



Comparing the Nutrient Uptake of *Amaranthus hybridus* L. subsp. *cruentus* (L.) Thell. and *Hordeum vulgare* L. on Different Soil Types

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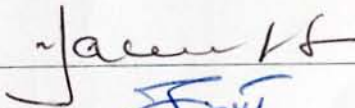

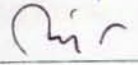
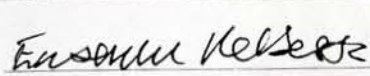
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ABSTRACT

The purpose of this study was to compare the nutrient uptake of *Amaranthus cruentus* and *Hordeum vulgare* on different soil types at Ziway. Minerals are essential for human nutrition and plant growth and development. Nutrient concentration in plants varies in many factors, including soil types. The impact of soil types on nutrient accumulation in amaranth and barley grown in high and medium productive soils and low or poor soil was studied. Treatments were laid out in factorial experimental design and replicated four times. Leaf samples both *Amaranthus hybridus* subsp. *cruentus* and *Hordeum vulgare* L. were collected at 50% flowering stage and analyzed for their macro and micronutrient content. The collected data was subjected to ANOVA. Significant difference between the means were separated using t test at $p < 0.05$. The results showed that the nutrient uptake of both *Amaranthus hybridus* subsp. *cruentus* and *Hordeum vulgare* L. increased with increasing order of soil productivity, high productive soil followed by medium productive soil and low productive soil. The contents of TN, P, Fe, Zn and Cu of amaranth grown in high productive soil, medium productive soil and poor soil were higher than those in barley grown in soils of similar productivity. On the other hand, the contents of Mn in amaranth grown in high productive soil, medium productive soil and poor soil were lower than those in barley grown in the same soils and differences were significant ($p < 0.05$).

Key words - nutrient uptake, *Amaranthus hybridus* subsp. *cruentus* and *Hordeum vulgare* L.

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CHAPTER ONE

1. INTRODUCTION

1.1 Background

Modern agriculture has grown to be a major contributor to the economy of the world. However, in many countries, it has not done enough in addressing key issues of hunger and malnutrition (Aphane *et al.*, 2003). One of the causes was increasing frequency of dry periods in many regions of the world and the problems associated with salinity in irrigated areas. Currently, 50% of all irrigation schemes are affected by salinity (Champagnol, 1979). Nutrient disturbances under both drought and salinity reduce plant growth by affecting the availability, transport and partitioning of nutrients. However, drought and salinity can differentially affect the mineral nutrition of plants. Salinity may cause nutrient deficiencies or imbalances, due to the competition of Na^+ and Cl^- with nutrients such as K^+ , Ca^{2+} , and NO_3^- (Sanchez, and Miller, 1989).

Drought, on the other hand, can affect nutrient uptake and impair acropetal translocation of some nutrients (Grattan and Grieve, 1999). Despite contradictory reports on the effects of nutrient supply on plant growth under saline or drought conditions, it is generally accepted that an increased nutrient supply will not improve plant growth when the nutrient is already present in sufficient amounts in the soil and when the drought and salt stress is severe. A better understanding of the role of mineral nutrients in drought and salinity plants resistance will contribute to an improved fertilizer management in arid and semi-arid areas and in regions suffering from temporary drought. Resistant crops could alternatively play a major

role in alleviating problems associated with drought and salinity as they could supply enough protein, vitamins, calories and other nutrients needed in a balanced diet. Most indigenous and traditionally grown plant species could tolerate these conditions (Van den Heever, 1995; Allenman *et al.*, 1996).

Amaranth (*Amaranthus hybridus* subsp. *cruentus*) is an herbaceous annual with upright growth habit and dicotyledonous warm-season plant cultivated for both its seeds which are used as a grain and its leaves which are used as a vegetable or green. Both the leaves and seeds contain protein of an unusually high quality (Henry, 1985). The grain is milled for flour or popped like popcorn. The leaves of both the grain and vegetable types may be eaten raw or cooked. Amaranth is grown principally for vegetable use and has better tasting leaves than the grain types (National Research Council, 1984).

Amaranths are grown (0.5 to 2 m or 2 to 8 ft) and moderately branched from the main stem. They are indeterminate in growth habit, but may set seed at a smaller size during short days (National Research Council, 1984). Amaranth has a "**C-4**" **photosynthetic pathway** (along with such plants as corn and sorghum), which enables it to be uniquely efficient in utilizing sunlight and nutrients at high temperatures. It is more drought-resistant than maize and thrives in 30-35°C temperatures. It tolerates poor fertility and drought, although the tolerance mechanism is not well understood. Plant quality however, is poor under stressful conditions. Amaranth responds well to fertilizers (National Research Council, 1984).

Amaranth is not in the grass family, therefore is not considered a **cereal grain**. However, since it is used much like cereal grains, it is often called a **pseudocereal**. As with other small grains, amaranth may be processed in popped, flaked, extruded and ground flour forms. In Mexico, the popped amaranth confection, alegría is a popular favorite drink among locals and tourists alike. The flour or flaked forms are combined with wheat or other flours to make cereals, cookies, bread and other baked goods. Originally it was recommended that amaranth make up only 10-20% of the flour blend, but studies have shown that it can be blended at 50-75% levels and still maintains functional properties and flavor (Mwangi, 2003).

Barley (*Hordeum vulgare* L.) is one of the most important food crops in the highlands of Ethiopia, occupying about 12% of the total area of major cereal crops and accounting for 10% of the total annual cereal production in 1999 (CSA, 2003). In the Northern Highlands, barley grain is used for food, while its straw is used either for animal feed or for soil organic amendments. Barley yields are stagnant or declining in many parts of the highlands of Ethiopia (Chilot Yirga *et al.*, 1998), which could be the result of a decline in the natural supply of one or more crop nutrients. On the other hand, population is growing at an annual rate of 2.7% and land holdings in the area are less than 2 ha per household (CSA, 2003).

Barley (*Hordeum vulgare* L.) is one of the major cereal crops grown in Ethiopia. For millennia it has been supplying the basic necessities of life (food, feed, beverages and roof thatching) for many in the Ethiopian highlands. However, the ever-increasing human and livestock populations are places an increasing pressure on the resources in highland environments. Improving productivity and food security in these areas

has become imperative. Although Ethiopia is a centre of diversity for barley, most of the country's farmers still obtain very low yields due to a combination of genetic, environmental and socioeconomic constraints. Research has been on-going since 1955 to address these constraints and improve the livelihoods of farmers by increasing the production and productivity of barley. Over this period, barley research in Ethiopia, with the participation of all stakeholders, has generated appropriate production technologies that have improved production, supplied surplus produce to local markets and provided the malt processing industry with good quality malt barley grain. However, malt barley production in Ethiopia has not expanded as expected, despite the potential of the country to grow malting barley in both the quality and quantity required. Malt barley could serve as a source of cash income and would help to significantly improve the livelihoods of highland farm households (Fekadu & Parlevliet, 1997).

Barley has a wider ecological range than any other cereal because it is more adaptable than other cereals, tolerating many diverse environments except for acidic and wet soils (Young, 2001). Barley can be grown on soils unsuitable for wheat, and at altitudes unsuitable for wheat or oats. Because of its higher levels of soil salinity and drought tolerance another attractive trait is that it can be grown near desert areas (Duke, 1983) and similarly it can be cultivated in stressed areas where soil erosion, occasional drought or frost limits the ability to grow other crops (Berhanu Bekele *et al.*, 2005). This study was set up to investigate the soil nutrient extraction abilities of the two crops (*Amaranthus hybridus subsp. cruentus*) and (*Hordeum vulgare L.*) on different soil types.

1.2 STATEMENT OF THE PROBLEM

Hunger and malnutrition mostly experienced in developing countries, affect growth and development of children (Aphane *et al.*, 2003). Foods of animal origin, which are major sources of vitamins and proteins, are often too expensive for poor households (Aphane *et al.*, 2003; Wehmeyer and Rose, 1983), whereas vegetables that supply abundant amounts of protein, vitamins, calories and minerals, needed in a diet, could alleviate problems associated with malnutrition. However, harsh climatic and resource-poor conditions in most rural areas, where problems of malnutrition occur, make production of exotic vegetables difficult. More than 100 different indigenous species, including *Amaranthus sp.*, *Corchorus* genera, *Cleome gynandra*, grow well in such areas (Aphane *et al.*, 2003). They are popular to communities such as in former Transkei, South Africa, where their leaves were gathered from the wild, chopped and mixed with maize meal to prepare a traditional meal known as 'imifino' or 'isigwampa' (Wehmeyer and Rose, 1983). *Amaranthus* could be cultivated in areas of southern Africa where there is inadequate or unreliable rainfall (Jansen Van Rensburg *et al.*, 2004) but information on its fertility requirements is limited (Elbehri and Schmitt, 1993). Amaranth crop is found to be a good solution for food insecurity in developing countries. Barley is a great source of dietary fiber and actually contains both soluble and insoluble fiber. Soluble fiber is effective in lowering blood cholesterol and can reduce the risk of heart disease. Soluble fiber is also beneficial in slowing the absorption of sugar and reducing the risk for developing type 2 or non-insulin-dependent diabetes. The insoluble fiber found in barley may be beneficial in helping the body maintain regular bowel function. Insoluble fiber may also help

lower the risk for certain cancers such as colon cancer. This research was done by growing amaranth (*Amaranthus hybridus subsp. cruentus*) on different soil types and comparing it with barley, to get information about its nutrient uptake and how it is good in nutrition value comparing it with barley (*Hordeum vulgare L.*) in south Ethiopia.

