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Yield, water use efficiency and Harvest Index of *Amaranthus cruentus* grown under micro-sprinkler Irrigation system

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Abstract The yield, water use efficiency and harvest index of Amaranthus cruentus grown under micro-sprinkler irrigation system were investigated. The specific objectives of the work were: to determine the growth and yield of Amaranthus cruentus under micro-sprinkler irrigation systems, to determine the water use pattern of Amaranthus cruentus grown using sprinkler irrigation systems and to evaluate the Harvest index of Amaranthus cruentus at the different crop growth stages. This project report discovered that adequate soil water will enhance a better crop production during the dry period. The field experiment was carried out in a phase using field plots of 6m x 4m for micro- sprinkler irrigation system. The plot was divided into six crop beds of 1.36m x 1.36m and micro sprinkler was on each of the crop beds. Micro-sprinkler irrigation is a system that operates under low pressure with small-sized wetting patterns and low discharges. However, because of the low pressure and low volume, the wetted diameter is relatively small. The emitters are small and usually placed on short risers. Consequently, the water droplet has a short distance to travel before it reaches the soil surface. The advantages of micro-sprinkler irrigation systems are the potential for applying water, and lower susceptibility to clogging. The project was aimed at investigation the influence of irrigation water management on the growth and yield of Amaranthus cruentus. This study evaluates the performance of Amaranthus cruentus under different irrigation water treatment. Treatments A1 and B1 produced the higher moisture content of 25.69% and 25.26% respectively. Conclusively, results showed that Amaranthus cruentus responded well to three days intervals of irrigation water application in growth, development and yield.

Keywords water-use efficiency, yield, growth and irrigation water management

1. Introduction

The earliest archeological record of pale seeded grain amaranth is that of *Amaranthus cruentus*, found in Tehuacan Puebla, Mexico, about 400BC (pal and Khohoo,1974; saver 19790, making it one of the oldest known food crops; probably originated in central and south America (Grubben and van stolen,1981). *Amaranth* was a major grain crop in the pre-conquest Aztec empire saver, 1950B; (Pal and khoshoo, 1974; Early (1977); Haughton, 1978). Ancient Mexicans made idols of dough from seeds of the crop they called huehtli, which has been identified as grain amaranth (saver, 1950B, Marx, 1977).

Pale – seeded *Amaranthus* were also grown in Germany in the 16th century, India and Ceylon in the 18th century, Himalayas in the early 19th century, and interior China and Siberia in the late 19th century (saver, 1977). Present uses of *Amaranthus Caudatus*, *Amarantus Cruentus*, and *Amaranthus hypochondriacus* have been identified (NAS, 1975) as having the potential to increase world food production. *Amarantus Caudatus* is grown in the inter- Andean valleys of peru Boliva (Sumer, 1983). *Amaranthus Cruentus* is cultivated as a grain crop in Guaternala, and *Amaranthus hypochondriacus* is grown in Mexico (NAS, 1975). In Mexico, grain amaranth is used chiefly for making alegria candies from popped seeds and molasses (Early, 1977) for preparing atole, a drink from roasted and powdered seeds mixed with syrup and water (Oke, 1983). In peru, seeds are popped and ground into flour bound with syrup and made into belles (summer, 1983). In India, the seeds are mostly commonly used in the form of candy known as Laddoos, (vietineyer, 1978). Though the seeds are parched, ground into flour and eaten as gravel (sattoo) in Nepal, while it is consumed as Chapattis in the Himalayas (vietineyer, 1978). The crude protein content of grain amaranth ranges from 12.5 to 17.6% dry matter. This is higher in most common grain except soybeans. Grain amaranth protein contains around 5% lysine and 4.4% sulfur amino acids, whch are the limiting amino acid in other grain (senft, 1980). The amino acid composition of *Amanranth* protein compares well with the FAD/WHO protein standard. The total lipid content of grain amaranth ranges from 5.4 to 17.0% dry matter and has a high level of unsaturation (about 75%) containing almost 50% linoleic acid (opute, 1979, Carlson, 1980, becker et al; 1981; Badami and pahil, 1976).

Ultimately, good stands were obtained of all crops except sun flower 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 availability 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 latter after rainfall, or not at all.

Justification

Adequate soil water will enhance a better crop production during the dry period. Various investigations into the effect of soil water on the growth and yield of *Amaranthus Cruentus* had been done; little assessment of the water use potential of the crop has been carried out in this locality. Hence, this project was aimed at investigating the influence of irrigation water management on the growth and yield of *Amaranthus Cruentus*. The establishment of the relationship between the three different irrigation management schedules and the growth and yield of the crop will provide basis for strategic management of the crop for optimum production.

Objectives

Aims of the research work

- to determine the growth and yield of *Amaranthus Cruentus* under micro sprinkler irrigation systems.

Specific Objectives

- to determine the water use pattern of *Amaranthus Cruentus* grown sprinkler irrigation systems.
- to evaluate the Harvest index of *Amaranthus Cruentus* at the different crop growth stages.

Materials and Methods

Description of Study Area

The field experiments were conducted at the Agricultural Engineering Teaching and Research Farm, Federal University of Technology, Akure from the month of Jan to March, 2021. Akure was located within the humid region of Nigeria, at latitude 7°14'N and longitude 5°08'E. It lies in the rain forest zone with a mean annual rainfall of between 1300mm – 1600mm and with an average temperature of 27.5^{0}c. The relative humidity ranges between 85% and 100% during the rainy season and less than 60% during the harmattan period. Akure is about 351m above the sea level. The soil on the site was sandy loam.

System Layout of the Field

The field experiment was carried out in a phase using field plots of 6m x 4m for micro- sprinkler irrigation system. The layout of the field plot is as shown in Figure 1 the plot was divided into six crop beds of 1.36m x 1.36m. Micro sprinkler was on each of the crop beds

Micro-sprinkler irrigation is a system that operates under low pressure with small-sized wetting patterns and low discharges. However, because of the low pressure and low volume, the wetted diameter is relatively small. The emitters are small and usually placed on short risers. Consequently, the water droplet has a short distance to travel before it reaches the soil surface. The advantages of micro-sprinkler irrigation systems are the potential for applying water, and lower susceptibility to clogging.

