Leaf and Seed Yield Response of Vegetable Amaranths to Nitrogen Fertilizers Applications and Harvesting Frequency at Jimma, South West, Ethiopia

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ABSRACT

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1. INTRODUCTION

Amaranths are alternative crop species that are used traditionally for their food, fibber, fodder, oil or medicinal properties. They have an under-exploited potential to contribute to food security, nutrition, health, income generation and environmental services [1]. Amaranths are recommended as a necessary food source as they are accessible to low-income people, inexpensive and readily affordable for the majority of people in rural, peri-urban and urban areas, which may easily improve their food security and nutritional status [2]. Amaranths are the collective name for the domesticated species of the genus Amaranthus. Amaranth (Amaranthus spp) consists of about 70 species belonging to the genus of Amaranthus and the Amaranthaceae families [3]. Amaranths spp. are distributed worldwide with wider ecological adaptability to diverse agro-climatic conditions from the primary centres of diversity (Central and South America, India and South East Asia) and West and East Africa secondary diversity of the crop [4].

According to importance, Amaranths species can be categorized as a seed or a leafy vegetable for human food, animal forage and as an ornamental crop [5]. A.caudatus, A.cruentus and A. hypochondriacus are domesticated for seed production purpose whereas A. blitum, A. dubius, A. spinosus, A. tricolor and A. viridis are grown as leafy vegetables [1]. Amaranths have dual-purposes and yet no clear demarcation between leafy vegetable and seed types as their intended utilization depends on the producers' demand. Amaranths can be used in numerous recipes viz., popped amaranths snack, porridge, stiff porridge, chapatti or flat bread, bread, creamy soup, pancakes, cakes, scones, pizza [6]. Leaves can be used as greens in salads, boiled or fried in oil and mixed with meat or fish. Cooked greens can be used as a side dish in soups or as an ingredient in sauce and baby food [1, 3].

Amaranths has long been part of indigenous agriculture and is semi-domesticated in Ethiopia as a vegetable [7]. The crop has a wide-adaptability area and grows successfully in most agro-ecological zones of Ethiopia. The crop grows partly as a wild food crop and partly cultivated as a leafy vegetable by-resource poor farmers in southern Ethiopia. Benishangule Gumuz, Gambella and Oromia National Regional States were reported for Amaranths production and consumption [7]. Both seed and leaf yields are of interest when promoting the cultivation of Amaranths. Seed yields of 0.45-0.70 t ha-1 in lower rainfall areas and 0.90-2.0 t ha-1 under high rainfall or irrigated condition were reported using improved cultivar and good agronomic practices for East African regions [8, 9]. Alemayehu et al. [10] reported that the maximum yield in Mexico and Peru was 7 t ha-1, compared to 3 t ha-1 in Africa, including Ethiopia, a wide-adaptability-area

The cultivated Amaranths in Ethiopia are low yielding relative to their attainable leaf yield and seed yield. Seed yield is variable and depends on genetic or cultivar, environmental conditions and management practices, including planting density, nitrogen rate, harvesting frequency and sowing date [11]. Low leaf yield and poor crop growth are also ascribed to inappropriate sowing dates, plant spacing, harvesting interval and fertilizer application rates [10]. Among inorganic fertilizer, nitrogen is the first and most important inorganic fertilizer and primary macronutrient of plants, the supply of which can be controlled by growers. Amaranthus requires an ample supply of soil nutrients, especially N for its optimum growth. Adequate N supply is responsible for the dark green color of the leaves, vigorous growth, branching, canopy development, leaf formation rate and enlargement of the surface [12].

On the other hand, the harvesting interval between two leaf cuttings is crucial for the final leaf yield, because the leaves and buds left behind need time to accumulate dry matter. To achieve this, leaf harvesting every two or three-week interval was suggested [3]. However, it is not sure to adopt such tentative recommendations due to agro-climatic variability in growing regions. Thus, there is a need to carry out research to determine the effect of N levels and harvesting frequency practices that improve production of Amaranths under Jimma condition. In view of this, the objective of this study is to determine the effect of nitrogen levels and harvesting frequencies on leaf and seed yield and growth of Amaranth (Amaranthus cruentus L.) in southwest Ethiopia.

2. MATERIALS AND METHODS

The experiment was carried out at Eladale research site of Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) located in Ifa bula Kebele, Jimma City Administration found at 356 km on the Southwest of Addis Ababa and 7 km away Northwest of Jimma city. It is situated at 1710 m.a.s.l and at 7°33'N latitude and 36°57' E longitude in Jimma Zone, Oromia National Regional State. The mean annual maximum and minimum temperatures are 26.8 and 11.4°C and the mean annual maximum and minimum relative humidity are 91.4 and 39.92%, respectively. The mean annual rainfall of the study area is 1250 mm. The soil of experimental site is well-drained clay to silt clay with pH of 5.5. The most common and dominating soil type is Nitosol [13].

Amaranths seed was obtained from Asian Vegetable Research and Development Center (AVRDC) /African Regional Branch (Arusha, Tanzania). Treatments consisted of five levels of N (0, 34.5, 69, 103.5 and 138 kg N ha^{-1}) in the form of urea (CH_4N_2O, 46% N)[14] in combination with three harvesting frequencies (weekly, two weeks and three weeks) harvesting intervals until flowering stage. Harvesting begin three weeks after transplanting (WAT). Extending harvesting intervals beyond three weeks is not suggested as the leaves of Amaranths are not palatable for leafy vegetable purpose. MARC was tried to evaluate the cultivar over 16 locations across the country and they suggested that cultivar Madiira-2 is a promising. Know the Cultivar on the way for registration by MARC Vegetable Research Team. The treatments combinations are 5 x 3 = 15 treatment combinations, replicated three times and 45 observations with factorial arrangements in a Randomized Complete Block Design.

The field was cleared by removing all unwanted weeds (grasses, and plant debris) before ploughing. Then, the plot was ploughed twice to make fine tilt. Two seedling beds both having dimensions of 1.2 m x 5.0 m were harrowed using hoe, spade and rake. Seedling beds then divided into 15 cm row distance and seeds were sown on September 04, 2017 at a depth of 1.30 cm. Seeds were covered carefully with fine soil to facilitate good germination and seedlings emergence. Following this step beds were carefully covered with mulching grasses and immediately watered to enhance seeds germination. Right after about 10% of seedlings emergence mulches were removed and shade was constructed.

Seedlings were transplanted to experimental plots after 30 days. Individual plot size is 3.6 m x 2.7 m (8.1 m^2). Each plot consisted of five rows with 25 cm between plants and 60 cm between rows with a row length of 3.6 m. The distance between successive plots and adjacent blocks were 0.5 m and 1.0 m, respectively. The gross experimental area is 608.0 m^2. The different N levels (0, 34.5, 69, 103.5 and 138 kg N ha^{-1}) were applied to assigned plots in the form of Urea, 46% N using side-dressing method close to seedlings in two installments. The first installment was applied one WAT, while the remaining after two weeks. Single Super Phosphate (SSP) fertilizer was applied at the rate of 45 kg P_2O_5 ha^{-1} to all the experimental plots [16]. The plants were irrigated manually using a watering can. The field was weeded manually using a small hand hoe by two weeks intervals after transplanting until plant flowering.