1.3 OBJECTIVE OF THE STUDY

The main objective of the study was:

1.3.1 Main objective

(a) To compare the nutrient uptake of amaranth (*Amaranthus hybridus subsp. cruentus*) with barley (*Hordeum vulgare L.*) on different soil types.

1.3.2 The specific objective were

(a) To determine the nutrient uptake of *Amaranth* (*Amaranthus hybridus subsp. cruentus*) in Ethiopia.

(b) To determine the nutrient uptake of barley (*Hordeum vulgare L.*) in Ethiopia.

(c) To evaluate the effects of different soil types on nutrient uptake of *Amaranth* (*Amaranthus hybridus subsp. cruentus*) and barley (*Hordeum vulgare L.*).

CHAPTER TWO

2. LITERATURE REVIEW

2.1. About Amaranth (*Amaranthus hybridus* subsp. *cruentus*)

Originating in the Americas and Europe, amaranth has been cultivated for more than 8,000 years, dating back at least to the Mayan civilization of South and Central America (Brenner et al., 2000). Amaranth consists of 60-70 species, 40 of which are considered native to the Americas. Over 400 varieties within these species are found throughout the world in both temperate and tropical climates and fall roughly into one of four categories: grain, vegetable, ornamental or weed. Vegetable amaranth has been used in China for over 400 years, yet is commonly found in the Caribbean and Africa. Grain amaranth was cultivated and revered by the Aztecs in Mexico, the Mayas in Central America and the Inca in South America (Jansen van Rensburg *et al.*, 2004). Of the various species of amaranth, 3 have been selected over the years as the choice for human and animal consumption. *A. hypochondriacus* (prince's feather) and *A. cruentus* (purple amaranth) are commonly grown for grain and *A. tricolor* (tampala) is grown primarily for the leaves. A fourth, *A. caudatus* (love-lies-bleeding) is a third type of grain species, although is often grown more as an ornamental. When used as a grain type, *A. caudatus* varieties are best adapted to the tropical highlands. Other vegetable amaranths are represented by *A. dubius*, *A. blitum* and *A. cruentus* (purple amaranth) (Jansen van Rensburg *et al.*, 2004; National Research Council, 1984).

All the cultivated amaranths are considered underutilized crops and received little research attention. Grain amaranths 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 (Makus, 1984).

Amaranthus hybridus subsp. *cruentus* is extensively cultivated; and due to its early maturity and ability to survive when grown with other arable crops, remains the most preferred crop by many farmers for timely revenue generation. *Amaranthus cruentus* is produced under different cropping systems in home gardens, farms, inland valleys (*fadamas*) and peri-urban garden. About 30-40% of total *A. cruentus* production by individual farmers is used for family consumption while the rest is marketed (Denton, 1996).

The most optimal soil for amaranth is humid and well-structured soils but the crop tolerates any soil conditions. Amaranth is thermophilous plant and especially for germination higher temperature of soil is necessary; otherwise older plants tolerate even short-term frost. This crop is resistant to drought thus it does not require as much moisture as other crops. The only exception is germination stage and first couple of weeks in growing season until strong root system is established. Dry and warm weather is welcome at harvest time to press losses of crop on minimum (Pernarrieta, 2008).

Amaranth grain maintains a high protein content, averaging 15 grams per 100 grams dry weight (moisture content of about 10% for whole grain) across the three cultivated species, and compares well with conventional grains. For example, wheat, maize, and rice average a protein content of 14, 9, and 7%, respectively (Senft, 1980).

More than quantity, amaranth grain is remarkable for its protein quality,

maintaining high levels of the essential amino acid lysine, along with uncommon sulfur-containing amino acids like methionine and cysteine. The diets of the malnourishes are often deficient in lysine and grain amaranth's amino acid constitution closely approximates the standard protein recommended by FAO/WHO for optimum human nutrition (Denton, 1996).

Amarantus cruentus contains relatively high amounts of Fe and Ca and is also high in magnesium, phosphorus, and potassium. It's also the only grain documented to contain vitamin C. Very little research has been conducted on amaranth's beneficial properties, but the studies that have focused on amaranth's role in a healthy diet have revealed three very important reasons to add it to human diet. When compared with other vegetables, its leaves are eaten as vegetable when boiled. It is a hebecaceous plant used for culinary purposes. It is used to improve the quality of soups and also for its dietary potentials. Fresh vegetables are of great importance in the diet because of the presence of vitamins and mineral salt (USDA Research Service, 1999).

In comparison with common cereals, quinoa and amaranth have relatively high protein content with excellent composition of essential amino acids (Bressani, 1993) and (Repo-Carrasco, 2003). The essential amino acid composition of these crops is close to international standards on amino acid requirements (Repo-Carrasco, 2003). They are also good sources of dietary fiber and specific bioactive compounds (Peñarrieta, 2008) and Repo-Carrasco-Valencia R (2009).

The nutritive composition of vegetable amaranth has been extensively studied (Bressani, 1990) and tested for its conversion into fertilizers, there were no effects of

rate of manure application on N, P, K, Ca, Mg, and Zn composition of *Amaranthus* leaves at 30 DAT (date after transplanting). These results agree with those of Ore-Oluwa *et al.* (1981) who reported no effects of nitrogen on accumulation of Ca, K, N, Na, Cu and Zn in *Amaranthus* leaves. The concentrations of N, P, K and Mg in leaves of *Amaranthus* were lower than those reported by Makus (1984) and Mhlontlo *et al.* (2007) who conducted their studies under field conditions. The difference could be as a result of the photoperiod effect affecting the pot study commenced in January compared to the field studies that were established in December. 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.

When *Amaranthus* was intercropped with maize in the Ntselamanzi soil, under field conditions, both sole and intercropping systems responded significantly to manure at 30 and 60 DAT (date after transplanting). Cropping system did not affect fresh stem and shoot matter, and dry matter yield of *Amaranthus* both at 30 and 60 DAT (date after transplanting), and the trend could be explained by uptake of the different nutrients. Uptake of N, P, K, Ca and Mg increased with increase in manure application in both cropping systems. However, uptake of N, P, K and Ca of sole cropped *Amaranthus* grown with $\leq 2.5 \text{ t ha}^{-1}$ manure compared well to unfertilized control while manure rates $\geq 5 \text{ t ha}^{-1}$ resulted in uptake similar to NPK fertilizer by (Makus, 1984).

Another study conducted by Clark and Myers (1994) examined eight crops, namely soybeans and sorghum as traditional crops, and sunflowers, pearl millet, cowpeas,

mung beans (*Vigna radiata*), amaranth, and sesame (*Sesamum indicum*) as alternative crops. Stand establishment of all eight crops was good in the regular soil plot area. In the sandy plots, establishment was delayed by dry conditions until the first rainfall, which came a week after planting. Only amaranth germinated prior to rainfall, which was rather remarkable considering the very low moisture content in the seed zone of the sand. After rainfall, emergence was slow for some crops due to inconsistent planting depth in the sand. Ultimately, good stands were obtained of all crops except sunflowers and amaranth, which had partial stands. The partial stands of amaranth were probably due to the very dry seed zone conditions when the seed was planted, and began to germinate. Although some amaranth seedlings became established, other seeds probably only imbibed water, or barely sprouted, before running out of moisture. The other crop seeds which sat idle until the first rainfall a week after planting had much more moisture available during establishment. The tendency of amaranth seeds to imbibe moisture and start germinating even under rather limited moisture conditions has been noted in regular field plots, and is somewhat of a problem, occasionally leading to ragged stands, where some plants emerge quickly, and others emerge later after rainfall, or not at all.

2.2. Role of Amaranth in human health

Calcium, iron and zinc are essential minerals required for diverse physiological and biochemical functions. Milk and dairy products are good sources of calcium, while meat and meat products of iron and zinc. In many geographic areas, such as Peru, the consumption of these products is limited owing to economic and cultural factors. In South America about 65–75% of the population suffers from lactose intolerance and cannot consume dairy products (de Vrese, 2001). In Peru the consumption of

meat products is not widespread and iron deficiency anaemia is a prevalent nutritional problem (FAO. 2000). Zinc is the fourth most important micronutrient next to vitamin A, iron and iodine, and is receiving increasing global attention (Hemalatha, 2007). In developing countries, iron, zinc and calcium are mainly derived from food grains. Certain vegetable foods, like seeds and pulses, are good alternative sources of these minerals. The bioavailability of the minerals in plant sources is lower than that in animal sources, because of the presence of certain compounds, like dietary fiber, phytate and oxalate, which have negative effects on mineral absorption. In the case of iron, this mineral is present in foods in two different forms: heme iron (HI) and non-heme iron (NHI). The absorption of these forms of iron is different: HI is high and NHI is low. The cereals contain iron in nonheme form. NHI absorption is greatly influenced by interactions with enhancers and inhibitors (Kapanidis, 1995)

Increased food security for the targeted households and contributed for the reduction of child malnutrition by feeding amaranth grain as well as the leaves for lactating mothers of targeted beneficiaries children benefited a lot by getting more milk from their mothers than earlier. Pregnant women who used amaranth as food also witnessed the help of amaranth for their health improvement. (Hemalatha, 2007).

2.3 CISO Experience on Amaranth farming in Ethiopia

CISO (Community Initiative Society Organization) under its Secure Livelihoods Program has made great efforts to work with concerned bodies towards accelerating the improvement of livelihoods through research and sustainable intensification of agricultural production in Southern/Oromia Regional States and to share best practices, innovative ideas and lessons learned towards ensuring food security in the country through introduction and promotion of Amaranth. The certification of amaranth as national crop by Ethiopia Ministry of agriculture as national crop for commercial use as well as daily food consumption is the primary agenda for CISO. This will be granted after repeated field evaluation and after meeting the criteria set by the variety release committee of the country. To achieve the Amaranth crop introduction and promotion objective CISO took the first Amaranth initiative in Ethiopia starting from 2008 and making utmost efforts in collaboration with different development actors including DCA (Danish Church Aid).