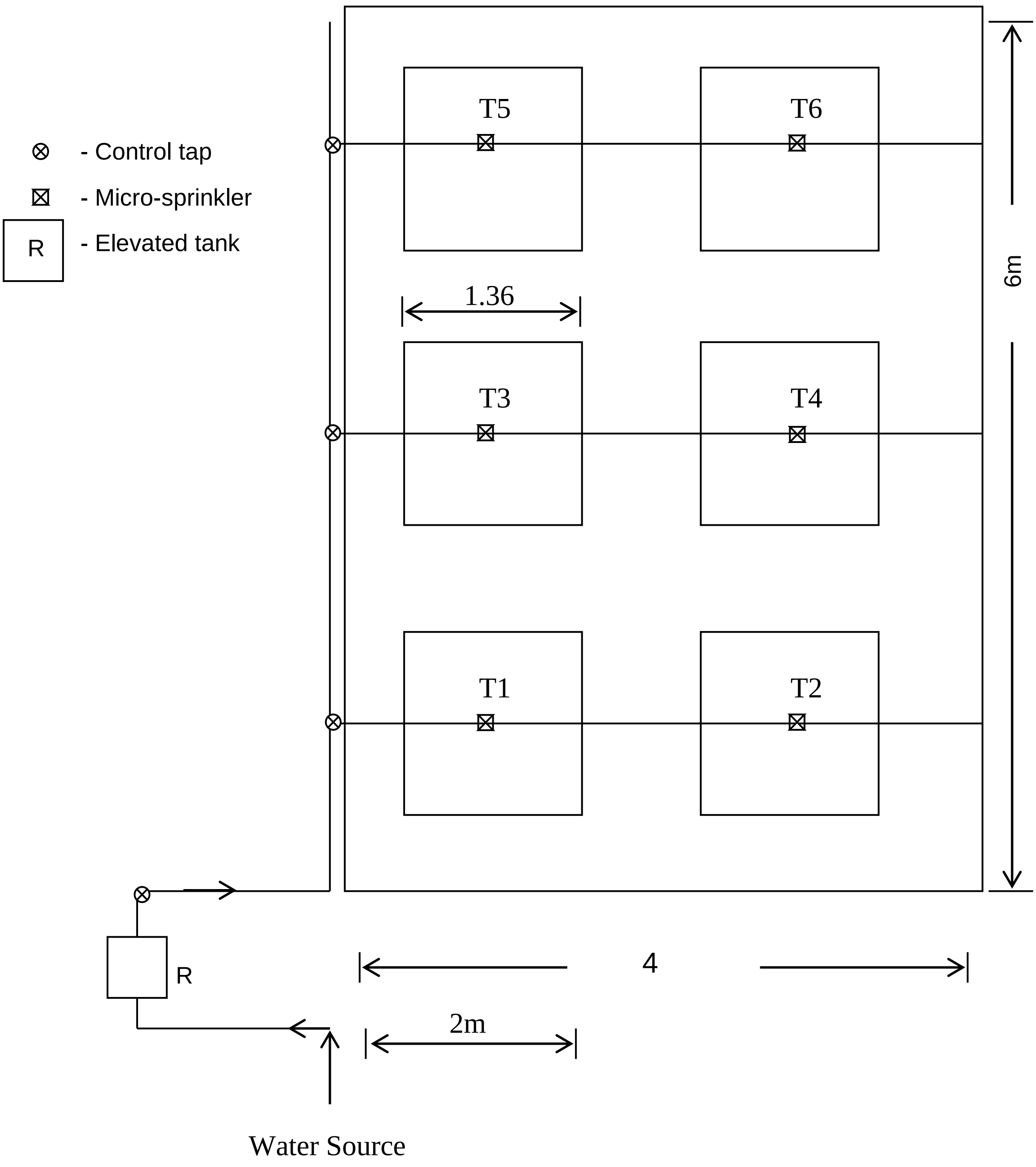

Figure 1: Layout of Field Plots

Treatment and Experimental Procedure

The field experiments were conducted from Jan to March, 2021. *Amaranthus cruentus* seeds obtained from Ondo State Agricultural Development Project (ADP) Akure, were broadcasted on the field on each of the crop beds on 20th January, 2021.

The water application method adopted was the micro-sprinkler irrigation system. Water was pumped by means of an electric pump to an elevated tank. By means of gravitation, the water was delivered to the experimental field by the micro-sprinkler head through pressure.

There were pre-irrigation for about two days before planting of Amaranthus and subsequently for two weeks after planting (2 WAP) for well establishment of the crops. Therefore, the adopted irrigation water treatment started. Thinning was done two weeks after planting to allow for the spacing of the crop. Fertilizer was applied accordingly two weeks after planting and manual weeding was carried out on weekly basis.

There were three irrigation treatments based on different water stress levels. These treatments were typified by the difference in the soil moisture tension. The first treatment was application of irrigation water at 50 Mpa, the second treatment was application of irrigation water 60 Mpa and the third treatment was application of irrigation water at 70 Mpa. Duration of irrigation for each of the three treatments was one hour (5 – 6 pm daily). The summary of the treatments is shown in Table 1.

Table 1: Irrigation water treatments on the field

Treatments	Definition
T1 and T2	Irrigation water application at 50 Mpa
T3 and T4	Irrigation water application at 60 Mpa
T5 and T6	Irrigation water application at 70 Mpa

Crop Data

Measurement of the plant height, leaf width, leaf length, number of leaf, leave area and leaf area index were carried out during the 3rd, 4th, 5th, 6th, 7th and 8th weeks after planting on randomly selected plants from each crop bed. The yield parameters were also taken such as the fresh and dry weights of leaves, stem and root using an electrical balance. The yield parameters were taken for the 4th, 5th, 6th, and 7th, weeks after planting. On the 8th week after planting, the weight of the leaves, stem, root and the seeds were taken both fresh and dry.