For harvesting frequency assessment, the first harvesting started at 21 DAT. The plants were harvested every week, every two weeks and every three weeks as per treatment. The less severe harvesting procedure (topped by 25% of their heights) was made in all harvests. During the first harvest, the plants were topped by 25% of main stem height and afterwards all side-shoots longer than 3 cm were also topped in the same manner. Plants were harvested once when inflorescence change color to yellow for seeds yield carefully. The cut plants were threshed and seed cleaned. In the final harvest, the randomly selected aboveground plants were removed. The experiment was conducted from 04, September 2017 to 05, February 2018 under irrigated condition.

Before planting composite soil samples were collected from the experimental plots at the depth of 20-30 cm using an auger. The samples were mixed and air dried, sieved through a 2 mm sieve mesh. The composite samples were analyzed for selected physical properties (soil structure and texture) and chemical properties (total N, available P, pH, CEC, EC) (Table1.).

TABLE 1.SOIL PHYSICO-CHEMICAL PROPERTIES OF THE EXPERIMENTAL PLOTS BEFORE PLANTING

Property	Value	Rating	Reference
pH (1:2.5)	5.51	Moderately acid	Landon (1991)
Organic carbon (%)	2.8	Low	Hazelton & Murphy (2007)
Total N (%)	0.21	Medium	Bruce & Rayment (1982)
Organic matter (%)	2.6	Medium	Hazelton & Murphy (2007)

Available P (ppm)	4.7	Low	Hazelton & Murphy (2007)
CEC Molc/kg	16	Medium	Landon (1991)
Sand (%)	29		
Silt (%)	38		
Clay (%)	33		
Texture class	Clay loam		

Source: *JUCAVM soil laboratory*

2.1. Variables recorded

Data on plant growth, leaf yield and seed yield were recorded from ten randomly selected plants for harvesting from three middle rows of each plot.

Days to 50% flowering (day): The number of days from transplanting to the date when about 50% of plants in a plot begin to bloom were recorded.

Days to 50% maturity (day): The number of days from transplanting to the date when about 50% of previously randomly taken plants produce mature seeds were recorded.

Number of leaves per plant (harvested): Number of leaves per plant was determined by counting fully-grown leaves of randomly sampled plants per plot starting from three WAT until flowering stage, and the sum was used for analysis.

***Leaf area* (cm^2 plant^{-1}):** Leaves length in cm and width in cm were multiplied by a constant value (0.64) as described by Tongos [16] and the randomly sampled plants per plot starting from three WAT until flowering stage were determined and the mean value was recorded and calculated as follows:

Leaf area, LA (cm^2) = L (cm) x W (cm) x 0.64

***Leaf length (cm)*:** The measurement was done from base to tip of the leaf. Data were recorded as the average of 10 leaves taken from the randomly sampled and tagged plants from each plot starting from three WAT until flowering. The mean value was recorded and expressed in centimeter (cm).

***Leaf width (cm)*:** Leaf width was determined in a very similar fashion to leaf length but from left edge to right edge using a meter from three WAT until flowering.

Plant height (cm): Plant height was measured using a measuring tape from randomly sampled plants from the ground level to the tip or apex of the tallest stem of the plant at flowering (95 DAT) from each plot.

Number of branches per plant: It was determined counting fully grown branches per plant from the already randomly sampled plants per plot and average was recorded at flowering stage.

Above ground fresh biomass (g plant^{-1}): The total above ground fresh biomass yield from randomly sampled plants per plot were severed to the ground level and the plants' fresh biomass was weighed using sensitive balance model: KERN FOB 1.5 K 0.5 at full maturity stage of seed (when plant still green).

Above ground dry biomass (g plant^{-1}): Above ground dry biomass per plant (g) was recorded from randomly sampled fully-grown ten plants of central rows per plot, severed to the ground level at full maturity stage. Then, from these samples stems and leaves were separately prepared. These leaves and stems were chopped into small sized sample and dried using an oven-drying chamber as described by Olaniyi [26] at 65°C for 48 h. Thereafter, the above ground dry biomass plant^{-1} was determined using sensitive digital balance (model: KERN FOB 1.5 K 0.5).

***Dry matter content (%)*:** Dry matter content was quantified from mass of the randomly selected 100 g of (stem + leaf); stem samples separately sliced into very thin pieces were put into envelop along with the leaves and placed in oven maintained at 65°C for 48 h. The samples were allowed to cool down at room temperature. The sum of final (stem + leaf) mass of the samples were calculated. The dry matter content of (stems + leaves) was computed as described by Nizam [27] using the following formulae.

$$DMC\ (\%) = \{DB(\frac{g}{plant}) \div FB(\frac{g}{plant})\} \times\ 100$$

Where, DMC = the dry matter content of plant, DB = the dry biomass of plant, FB = the fresh biomass of plant.

Leaf yield (g plant $^{-1}$and t ha^{-1}): Leaf yield was determined separately according to harvesting frequencies treatments by considering the fully expanded tender leaves starting from three WAT until final leaf harvesting date. The average sums of all harvesting frequencies record for leaf yield [28].

Seed yield (plant $^{-1}$and t ha^{-1})**:** Seed harvesting was undertaken when inflorescences change to yellow color [28]. Inflorescences of each plant were severed, threshed and seeds cleaned. Winnowing was performed to remove any shriveled and underdeveloped seeds to obtain clean seeds. Seed yield of different plots was established by hand threshing using work gloves, then drying inflorescences in sisal sacks. Seed yield was determined from randomly collected fully matured ten previously taken plants of the central rows using sensitive balance (model: KERN FOB 1.5 K 0.5).

Thousand seed weight (g): After the seeds were collected from the sampled plants, sun dried and thousand seeds were counted using seed counter machine known as Cantador 2 manufactured by *Pfeiffer* company having a model 230 V/50 Hz (24 V). Then, thousand seed weight was weighed using sensitive digital balance (model: KERN FOB 1.5 K 0.5).

