RESEARCH PAPER

Growth comparison of Banana cv. Mchare (Huti Green) under full and deficit irrigation conditions in Northern Highlands, Tanzania

Erick A. Kibona[*1], Ernest R. Mbega[1], Kelvin M. Mtei[2], Patrick A[1], Ndakidemi[1]

[1]*Department of Sustainable Agriculture, Biodiversity and Ecosystems Management, Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania*

[2]*Department of Water and Environmental Sciences, Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania*

Abstract

Drip irrigation in banana farms is an uncommon practice as compared with other horticultural crops. Records for East African Highland Banana (EAHB) diploid (AA subgroup) cv Mchare-Huti Green (HG) cultivated under drip irrigation remain unavailable in the study area. The objective of this study was to assess the influence of drip irrigation on banana growth and bunch yield in the research site situated at 3°23′ 58″ S and 36°47′ 48″ E at an altitude of 1,188m above sea level in Arumeru District, Arusha Region, northern highlands of Tanzania. We investigated the performance of HG under Full irrigation (FI) and Deficit Irrigation (DI) treatments, to assess the influence of drought on banana growth parameters and bunch yield. The results exhibited significant differences within and between treatments of most tested variables. The mean bunch weight in FI was (28.3± 1.75kg plant⁻¹) and DI (19.6±0.97kg plant⁻¹) at (p<0.05) and fresh Aboveground biomass (AGB) in FI (78.81±2.61kg plant⁻¹) and DI (59.23±1.06kg plant⁻¹) at (p<0.05). The correlation coefficient in this study for growth parameters and bunch weight versus AGB indicated significant closer association exemplified by pseudostem girth, pseudostem volume height and bunch weight, with correlation 0.44 to 0.73. Conversely, for bunch weight and its components, correlation ranged from 0.30 to 0.50. The variation in allometric growth parameters calls for integrated soil water management in banana production to ensure the optimal level of available moisture for better performance from the vegetative phase to the generative phase.

* **Corresponding Author:** Fahad Alghabari ✉ falghabari@gmail.com

Introduction

Edible fruit and cooking banana (*Musa* spp.) are planted in more than 135 countries in the tropical and subtropical regions (Brown *et al.*, 2017). Globally, banana is the most important fruit crop with regard to production volume and trade and vital staples to millions of people (UN 2014, Ortiz and Swennen, 2014). Research evidence shows that between 400-500 million people in Africa, Asia, and South America depend on bananas as a major source of nutrition and household revenue (Nelson *et al.*, 2006). In the Great Lakes of the region of East Africa, the East African highland banana (EAHB) a distinct group of AAA bananas is a staple of 80 million people in the area (Nyombi, 2010). In East Africa alone, bananas and plantains offer food and income to more than 50 million smallholder farmers, with a yearly production value of US$ 4.3 billion, corresponding to nearly 5% of the region's overall domestic product (UN, 2014)

Nevertheless, the biggest abiotic threat to banana production is drought stress (Turner *et al.*, 2007) and a sub-optimal supply of water may lead to physical damage, physiological interruptions, and biochemical changes in the plant (Okech *et al.*, 2004, Surendar *et al.,* 2013). Bananas need high rainfall of 1400 mm for high banana productivity (Nyombi, 2010) and yield losses may run to about 20-65% forfeit in the bunch weight at the rate of 1.5-3.1kg or 8-10% for every 100mm decline in rainfall (van Asten *et al.*, 2011). It is projected that the danger of global climate shift will likely continue to escalate the decrease of crop water accessibility and threaten the production of the rainfall-dependent agro-ecosystem in East Africa, Africa and Worldwide at large (Adhikari *et al.*, 2015 and Molua, 2007). Use of irrigation (especially drip irrigation as compared with other means of irrigation) is reported to maximize water use and fertilizers can be applied together with water through fertigation. Hence, in banana farming, drip irrigation could be one of the coping strategies for drought (Salau *et al.*, 2016, Pramanik and Patra, 2016).