Plant Height

The height of the plant was measured from the soil surface to the tip of the plant using tape. Four plants per crop bed were sampled for height measurement and the average represented the plant height for each crop bed. The plant height was measured on the 3rd, 4th, 5th, 6th, 7th and 8th weeks after planting

Number of Leaves

Four plants were selected from each crop bed for leaf counting, from which average number of leaves was obtained for number of leaves per crop bed. These were carried out during the 3rd, 4th, 5th, 6th, 7th and 8th weeks after planting.

Root Depth

The method for the estimation of root zone depth was the trench profile method. With the aid of spade and sharp cutlass, trench profiles were dug about 10mm near the sample plant on each crop bed. The depth of trench depends on the length of roots. Also four plants were sampled for the root depth and the average root depth was taken for each of the crop bed for 3rd 4th, 5th, 6th, 7th, and 8th, weeks after planting.

Leaf Area

Samplings for leaf area measurement were taken on four plants per crop-bed. The leaf area was traced out on graph paper to measure area. From this measurement, leaf surface area (cm^{2}) and leaf area index were estimated by the formula:

$$Leaf\ \ Area\ Index\,(LAI) = \frac{Total\ surface\ area\ of\ \ plant}{Soil\ surface\ area\ \mathrm{cov}ered\ by\ plant} \qquad (1)$$

These were carried out during the 4th, 5th, 6th and 7th weeks after planting.

Above Ground Biomass

The sample of the plant after being uprooted was weighed at its fresh state using the electrical balance. The weight of the leaves, stems, and roots were noted and then the samples were transferred into the oven and dried at 80ºc for 24hours. The weight of the dried matter was then recorded and the "Above Ground Biomass" computed as follows:

$$AGB = \frac{F.Mb}{10^6} \quad (2)$$

Where AGB = Above Ground Biomass

Mb = Sun total of M_L, Ms, M_d

ML = Weight of leaves (g)

MS = Weight of stems (g)

Md = Weight of seeds

F = L / s (3)

Where L = 1 hectare (10^4 m^2)

S = Spacing between plants (m).

F = The multiplying ratio (per ha).

The aboveground biomass was taken at the 4th, 5th, 6th, 7th, and 8th weeks after planting for each of the crop bed.

Harvest Index

The harvest index of *Amaranthus cruentus* was determined at the two phonological stages i.e. flowering and maturity. The harvest index was estimated from the following relationship:

$$H.I = \frac{Yield\ biomass}{Cummulative\ aboveground\ biomass} \quad (4)$$

Estimation of Crop Water Use (ET)

This is the actual amount of water loss to the atmosphere by the crop, which depends not only on the existing meteorological conditions but also in the availability of water to meet the atmosphere demand.

The crop water use was determined from the principal of inflow – out flow (water Balance Method) as below:

$$ET = P + I - R \pm \Delta S - D \quad (5)$$

where

ET = Evapotranspiration

P = Precipitation (Rainfall).

R = Runoff

↸s = Change in groundwater storage

D = Drainage

The precipitation (p) measurements during the period of experiment were taken by rainfall recording equipment (rainguage) placed on the farm site.

The Runoff (Ro) was determined by installation of 3,600cm^2 runoff catchments made of woody materials, surface out flow from the catchment were measured immediately from a collection bowl place adjacent to the runoff catchment. The runoff values were determined using the relationship =

$$R_o = \frac{V_w}{A_c} \quad (6)$$

Where

V_w = Volume of water collected (cm^3) Ac = Are of catchment (cm^2)

Ro = Runoff (mm).

The change in soil water storage (⇱s) was calculated from the difference in water content of the not zone before irrigation and water content often irrigation. The change in the ground water storage can be calculated as shown below:

$$\Delta s = SMA - SMB \quad (7)$$

Where

Δs = change in groundwater storage

SMA = Soil Moisture content after irrigation

SMB = Soil Moisture content before irrigation

The drainage (D) during the period of experiment was assumed negligible because the occasional rainfalls that occurred during the period of experiment were not enough to cause deep percolation.