In year 2009, CISO in collaboration with SNNPR (South Nation Nationality People Representatives) agriculture development bureau also undertook preliminary assessment in two districts of SNNPR where there is great potential for further promotion of the crop. The assessment report reveals that these districts are producing what they can consume themselves and small quantities for selling locally.

Continuing from the assessment, CISO has started introducing Amaranth in Sidama and Borena zone of Oromia in order to contribute for the livelihood improvement of the target community by introducing the multiple benefits of Amaranth. The

implemented grain Amaranth introduction project of Chuko, Hawassa Zuria (Dorebafano) of Sidama Zone and Abaya districts of Borena Zone achieved the following key results.

2.4 Barley (*Hordeum vulgare* L.) development in Ethiopia

Barley (*Hordeum vulgare* L.) is the fifth most important crop in Ethiopia after teff, maize, wheat and sorghum. It is believed to have been cultivated in Ethiopia as early as 3000 BC (CSA, 2003). It is cultivated in a wide range of environments, from high altitude areas (>3000 masl) to low-rainfall environments, including the Rift Valley. A long history of cultivation, together with wide agro-ecological and cultural diversity in the country, has resulted in a large number of landraces of the crop, which can adapt to different environmental conditions. Among the important traits that could exist in the landraces are earliness, high nutritional quality, disease and pest tolerance, tolerance to drought and other forms of a biotic stress, and characters useful for low input agriculture (CSA, 2003).

Barley holds a unique place in farming system in Ethiopia and various sources agree that it has been cultivated for at least the past 5000 years in the country (CSA, 2003). The first Ethiopians to have ever cultivated barley are believed to be the Agew people, in about 3000 BC (Zemedede Asfaw, 1996). Barley (*Hordeum vulgare*) is an important cereal crop grown by small-scale farmers for subsistence. Among the major cereals, barley ranks fourth in area and productivity and fifth in total production in Ethiopia. It is produced in all regions of Ethiopia, but the major producers are Shewa, Gojam, Arsi, Gonder, Wollo and Bale, from where more than 85% of the total production comes (Chilot Yirga *et al.*, 1998). In some parts of

Ethiopia, barley is produced twice annually (bimodal rainfall), i.e. during the main rainy season, *Meher* (from June to September), and the short rainy season, *Belg* (from February to April). *Belg* barley is important in Wollo, Bale and North Shewa. Although barley grows in areas between 1800 and 3000 masl, it is predominantly grown between 2000 and 3000 masl (Berhane Lakew et al., 1996). In high altitude areas above 2700 masl, traditionally known as *dega*, it may be the only crop grown. Barley has a number of attributes that makes it desirable among farming communities in the country because it is a source of food and suitable for the *Belg* season; it performs well in marginal areas; provides an earlier harvest than some other cereals; and requires low investment. It is grown in a wide range of agroclimatic regions under several production systems. At altitudes of about 3000 masl or above, it may be the only crop grown that provides food, beverages and other necessities to many millions of people.

The diversity of barley ecologies is high, with a large number of folk varieties and traditional practices existing in Ethiopia, which enables the crop to be more adaptable in the highlands (Fekadu Alemayehu, Berhane Lakew and Berhanu Bekele, 2002). According to Marlett (1991) barley is nutritionally superior to other cereals in providing essential nutrients in biologically available forms. In the last century, the use of barley as food has decreased compared with wheat because of lesser palatability, poor baking quality and inferior milling characteristics. Nowadays, barley is being used in different forms, such as popped grain, flakes, sprouts, barley starch and sweeteners, malt flour supplements, malted milk, infant food, barley tea or coffee substitute, and as a rice extender.

One of the areas where barley was grown in earlier times was Ethiopia (Pedersen and Eggum, 1983). Today, barley is consumed in many parts of Ethiopia, in various forms, including porridge, gruel, popped (roasted), fermented and unfermented thin bread. Additionally, barley is being used in the preparation of local and commercial alcoholic beverages.

2.5. Effect of soil types and plant development stages

The physical condition of soil has a major influence on the way chemical factors influence the nutrition of plants. Drainage as it affects aeration and soil moisture content is a key factor. The drier the soil, the more sulphur is oxidized to sulphate, the lower the pH drops, the higher the concentration (in solution) of hydrogen, aluminium, and ferric iron ions. The levels to which any of these components rise or fall depends upon the chemical nature of the parent material and upon the solubilities of the metals involved (Sparling, 1967).

Plants require a balanced supply of nutrients throughout their development. Generally, they accumulate most of their nutrients between flowering and ripening stages. Approximately 50 to 90 percent of N and P in the plant at flowering stage moves from the leaves and stem to the developing seed (Chapin and Wardlaw, 1988). Therefore, low nutrient uptake early in a plant's growth lowers nutrient quantity for the seed, affecting both yield and quality. In a nutrient uptake study on dry land spring wheat in Mandan, North Dakota, the time of maximum N accumulation depended on nutrient availability. The stands that received both N and P peaked in N accumulation during heading; those stands fertilized with only N reached peak accumulation during ripening; and those that were not fertilized were

still taking up N at maturity (Boatwright and Haas, 1961). Maximum P accumulation occurred by heading, independent of available N levels (Malhi *et al.*,2007).

Maximum K accumulation occurred just after flowering, or mid heading, in the Montana study (Malhi *et al.*,2007). In the Saskatchewan study, maximum K accumulation was reached slightly earlier, during flowering and early heading (Miller *et al.*, 1994). Unlike N and P, very little of the accumulated K is used for grain fill (less than 20 percent). Yet, K deficiency early in the growing season would limit N uptake and compromise yield and protein.

CHAPTRE THREE

3. AREA OF THE STUDY

The amaranth and barley experiments were conducted in Castel Winery at Ziway. The project site is located at Adami Tulu Jido Kombolcha Woreda found in East Shewa Zone of Oromia Region at 7°37'- 8°04' latitude north and 38°32' - 39°04' longitude east. The average elevation above the sea level of the Woreda is between 1500 to 2300 meters. The Wereda is bounded by Dugda Wereda in the North, Arsi Nagale in the south. The site can be accessed through an asphalt road that connects Addis Ababa and Awassa via Shashemene and Batu (ziway) town.

3.1 Climate

The average temperature of the Wereda varies between 15 - 25 °C and most of the land which is about 90% of the total area arid while 10% the total area is said to be semi arid. Even though the actual rain fall varies from place to place by average the annual rain fall of the Wereda is about 700 mm. The major meteorological parameters analyzed were rainfall, temperature (minimum and maximum), soil temperature and relative humidity. The record on rainfall data shows that the area

has uni-modal rainfall type. The heavy rain begins in the area during the June and lasts until beginning of September. The mean total annual rain fall in the area is 647.5mm. This value seems low as different researchers' estimated annual precipitation of the area using average results from different meteorological stations to be 730 mm/year (A.Dirbissa 2006).

As it can be seen from figure 1, the trend of both maximum and minimum temperature is similar for the station irrespective of the value. Minimum air temperature is similar during mid of July to mid of August during which the maximum air temperature shows least value. The highest temperature is in March (30.2 °C), and the lowest temperature is in December (11.5°C).

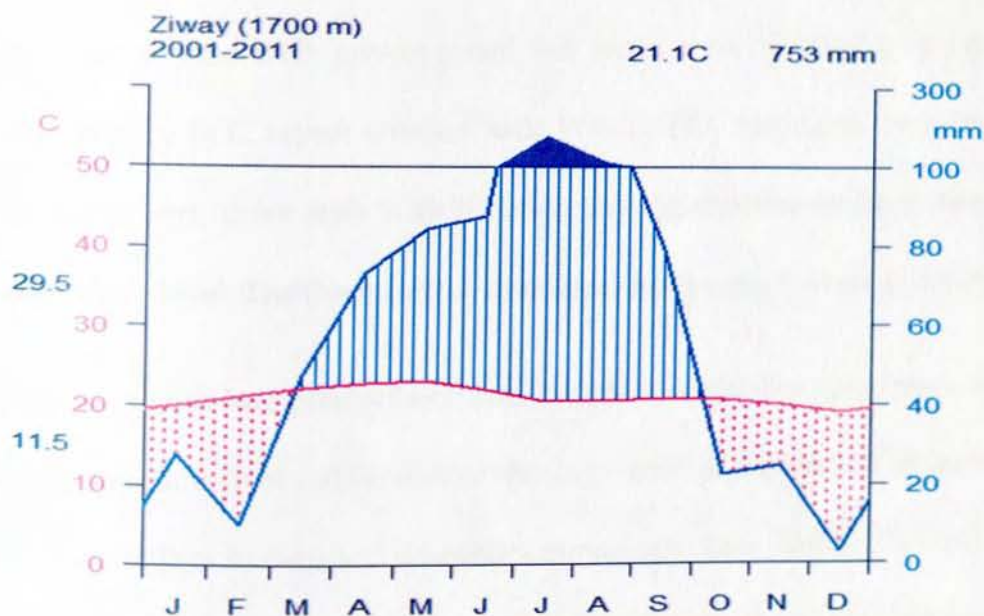


Fig 1. Mean monthly rainfall (mm) and temperature (°C).

