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Irrigation Strategies during Dry Season Cultivation and Urea Micro-Dosing Rate on Growth and Yield of *Amaranthus viridis*

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Abstract
Excessive nitrogen application and water scarcity have become a major challenge to crop production due to climatic changes. The study investigated the effects of dry season irrigation and fertilizer micro-dosing application methods on the height, chlorophyll content and fresh yield of *Amaranthus viridis.* The field study was conducted during the 2022 and 2023 dry planting seasons of rainforest in southwestern Nigeria. The experimental design was a randomised complete block design with four replicates. The treatments compared two irrigation methods (capillary and manual sprinkler) combined with urea fertilizer rates (0 and 40 kg N/ ha) by fertigation, drilling, spot placement, and broadcasting methods. 40 litres of water were applied at two days intervals. Forty (40) kg/ha urea-N micro-dosing rate significantly improved fresh yield, chlorophyll content and height of *Amaranthus viridis.* The methods of application did not have a negative effect on the vegetable quality. The Capillary irrigation innovation displayed a capacity that significantly improved the yield of the leafy vegetable during the dry cultivation period. It produced more yield compared to the watering can irrigation method.
Keywords: Capillary irrigation, Sprinkler irrigation, Fertilizer micro-dosing, and Amaranthus viridis

Introduction

Irrigation and fertilizer application should be adequately utilized to achieve high vegetable yields. Potential yield is set by the genetics of the species and the variety grown. However, the interaction of crop management and the environment determines its actual yield (Fischer *et al.* 2014). Irrigation effects and water stress at different developmental stages on amaranthus growth and yield have been evaluated across different studies (Jomo *et al.,* 2015). Biomass reductions of 28–32% occurred after short-term water deficits during vegetative stages and up to 40% yield losses occurred when water deficit occurred during sensitive growth stages (Oniango, 2001). Water through irrigation and rainfall can significantly influence vegetable yields. Moisture needed for plant development and growth in a dry season is sourced from irrigation. Due to large spatial and temporal rainfall variability, associated with well-drained soils (Oyedele and Tijani, 2010), irrigation is frequently relied upon for successful crop production especially during dry cultivation periods (Kisekka *et al.,* 2016). Irrigation depends on weather, soil fertility status, plant density and crop maturity period. Irrigation scheduling (timing and depth) is more efficient when based on evapotranspiration or soil moisture sensors. This determines when and how much water needs to be replaced in the soil root zone to achieve plant requirements. The beneficial effects of reduced labour, fertilizer, herbicide and pesticide costs have motivated vegetable growers' interest in alternative irrigation application techniques (Cornish *et al.,* 2005). Surface irrigation often results in water runoff, and soil and nutrient loss. These challenges are more prominent in intensively vegetable-cultivated areas. Micro-dosing fertilizer application with irrigation water in vegetable cultivation is an effective means to apply nutrients and moisture through the subsurface rhizosphere. The method increases nutrient absorption and its accurate placement for optimum plant growth. For its efficient use, water and nutrient application must be precisely managed to prevent over-watering and nutrient leaching. Its effective installation and application will increase the soil moisture content and nutrient availability, and as a result, could increase crop uptake and fertilizer efficiency. Nitrogen (N) is an essential nutrient element required for achieving optimal vegetable yields. Micro-dosing fertilizer application rates based on crop needs aim at maximizing farmers' profit and reducing nutrient wastage. *Amaranthus viridis* is one of the species of *Amaranthus* used in the common diets of Africans (Olaniyi *et al.,* 2008). Water scarcity affects its production as availability and access to water a major threats to its growth. These result in severe stress and a reduction in its yield. There is a need to monitor fertilizer micro-dosing rate by different application methods on growth parameters of *Amaranthus viridis* concerning irrigation rate for enhancing its growth and production. This study aims to analyze the effects of irrigation and fertilizer micro-dosing on amaranth growth parameters in a rainforest.