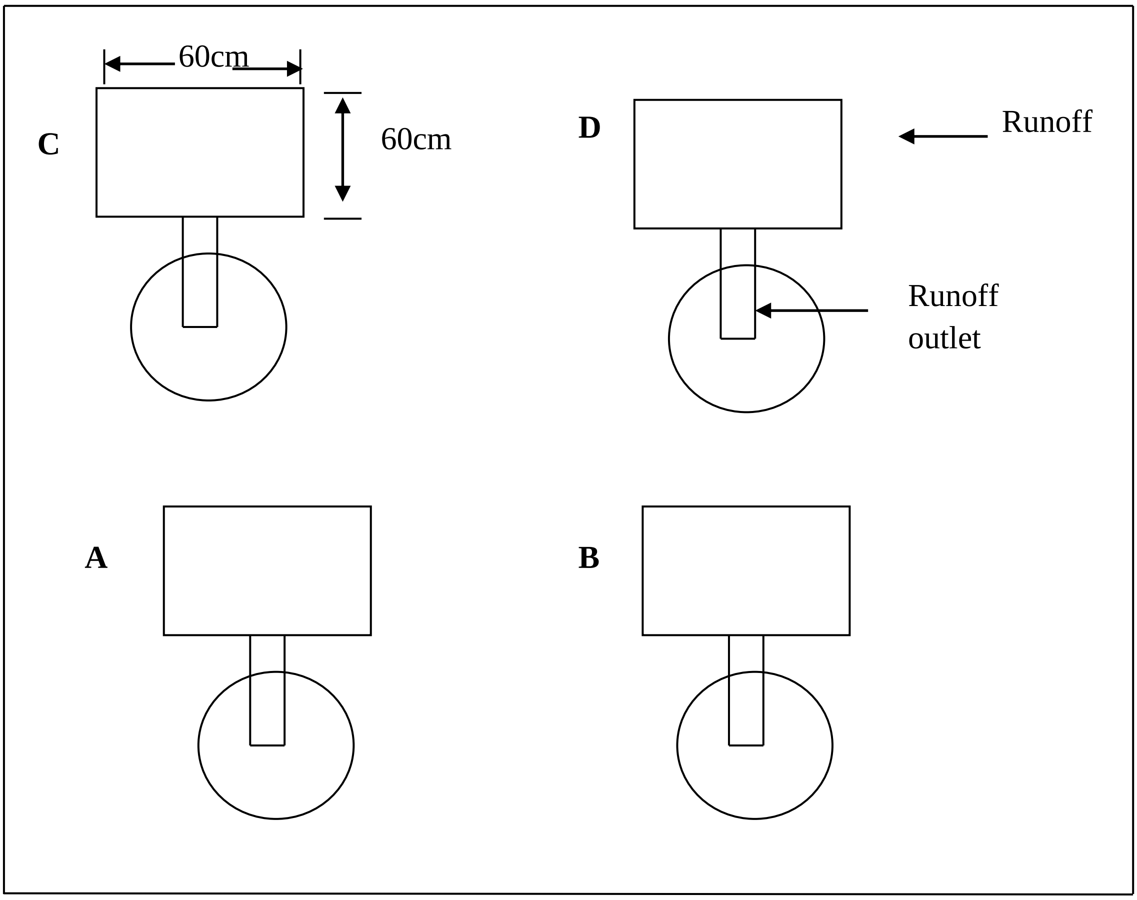

Figure 2: Layout of Run-off meter in the Field

Water Use Efficiency (WUE)

According to Hillel and Guron (1973), water use efficiency on Irrigation field can be estimated mathematically using the following relationship:

$$WUE = \frac{Yield}{Irrigation} \; g/cm^3 \quad (8)$$

Where WUE is the crop water used efficiency in g/m^3, yield is the sum of fresh weight of leave stems and root in g, and irrigation is the amount of water used in cm$^{3.}$

Soil Moisture Content

The soil moisture content at depths, 10cm, 20cm, 30cm and 40cm from each crop-bed were determined once in a week using the gravimetric method. Samples of the soil were taken at different depths of 10cm, 20cm, 30cm and 40cm from each crop-bed and placed in different containers of known weight, with a lid on to prevent evaporation. The containers and soil are weighed and then placed in an oven at 105°c, with the lid removed, until the sample id dry. The containers, and dry soil are weighed again the loss in weight is the weight of water in the original samples, and the weight of solids is final weight less the weight of the container. Hence the moisture content of the soil and be determined using this relationship:

$$Soil\ moisture\ content\ (SM) = \frac{Weight\ of\ water}{Weight\ of\ solids} \quad (9)$$

Soil Bulk Density

The density of the complete soil (i.e solids and voids) is usually expressed as bulk density. Samples of the soil were taken from the experimental field for the determination of Bulk density. The bulk density was calculated using the formula below:

$$Bulk\ Density\ (BD) = \frac{Mass\ of\ oven\ dried\ soil}{Volume\ of\ soil} \quad (10)$$

$$Dry\ Density\ (DD) = \frac{Bulk\ density}{1 + Moisture\ content\ \%}$$

Statistical Analysis of Data

Results obtained during field experimentation were subjected to statistical analysis. The mean was determined and the levels or significance and analysis of variance (ANOVA) were performed.

Results and Discussions

Climatic Conditions of the Environment during the Experiment.

The climatic condition during the experiment is summarized in Table 2. There were little rainfalls in the month of May. Higher air temperatures were observed in the month of May; hence solar radiation was also high when compared to the month of March and April. The wind speed was highest in the month of March and this was accompanied by low relative humidity.

Table 2: Climatic parameters during the experiment

Climatic parameters	March	April	May
Average air temperature (°C)	23.54	24.50	27.03
Rainfall (mm)	27.10	25.30	14.10
Wind speed (m/s)	1.04	0.31	0.23
Wind direction (Degree)	60.75	207.60	242.14
Relative humidity (%)	57.96	73.87	71.89
Solar radiation (Watt/m^2)	263.06	384.62	758.97
Net radiation (Watt/m^2)	3.26	6.76	7.79
Air pressure (HP)	977.21	989.81	979.57

Source: FUTA Observatory Station

Water Applied to the Treatments during the Experiment

Table 3 gives the total water applied to the treatment beds during the experiment. For the 1st treatment (T1 and T2) the cumulative amount of water applied per irrigation was 262.35mm, while for the 2nd treatment (T3 and T4) it was 258.36mm and the 3rd treatment (T5 and T6) received 268.16mm. The variation in the amount of water applied was due to the non-uniformity in the discharge rate of the micro-sprinkler head.

Table 3: Total applied water to the treatments during the experiment

Treatment	Time (hr)	Irrigation water applied (mm)	Cumulative amount of water applied to the treatment
T1	1	138.13	
T2	1	124.22	262.35
T3	1	122.93	
T4	1	135.43	258.36
T5	1	135.75	
T6	1	132.41	268.16

Soil Water Regimes

The soil moisture content in various treatments from 3 -8 WAP are represented in table 4. The soil water regimes reflected the amount of water applied i.e. soil moisture content was higher in irrigation treatment of daily water application than three and five days interval irrigation treatments.

The soil moisture contents after irrigation were observed to be higher than soil moisture contents before irrigation for all the treatments. The differences in the two moisture contents (before and after irrigation) give the change in the soil moisture storage, ΔSM. It was noticed throughout the treatments that the higher the soil depth, the higher the soil moisture content both for before and after irrigation. This is an indication of the fact that more moisture is stored at the root zone depth of the crop.

An increment in the soil moisture was observed from 3 WAP to 6 WAP for all the treatments. At the 7WAP and 8WAP, the moisture content was decreasing both for before and after irrigation. This was as a result of higher consumptive use of water during maturing stage.