Given the inadequate of records and unusual cultivation of banana under drip irrigation as compared to other horticultural crops, the overall objective was to assess the influence of drip irrigation on banana growth and bunch yield. This paper aims to investigate the performance of banana cv. Mchare-Huti - Green (AA-genome HG under optimal irrigated (FI) and deficit Irrigated (DI) regimes. Thus, this study was conducted to: (i) assess the influence of drought on banana growth parameters and bunch yield.(ii) assess the correlations between bunch weight and aboveground biomass to pinpoint important characteristics which might prove promising in growth allometry (parameters which have a high correlation with bunch yield and aboveground biomass.

Materials and methods

Site characterisation

The experiment was conducted within a banana research-based farms owned by public academic and research Institution of Nelson Mandela African Institution of Science and Technology (NM-AIST) and International Institute of Tropical Agriculture (IITA). It is situated in Arumeru District, Arusha Region, Tanzania in the South West within the mid-slope of Mount Meru between Latitude 3°23′ 58″ S and Longitude 36°47′ 48″ E at an altitude of 1,188 meters above sea level. The area receives a bimodal pattern of rainfall with the long rainy spell named by "Masika" distributed from late March to early June and the short named by "Vuli" rainy spell from October to December. The soils class in the area are Phaeozems as per FAO soil classification system (Wrb, 2014) The chemical and physical properties of soils in the area satisfactorily suit banana production. The chemical properties are, neutral pH (around 7), high Cation Exchange Capacity (CEC) of around (60 $cmol_c$/kg), high percentage base saturation (PBS %) (based on pH), and total organic carbon range from moderate to high, total nitrogen and very high P-Olsen contents). The physical properties are, brownish-black colour, silty clay loam to silty clay textural class, well-drained, brownish-black colour and its depth range from moderately shallow 60-90cm) to >120cm.

Plant Materials

In vitro, banana cv. Mchare-Huti Green (HG) EAHB was used as planting material. Mchare Huti Green

was planted on 3 May 2017. Plants were spaced 2x3m (row x line) in holes with dimensions of 60cm width x 60cm length x 60 cm deep with a density of 1666 plants ha⁻¹. Two plants were maintained per hole comprising of a mother (cycle 1) and daughter (cycle 2).

Methodology

Experimental trial and treatments allocation

The experimental design was blocked but could not abide by normal Randomized Complete Block Design (RCBD) due to the nature of the layout of drip lines. However, it comprised of 2 blocks each with 5 rows of 15 plants spaced at 3m x 2m. Block 1 was allocated with Deficit irrigation (DI) treatment and block 2 Full irrigation (FI) respectively. Individual blocks of HG with five rows of 15 plants/row were split to three plots with a total of 25 plants within which three replications (rows) of nine plants (3x3). The central nine plants (3x3) of plants belonging to two split plots were used for continuous data collection throughout the entire time of the experimental time frame. The remaining plants were used as a borderline (Fig. 1).
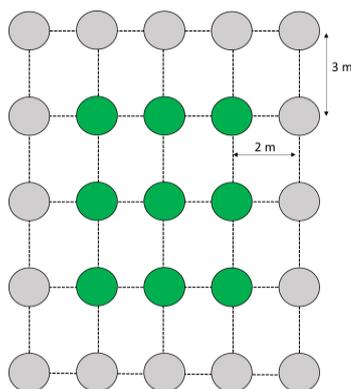

Fig. 1. Part of experimental layout showing continuous sampling plants (Green) and border line in (Grey).