Materials and Methods

The study involved field experiments and laboratory analyses at the teaching and research farm, Ekiti State Polytechnic, Isan-Ekiti. The study area (Isan-Ekiti, Nigeria) lies approximately between latitudes 15°39′ 15′ and 15° 36′ 19″ N and longitudes 70° 12′ 33″ and 70° 10′ 40″ E at an altitude of about 544 m above mean sea level. It is located in the rainforest agroecological zone, Southwestern region of Nigeria. The climate is hot and humid with distinct dry and wet seasons with annual rainfall of about 1350 mm which is bimodally distributed with peaks in July and September. The average solar radiation of this zone is 17.2 MJ m^{-2} d^{-2}. The average value for humidity is 74.84%; the mean annual temperature is 24.3 °C, sunshine hour is 5.60, potential evapotranspiration (PET) is 4.01 mm d^{-1} and wind is 1.92 km d^{-1} (Akintola, 1986). The soil at the experimental site was derived from medium-grained granite and gneiss and classified as Ondo association (Smyth and Montgomery, 1962) and Ultisol (Periaswamy and Ashaye, 1982). The vegetation over the soil was cleared with a cutlass before the soil samples were collected. Bulk topsoil (0-15 cm) samples were obtained randomly in the field with a soil auger before being sub-sampled for analysis. The soil sampled was classified as Ultisol. Ultisols are low-base status soil with finer textured sub-soil horizons. It is acidic and contains low organic matter content. The soil was sieved through a mesh of 2 mm diameter to determine selected laboratory analyses for the physical and chemical properties of the soil before the commencement of the experiment. The analyses were particle size distribution (Gee and Bauder, 2002), soil bulk density (Blake and Hartge, 1965), porosity (Flint and Flint, 2002), field moisture capacity (Flint and Flint 2002), soil pH (Peech *et al*., 1953), soil organic carbon (Nelson and Sommers, 1996) and soil exchangeable cations (Thomas, 1982). The experiment was laid in a randomized complete block design with four replicates on the field The treatments were as follows: (**1**) 40 kg N/ ha (broadcasting) + sprinkler irrigation, **(2)** 40 kg N/ha (fertigation) + capillary irrigation **(3)** 40 kg N/ha (spot placement) + sprinkler irrigation **(4)** 40 kg N/ha (drilling) + sprinkler irrigation **(5)** 40 kg N/ha (fertigation) + sprinkler irrigation **(6)** 0 kg N/ha + sprinkler irrigation (control). Vegetable seedlings were transplanted from the nursery beds at a spacing of 0.1 m within rows and 0.2 m between rows in each plot to prevent overcrowding of the seedlings. Two transplantings were done per dry season within the two-year study. Urea fertilizer was applied at 0 and 40 kg N/ha by four different methods: fertigation, drilling, spot placement, and broadcasting method a week after transplanting. 40 kg N/ha is the recommended fertilizer microdosing rate. Capillary and manual sprinkler irrigation (watering can) was applied accordingly. The capillary irrigation method was combined with fertigation while the watering can manual sprinkler irrigation method was combined with other methods of fertilizer application and fertigation adopted in this study. Approximately 40 litres of water was applied at two days intervals throughout the cultivation period. The capillary irrigation system is an innovation used to apply fertilizer with irrigation water to leafy vegetables. It consists of 10 cm diameter PVC pipes, conducting and water transmitting nodes of smaller diameter pipes (5cm) filled with conducting materials arranged on the top side of the 10 cm diameter PVC pipes. The bigger PVC pipe was closed at one end with a cap and a water inlet was attached at the other end. The sprinkler method is a manual watering can method adopted by farmers. Plant height and chlorophyll index were taken before each harvest with measuring tape and chlorophyll meter SPAD 502-Plus (Koncal Minolta, USA) respectively. The mature vegetable stems were harvested and weighed with a stainless steel knife and weighing balance respectively 3 weeks after transplanting. Data obtained were subjected to ANOVA and significant means were separated with Duncan's multiple range test.

Results and Discussion

The results of the physical and chemical properties of the soil used for the analyses are shown in Table 1. The surface soil textures were predominantly sandy loam. The loamy sand nature of the surface horizon may be due to granitic parent material as reported by Buol *et al.* (2011). This also suggests that the soil texture is homogenous, and variations did not exist on the experimental site. Soil bulk density value is an indication of the dragging of trees on the soil after felling which might have caused the smearing of soil on the experimental site Mambani (1986). However, the porosity indicates little or no variations compared to standard values for sandy soils. Differences in the field moisture capacity for standard sandy loam soil were also not significant. The soil pH value ranged from low to moderately acidic (Adepetu *et al.*, 2014) as a result of the acidic nature of the parent material and the acidification effect. The soil pH value is however suitable for leafy vegetable cultivation (Liu and Hanlon, 2015; Havlin *et al.,* 2005). Low content of exchangeable cations may be a result of plant uptake and leaching. The organic carbon content of the soil ranged from low to medium. This may be a result of historical records of continuous cultivation on the site. Organic carbon improves soil structure through cementation processes, this brings about a change in soil and its hydraulic processes.