Table 4: Moisture content (%) before (SMB) and after (SMA) irrigation at the three different irrigation treatments for 3WAP and 4WAP

Treatment		3 WAP			4 WAP		
	Depth of Soil (cm)	SMB (%)	SMA (%)	ΔSM (%)	SMB (%)	SMA (%)	ΔSM (%)
T1	0-10	16.06	17.05	0.99	18.88	19.19	0.31
	10-20	16.62	17.73	1.11	19.80	19.93	0.31
	20-30	17.25	18.43	1.18	19.96	20.41	0.45
	30-40	18.87	20.23	1.36	20.21	21.00	0.79
T2	0-10	16.01	16.95	0.94	18.67	19.00	0.33
	10-20	16.45	17.55	1.10	19.29	19.44	0.15
	20-30	16.86	18.00	1.14	19.63	20.11	0.48
	30-40	18.53	19.82	1.29	20.06	20.86	0.80
T3	0-10	14.10	15.07	0.97	16.90	18.00	1.10
	10-20	15.41	16.07	0.66	18.66	18.77	0.11
	20-30	16.03	17.17	1.14	18.84	19.24	0.40
	30-40	17.56	19.00	1.44	19.10	19.89	0.79
T4	0-10	13.36	14.35	0.99	17.08	18.21	1.13
	10-20	15.49	16.12	0.63	17.86	19.00	1.14
	20-30	16.24	17.41	1.17	19.29	19.72	0.43
	30-40	16.67	19.05	1.38	19.30	20.11	0.81
T5	0-10	12.16	13.65	0.89	14.75	15.11	0.36
	10-20	14.03	15.04	1.01	16.65	16.98	0.33
	20-30	14.93	16.10	1.17	17.89	18.00	0.11
	30-40	15.23	16.21	0.98	18.27	18.79	0.52
T6	0-10	12.44	13.35	0.91	14.67	15.04	0.37
	10-20	14.50	15.53	1.03	16.59	18.91	0.32
	20-30	14.73	15.91	1.18	17.20	17.33	0.13
	30-40	15.12	16.08	0.96	17.98	18.48	0.50

Agronomic Measurement of Amaranthus cruentus

Plant Height

The height of *Amaranthus cruentus* during the experiment are represented in figure 3. It can be seen from figure 3 that *Amaranthus* height in treatment (T3 & T4) were taller than those in (T1 & T2), while those in (T1&T2) were taller than the ones in (T5&T6). A rapid increase was observed in the height between 35-49WAP for the treatment (T3&T4) and (T1&T2), while in treatment (T5&T6), the height increases gently. The highest height attained by the treatment (T5&T6 was 53.50cm, while in treatment T1&T2 was 110.50cm, and treatment T3&T4 which gives the highest growth at 63DAP was 124.50cm. The relatively low growth in treatment T5&T6 was as a result of moisture stress.

Number of leaves

Figure 4 shows the responses of *Amaranthus cruentus* with respect to number of leaves produced by each of the treatments. There was a rapid increase in the number of leaves produced between 35-42DAPfor the treatment T3&T4. It was observed that no new leaves were produced by the *Amaranthus* in the treatment T3&T4 between 56-63DAP.There was also a rapid increase in the number of leaves produced by the plant in the treatment T1&T2 between 35-49DAP.Between 56-63DAP, there was only one leaf produced by the plant in the treatment T1&T2. The highest number of leaves at the 63DAP was observed in the treatment T3&T4 (182 units). The lowest number of leaves was observed in the treatment T5&T6 (82units).

Root Depth

The root depths of *Amaranthus cruentus* during the experiment for different irrigation treatment are represented in figure 5. The root depth of the plant in the treatment (T1&T2) and (T3&T4) were observed to be the same i.e. 10.18 cm. The root depth in the treatment T5&T6 was the lowest throughout the days of the experiment.

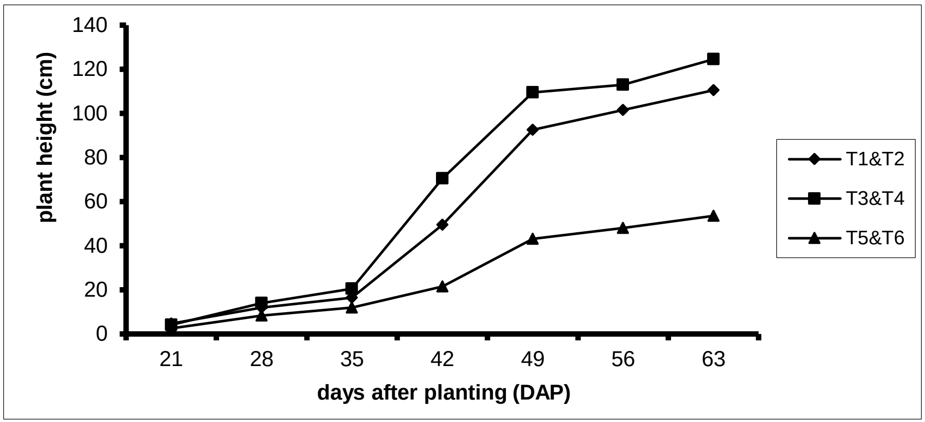

Figure 3: Height of Amaranthus Cruentus under different treatments during the experiment