2.2. Data Analysis

All data were first checked for normality test and then analysis was preceded. The gathered data on different growth, leaf and seed yield variables were subjected to Analysis of variance (ANOVA) using SAS version 9.3 Statistical Analysis Software. All pairs of treatment means were compared using Least Significant Difference (LSD) test at 5% probability level. Correlation analysis among growth, leaf and seed yield variables were performed

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3. RESULTS AND DISCUSSION

3.1. Days to 50% flowering

The effect of N levels and harvesting frequency significantly (*P<0.05*) influenced days to 50% flowering. Delayed days to 50% flowering (97.33 day after transplanting) was recorded with application of 138 kg N ha^{-1} and two weeks harvesting frequency. This result is statistically at par with application of 103.5 kg N ha^{-1} and two weeks harvesting frequency, 138 kg N ha^{-1} and 103.5 kg N ha^{-1} and weekly harvesting frequency. Earlier days to 50% flowering (71 DAT) was recorded with 0 kg N ha^{-1} and weekly harvesting frequency, which is statistically in parity with no N application and two weeks and every three weeks harvesting frequencies (Table 2).

Application of 138 kg N ha^{-1} and two weeks harvesting frequency delayed the number of days to 50% flowering by 16 days compared to 0 kg N ha^{-1} and weekly harvesting interval. This significant difference (*P<0.05*) is probably due to increased plant vegetative growth and prolonged flowering as a result of increased application of N. The present finding is in line with this finding, Ainika *et al.* [29] reported, application of 50 kg N ha^{-1} significantly increased the vegetative growth and development of seed amaranths. In contrast to this finding Masvanhise [30] reported that application of N fertilizer has no significant effect on days to 50% flowering probably because of contribution of inherent soil fertility.

In this study, except 0 kg N ha^{-1} regardless of N levels relatively extended flowering days was recorded with two weeks harvesting interval whereas shorter flowering days observed with every three weeks harvesting interval. According to Iftikhar *et al.* [31] harvesting frequency also affected days to 50% flowering via removal of apical dominances of the central stem promoting vegetative growth. This enhances vegetative growth resulting in delayed flowering which might be attributed to pinching altering the source-sink relationship thereby advancing the reproductive phase [32]. The present finding is in conformity with the work of Love [33] who reported that harvesting frequency delayed flowering of amaranths and plants that were not harvested frequently took the least number of days to flowering compared with frequently harvested plants.

3.2. Days to 50% physiological maturity

The number of days from transplanting to the date when about 50% of plants in a plot produce mature seeds termed as days to 50% physiological maturity. Significant differences ($p<0.05$) due to N levels and harvesting frequencies were observed among treatments. Longer days to 50% physiological maturity (DPM) of 124 days was recorded with 138 kg N ha^{-1} and two weeks harvesting interval while shorter DPM of 96 days was registered with 0 kg N ha^{-1} and weekly harvesting interval. Delayed DPM was registered both in 138 and 103.5 kg N ha^{-1} at two weeks harvesting interval which is statistically at par. Significant delay in DPM is due to high N levels (138 and 103.5 kg N ha^{-1}) which increased vegetative growth. Shorter DPM of 96-101 days were registered with 0 kg N ha^{-1} and all harvesting treatments and 34.5 kg N ha^{-1} and weekly harvesting interval which are statistically in parity (Table 2).

This finding in line with the work of Jasso-Chaverria *et al*. [34], who ascribed that N deficiency results in a poor growth rate, early maturity and shortened vegetative growth phase. When the plants are N deficient they mature quickly, which is one of escape mechanism of plant from non-conducive condition for normal growth. Mohil and Jain [35] reported that amaranths yield respond to improved N application, high rates of N fertilizer can affect seed harvest in place of excessive plant height, increased lodging and delayed crop maturity.

On the other hand harvesting frequency also prolonged DPM by promoting vegetative growth when heavily fertilized with N (both in 138 and 103.5 kg N ha^{-1}). Similar findings were reported by [36, 37] where the result indicated that multiple harvests prolonged the vegetative growth phase.

3.1. Number of leaves per plant

The influence of N application and harvesting frequency were highly significant ($p<0.01$) for number of leaf per plant. Application of 138 kg N ha^{-1} and two weeks harvesting frequency registered highest number of leaves per plant (301), which is statistically at par with 103.5 kg N ha^{-1} and two weeks harvesting frequency. Minimum number of leaves per plant (70.67) was recorded with 0 kg N ha^{-1} and weekly harvesting interval, which is statistically at par with 0 kg N ha^{-1} and two weeks harvesting frequency and 0 kg N ha^{-1} and every three weeks harvesting interval (Table 4).

As the level of N increased number of leaves per plant increased due to the ability of N that promoted leaf yield via cell division and elongation [38]. The result is inconformity with this finding indicating role of N in promoting vigorous vegetative growth in leafy amaranths. Ayalew [14] also reported that amaranthus received 69 kg N ha^{-1} produced the highest number of leaves was obtained compared to amaranthus that received no fertilizer produced the least leaves number per plant at 4, 6, 8, 10 and 12 weeks after sowing respectively. Maseko [39] reported that as the rate of N level increased from 0 kg to 44 kg N ha^{-1} *A. cruentus* leave number was also increased.

Number of leaves per plant significantly increased with two weeks harvesting frequency, cutting the leaves with tender shoot two weeks produced the highest number of leaves per plant with all N levels followed by weekly harvesting interval but the numbers gradually declined when the cutting frequency was decreased to every three week. This is because the crop cannot fully open more number of leaves in one week and low yield from the three weeks harvesting interval is also attributed by the fact that some of the leaves produced between harvesting intervals would surpass the consumable stage before the next harvest. Because of only young and tender leaves are consumed as vegetables. Increased number of leaves also due to harvesting was removing of terminal buds which increase vegetative growth. The present finding (high leaves number from two weeks harvesting interval) is in line with work of Materechera and Medupe [40] who showed that frequent harvesting increased leaves number but decrease leaf size and the leave were unmarketable with weekly harvesting frequency. Isah *et al.* [41] also reported that pinching increased leaves number per plant.

TABLE 2: EFFECT OF N FERTILIZER AND HARVESTING FREQUENCY ON DAYS TO 50% FLOWERING (DTF) AND DAYS TO 50% PHYSIOLOGICAL MATURITY (DPM)

Treatments		Variables	
N	HF	DTF	DPM

0	Weekly	71.33^{g}	96.00^{f}
	Two weeks	73.00^{g}	99.66^{f}
	Every three weeks	73.66^{g}	99.66^{f}
34.5	Weekly	83.33^{ef}	101.00^{ef}
	Two weeks	91.00^{bc}	108.66^{d}
	Every three weeks	81.33^{f}	105.00^{de}
69	Weekly	86.00^{de}	109.00^{d}
	Two weeks	91.33^{bc}	116.33^{c}
	Every three weeks	81.33^{f}	106.33^{d}
103.5	Weekly	93.33^{abc}	115.66 ^{c}
	Two weeks	96.33^{a}	122.00^{ab}
	Every three weeks	86.33^{de}	108.66^{d}
138	Weekly	95.00^{ab}	117.33^{bc}
	Two weeks	97.33^{a}	124.00^{a}
	Every three weeks	90.00^{cd}	110.00^{d}
LSD(0.05)		4.2	4.67
CV %		2.6	2.6