Irrigation system

Drip irrigation pipes were installed together with water flow meters reading irrigation amounts per 2 driplines. The drip system comprised of two driplines per banana row, with 4 emitters plant⁻¹, each dispensing 4 l h⁻¹ at 110 kPa pressure. Daily, soil moisture remained checked by Time Domain Reflectometry (TDR). Every day, continuous measurement plot where plant data were collected, was fitted with two in-house built 30cm long TDR

probes installed vertically, reading soil moisture at two soil depths, one at the outermost layer of soil (0-30m) and another at the soil under the topsoil (30-60cm). Every morning before irrigation, TDR-probes were read out individually by a TDR-200 (Campbell Scientific, Inc). Based on TDR volumetric water contents, the need for irrigation by the plant was determined. Before splitting plots into respective treatments FI and DI, all plants were irrigated until four months after planting (MAP). The plot allocated with treatment FI received water when a critical moisture level reached 25% total available water (TAW) in the first (0-30cm) or (30-60cm) depth. This corresponded to 37.5% and 41% volumetric water content (VWC). No water was applied in the DI plots until plants showed visible signs of water stress like petiole collapse and leaf wilting, after which irrigation was supplied.

Experimental management

Apart from irrigation, plants received both mineral and organic fertilizers. Mineral fertilizers were applied in splits both in the rainy season and dry season. Mineral fertilizers composed of Urea (46% N) at the rate of 333kg ha⁻¹ yr⁻¹, Muriate of potash (MOP) (60%K) (416kg ha⁻¹ yr⁻¹, Mg, and S as MgS (16% MgO, 32% SO₃) (200kg ha⁻¹ yr⁻¹). During the rainy season, mineral fertilizers were applied every month and every 2 months in the dry season, while TSP (46% P_2O_5) (200 kg ha⁻¹yr⁻¹) was applied every five months. The fertilizer materials were placed in a ring at 0.4-0.5m a distance from the base of the pseudostem during the wet season while during dry season fertilizers were placed within the wetted zone by the drippers. Organic fertilizer was applied twice yearly right at the onset of the rainy season.

The type of organic fertilizer applied was farmyard manure at the rate of 20L per plant hole. The emerged suckers were left to grow until four months after planting (MAP) when all suckers were pruned except for one sucker of 30cm height situated at the south side of the plant. Afterwards, sucker assortment and removal of unselected ones were carried out monthly. Removal of dead leaves was performed every month and regular weeding manually using a hand hoe.

Data collection

Data on bunch weights and other banana plant characteristics were collected over the course of two growth cycles from planting to harvest. A distinction is made between vegetative growth parameters and generative growth parameters.

Vegetative growth parameters

Measurements were taken monthly from the central 3x3 plants in each measuring plot. Phenotypic vegetative descriptors measured were pseudostem girth at (base, 1m high and mid-height), the stature of the plant measured from the soil up to the "V" formed by petioles of the two last issued leaves fully unfolded, the amount of functional leaves, the amount of dead leaves, the lamina length and width of the 3th youngest fully unfurled leaf and internode distances (Table 1).

Generative growth parameters

The generative phase of the bunch development commences with the emergence of the flower apex and reaches up to the maturity stage of the bunch (Wairegi *et al.*, 2009). The maturity stage of the bunch is attained through a transition in the size, shape, length, and volume of the fruit as bunches advance in age. Key indices to the maturity of a banana can be observed through the types of ridges it forms on the peel. After flowering, the monthly check on bunch characteristics was focused on three middle fingers of the outer whorl of the second hand from the top. The quantitative measurements taken included; angularity of fruit (usually becomes less angular/rounder when filling), finger circumference (measured in the middle part), finger length (measured by the convex) and finger fullness index (weight/length, especially at harvest).

Data collection at harvest

The destructive sampling of the proven mature bunch was done referring to standard morphological descriptors for banana (Nyombi *et al.*, 2009). At harvest, the following parameters were measured: vegetative growth parameters, generative growth parameters, bunch weight with and without peduncle, the number of hands per bunch, fresh weight of individual hands and fingers, the length of the convex side and circumference of every finger of the bunch. Weights were measured using a Kern EOC 100K-3L balance (60kg±2g).

Table 1. Summary of the plant growth parameters measured between growth phases (Vegetative& Generative) and destructive sampling at harvest.