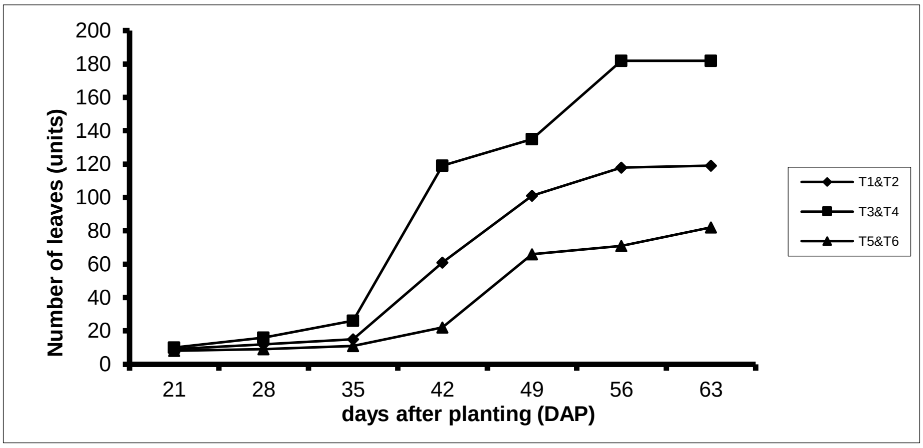

Figure 4: Number of leaves of Amaranthus Cruentus under three different treatments during the experiment

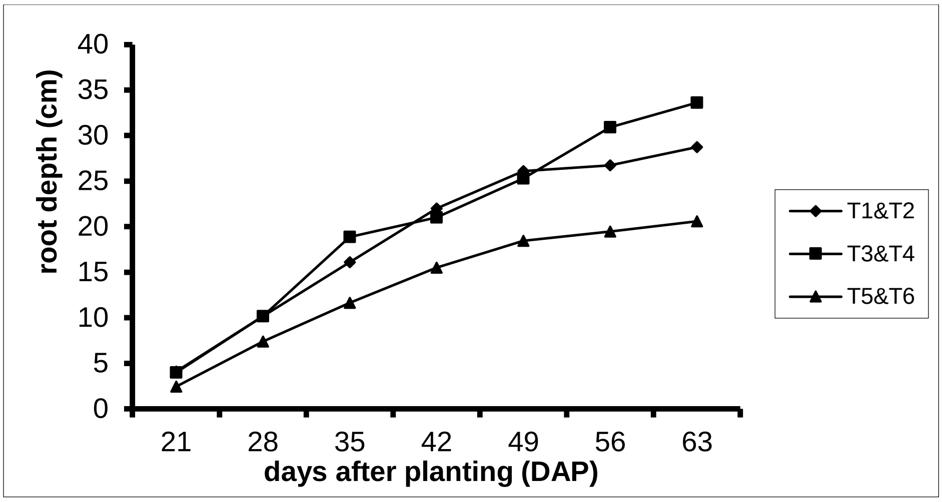

Figure 5: Root depth of Amaranthus cruentus under three different treatments during the experiment

Leaf Area Index

The Leaf Area Index (LAI) values which were determined at the 3rd, 5th, 6th and 7th WAP. The treatment T3 &T4 produced more leaves and luxuriant growth when compared to other treatments. Marketable difference was observed at 5ht, 6th, 7thWAP among the different. The value of LAI were found to be highest in the treatment T3&T4 at the 3WAP and lowest in the treatment T5&T6 at the 6WAP and 7WAP.

Water use of *Amaranthus Cruentus*

This is the actual amount of water loss to the atmosphere by the crop, which depends not only on the exciting meteorological conditions but also on the availability of water to meet the atmospheric demand. The highest consumptive use of *Amaranthus* in each of the treatment beds was observed at 35 DAP. This might be due to low runoff value recorded during the period. The consumptive use of *Amaranthus cruentus* in treatment T1 was observed to be highest at 35 DAP (i.e. 123.70 mm/wk) and lowest at 28 DAP (i.e. 104.85 mm/wk). The least value of consumptive use, 22.87 mm/day during the experiment was observed in Treatment T6 at 56 DAP.

However, the collected data from FUTA meteorological station were used to estimate the potential Evapotranspiration (PET) using Thornthwaite method. The highest value of PET was observed at 70 DAP when the experiment has already been terminated and the lowest value was recorded before the treatments started i.e 7DAP. Since temperature is the only climatic parameter consider for the estimation of potential Evapotranspiration PET using Thornthwaite method, then it can be concluded that PET value increases with respect to temperature increase. The highest and lowest values of PET recorded from Thornthwaite method are 15.39 mm/day 13.35mm/day respectively. The water use efficiency was determined at 4th, 5th, 6th, 7th and 8th WAP (on fresh weight basis) for al the treatments during the Experiment. The highest and lowest values of water use efficiency (WUE) on weekly basis were observed in treatment B_1 and treatment A_2 respectively. The daily irrigation treatment (i.e. A_1&A_2) gave the least values of water use efficiency, while three days interval irrigation treatment (i.e B_1&B_2) gave the highest values of water use efficiency in all the observable weeks. At 8th WAP the highest value WUE (259kg/m^3) was observed in treatment B_1 treatment and at 4th WAP the least value of WUE (0.644kg/m^3) was observed in treatment A_2. Also at the 6th WAP, the highest value of WUE (81.347kg/m^3) and lowest value (6.923kg/m^3) were observed n treatment B_2 and A_2 respectively.

Table 5: Estimated values of applied irrigation water, yield and water use efficiency of Amaranthus Cruentus for the various treatments.

WAP	Treatment	Irrigation I (mm)	Water use efficiency WUE (kg/m^3)
4	T1	690.65	0.724
	T2	621.10	0.644
	T3	245.86	5.288
	T4	270.86	4.430
	T5	135.75	5.157
	T6	132.41	5.287
5	T1	828.78	1.931
	T2	745.32	1.744
	T3	368.79	11.389
	T4	406.29	8.861
	T5	271.50	4.052
	T6	264.82	4.909
6	T1	960.65	8.543
	T2	621.10	6.923
	T3	122.93	81.347
	T4	135.43	37.658
	T5	135.75	19.153
	T6	132.41	15.860
7	T1	828.78	16.651
	T2	745.32	13.820
	T3	245.86	66.298
	T4	270.86	40.981
	T5	271.50	24.678
	T6	264.82	29.832
8	T1	828.78	72.637
	T2	745.32	35.689
	T3	368.79	259.497
	T4	406.29	170.568
	T5	135.75	172.376
	T6	132.41	86.852