In the study area, the natural vegetation is relatively fragmented and modified by man. This has reduced the types and the numbers of species that presently exists in the area. Currently, the major vegetation types observed in the Project Site is dominated by (i) *Acacia* woodland, (ii) *Lantana camara-Cactus* shrubland, (iii) Riverine vegetation, and (iv) Grassland.

3.2 MATERIALS AND METHODS

3.2.1 Treatments and experimental design

Three soil types were selected for the study. The experimental set-up was a factorial experimental design replicated four times. The soil types were classified based on productivity level on study area.

3.2.2 Site and Soil type selection

Experimental sites with pre-proposed soil types were selected in presence of the Castle Winery PLC expert within Castle Winery PLC farmland. In communication with the expert, three sites with different soil types were selected based on their productivity level. The three soil types selected for the study were as follow:

1. Soil site I with low productivity due to high vulnerability to erosion, compaction, salinization, and over cultivation of the farm with high nutrient demanding crops and as a result of human and domestic animals activities. Hence, this soil is believed to be degraded and deteriorated soil which has lost its quality and productivity. This can happen when the soil loses its nutrients, or its organic matter, when the soil structure breaks down, or if the soil toxified by polluted (Ange, 1992).

The soil type was obtained from a farm where at the beginning Castel Winery PLC used to cultivate corn. The site that contained poorly productive soil (Soil site I) used for the experiment was selected based on the following criteria.

- A. The farm land used to be frequently cultivated with Maize without the application of crop rotation. It is believed that maize by its nature is heavy feeder so depletes nutrients from the soil (Ange, 1992).
- B. The plots are termed as degraded because the top soil was excavated by heavy machinery for canal construction and due to this the fertility of the soil is highly reduced.



Plate 1. Low productive soil

2. Soil site II was selected from a normal land where cultivation was not practiced. It was, therefore, considered to be medium productive soil. When it was compared with soil type I, the soil color could tell about the organic matter content, where the organic debris having light black color was dominant. The site was selected with deeper top soil and had less disturbance and with higher dead plant materials.

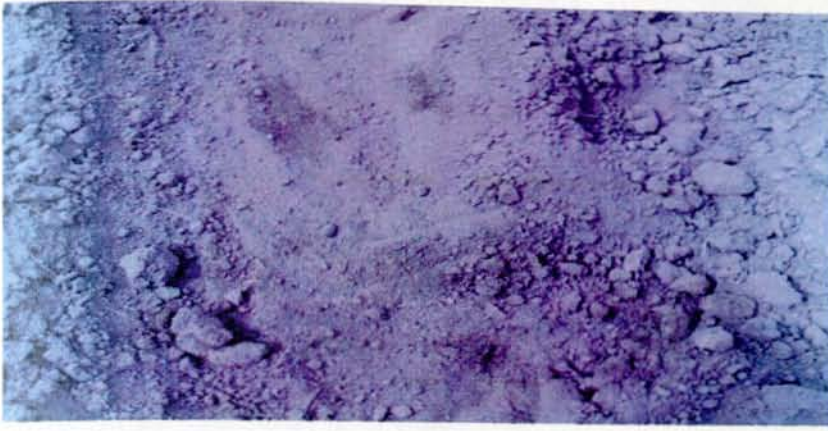


Plate 2. Medium productive soil type

3. Soil site III was highly productive because this soil was selected from the site where soil has been prepared by the company for their grape production. The soil was treated with compost and inorganic fertilizers with sufficient NPK.

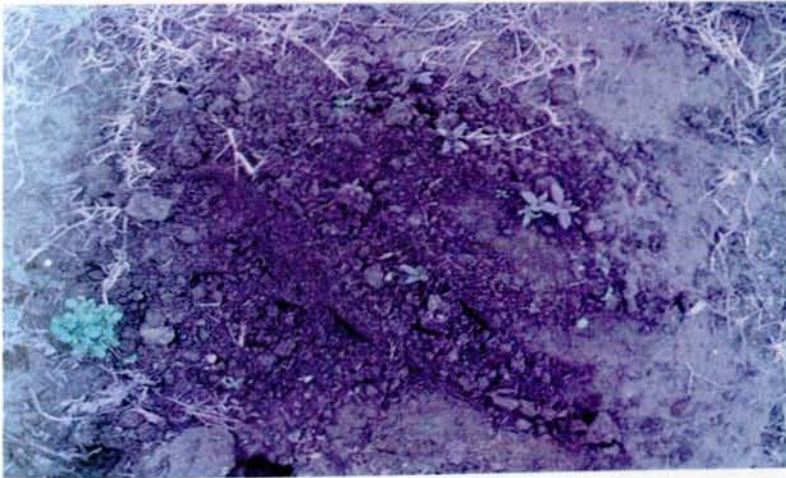


Plate 3. High productive soil type

Amaranth (*Amaranthus hybridus subsp.cruentus*) and Barley (*Hordeum vulgare L.*) were grown in 4mX4m plots having the three different soil types in 3² factorial experimental design with four replications under field condition.

Amaranth (*Amaranthus hybridus subsp.cruentus*) can be planted by direct seeding or transplanting (Palada and Chang 2003). The direct seeding method was used.

Amaranth (*Amaranthus hybridus subsp.cruentus*) and Barley (*Hordeum vulgare L.*) seeds were planted sequentially in each plot. Amaranth was sown on 18/01/2013 and barley was sown on 03/01 /2013 on each soil type following the previously described methods. The seeds were sown in rows spacing - 80cm in between; Seedling Distance - 50cm for amaranth and 12 - 18 cm apart in-row, then 24 cm between rows for barley . Watering was done every three days for three weeks since adequate watering is necessary for the newly plant seeds to emerge. After the seedlings develop, watering was done once a week for three weeks using water cans. *Amaranthus* seeds require well moistened soil to germinate in addition to the arid environment of our study area. Therefore, to reduce the evaporation rate, mulching was used. The practice of spreading plant residue or any other material like straw on the soil surface to reduce water evaporation is called mulching. Appropriate tillage and mulch practices are used to conserve soil moisture and increase the yield of crops (Tisdall and Adam, 1986). To attain the desired plant population densities, hand pulling of weeds was done in four week. Harvesting of amaranth was done on 10/04/2013 and also harvesting of barley was done on 28/04/2013. Grain yield for the different treatments were established by hand threshing. Seed yield was recorded by weighing the seeds in an electric weighing balance.

3.2.3 Soil samples collection and analysis

Surface (0-15cm) nine soil samples were randomly collected with auger before the experiment was conducted. The soil samples were air dried, crushed and sieved to pass through a 2 mm sieve after which physical analysis was carried out using the hydrometer method as described by Bouyoucos (1962). Total N was analyzed using the macro Kjeldahl procedure as described by Jackson (1958). Organic carbon analysis was done using the Walkley and Black procedure as described by Nelson and Sommers (1982). The organic matter content was derived by multiplying organic carbon content by 1.72. pH was determined by potentiometric and water extract. Available phosphorus was determined by vanadomolybdophosphoric acid and colorimetric as described by Bray and Kurtz (1945). Electrical conductivity (EC) was determined by conductometric and water extract. Exchangeable K, Ca and Mg were determined by extraction with 1 M ammonium acetate at pH 7.0 and the amounts of K, and Ca in the filtrate were determined using potentiometric method and a Corning flame photometer with appropriate filter, while Mg was determined by using a Perkin-Elmer Atomic Absorption Spectrophotometer (AAS). Micronutrients: Cu, Zn, Mn and Fe were determined by using AAS, and Effective cation exchange capacity (ECEC) of the soil samples was determined by flame photometry.

3.2.4 Plant Analyses

At 50% flowering, 25 amaranth leaves and 50 barley leaves were taken on each plot for nutrient determination. Mortar and pestle were used to grind the air dried leaf samples and sieved. The leaf samples were digested with a mixture of hydrochloric-nitric - perchloric acid (Tel and Hagarty, 1984). The nutrients were thereafter determined as described for soil.

3.2.5 Data analyses

A t-test was used to assess differences in concentration of nutrient on different soil types. A significance level of $P < 0.05$ was used through the study to compare the means between the different minerals.

CHAPTER FOUR

4. RESULTS

4.1. RESULT OF SOIL ANALYSIS

4.1.1 Physical and chemical analysis of soil samples

The results of soil analysis are presented in Table 1. The high productive and medium productive soils were sandy loam in texture, while the low productive soil was loamy sand. The values of soil pH showed variation with slight differences in the high and medium productive soils and low productive soil. In general, for all sampled field sites, soil pH values were above 8 and can be rated to range from slightly alkaline to strongly alkaline in reaction. In addition, the high productive soil had higher organic carbon, P and N content compared with medium and low productive soils. In fact, high content of P is a common characteristic of soils characterized by arid climates as in the present study area (Young, 1976). Thus, high concentration of P in soils could be an indication of soil fertility (Donovan and Casey, 1998).

The available K was similar at the two locations. Exchangeable base at high productive soil was higher than medium productive and low productive soils. Amount of exchangeable sodium was very high in all soil sample sites. In fact, high contents of Na would be expected in the low rainfall areas as in the study area, justifying the need for additional fertilizer input to boost crop yield.

In the study area, electrical conductivity was high. The absolute values varied between 246mS cm⁻¹ and 835mS cm⁻¹. This indicates that current as well as potential salt toxicity would be a problem in the study area. Therefore, soils of the farm under discussion, if not properly managed for irrigation of water, will face potential threat of salinity and sodicity due to the presence of high salt in the soil solution. The high CEC with high pH value of the present soils are expected to be high in fertility. The high CEC soils of the area present conducive conditions for land use, which means the capacity of the soils to fix and store nutrients is very good.