Time resolution	Variable measured	Units
Vegetative growth measurements		
Monthly	Pseudostem girth at the base, at 1m and height	Cm
Monthly	Number of dead leaves	Amount
Monthly	Number standing functional leaves	Amount
Monthly	Internode distance of 4th,5th and 6th youngest leaf	Amount
Monthly	Allometric [pseudostem (base girth,1m, height, leaf (width &length)	Cm
Generative growth parameters		
Weekly	Harvest readiness qualitative	the colour change of fruits fruits bursting, angularity, dryness of flowers
Weekly	Bunch characteristics (three middle fingers of second hand from top) angularity, finger girth, and length)	Cm
Harvest		
At harvest	Weight of pseudostem, leaves, and petioles	G
At harvest	Bunch characteristics	
	Weight of bunch	G
	Number of hands	Amount
	Weight of hands	G

Statistical analysis

From raw data of growth parameters (plant height, leaf length, leaf width) conversion were done through simple mathematical calculations prior to doing direct analysis on some of the data of some allometric growth parameters summarized (Table 1). New variables created through calculations included; the volume of pseudostem, leaf area (LA) and leaf area index (LAI) after destructive sampling at harvest time. An assumption was made to calculate the radius of a plant from the girth of the plant $circumference\ (c) = girth = 2\pi$; thus $r = c/2\pi$, then the volume of the pseudostem was first computed as a cylinder, then as a cone.

$$Vcylinder = \pi * r^2 * h\ (1)$$

$$Vcone = Vcylinder * \frac{1}{3}\ (2)$$

Leaf area (LA) was calculated according to $LA = laf \times l \times w,$ Whereas, LA signifies the leaf area, laf signifies the lamina area factor, l signifies the lamina length (m) and w signifies the greatest part of lamina width (3) $LAI = \frac{laf}{area}\sum_{i=1}^{n}(li \times wi \times ni)\ (4)$

Where laf signifies for area factor, li stands for leaf length (m), wi signifies the maximum lamina width (m), the $area$ is the total ground area and ni is the number of leaves. The calculation for leaf area individual leaves followed the approach by (Nyombi *et al.*, 2009). Correlation coefficient according to Pearson (r) were obtained using Origin Pro 2015 software, means and variances equality test through t-test between treatments were obtained using Gen Stat Discovery version 4 edition statistical software and boxplots Fig.s were obtained by R statistical software. Fisher's least significance was used to compare means at the p=0.05 level of significance.

Results

Correlations of growth parameters

For Mchare plants, correlation coefficients established from allometric growth parameters sampled during destructive sampling at harvest are presented in Table 2. The aboveground biomass (AGB) was significantly correlated with pseudostem girth, pseudostem volume, height and bunch weight.

The correlation ranged from 0.44 to 0.73. Bunch weight was also significantly correlated with pseudostem girth, pseudostem volume, height, and LAI. In addition, across all analyzed allometric growth parameters, a strong correlation was detected between leaf area (LA) and pseudostem volume (r²=0.8587, p<0.001), leaf area index (LAI) and pseudostem volume (r²=0.8261, p<0.001) and girth at 1m and plant height (r²=0.7578, p<0.001).

Yield and correlation of banana yield characteristics and bunch weight

The results presented in Table 3, Fig. 1 and Fig. 2 indicate that banana bunch parameters fruits/bunch (nr), fruit girth (cm), fruits/hand, fruit length (cm), fruit weight (kg), hand weight (kg) were significantly correlated with bunch yield (kg plant ¹). The correlations ranged from 0.30 to 0.50 and bunch yields of 28.30±1.75kg plant⁻¹ in FI and 19.06±0.97kg plant⁻¹ in DI were achieved. The mean bunch weight (kg), fruit/bunch (kg), fruit girth (cm), fruit length (cm), fruit weight (kg) and hand weight (kg) differed significantly between FI and DI.

Effects of irrigation on growth parameters

Box plots were used to assess the influence of water regimes on the banana growth characteristics and bunch yield of the tested banana in FI and DI.