Means within columns for each variable followed by different letters are statistically different from each other at (p<0.05) HF = Harvesting frequency

3.2. Leaf area

Effect of N level and harvesting frequency on leaf area three weeks after transplanting of amaranths was not varied significantly. The non-significant difference on leaf area at three weeks after transplanting might be due to the seedling was not recovered from transplanting shock and not efficiently absorbs the nutrient from the soil. However, highly significant difference ($p<0.01$) due to effect of N levels and harvesting frequency on leaf area at nine weeks after transplanting and flowering of amaranths was registered. The highest leaf area (360.46 cm^2) followed by (351.97 cm^2) at nine weeks after transplanting were recorded with 138 and 103.5 kg N ha^{-1} respectively, every three weeks harvesting interval. Leaf area increased with increasing N levels at nine weeks after transplanting and at flowering probably because N promotes growth through cell division and expansion and N is an essential component of chlorophyll, protoplasm, protein and nucleic acid and high photosynthetic area [42]. The finding of this study is in agreement with the work of Babajide and Olayiwola [43] who reported that LA in *A. cruentus* increased as N level increased from 0 kg N ha^{-1} to 88 kg N ha^{-1}. In other research report LA increased significantly as N application increased from 0 kg up to 100 kg N ha^{-1} and declined at 125 kg N ha^{-1}. The least leaf area (63.20 cm^2) was recorded with 0 kg N ha^{-1} and weekly harvesting interval at nine weeks after transplanting.

At flowering, application of 138 and 103.5 kg N ha^{-1} with two weeks harvesting interval registered the highest leaf area (345.05 cm^2) followed by (338.80 cm^2) which is statistically in parity. The least leaf area (87.77 cm^2) was recorded with 0 kg N ha^{-1} and weekly harvesting interval which is also statistically at par with no application of N and two weeks harvesting interval (84.42 cm^2). Ainika *et al.* [29] also disclosed that N application encourages above ground vegetative growth leading to higher leaf area. The main effect of harvesting frequency significantly influenced leaf area only at flowering. LA increased with decreased harvesting frequencies from weakly to every three weeks interval which might be due to harvesting promoted inactive bud to grow and generate more leaves despite the crop is unable of produce more fully opened leaves within a week and the LA was small at weekly harvesting interval.

3.3. Leaf width

The effect of N levels and harvesting frequency were highly significant ($p<0.01$) on leaf width of amaranths at nine weeks after transplanting and flowering. Non-significant difference ($p>0.05$) was observed for leaf width at three weeks after transplanting. The highest leaf width (21.0 cm) was recorded from 138 Kg N ha^{-1} and followed by 103.5 kg N ha^{-1}(20.66 cm) and every three weeks harvesting interval which is statistically in parity to each other.

These values are also statistically at par with138 kg N ha^{-1} and two weeks harvesting interval (20.00 cm) at nine weeks after transplanting. Application of 103.5 kg N ha^{-1} and two weeks harvesting interval recorded (19.00 cm) which is statistically at par with treatment 138 kg N ha^{-1} and two weeks harvesting interval. Mean shorter leaves width (7.66 cm) were observed from 0 kg N $ha^{-1}$and weekly harvesting interval (Table 4).

Leaves width increased with increasing N levels from 0 kg N $ha^{-1}$to 138 kg N ha^{-1} probably indicating that N promoted cell expansion in leaves similar to the findings of Mshelia, and Degri [44] that leaves width per plant were found significantly influenced by N fertilizer source like PM application in amaranthus. Mean longer leaves width per plant were recorded from application of 15 t ha^{-1} while the mean shorter leaves width in the range of 2.17-3.70 cm were recorded from plot that not received PM (N fertilizer source). Leaf width decreased with increasing harvesting frequency from every three weeks to weekly harvesting interval because of the fact that frequent harvesting encouraged dormant bud to increase leaves production which might reduce leaves size or width because the crop unable to fully open the leaves in a week.

3.1. Plant height

The effect of N levels and harvesting frequency on plant height showed highly significant difference ($p<0.01$). Plants in plots that received 138 kg N ha^{-1} and harvested every three weeks interval recorded higher plant height (149.67 cm) followed by plants in plots that received 103.5 kg N ha^{-1} and harvested every three weeks interval (140.50 cm). The shortest plant height (63.66 cm) were observed from 0 kg N $ha^{-1}$and weekly harvesting interval followed by 0 kg N $ha^{-1}$and two weeks harvesting interval (Table 5). The average plant height increased with increasing quantities of N application levels. These results are attributed to the additive nutrient supply and to a better synchrony of nutrient availability with crop demand [45]. The finding result is in agreement with the earlier finding of Materechera and Medupe [40] who ascribed that amaranths plant height increased with the application of N fertilizer. Ainika *et al.* [29] were also disclosed that the highest plant height was obtained by application of 50 kg N ha^{-1}.

Maseko [39] (2014) reported that *A. cruentus* plant height was increased as the rate of N level increased from 0 kg to 44 kg N ha^{-1}. Islam *et al.* [46] from their two years experimentations further evidence that the highest plant height was record from applications of 2.5 t ha^{-1} of PM and $N_{100}P_{18}K_{50}S_5$ kg ha^{-1} and the shortest plant height was registered in plot that receive not N. Plant height decreased with increasing harvesting frequency because harvesting is removing of tender shoot and young leaves with apical growing shoots of plant increased canopy development in place of vertical elongation. According to Materechera and Medupe [40] research report, plants that were harvested every week shorter compared to those harvested two weeks. Pinching removes the apical dominance of the central stem thus allowing other buds on the stem to open up and develop into lateral stems. Once pinched the plant concentrates on re-growing dormant buds other than growing height [31].

3.2. Number of branches per plant

The result showed that highly significant differences ($p<0.01$) on branch number per plant due to effect of N levels and harvesting frequency and their interaction were recorded. The amaranth plants in plots that received highest dose of N fertilizer (138 kg N ha^{-1}) and weekly harvesting frequency was recorded highest number of branches per plant (31.00) which is statistically at par with 103.5 kg N ha^{-1} and weekly harvesting interval (28.33). The lowest number of branches per plant (9.00) was recorded from the 0 kg N ha^{-1} and every three weeks harvesting interval which is also statistically at par with plot that received 0 kg N ha^{-1} and two weeks harvesting interval (11.67) branches per plant and 34.5 kg N ha^{-1} and every three weeks harvesting interval (11.67) (Table 5).

Increasing N levels from 0 kg N ha^{-1} to 138 kg N ha^{-1} increased mean number of branches per plant from 11.33 to 23.33 indicating that N role in vegetative growth (promoted leaves, stems and buds growth) and development. N enhanced rapid early leaves growth, improve fruit quality and might increase protein content crops. N probably also encourage the uptake and utilization of other nutrients such as potassium and phosphorous and check overall growth of plant [47, 48]. As Ayalew [14] reported amaranths that received 69 kg N ha^{-1} produced highest branches at 12 weeks after sowing, while lowest branches number per plant was produced by *Amaranthus* that received no N fertilizer.