Table 1. Some physical and chemical parameters of studied soil

Soil types	High productive soil	Medium productive soil	Low productive soil
pH	8.2	8.19	8.7
Orgn.C (%)	1.5	1.4	0.8
Total N (%)	0.30	0.22	0.07
Ca (cmol+Kg-1)	15.25	13.66	12.44
Mg (cmol+kg-1)	1.94	1.87	3.68
K (cmol+Kg-1)	4.49	3.98	2.94
Na (cmol+Kg-1)	1.01	0.81	1.26
CEC (cmol+Kg-1)	19.54	18.72	16.7
Avail.P (mgkg-1)	59.99	41.82	8.37
Avail.k (mgkg-1)	4.28	3.97	3.53
EC(mS cm ⁻¹)	246	583	835
Physical characteristics of soil			

Sand (%)	78	75	82
Silt (%)	10	13	10
Clay (%)	12	12	8
Texture class	Sandy loam	Sandy loam	Loamy Sand

4.1.2 Concentration of trace elements in the three soil types

In the study area based on the environmental standards of the country (FDRE and UNIDO, 2003) or the established critical "threshold" level criteria, most of the trace elements are above the critical limits. The threshold limits are exceeded by the concentrations in the soils except for Zinc (Zn) and Copper (Cu) that are reported to be low. In other words, the micro nutrients are available in excess beyond the required level for the plant growth.

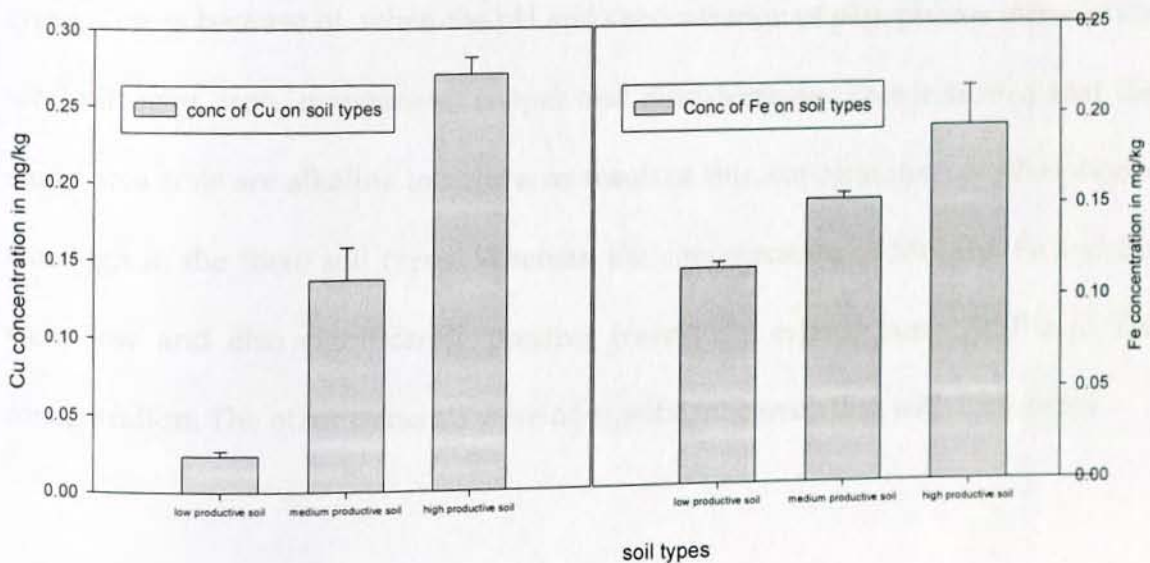


Fig 2. Concentration of Fe and Cu in the different soil types

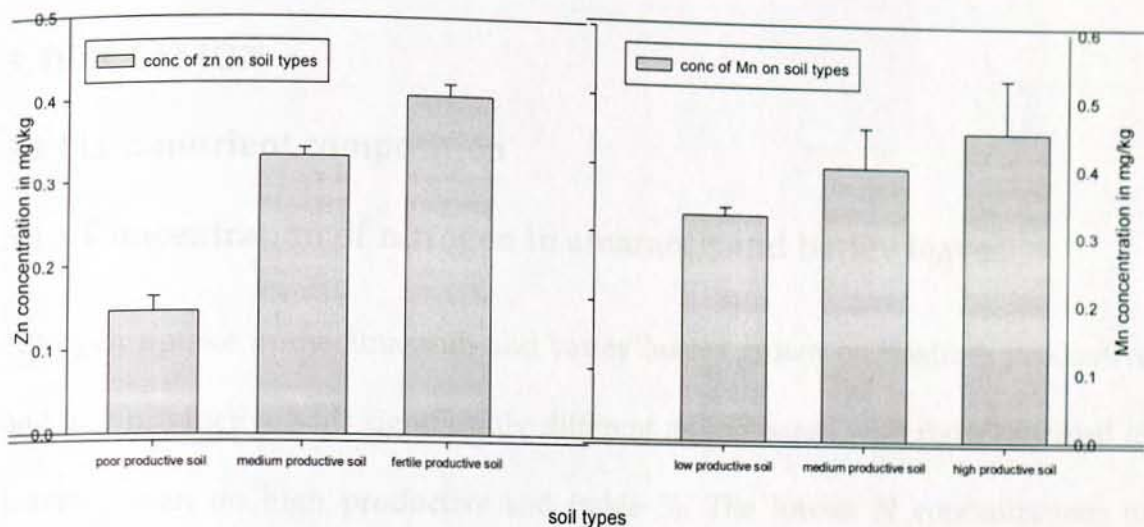


Fig 3. Concentration of Zn and Mn in the different soil types

4.1.3. Correlations among Nutrient concentration on the three soil types

The result of correlation indicates in table 2. Significantly positive correlation between pH and concentration of phosphorus and negative correlations existed between pH and total nitrogen, iron, manganese, copper and zinc in the three soil types. This is because of, when the pH and concentration of phosphorus increase the total nitrogen, iron, manganese, copper and zinc decrease. This indicated that the study area soils are alkaline in nature, as result of this, concentration of phosphorus was high in the three soil types. Whereas, the concentration of Mn, Cu, Fe and Zn were low and also significantly positive correlation existed between P and TN concentration. The other minerals were no significant correlation with each other.

CHAPTER FIVE

5. DISCUSSION

5.1 Plant nutrient composition

5.1.1 Concentration of nitrogen in amaranth and barley leaves

Nitrogen uptake in the amaranth and barley leaves grown on medium productive and low productive soils significantly different as compared with those obtained in leaves grown on high productive soil (table 3). The lowest N concentrations in amaranth leaves were obtained from plants grown on low productive soil followed by medium productive and high productive soils. Amaranth grown on medium productive soil had much similar nutrient composition with barley grown on the same soil types. Salinity can reduce N uptake in plants. This is not surprising since an increase in Cl^- uptake and accumulation is often accompanied by a decrease in shoot NO_3^- concentration. Generally, it was noted that amaranth leaves had a significant different on nitrogen uptake on the three soil types compared with barley.

Many scientists attributed this reduction of N concentration to Cl^- antagonism of NO_3^- uptake, while others attributed the response to soil types has effect on the uptake of nutrient (Alam, 1999). This study indicates that N uptake or accumulation in the leaves may reduce when the soil productivity decrease. The graph shows that the comparisons between N concentrations in amaranth on different soil types were higher than from N concentration in barley on different soil types as showed in the table 3.

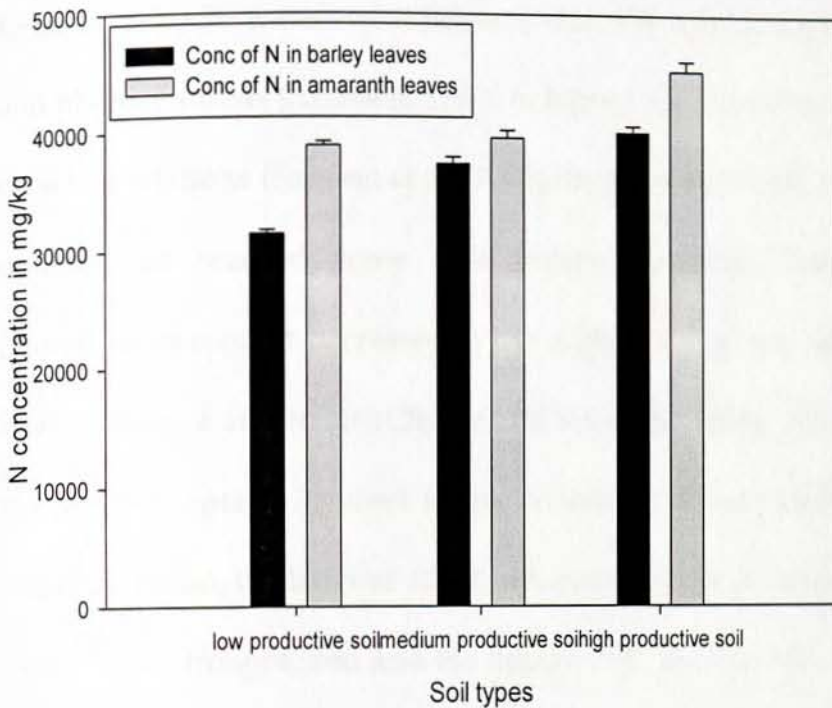


Fig 4. Concentration of nitrogen in amaranth and barley leaves

5.1.2 Concentration of phosphorous in amaranth and barley leaves

Although there were significant differences as showed in the table 3, at 50% of flowering stage on amaranth and barley growth on different soil types, phosphorous concentration (mg kg^{-1}) was found to be less in low productive soil than in medium and high productive soil. There was significant difference between phosphorous uptakes by amaranth and barley crops in different soil types. The uptake increased sharply with the soil productivity level, but the rate of P uptake showed a gradual decrease, this is because of plant accumulate more P on early flowering or heading stages than there maturity stage.