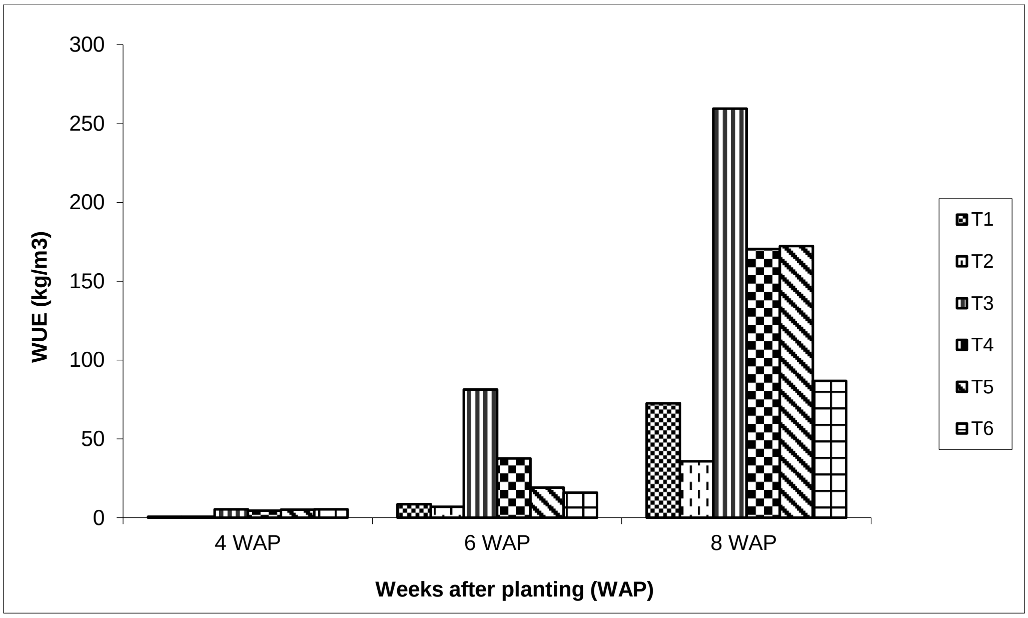

Figure 6: Water use efficiency at the 4th, 6th and 8th WAP for the various treatment

Conclusions and Recommendations

Conclusion

This study evaluated the performance of *Amaranthus cruentus* under three different irrigation water treatments. The aim was to investigate the consumptive use (ET_A), the growth, development yield and other agronomic of *Amaranthus cruentus* responses under the varying irrigation water management.

Soil moisture content was closely monitored to show the effect of the irrigation treatments on soil water regime. Treatment A_1 and B_1 produced the higher moisture content of 25.69% and 25.26% respectively but the 6th WAP. Yield of *Amaranthus cruentus* (fresh Biomass) was highest at 8th WAP in treatments T3 and T4 i.e. 957 t/ha respectively. The consumptive use (ET_A) of *Amaranthus cruentus* decreased in the order of T1, T2, T4, T5, T6 and T3 at the 6th and 7th WAP. It was observed that soil water balance properly reflected soil water regime in the treatment and biomass yield of the crop. The notable difference in the performance of *Amaranthus cruentus* among treatment for the roves the necessity of accurate water supply in plant growth and yield.

Conclusively, results show that *Amaranthus cruentus* responded well to three days intervals of irrigation water application in growth, development and yield. It will therefore be economically feasible if irrigation for *Amaranthus cruentus* is production based on the experiment results.

Recommendations

Based on the outcome of this study, it is strongly recommended that:

- Further studies should still be conducted to confirm the feasibility of maximizing the yield of *Amaranthus cruentus* under a wide range of defined climatic condition.
- There is the need to instill an automatic mini-Meteorological station permanently on the form site for easy collection of Climatological data.
- Modernized equipment and sensitive instruments should be used to monitor the soil and plant water status for proper relationship with applied irrigation water.

References

[1]. Badami, R. C, and Patil, K.B. (1976): Studies on vegetable oils of genus amaranthus. J. Oil Technol. Assoc. India 8:131.

[2]. Becker R, Wheeler, E.L, Lorenz, K, Stafford, A.E; Grosjean, O.k; Betschart, A.A; and saunders, R .M. (1981): A compositional study of amaranth grain. J. Food science. 46= 1175.

[3]. Betschart, A.A; Irving, D.W; Shepherd, A. D; and Saunders, R.M. (1981). Amaranthus cruentus: Milling characteristics distribution of nutrient within seed components, and the effects of temperature on nutritional quality. J. Food Sc. 46-1181.

[4]. Breene, W. M; (1991). Food use of grain amaranth. Cereal Foods World 36:426-430.

[5]. Bressani, R; Sanchez Marroqui, A; and Morales, E. (1992). Chemical composition of grain amaranth, Food Rev. Int. 8;5-21.

[6]. Carlsson, R. (1980). Quantity and quality of Amaranthus grain from plants in temperate, cold and hot, and subtropical climaters- A review. In "proceedings of the second Amaranth conference" p. 48. Rodale press, Emmaus, PA.

[7]. Crookston, R.K. (1976). "Agronomic cropping for Maximum Biomas production" Agronomic Jeurnal P. 702-899.

[8]. Curwen D; and Massie, L. R. (1995). "WISP – The Wisconsin irrigation Scheduling Programme" Advances in Evapotranspiration; Proc. Nat. Conf. On Adv. In Evapotranspiration; Ameri Soc. Of Agric. Engineers (ASAE). St. Joseph, Mich. P. 351-356.

[9]. Darrel, S.M; and Donald, M.E. (1980): Crop Production Principles and Practices First Edition.Macmillan Publishing Co. Inc. New York P. 129-139, 178-200.

[10]. Donald, C.M; and Hamblin, K. (1976): "Biological Yield and Harvest Index of cereal as Agronomic and plants Breeding criteria" Advances in Agronomic 28; P. 35, 361-405.