Test for equality growth parameters variances and means between treatments

For HG, differences of parameters between FI and DI are shown in Fig. 3. The pseudostem girth, height and leaf width in DI plants were found to be significantly lower than those ones in FI plants (p<0.001) while the leaf length was insignificantly at (p>0.05) (Fig. 3). A two-sample student's unpaired t-test was used to test the hypothetical equality of variances and means for growth parameters existed between two treatments of FI and DI. The means for pseudostem girth, leaf width and height were statistically different between FI and DI (p<0.001) while the means for leaf length was statistically not different (p>0.05). Similarly, the variances for pseudostem girth, leaf width and height were statistically different (p<0.05) but the variances for leaf length were not different (p>0.001).

Effects of water of irrigation regimes on the bunch yield (weight) and aboveground biomass

Variations of bunch weight and aboveground biomass between plants across treatments

The weight of bunch in FI 28.3± 1.75kg plant^{-1} and DI 19.06±0.97kg plant^{-1} was significantly different p<0.001 (Table 3 and Fig. 3). AGB in FI 78.81±2.61kg plant^{-1} and DI 59.23±1.06kg plant^{-1} was also significantly different p<0.001 (Fig. 3).

Test for equality of bunch weight and biomass variances and means between treatments

Bunch weights and ABG in FI varied more than bunch weights in DI (t-test<0.001) respectively. The means for bunch weights and AGB were statistically different between FI and DI (p<0.001). The variances for bunch weights were different between FI and DI (p<0.011) whereas, the variances for AGB were not different between FI and DI (p>0.05).

Table 2. The Pearson correlation coefficient (r) values of Bunch mass (MB) and Aboveground biomass (AGB) in association with the allometric growth parameters of the banana plant.

|	AGB	Girth base	Girth 1m	Girth mid	Height	LA	LAI	MB	Volume
AGB									
Girth base	0.52***								
Girth1m	0.53***	0.71***							
Girth mid	0.50***	0.67***	0.56***						
Height	0.45***	0.61***	0.76***	0.68***					
LA	0.23ns	0.51***	0.32*	0.40***	0.38**				
LAI	0.23ns	0.58***	0.34*	0.41***	0.32*	0.86***			
MB	0.74***	0.48***	0.38*	0.51**	0.47***	0.32*	0.29*		
Volume	0.14ns	0.68***	0.41***	0.49***	0.51***	0.86***	0.80***	0.38**	

Key: AGB: Above ground biomass; LA: Leaf area; LAI: Leaf area index; MB: Mass of the bunch; Girth of pseudostem, Volume of pseudostem*** asterisks connote significant at *p* =0.001;**= significant at *p* =0.01 ;*= significant at *p*= 0.05 and ns non- significant.

Table 3. Bunch yield and yield attributing components differences between treatments and their correlation with bunch yield.

Bunch components	Yield between treatments (mean ±SE)		Mean difference (p-value)	Correlation coefficient(r)	(p-value)
	(FI)	(DI)			
Bunch weight (kg)	28.30±1.75	19.06±0.97***	<0.001		
Fruits/bunch (kg)	56.26±3.67	38.76±2.65***	<0.001	0.40**	0.004
Fruit girth (cm)	124.5±2.03	113.2±3.48**	0.008	0.50***	0.0000
Fruit/hand (nr)	18.00±0.34	16.37±0.76ns	0.058	0.30*	0.0253
Fruits length (cm)	270.5±21.30	244.9 ±6.39**	0.002 0.42***	0.0028	
Fruit weight (kg)	0.18±0.006	0.12±0.007***	<0.001	0.45***	0.0013
Hand weight (kg)	3.07±0.16	2.41±0.14**	0.003	0.30*	0.0256
Hands/bunch (nr)	9.37(±0.34)	9.19(±0.18)	0.630-0.11ns	0.7635	

Two tailed t -test summary				
Variable	μ1- μ2	Sed	t-value	p-value
Bunch weight (kg)	9.246	1.998	4.63	<0.001
Fruits/bunch (kg)	23.704	9.201	2.58	0.014
Fruit girth (cm)	11.259	4.030	2.79	0.008
Fruit/hand (nr)	1.630	0.832	1.95	0.058
Fruits length (cm)	25.630	7.587	3.38	0.002
Fruit weight (kg)	0.044	0.009	4.51	<0.001
Hand weight (kg)	2.238	0.144	15.50	< 0.001
Hands/bunch (nr)	0.185	0.382	0.48	0.630