It is evident from the data that amaranth P concentration was better in high productive soil followed by medium productive soil and low productive soil than

barley. The positive effects of P on plant growth under drought have been attributed to an increase in water-use efficiency, stomatal conductance (Bagayoko et al., 2000), and photosynthesis (Ackerson, 1985), to higher cell-membrane stability, and to effects on water relations (Sawwan et al., 2000). In an earlier study, maximum phosphorous uptake was reached some time before maximum flowering stage and the phosphorous content decreased as the grain matured and then P was lost from the plant in case of all cereals (Chapin and Wardlaw, 1988). An important approach for increasing P uptake involves taking advantage of the symbiosis between the roots and mycorrhiza, the latter of which enhance both the growth and resistance of plants subjected to drought, and also the uptake of P, Zn, Cu, Mn, and Fe (Bagayoko et al., 2000).

The soil of the study area were high in phosphorous concentration as, it is evident from the summarized results in Fig 4, even in low productive soil, the amount of P uptake (mg kg^{-1}) by amaranth at 50% flowering stages increased significantly, with 95% confidence, in comparison with barley at 50% flowering stages in both, high and medium productive soils, there are significant differences ($P < 0.05$) in P uptakes by amaranth and barley crop in 50% flowering stage, with 95% confidentiality.

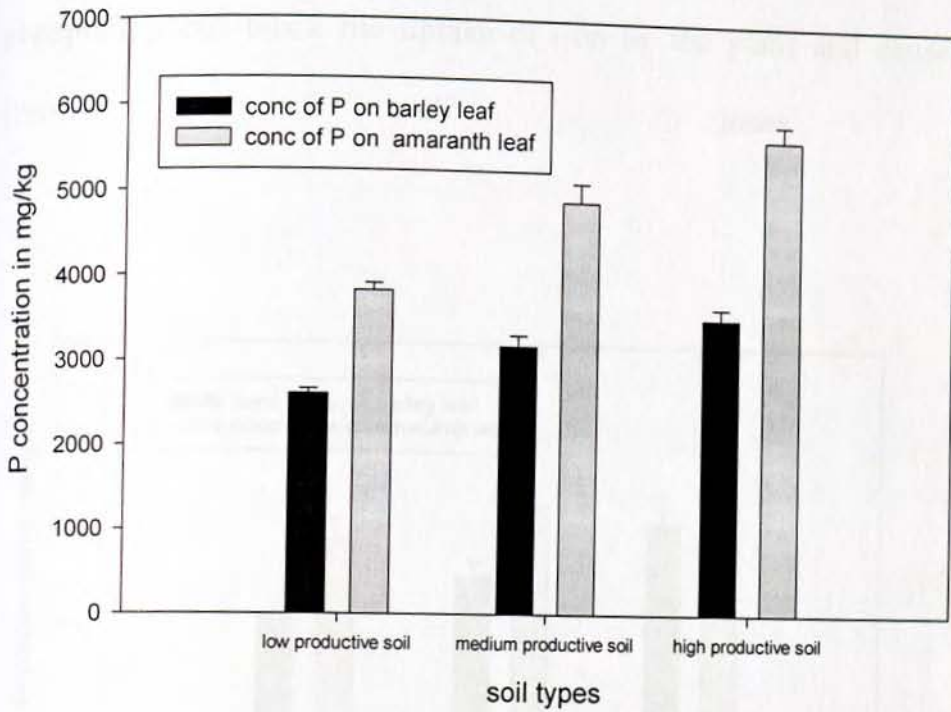


Fig 5. Concentration of Phosphorous in amaranth and barley leaves

5.1.3. Concentration of iron in amaranth and barley leaves

With regards to Fe uptake, the soil types had statistically significant differences in Fe concentration (mg kg^{-1}) in amaranth and barley leaves as showed in the table 3. There was higher Fe uptake in amaranth than barley at all soils, namely high and medium productive soils and low productive soil. Earlier studies by (USDA, 1999) confirm these results which stated that *Amarantus hybridus subsp.cruentus* contains relatively high amounts of Fe even when grown on poor soils. Generally, it was noted that amaranth leaves had a significant different on iron uptake on the three soil types compared with barley. Iron is a nutrient that all plants need to function. Many of the vital functions of the plant, like enzyme and chlorophyll production, nitrogen fixing, and development and metabolism are all dependent on iron.

Without iron, the plant simply cannot function as well as it should. Too much phosphorus can block the uptake of iron by the plant and cause leaf chlorosis (Brown and Jones, 2006).

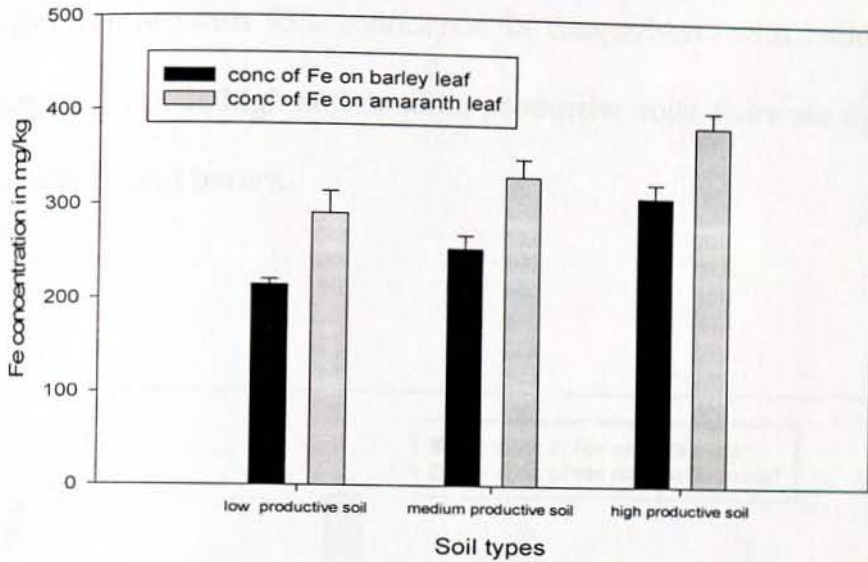


Fig 6. Concentration of iron in amaranth and barley leaves

5.1.4. Concentration of manganese in amaranth and barley leaves

Although there was a significant difference as showed in the table 3, at 50% of flowering stage on amaranth and barley growth, manganese concentration (mg kg^{-1}) was higher in low productive soil than in medium productive soil. The differences between manganese uptakes by amaranth and barley crop in different soil type's were significant ($p < 0.05$). It is evident from the data that Mn concentration in amaranth leaves was high in low productive soil followed by high productive and medium productive soils than barley. Manganese is involved in many biochemical functions, primarily acting as an activator of enzymes such as dehydrogenases,

transferases, hydroxylases, and decarboxylases in respiration, amino acid and lignin synthesis, and hormone concentrations (Pahlavan-Rad and Pessarakl, 2009), but in some cases it may be replaced by other metal ions (e.g., Mg).

As is evident from the summarized results in figure 6, in low productive soil, the amount of Mn uptake (mg kg^{-1}) by amaranth at 50% flowering stages increased significantly, with 95% confidence, in comparison with barley at 50% flowering stages. In both, high and medium productive soils, there are significant different in amaranth and barley.

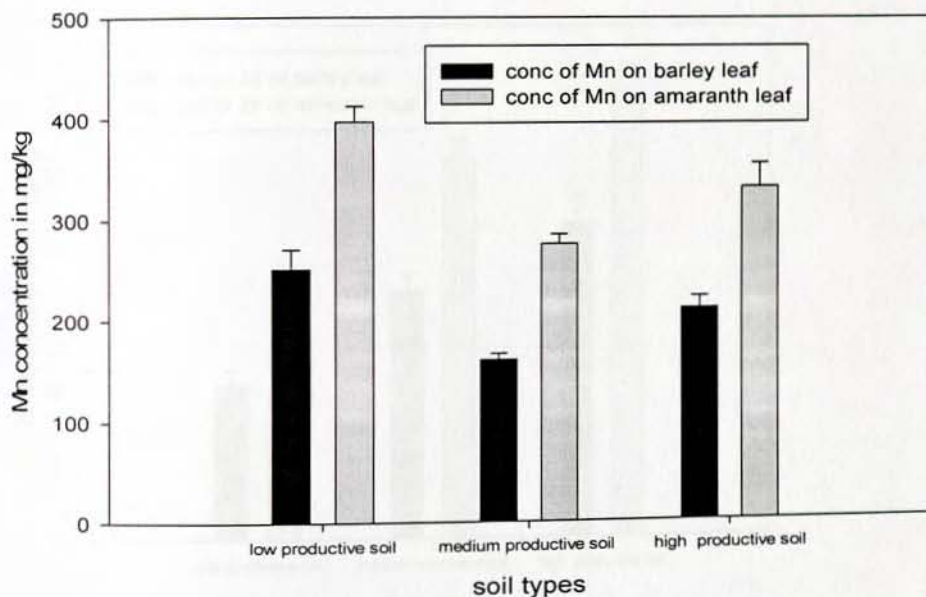


Fig 7. Concentration of manganese in amaranth and barley leaves

5.1.5. Concentration of zinc in amaranth and barley leaves

The data regarding the effect of soil types on zinc concentration (mg kg^{-1}) in leaves at 50% flowering indicated that soil types affected Zn uptake significantly as showed in the table 3 in amaranth and barley. The mean maximum Zn uptake was observed in

high productive soil and minimum in low productive soil on amaranth leaves and also in barley leaves. Mean maximum Zn concentration in amaranth leaves was observed in high productive soil, followed by medium productive soil and low productive soil at 50% flowering stages. Similar trend was observed in barley leaves at 50% flowering stages. These results showed that when soil productivity levels were increased also uptake of Zn significantly increased. Maximum Zn concentration was observed at 50% flowering stage of amaranth in high productive soil than barley and followed by medium productive soil. Similarly, minimum Zn concentration was observed in low productive soil in barley than amaranth.