[11]. Early, I.K. (1977): Cultivation and uses of amaranth in contemporary Mexico. In "Proceedings of the first Amaranth Seminar" P. 39. Rodale Press, Bumaus, PA.

[12]. Elbehri, A.; Pkutnam, D.H; and Schmitt, M. (1993). Nitrogen fertilizer and cultuvar effects on yield and nitrogen use efficiency of grain amaranth. Agran. J. 85: 120-128.
[13]. Feine, L.B; Harwood, R.R; Kauffman, C.s; and Senft, J.P. (1979). Amaranth: Gentle giant of the past and future. In “New Agricultural crop” ed. G.A. Ritchie, P 41. Westview Press, Boulder, Co.
[14]. Grubben, G. J,H; and van sloten, D.H. (1981). “Genetic Resources of Amaranth “Intl. Board for plant Genetic Resources, Food and Agric. Org., Rome.
[15]. Haan, C. T. (1972): A water Yield model for small Water sheds. Water Resources Research 8 (1): 58-69. “ASCE Manual and Rep. On Engrg. Pract. No70 ASCE New York”.
[16]. Hagain, R.M; Haize, H. R,; and Edministe, R. Q. (1967): Irrigation of Agricultural Lands, Academic Press, Inc, New York; 444-455.
[17]. Haughton, C.S. (1978): “Green Immigrants: Plants that Trains-formed America “Harcourt Brace Jovanovich, New York.
[18]. Hulugalle, N.R, and Lal, R. (1986): Soil Water Balance of Inter cropped Maize and cowpea Grown in A Tropical Hydromorphic Soil in Western Nigeria. Agronomy Journal 77:86-70.
[19]. Idso, S.B; Jackson, R.D; Pinter Jr. P.J; Reginato, R. J; and Hartfield, J.L. (1981): Normalizing the stress Degree Day parameters for Environmental Variability. Agric. Motorola; 24: 45-55.
[20]. Irmark, S; Haman, D.Z; and Bastug, R. (2000): Determination of crop water stress index for irrigation Tinning and Yield Estimation of corn. Agronomy Journal Vol.92, 1221-1227.
[21]. Irving, D.W; Betschart, A.A; and Saunders, R.M. (1981): Morphological studies on Amaranthus Cruentus. J. Food Sci. 46-1170.
[22]. Jain, S.K; and Hauptli, H. (1980): Grain amaranth: A New crop for california, Agronomy Prog. Rept. 107, Agric. Exp. Station, Univ. of california, Davis.
[23]. Jensen, M.E. (1973): Consumptive use of water and irrigation water requirements. A report of the Technical Committee on Irrigation and Water Requirements of the Irrigation and Drainage Division of the American Society of Civil Engineers, 25-37.
[24]. Lascano, R. J. (2000): A general system to measure and calculated daily crop water use. Agronomy Journal, Vol. 92, P. 821-832.
[25]. Martin,F.W; and Ruberte, R.(1979): Edible leaves of the27tropics. U.S. Dept. of Agriculture, Mayaguez Inst. Of Tropical Agriculture, Mayaguez, Puerto Rico.
[26]. Martin, F.W; and Telek, L. (1979): Vegetables for thehothumid tropics. U.S. Dept. of Agriculture, New Orleans, L.A.
[27]. Marx,J. L. (1977): Amaranth: A comeback for thefood of the Aztecs? Science 198:40.
[28]. Myer, R.L. (1996): Amaranth: New crop Opportunity, P. 201-220. Int. J. Jamick (ed), Progress in New crops. Astts press, Alexandria, V.A.
[29]. NAS. (1975): “Underexploited Tropical Plants with promising Economic value, “Natl. Acard. of Sciences, Washington, Dc.
[30]. Neal, C.S. (1981): Understanding crop production. First Edition. Reston Publishing Company, Reston. Virginia, Priton Hall Company P. 39-74.
[31]. Oke, O.L. (1983): Amaranth. In Handbook of Tropical foods.” Ed. H.T. chan Jr., P.1. Marcel – Dekker, Inc., New york.
[32]. Okiei, W. and Adanson, I. (1979): Nitrate nitrite, vitamin C and in-vitro methemoglobin formation from some vegetables. Nutria. Rep. Intl. 19-241.
[33]. Oliveira, J.S; and decarvalho, M.F. (1975): Nutritional value o some edible leaves used in Mozambique Eon. Bot. 29:255.
[34]. Olufayo, A.A. (1996): Using Infra-Red Thermometry to estimate Grain sorghum Yield and Evapotranspiration, Journal of Agric Engineering and Technology 4:15-25.
[35]. Olufayo, A; Baldy, C: and Ruele, P. (1996): Sorghum yield, water use and canopy Temperatures under Different levels of Irrigation. Agric. Water Management, 30:77-90.
[36]. Opute, F.I. (1979). Seed Lipids of the grain amaranths. J. Ex. Bot. 30:601.

[37]. Pal, M: and khoshoo, T.N. (1974): Grain amaranths. In “Evolutionary studies in world crop “ed. J. Hutchinson, P.129. Cambridge univ. Press, canbridge, England.
[38]. Perrier, E.R: and Evans, D.D. (1960): Soil moisture Evaluation by Tensiometer. Soil Sci. Soc. Amer, proc, 25:173-175.
[39]. Perrier, E.R.: and Johnston, W.R. (1962): Distribution of thermal Neutrons in a soil- water system, soil sci. 93:104—112.
[40]. Phene, C.j: and Campbell, R.B. (1975): Agricultural meteorology, 15(1975): 181- 191.
[41]. Sanchez- Marroquin, A. (1980): Potencialidad agro industrial deI amaranths. cnetrode, Studios Economics socials del tercer mundo, san jeromino lidice, mexico.
[42]. Sanders, R.M, and Beciker, R. (1984): Amaranthus: A potential food and feed resource. In “Adv. Cereal sci. technol,” Vol. VI, ed. Y. Pomeranz, P.357. Amer. Assucereal chemists, St : Paul, MN.