From Table 5, it can be observed that regardless of N levels decreasing harvesting frequency from weekly to every three weeks harvesting interval in the column decreased number of branches per plant probably due to removal of apical dominance in young shoot tips that promoted more emergence of lateral buds resulting in more number of branches. Corroborating to present research results, Cline [49] asserted that higher number of branches per plant obtained from those plants harvested in a two weeks harvesting interval in four times compared to those plants harvested in every three weeks harvesting interval in three times. In a like manner, Norman and Shongwe [50] also reported that an increase in side-shoots number per plant in two weeks harvesting interval in *A. hybridus*.

Other workers Ogar and Asiegbu [51] further disclosed that intervals of cuts progressively decreased the number of branches per plant emphasizing that highest branches being produced with two weeks cuts followed by 4-weeks cut while the 6 and 8 weeks cuts. According to them among 2, 4, 6 and 8 weeks cuts 2-4 weeks harvest interval with 750 kg $N_{20}P_{10}K_{10}$ ha^{-1} produced the highest number of branches. Corresponding to this result highest number of branches per plant were found from weekly, two weeks and every three weeks harvesting interval with 138 kg N ha^{-1}.

Table 3: Effect of nitrogen levels and leaf harvesting frequency on leaf number (LN), leaf width (LD) and leaf area (LA)

Treatments		Variables						
Nitrogen	HF	LN	LD_2	LL_2	LA_2	LD_3	LL_3	LA_3
0	Weekly	73.33^{h}	7.66^{i}	12.33	63.20^{h}	7.66^{i}	11.00^{g}	56.28^{h}
	Two weeks	74.67^{h}	9.66^{h}	13.00	86.43^{h}	9.66^{h}	13.00^{fg}	84.42^{gh}
	Every three weeks	70.67^{h}	12.00	13.33	103.85	11.66^{g}	14.33^{ef}	112.11^{ef}
34.5	Weekly	171.00^{e}	14.00	13.66	129.09	11.00^{g}	14.00^{ef}	103.40^{fg}
	Two weeks	184.33^{de}	15.00	15.66	157.45	14.33^{def}	15.00^{de}	144.27^{de}
	Every three weeks	106.00^{g}	16.66	17.33	193.63	15.66^{cd}	16.00^{de}	167.72^{cd}
69	Weekly	$208. 67^{d}$	14.33	16.33	156.78	13.33^{f}	15.00^{de}	134.00^{de}
	Two weeks	237.67^{c}	15.66	18.00	188.94	15.00^{cde}	17.66^{cd}	177.55^{cd}
	Every three weeks	136.33^{f}	17.33	19.66	228.25	16.33^{c}	19.33^{c}	211.27^{c}
103.5	Weekly	262.33^{bc}	15.00	17.33	173.53	14.00^{ef}	16.33^{de}	152.54^{de}
	Two weeks	297.33^{a}	19.00	23.66	301.95	18.00^{b}	22.66^{b}	274.03^{b}
	Every three weeks	185.00^{de}	20.66	26.00	351.97	19.66^{a}	25.66^{a}	338.80^{a}
138	Weekly	276.67^{ab}	15.33	18.66	192.51	14.33^{def}	17.66^{cd}	170.40^{cd}
	Two weeks	301.00^{a}	20.00	23.33	313.56	19.00^{ab}	23.00^{ab}	293.91^{b}
	Every three weeks	193.00^{de}	21.00	25.00	360.46	20.0^{a}	25.66^{a}	345.05^{a}
LSD(0.05)		24.7	1.47	2.49	39.36	1.29	2.74	42.89
CV %		8.0	5.51	8.00	11.03	5.1	8.84	13.16

Means within columns for each variable followed by different letters are statistically different from each other at (p<0.01). HF = Harvesting frequency; 2, 3 represents, 9 weeks after transplanting and at flower harvest, respectively.

3.1. Above ground fresh biomass

The result showed that above ground fresh biomass per plant (AGFBP) was highly significantly (*p<0.01*) affected by N levels and harvesting frequency. The highest AGFBP (384.67 g) followed by 380.00, 380.00 and 349.33 g at harvest were recorded from those plants in plots that received 138 kg N ha^{-1} and harvested every three weeks, 138 kg N ha^{-1} and harvested two weeks, 103.5 kg N ha^{-1} and harvested every three weeks and 103.5 kg N ha^{-1} and harvested two weeks interval, respectively which are statistically in parity among themselves. The lowest AGFBP (81.33 g) was recorded from 0 kg N ha^{-1} and weekly harvesting interval which is at par with those plants in plots received no N and two weeks harvest and 34.5 kg N ha^{-1} and weekly harvest interval (Table 5). As the N levels are increasing from 0 kg N ha^{-1} to 138 kg N ha^{-1} and mean AGFBP increased from 105.44 to 340.39 g revealing that N may promote plant growth and development. According to Maseko [39] report Increasing N from 0 kg N ha^{-1} to 44 kg N ha^{-1} significantly increased AGFBP; however, further increases up to 88 kg N ha^{-1} did not have any significant effect on AGFBP. Similarly, total AGFBP of *A. cruentus* increased significantly with approximately 80% as N rates increased from 0 kg N ha^{-1} up to 100 kg N ha^{-1} then declined at 125 kg N ha^{-1}.

The ANOVA showed that AGFBP was affected by harvesting frequency. As the harvest interval increased AGFBP is also increased because harvest intervals allow the plant with sufficient time for new leaves (photosynthetic tissues) emergence and development thereby accumulation of biomass. Vargas-Ortiz *et al.* [52] reported that the high stem yield was obtained from plants harvested at 3 weeks interval was due to accumulation of carbohydrate reserves in the stem. Translocation of carbohydrate reserves to the buds for re-growth of new leaves occurs in plants harvested every 2 weeks.