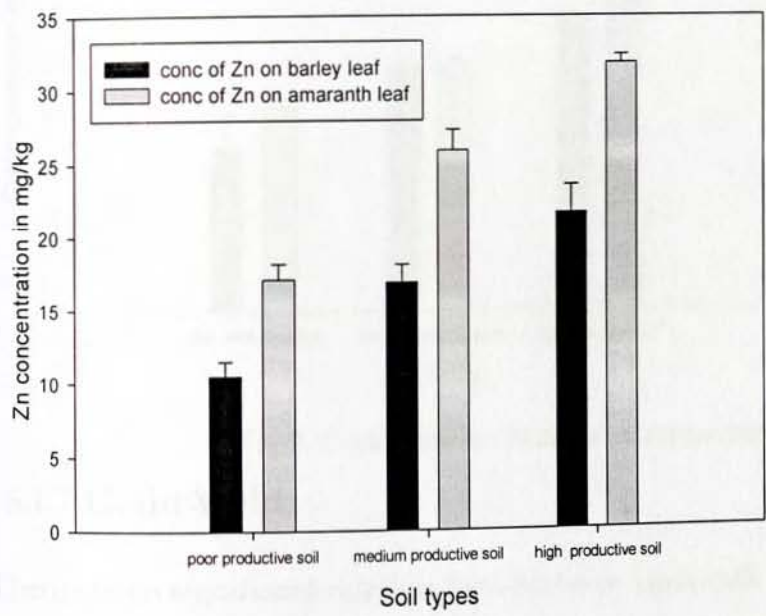


Fig 8. Concentration of zinc in amaranth and barley leaves

5.1.6. Concentration of copper in amaranth and barley leaves

The data regarding the effect of soil types on copper concentration (mg kg^{-1}) in leaves revealed that soil types had statistically significant effect on copper concentration in amaranth and barley leaves grown on high productive soil. At 50% flowering stages soil types had no significant effect as showed in the table 3 on Cu

uptake in low productive soil and medium productive soil, while significantly as showed in the table 3 in high productive soil in both amaranth and barley. The maximum copper concentration in leaves of amaranth was observed in high productive soil than barley. Minimum copper accumulation was observed in low productive soil on amaranth and barley. Similar results were found at medium productive soil at 50% flowering with amaranth and barley.

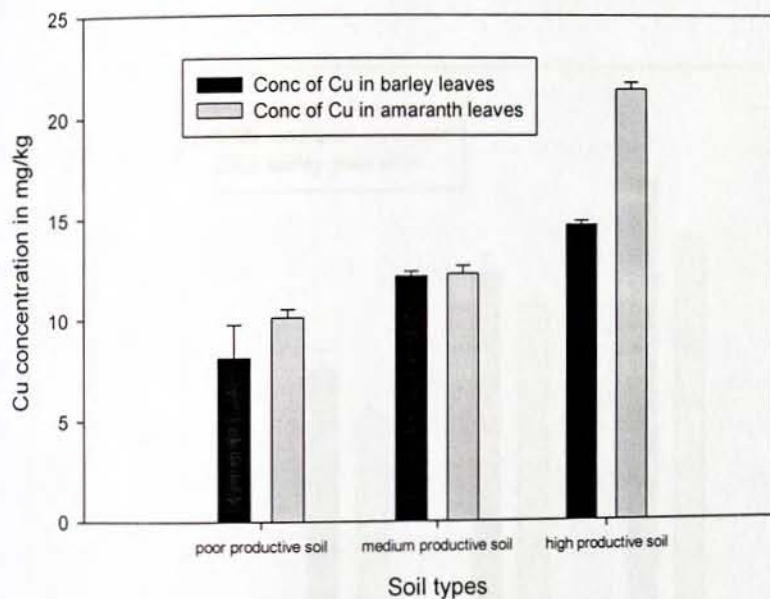


Fig 9. Concentration of copper in amaranth and barley leaves

5.1.7 Grain Yield

There are no significant relationships between amaranth and barley yield ($P > 0.050$). The yield responds positively to nutrient uptake and soil productivity as they both increased yield. The effect of increased nutrient uptake was observed to be more pronounced with increased soil productivity. Decreased nutrient uptake due to low soil fertility depressed yield. Grain yield of amaranth and barley were least with plants grown on low productive soil. High nutrient uptake on high productive soil resulted in highest yield in both amaranth and barley. Amaranth yield and barley yield were

least on low productive soil. Low productive soil, medium productive soil and high productive soil resulted in significantly ($p < 0.05$) lowest, moderate and highest grain yields. Grain yields of amaranth showed significant increase due to soil productivity at the 3 sites than barley. These yield responses underscore the significance of soil types in enhancing yield of amaranth and barley in the study area. The findings of (Barber, 1995), support that soil productivity enhances the yield of crops.

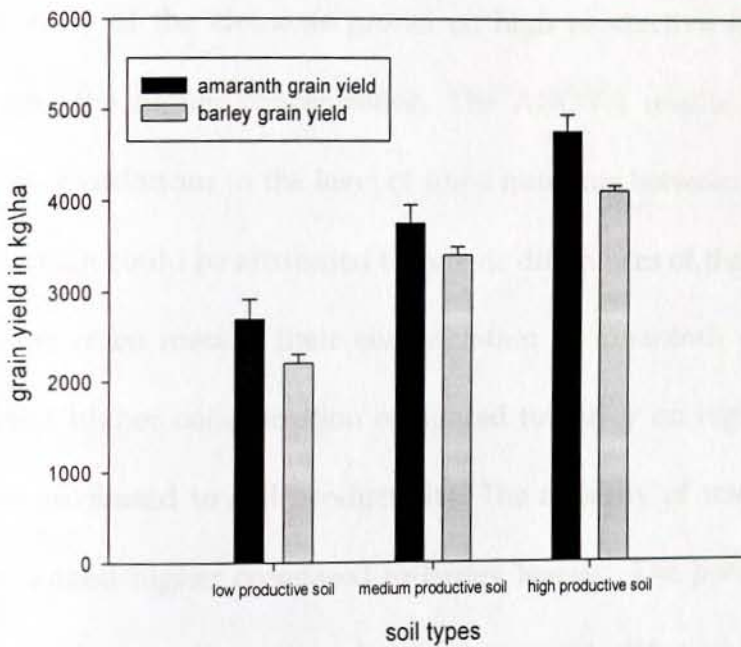


Fig 10 .Grain yield of amaranth and barley

5.2. Conclusions and Recommendations

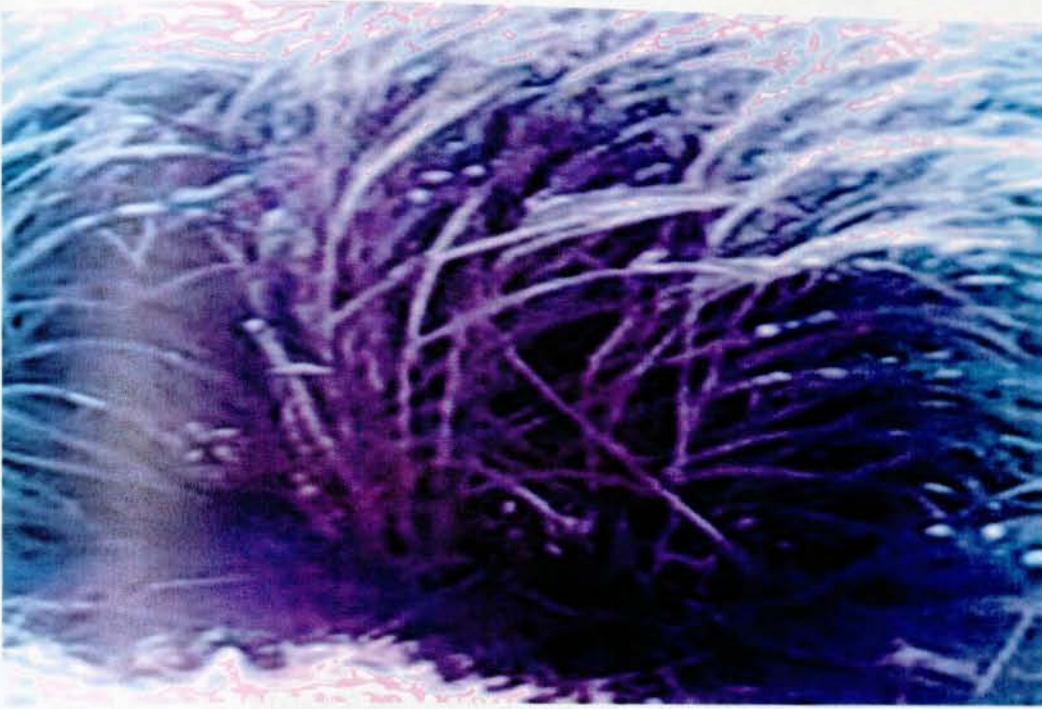
5.2.1. Conclusions

This study compares the nutrient uptake of amaranth and barley leaves on different soil types (high, medium and low productive soils) and the selected nutrients were analyzed. The results showed that both amaranth and barley contains appropriate concentrations of major, minor and trace metals. For the majority of the mineral nutrients, their concentrations were higher in amaranth compared to Barley and for the majority of the elements grown on high productive soil amaranth and barley contained the higher concentration. The ANOVA results suggest that there were significant variations in the level of some nutrients between the crops within the soil types, which could be attributed to genetic differences of the crops.