Figures one (1), two (2) and three (3) show the agronomic parameters of *Amaranthus viridis* as influenced by irrigation and urea micro-dosing rate. Biomass yield shows higher significance with 40 kg N/ha by fertigation combined with capillary irrigation method (5616.72 kg/ha) compared with other treatments. The capillary irrigation method with 40 kg N/ha applied by fertigation gave the best performance on the yield of the amaranth (figure 1). This was significantly higher ($P \leq 0.05$) than 40 kg N/ha applied by other methods combined with the manual sprinkler irrigation method. The reason might also be a result of adequate water supply through the capillary irrigation device at all the stages of growth of the vegetable combined with less evapotranspiration which is a characteristic of the rainforest agroecological zone.

Timely application interval by the capillary irrigation pipe aided effective root absorption of nutrients. This contributed to improved nutrient (nitrogen) uptake for chlorophyll development (figure 2), promoted rapid early growth and plant height (figure 3) and improved the fresh yield. The capillary irrigation method conserved more moisture which in turn enhanced more nutrient uptake by the vegetable roots and provided more favourable conditions for better nutrient uptake and in turn resulted in significant growth. This was demonstrated in the higher plant height obtained through this irrigation method. This implies that 40 Kg/ha urea combined with the capillary irrigation method can be a strategy to offset the higher rates of fertilizer applications thus cutting down on the production cost. This has similarly been reported by Hayashi *et al.* (2008). Regardless of irrigation and fertilizer application technique, control treatments recorded the lowest yields, indicating that fertilizer application and irrigation influenced vegetable yields.

Schmidhalter and Studer (1998) argued that adequate moisture and fertilizer application increases transpiration efficiency of crops resulting in yield increase (figure 1). The positive response of Amaranthus to this fertilizer application rate (40 kg N/ ha) can also be linked to the low inherent fertility of the soil type in this zone (Ultisol) which leads to the positive responses following improved soil fertility management practice (fertilizer micro-dosing). This is an indication that the micro-dosing application of nitrogen fertilizer (urea) would increase soil nitrate and maintain significant crop response. Similar result was obtained with fertigation over control, spot placement, drilling and broadcast on plant height (figure 3) through sprinkler irrigation. Zhaopeng *et al*. (2016) reported that the high plant height was a result of a moderate N application rate which had significant effects on the leafy vegetable growth. Fertigation by sprinkler irrigation influenced the accurate placement of nutrients and aided their absorption by the amaranth roots (Egbebi, 2021). The drill fertilizer placement method had high effects on the chlorophyll content index (figure 2) and yield (figure 1) of the vegetables. This is due to light interception, reduced temperature and radiation linked to the rainforest zone. This method reduced and prevented volatilization loss of the urea fertilizer applied and increased the efficiency and uptake of the nitrogen applied and transported to the vegetable leaves. Light interception, light use efficiency and temperature influence leaf chlorophyll content. Previous studies by Akram, 2014 reported that it was also due to slower leaf senescence. The prolonged presence of nitrogen in the soil due to controlled irrigation and drill application method of urea improved the amaranth photosynthetic rate and delayed leaf senescence.

This eventually improved the fresh yield over control, spot placement, broadcast and surface fertigation application methods. The capillary irrigation practice was sufficient to produce significant crop yield. This may be a result of the plant residue and residual effect combined with irrigation practice of the dry period. The plant residue might have reduced soil evaporative losses during the dry season and increased the soil nutrient availability to plants. The excess plant nutrient applied by the irrigation device which would have delayed maturity stays within the capillary irrigation device. Excess nutrients applied by other fertilizer application methods were lost to volatilization and runoff from sprinkler irrigation. Earlier reports by Gerard *et al.* (2001) identified the residual effects of chemical fertilizer especially phosphorus in sustaining the productivity of the subsequent crop and thus influencing seasonal yield differences. It is, however, likely that the little differences in yields and heights obtained in the current study could be due to this effect because a minimal residual effect could be expected. The timely and more precise release of water by the capillary irrigation device particularly during the period of moisture stress and high evapotranspiration rate by the vegetable seedlings might have also contributed to the effect. The subsequent increased ground cover development from plant residue contributed to reduced soil evaporative losses. This enabled the crop to effectively utilize the available moisture and fertilizer applied from the capillary pipe.

Conclusion

40 kg/ha urea-N is the optimum rate which significantly improves fresh yield, chlorophyll content and height of *Amaranthus viridis.* This rate did not constitute a negative effect on the vegetable quality. The Capillary irrigation innovation displayed a capacity and significantly improved the yield of amaranthus during the dry cultivation periods. It produced a better yield compared to the watering can irrigation method.

Conflict of Interest

The authors have not declared any conflict of interest.