TABLE 4: EFFECT OF N LEVELS AND HARVESTING FREQUENCY ON GROWTH AND YIELD COMPONENT VARIABLES

Treatments	Growth and yield component variables				
Nitrogen	HF	PH	BNP	AGFBP	AGDBP
0	Weekly	63.66^{k}	14.67^{d}	81.33^{f}	17.00^{h}
	Two weeks	76.66^{j}	11.67^{e}	116.00^{ef}	23.50^{gh}
	Every three weeks	92.00^{gh}	9.00^{e}	119.00^{e}	25.50^{g}
34.5	Weekly	83.33^{ij}	18.67^{c}	116.50^{ef}	25.75^{g}
	Two weeks	95.33^{fg}	15.00^{d}	144.00^{de}	34.50^{f}
	Every three weeks	103.33^{e}	11.67^{e}	172.50^{d}	43.56^{e}
69	Weekly	87.66^{hi}	22.667^{b}	146.50^{de}	35.50^{f}
	Two weeks	107.00^{e}	18.33^{c}	209.17^{c}	50.83^{e}
	Every three weeks	121.00^{d}	14.67^{d}	283.50^{b}	73.67^{c}
103.5	Weekly	101.66^{ef}	28.33^{a}	250.50^{b}	59.67^{d}
	Two weeks	123.00^{d}	21.67^{b}	349.33^{a}	93.33^{b}
	Every three weeks	140.50^{b}	17.00^{cd}	380.00^{a}	100.00^{ab}
138	Weekly	108.00^{e}	31.00^{a}	256.50^{b}	61.67d
	Two weeks	130.33^{c}	22.00^{b}	380.00^{a}	100.66^{ab}
	Every three weeks	149.67^{a}	17.33^{cd}	384.67^{a}	102.00^{a}
LSD(0.05)		7.7	2.8	35.82	7.94
CV %		4.0	8.4	9.7	8.5

Means within columns for each variable followed by different letters are statistically different from each other at (p<0.01) HF = Harvesting frequency; PH = Plant height; BNP = Branch number per plant; AGFBP = Above ground fresh biomass per plant; AGDBP = Above ground dry biomass per plant.

3.2. Above ground dry biomass

Highly significant differences (*p<0.01*) due to main effect of N levels and harvesting frequency and their interaction were observed on AGDBP accumulation. The maximum AGDBP (102.00 g) was recorded for those plants in plot that received 138 kg N ha^{-1} and harvested every three weeks interval which is statistically at par with 103.5 kg N ha^{-1} and every three weeks harvesting interval (100.00g) and plot receiving 138 kg N ha^{-1} and two weeks harvesting interval (100.66g). The lowest (17.00 g) AGDBP was recorded at harvest stage from plants in plots that received no N and harvested at weekly interval followed by (23.00 g) with no N and two weeks harvesting interval (Table 5). Increasing N levels from 0 kg N ha^{-1} to 138 kg N ha^{-1} increased mean AGDBP from 21.67 to 88.11 g indicating N functions in increasing the quality (AGDBP accumulation). The current observation is in agreement with the finding of Masvanhise [30] who reported that N levels significantly increased AGDBP. According to his observation the highest AGDBP was attained at higher doses of 150 and 200 kg N ha^{-1} with mean yield of 32.57 t ha^{-1} and 45.10 t ha^{-1} respectively, while the lowest was obtained with 0 kg N ha^{-1} with mean yield of 12.62 t ha^{-1}.

Similar to current findings Maseko [39] also reported that increasing N from 0 kg N ha^{-1} to 44 kg N ha^{-1}or increases up to 88 kg N ha^{-1} significantly increased AGDBP in *A. cruentus* during 2011/2012 while in 2012/2013 season increasing N from 0 kg N ha^{-1} up to 100 kg N ha^{-1} increased AGDBP but declined at 125 kg N ha^{-1}. Babajide and Olayiwola [43] further indicated that highest AGDBP of 37.4 t ha^{-1} which is 272% AGDBP increase from the control was obtained with application 3 t ha^{-1}.

There was a decrease in AGDBP with increasing harvesting frequency and vice versa. The lowest (17.0 g) AGDBP obtained in the plots which received weekly harvesting interval. This might mean that the plant compensated leaf loss by re-growth of new shoots though separation of the AGDBP into component parts such as leaves, shoots and grain could have made it easier. Babajide and Olayiwola [43] in their observation reported that highest AGDBP was obtained in mono-two weeks harvesting while the lowest AGDBP was recorded from mono-weekly harvesting.

3.3. Dry matter content per plant

Highly significant differences (*p<0.01*) were observed due to the main effect of N levels and harvesting frequency on dry matter content (DMC) of amaranth plants, whereas non-significant difference was observed due to interaction effect of N levels and harvesting frequency on DMC. The maximum DMC per plant (25.72%) was recorded from plants in plots that received 138 kg N ha^{-1} followed by plants in plots that treated with 103.5 and 69 kg N ha^{-1} with values of 25.53% and 24.87% consecutively, which are also statistically at par among themselves (Figure 1). The lowest DMC per plant (20.77%) was recorded from plants grown in plots without N application (Figure 1). Increasing N levels from 0 kg N ha^{-1} to 138 kg N ha^{-1} increased mean DMC per plant (20.77-25.72%) of amaranths showing the role of N in increasing the quantity of dry matter in amaranths. The current observation is in agreement with Maseko [39] work who asserted that N application resulted in a significantly higher biomass accumulation per plant thereby resulting in higher DMC per plant in *A. cruentus* vis-a-vis the control plot during his 2011/2012 and 2012/2013 experimentations.

According to his 2011/2012 season experiment, biomass significantly increased from 0 kg N ha^{-1} to 44 kg N ha^{-1}increasing DMC in a similar way despite further increases up 88 kg N ha^{-1} led to a decline in biomass thereby DMC. During 2012/2013 season, increasing from 0 to 100 kg N ha^{-1} increased biomass accumulation per plant in *A. cruentus* significantly by approximately 70% and remained constant thereafter. Other workers Nyankanga *et al.* [53] obtained the highest DMC in seed *Amaranths* in Western Kenya with the application 100 kg N ha^{-1} inorganic fertilizer. Significant increase in plant dry matter accumulation per plant with corresponding increase in the fertility levels up to a certain level.

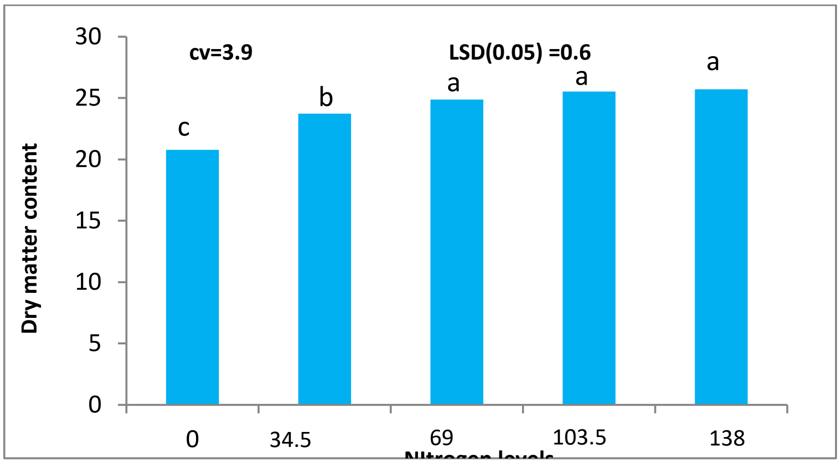

Figure 1: Effect of N levels on dry matter content of Amaranths

The maximum DMC per plant (25.76%) was recorded from every three weeks harvesting frequency, whereas the minimum DMC per plant (22.88%) was recorded from weekly harvesting frequency (Figure 2). The mean of DMC per plant decreased with frequently harvesting i.e. increased from weekly to every three weeks interval because frequent harvesting may discourage leaves and branches s growth thereby reducing competition for light and nutrient among plant organs in plots that are harvested less frequent like every three weeks harvesting interval.