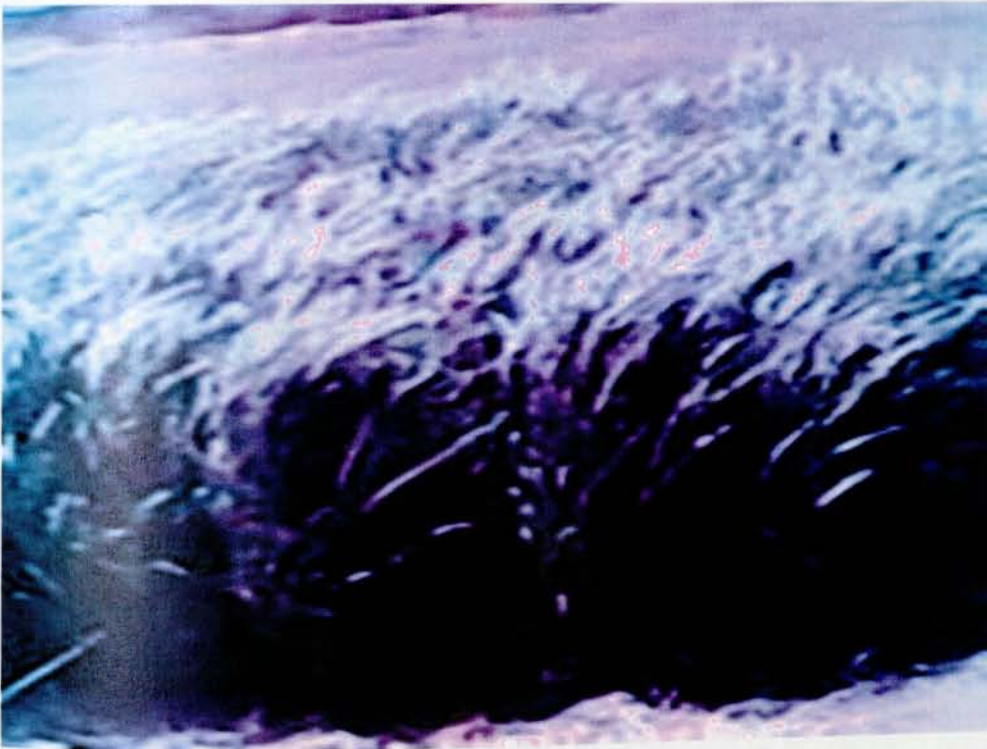
For some trace metals, their concentration in amaranth on high productive soil showed a higher concentration compared to barley on high productive soil, which may be attributed to soil productivity. The majority of trace elements in amaranth leaves ranged higher compared to barley leaves. The present study is believed to have give basic information about the nutrient status of amaranth and barley at different soil productivity conditions. To have complete and general information on amaranth and other crops further research should focus testing these at different parts of the region.

5.2.2. Recommendation

1. Although amaranth is known to be a low management crop that can grow in poor soil it needs good productive soil to get high yield and nutrient uptake.
2. Nutrient uptake and growth of amaranth on different soil types were the highest in comparison with barley on different soil types. Therefore, widespread use and acceptable productivity of amaranth can address the problem of food security in Ethiopia.
3. Additional experiments are needed to further evaluate the role of soil types on amaranth yield and nutrient uptake under more controlled conditions.



Plates 4. Barley grown on low productive soil



Plates 5. Barley grown on high productive soil

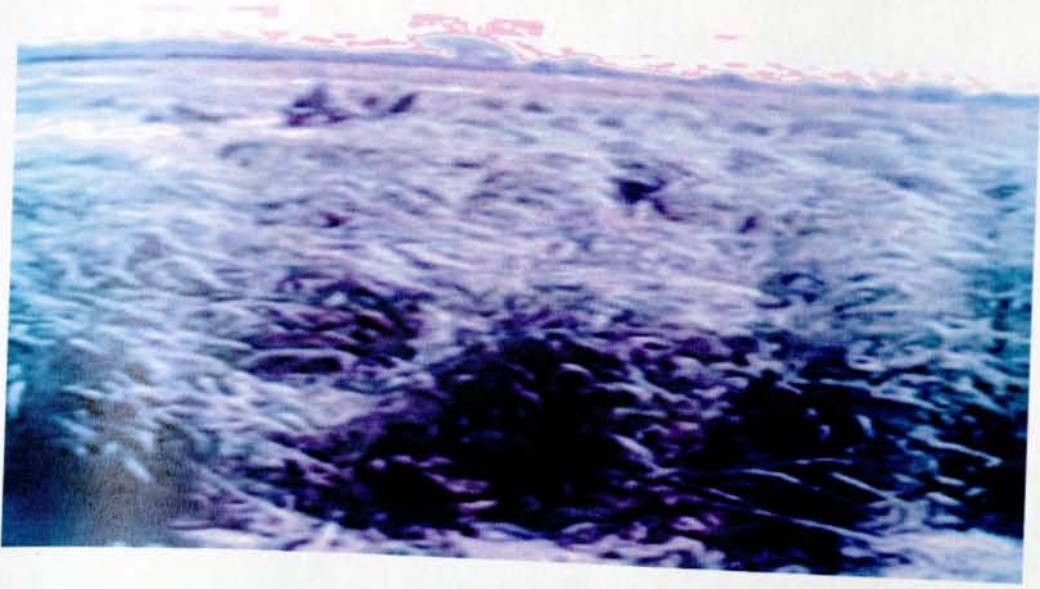


Plate 6. Barley grown on medium productive soil



Plates 7. Amaranth grown on high productive soil



Plates 8. Amaranth grown on medium productive soil



Plates 9. Amaranth grown on low productive soil

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Appendix

Table 2. Correlations between nutrients in the three soil types

Soil nutrients		TN	P	Mn	Fe	Cu	Zn	pH
TN	Pearson Correlation	1	.997(*)	.334	.993	.996	.943	-.989(*)
	Sig. (2-tailed)		.049	.783	.075	.053	.215	.045
	N	3	3	3	3	3	3	3
P	Pearson Correlation	.997(*)	1	.260	.981	.987	.966	.996(*)
	Sig. (2-tailed)	.049		.832	.124	.103	.166	.047
	N	3	3	3	3	3	3	3
Mn	Pearson Correlation	.334	.260	1	.442	.412	.002	.995(*)
	Sig. (2-tailed)	.783	.832		.709	.730	.998	.048
	N	3	3	3	3	3	3	3
Fe	Pearson Correlation	.993	.981	.442	1	.978	.898	-.985(*)
	Sig. (2-tailed)	.075	.124	.709		.061	.290	.046
	N	3	3	3	3	3	3	3
Cu	Pearson Correlation	.996	.987	.412	.978	1	.912	-.985(*)
	Sig. (2-tailed)	.053	.103	.730	.061		.269	.043
	N	3	3	3	3	3	3	3
Zn	Pearson Correlation	.943	.966	.002	.898	.912	1	-.992(*)
	Sig. (2-tailed)	.215	.166	.998	.290	.269		.045
	N	3	3	3	3	3	3	3
pH	Pearson Correlation	-.989(*)	.996(*)	-.995(*)	-.985(*)	-.985(*)	-.992(*)	1
	Sig. (2-tailed)	.045	.047	.048	.046	.043	.045	
	N	3	3	3	3	3	3	3

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

Table 3. Significant difference of nutrient for plant analysis

Significant difference table between nutrients on high productive soil					
Parameter I	Parameter J	Mean Difference (I-J)	Stander error	sig	95% Confidence Interval
N barley	N amaranth	12.70223(*)	245.58083	.000	-872.7712
P barley	P amaranth	-1686.33330(*)	245.58083	.000	-2571.8067
Fe barley	Fe amaranth	332.78113(*)	245.58083	.000	-552.6923
Mn bareyl	Mn amaranth	330.43000(*)	245.58083	.000	-555.0434
Zn barley	Zn amaranth	56.4537(*)	245.58083	.000	-555.0434
Cu barley	Cu amaranth	-248.26780(*)	245.58083	.000	-1133.7412
Significant difference table between nutrients on medium productive soil					
N barley	N amaranth	-7.9777(*)	245.58083	.000	-954.9364
P barley	P amaranth	3097.59887(*)	245.58083	.000	2212.1254
Fe barley	Fe amaranth	-321.86223(*)	245.58083	.000	-1207.3357
Mn bareyl	Mn amaranth	-319.51110(*)	245.58083	.000	-1204.9845
n barley	Zn amaranth	-10.37443(*)	245.58083	.000	-895.8479
u barley	Cu amaranth	-195.63557	245.58083	.999	-1081.1090
Significant difference table between nutrients on low productive soil					
N barley	N amaranth	.48113(*)	245.58083	.000	-884.9923
P barley	P amaranth	4451.63217(*)	245.58083	.000	3566.1587
e barley	Fe amaranth	-76.53557(*)	245.58083	.000	-962.0090
In bareyl	Mn amaranth	126.81667(*)	245.58083	.000	-758.6568
barley	Zn amaranth	8.59110(*)	245.58083	.000	-876.8823
barley	Cu amaranth	-245.32667	245.58083	.996	-1130.8001