.6413	8.6173
	stemgu50	-.43214	2.07153	1.000	-7.0615	6.1972

	stemgu100	-2.77696	2.07153	.827	-9.4063	3.8524
stemgc5	stemgc0	2.78532	2.07153	.825	-3.8440	9.4146
	stemgc10	-3.64150	2.74037	.832	-12.4113	5.1283
	Stemgc15	6.68846	2.74037	.224	-2.0813	15.4582
stemgc10	stemgc0	6.42682	2.74037	.263	-2.3429	15.1966
	stemgc5	3.64150	2.74037	.832	-5.1283	12.4113
	stemgc15	-1.71800	2.07153	.979	-8.3473	4.9113
Stemgc15	stemgc0	2.15850	2.07153	.739	-4.4708	8.7878
	stemgc5	-.62682	2.07153	.939	-7.2561	6.0025
	stemgc10	-4.26832	2.74037	1.00	-13.0381	4.5014
Yield u150	urea100	449.68750(*)	63.63305	.000	242.8302	656.5448
	urea50	1522.39500(*)	63.63305	.000	1315.5377	1729.2523
	control	1635.93750(*)	63.63305	.000	1429.0802	1842.7948
yieldu100	urea150	-449.68750(*)	63.63305	.000	-656.5448	-242.8302
	urea50	1072.70750(*)	63.63305	.000	865.8502	1279.5648
	control	1186.25000(*)	63.63305	.000	979.3927	1393.1073
Yieldu 50	urea150	-1522.39500(*)	63.63305	.000	-1729.2523	-1315.5377
	urea100	-1072.70750(*)	63.63305	.000	-1279.5648	-865.8502
	control	113.54250	63.63305	.572	-93.3148	320.3998
Yieldc15	comp10	128.12500	63.63305	.436	-78.7323	334.9823
	comp5	1184.43750(*)	63.63305	.000	977.5802	1391.2948
	control	1520.31250(*)	63.63305	.000	1313.4552	1727.1698
Yieldc10	comp15	-128.12500	63.63305	.436	-334.9823	78.7323
	comp5	1056.31250(*)	63.63305	.000	849.4552	1263.1698
	control	1392.18750(*)	63.63305	.000	1185.3302	1599.0448
Yieldc 5	comp15	-1184.43750(*)	63.63305	.000	-1391.2948	-977.5802
	comp10	-1056.31250(*)	63.63305	.000	-1263.1698	-849.4552
	control	335.87500(*)	63.63305	.001	129.0177	542.7323

* The mean difference is significant at the .05 level.

leafau →Leaf area of amaranth treated with urea
leafac→Leaf area of amaranth treated with compost
leafnu→ Leaf number of amaranth treated with urea
leafnc → Leaf number of amaranth treated with compost

stemgu→stemgirth of amaranth treated with urea
stemgc→ stemgirth of amaranth treated with compost
Yieldu →yield of amaranth treated with urea
Yieldc → yield of amaranth treated with compost

PLATES

1 Amaranthus hybridus subsp. cruentus at 3 weeks after sowing

2. Amaranthus hybridus subsp treated with 150 Kg/ha

3. ***Amaranthus*** **hybridus subsp.*cruentus*** **treated with 100 Kg/ha**

4. ***Amaranthus*** **hybridus subsp.*cruentus*** **treated with 50 Kg/ha**

5. ***Amaranthus* hybridus subsp.*cruentus* treated with 10 t/ha**

6. ***Amaranthus* hybridus subsp.*cruentus* treated with 5 t/ha**

7. ***Amaranthus* hybridus subsp.*cruentus* without fertilizer**