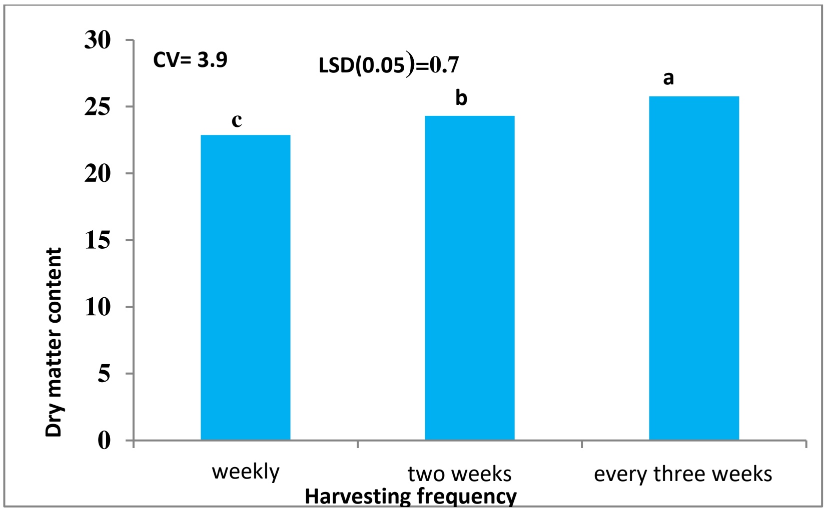

FIGURE 2: EFFECT OF HARVESTING FREQUENCY ON DRY MATTER CONTENT OF AMARANTHS

3.1. Leaf Yield

The results of the study showed that fresh weight of leaves per plant (FWLPP) and t ha^{-1} of amaranths varied highly significant (*p<0.01*) due to the main effect of application of different N levels and harvesting frequency and their interaction. The maximum FWLPP (457.67 g) or 30.5 t ha^{-1} was recorded from plants in plots that received 138 kg N ha^{-1} harvested two weeks followed by plants in plots that received 103.5 kg N ha^{-1} with two weeks harvesting (455.33 g FWLPP or 30.33 t ha^{-1}) which is statistically in parity to each other (Table 6). Increasing N from 0 to 138 kg N ha^{-1} increased mean FWLPP 89.56 to 376.33 g or 5.93 to 25.06 t ha^{-1} whereas application of 69 kg N ha^{-1} (check) was registered 343.94 g FWLPP or 22.93 t ha^{-1}. Lowest FWLPP of (71.67 g or 4.73 t ha^{-1}) was recorded from plants in plots that received no N and harvested every three weeks interval, because N may be an essential constituent of protein (build from amino acids that involves in catalyze of chemical and transportation of electrons) and chlorophyll (enable the process of photosynthesis) present in many major portions of the plant body, promotes leaves, stem and other vegetative part's growth and development [47, 48].

The present result is in agreement with the work of Masvanhise [30] who reported that mean highest FWLPP or yield was obtained with application of 200 kg N ha^{-1} while the lowest FWLPP or yield was obtained from the control. Maseko [39] also showed that increasing N from 0 kg N ha^{-1} to 44 kg N ha^{-1} significantly increased fresh yield of *A. cruentus* and further increases up to 88 kg N ha^{-1} did not have any significant effect on FWLPP or yield in 211/2012 while total fresh yield of *A. cruentus* increased significantly by about 80% as N rates increased from 0 to 100 kg N ha^{-1} then declined at 125 kg N ha^{-1} in 2012/2013. Mohil and Jain [35] also observed that N fertilizer at the rate of 180 kg ha^{-1} produced a yield increase of 42% relative to plants in plots receiving no N fertilizer. Similar results on *A. cruentus* leaf yield increase was reported due to N level increase [26, 29]. The increased in leaf fresh yield was attributed to the ability of N to promote leaf yield via cell expansion, division and elongation [38]. According to Maseko [39] report N application significantly increased fresh yield in *A. cruentus* during the 2011/2012 season fresh yield components increased significantly from 0 kg N ha^{-1} to 44 kg N ha^{-1}; however, further increases up to 88 kg N ha^{-1} did not have any significant effect on yield.

The result indicated that leaf yield increased with increasing harvesting intervals up two weeks and then after decreased. This might be due to the crop is not recover from previous harvesting stress to produce more fully opened and consumable leaf in a week and for more than two weeks interval leaves were surpass consumable stage until next harvest. This study is in line with report of Grubben [17] who mentioned only two harvests for *A. tricolor* with every three weeks interval for re-growth.

TABLE 5: EFFECT OF N LEVELS AND HARVESTING FREQUENCY ON FWLPP, FWLPH AND SYPH

Treatments	Yield variables			
Nitrogen	HF	FWLPP (g)	FWLPH (t)	SYPH (t)
0	Weekly	88.00^{fg}	5.83^{fg}	0.66^{g}
	Two weeks	109.00^{f}	7.23^{f}	0.76^{fg}
	Every three weeks	71.67^{g}	4.73^{g}	1.00^{ef}
34.5	Weekly	158.33^{e}	10.52^{e}	1.13^{e}
	Two weeks	219.33^{d}	14.60^{d}	1.40^{d}
	Every three weeks	167.33^{e}	11.13^{e}	1.70^{c}
69	Weekly	224.67^{d}	16.1^{d}	1.43^{d}
	Two weeks	348.67^{b}	23.25^{b}	1.76^{c}
	Every three weeks	246.67^{d}	14.97^{d}	2.36^{b}
103.5	Weekly	329.33^{bc}	21.96^{bc}	1.76^{c}
	Two weeks	455.33^{a}	30.33^{a}	2.53^{b}
	Every three weeks	310.33^{c}	20.67^{c}	3.23^{a}
138	Weekly	353.83^{b}	23.59^{b}	1.80^{c}
	Two weeks	457.67^{a}	30.46^{a}	2.56^{b}
	Every three weeks	317.50^{c}	21.13^{c}	3.26^{a}
LSD(0.05)		26.45	1.75	0.26
CV %		6.3	6.3	7.2

Means within columns for each variable followed by different letters are statistically different from each other at ($p<0.01$) HF = Harvesting frequency; FWLPP = Fresh weight of leaves per plant; FWLPH- Fresh weight of leaves per hectare; SYPH = Seed yield per hectare.