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Table 1: Some physical and chemical properties of the soil used for the experiment

Parameters	
Sand (g kg^{-1})	701.7
Silt (g kg^{-1})	128.3
Clay (g kg^{-1})	170.0
Texture	Sandy loam
Soil bulk density (g/cm^3)	1.27
Soil Porosity (%)	45
Field moisture capacity (%)	24
pH in 0.01 M $CaCl_2$	5.8
Organic carbon (g kg^{-1})	1.2
Exchangeable cations (cmolkg^{-1})	
K	0.17
Ca	0.14
Mg	0.21
Na	0.19

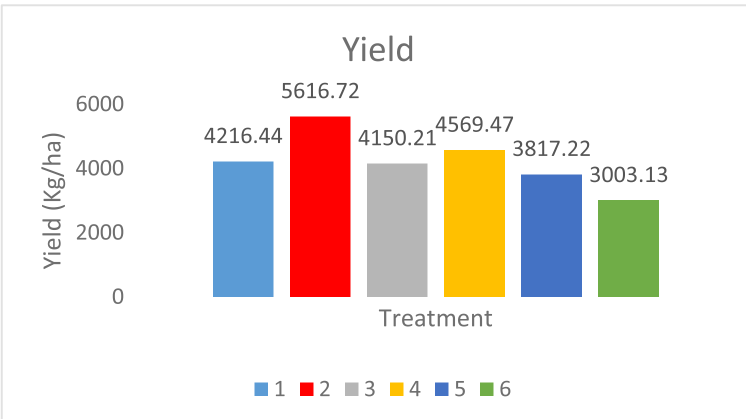

Figure 1: Yield of Amaranthus viridis under irrigation and urea micro-dosing application methods (1) 40 kg N/ ha (broadcasting) + sprinkler irrigation, (2) 40 kg N/ha (fertigation) + capillary irrigation (3) 40 kg N/ha (spot placement) + sprinkler irrigation (4) 40 kg N/ha (drilling) + sprinkler irrigation (5) 40 kg N/ha (fertigation) + sprinkler irrigation (6) 0 kg N/ha + sprinkler irrigation (control).

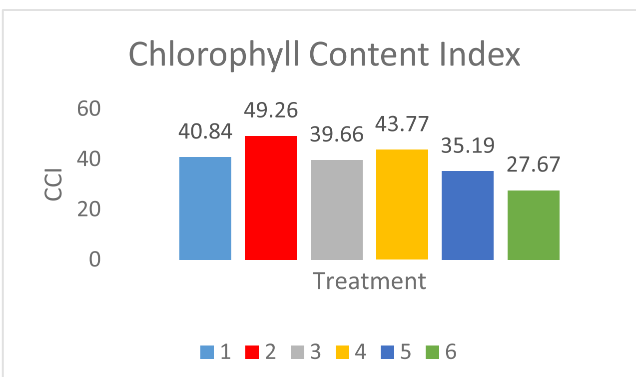

Figure 2: Chlorophyll content of Amaranthus viridis under irrigation and urea micro-dosing application methods (1) 40 kg N/ ha (broadcasting) + sprinkler irrigation, (2) 40 kg N/ha (fertigation) + capillary irrigation (3) 40 kg N/ha (spot placement) + sprinkler irrigation (4) 40 kg N/ha (drilling) + sprinkler irrigation (5) 40 kg N/ha (fertigation) + sprinkler irrigation (6) 0 kg N/ha + sprinkler irrigation (control).

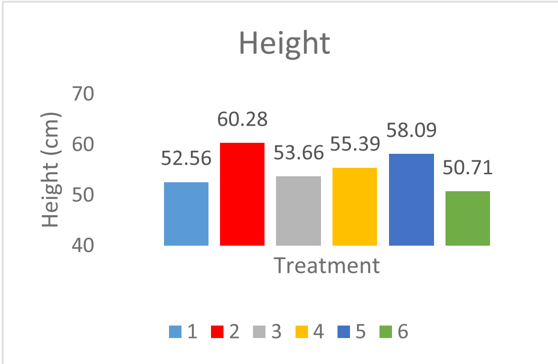

Figure 3: Height of Amaranthus viridis under irrigation and urea micro-dosing application methods
(1) 40 kg N/ ha (broadcasting) + sprinkler irrigation, (2) 40 kg N/ha (fertigation) + capillary irrigation (3) 40 kg N/ha (spot placement) + sprinkler irrigation (4) 40 kg N/ha (drilling) + sprinkler irrigation (5) 40 kg N/ha (fertigation) + sprinkler irrigation (6) 0 kg N/ha + sprinkler irrigation (control).