3.2. Seed yield

There was a highly significant difference ($p<0.01$) on the seed yield due to the effect of N levels and harvesting frequency. The highest seed yield per hectare (SYPH) (3.23 t ha^{-1}) was obtained from plants in plots that received 138 kg N ha^{-1} and every three weeks harvesting interval which is statistically at par with plants in plots that received 103.5 kg N ha^{-1} and every three weeks harvesting frequency. The lowest SYPH (0.66 t ha^{-1}) was obtained from the check plots with weekly harvesting frequency (Table 7).

Seed yield per hectare was decreased with decreasing N levels might be because of N is an essential constituent of structural and storage proteins, simple amino compounds, enzymes and chlorophyll, which is associated with the production of simple sugars from carbon, hydrogen, and oxygen. High amounts of chlorophyll and N utilize the sunlight as an energy source to carry out essential plant functions including nutrient uptake. The sugars produced play an important role in stimulating plant growth and development along with higher protein content in the seed. The increase in seed yield with increasing N may also because of increased plant growth, flowering and seed filling. The investigation result is in line with Ayalew [14] who reported that the highest seed yield (3.50 t ha^{-1}) was obtained with application of 69 kg N ha^{-1} while the lowest seed yield (1.86 t ha^{-1}) was obtained without N application. Masvanhise [30] report that the highest seed yield of 3.39 t ha^{-1} was recorded with application of 200 kg N ha^{-1} in the soil.

The present investigation indicated that the mean seed yield increased as frequent harvesting decreased from weekly to every three weeks harvesting which might be because harvesting of leaves less often left the plant with more foliage offering a greater photosynthetic area which favors seed formation. In an earlier study under greenhouse conditions Saidi *et al.* [54] reported that an increase in seed yields of two varieties as leaf harvesting frequency was decreased from one week to no leaf harvesting.

3.3. Thousand seed weight

The ANOVA indicated that amaranths thousand seed weight (TSW) was highly significantly ($p<0.01$) influenced due to the main effect of harvesting frequency, while the main effect of N levels and the interaction effect of N levels and harvesting frequency were non-significant. The TSW increased with decreasing harvesting intervals. The highest TSW of 0.77 g was recorded from every three weeks harvesting interval while the lowest TSW of 0.66 g was registered from weekly harvesting interval (Figure 3).

The increased TSW with decreasing harvesting intervals from weekly to every three weeks might be due to frequent harvesting decrease number of flower stem which decreased competition of inflorescence to photoassimilate. Current finding confirmed that the report of Isah *et al.* [41] pinching had significant effect on the TSW of seed amaranths and plants that were not pinched had the highest TSW of 1.19 g while the plants that were pinched 28 days after planting had the least (0.97 g) TSW. Pinching increased the number of flowering stems. According to Iftikhar *et al.* [31] the reduced TSW as a result of pinching could be because of photosynthesis partitioning to more growing points.

The finding results in contrast to observations reported by Gnyandev [32] while working on China aster and reported that pinching significantly increased the seed yield and TSW. He also reported that pinching increased the number of flowering stems, the number of flowers per plant and the number of seeds per plant. In this experiment, although leaves harvesting or pinching increased the number of flowering stems, the stems were thin with small size of flower heads and light seeds as shown by the results of TSW.

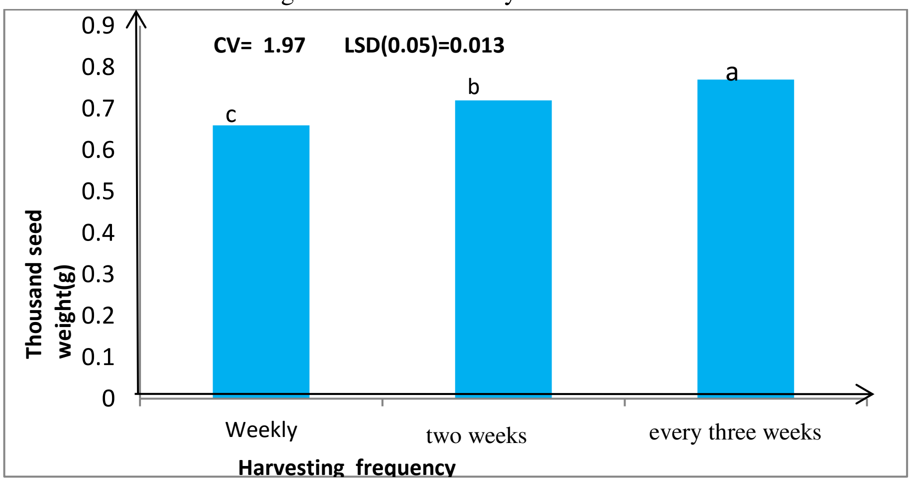

FIGURE 3: EFFECT OF HARVESTING FREQUENCY ON THOUSAND SEED WEIGHT OF AMARANTHS.

4. Conclusions and Recommendation

Amaranths (*Amaranthus spp.*) grow mostly as wild food plant but some are cultivated in different parts of Ethiopia. Despite the crop is categorized as neglected and underutilized species, it germinate, grown and widely distributed in different agro ecologies of the country, including southwestern and west parts with rain conditions. Therefore, this research was initiated with the objective of determining effect of N levels and harvesting frequency on growth, yield component and yield of Amaranths at Jimma, South west Ethiopia.

This research finding revealed that the growth, yield components and yield were influenced by the interaction effect of N levels and harvesting frequency. Application of 138 kg N ha^{-1} and two weeks harvesting frequency registered highest number of leaves (301). The maximum Fresh weight of leaf (30.5 t ha^{-1}) was recorded from plants received 138 kg N ha^{-1} harvested at two weeks interval. The highest seed yield (3.23 t ha^{-1}) was obtained from plants received 138 kg N ha^{-1} and harvested at every three weeks interval. Plant height, leaf area, leaf length, leaf width and number of branches were highly significant and positively correlated with leaf yield. Seed yield also highly positively correlated with, plant height, leaf area, leaf width, leaf length, days to maturity and thousand seed weight. In conclusion, the present finding indicated that nitrogen and harvesting frequencies improve leaf yield of amaranths and accordingly application of 138 kg N ha^{-1} and two weeks harvesting showed a high leaf yield that exceeds by (84.81%) as compared to the 0 kg N $ha^{-1}$and Every three harvesting. Whereas, application of 138 kg N ha^{-1} did not bring any significance difference in respect to103.5 kg N ha^{-1}level. Higher seed yield and yield component was obtained for application of 103.5 kg N ha^{-1} and three week harvesting. Therefore, farmers can benefit by practicing combined application of 103.5 kg N ha^{-1} and two weeks harvesting that resulted maximum leaf yield and application of 103.5 kg N $ha^{-1}$with three weeks harvesting gave maximum seed yield. However, the study was a single experimental work under irrigation condition, thus further research work would be carried out in different seasons across locations, with organic and inorganic source of nitrogen fertilizer and quality parameter of leaf at different harvesting frequency to draw a comprehensive recommendation for maximum leaf and seed yield production of amaranths.

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