Test of null hypotheses that means of DI variables are equal to means of FI variables

Key: The results of values presented are means with Standard error of (means ±SE); μ1- μ2; estimate for mean difference; Sed=Standard error of difference; *** asterisks connote significant at *p* =0.001; **= significant at *p* =0.01; *= Significant at *p*= 0.05 and ns non- significant and FI=Full irrigation, DI=Deficit irrigation=number.
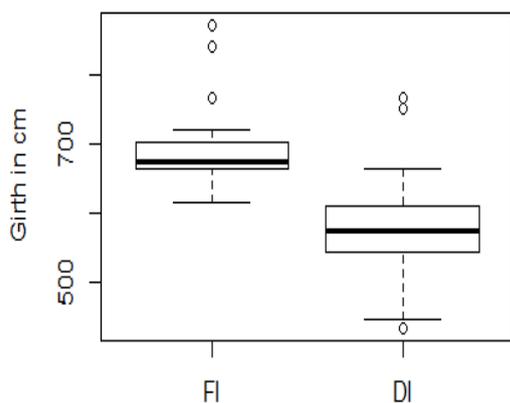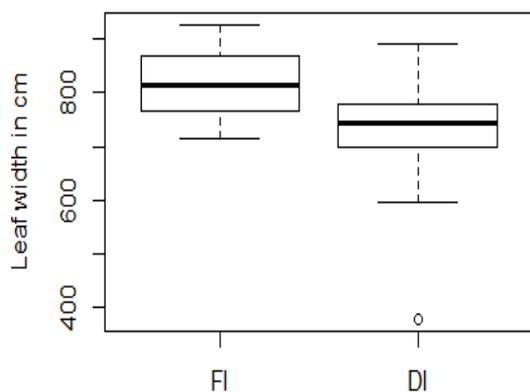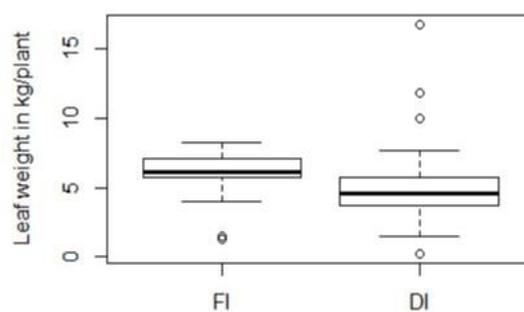
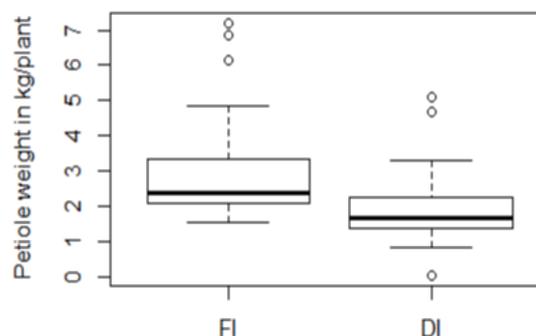(a) Plant girth at harvest.
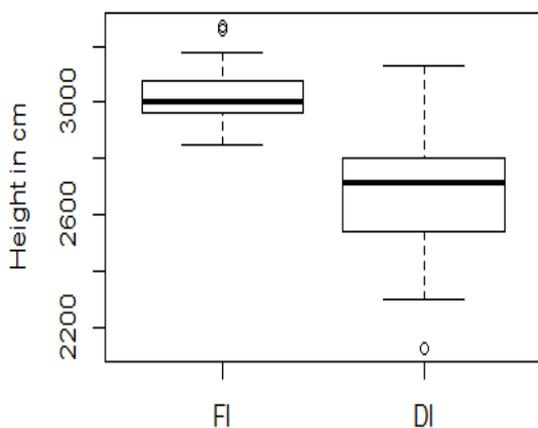
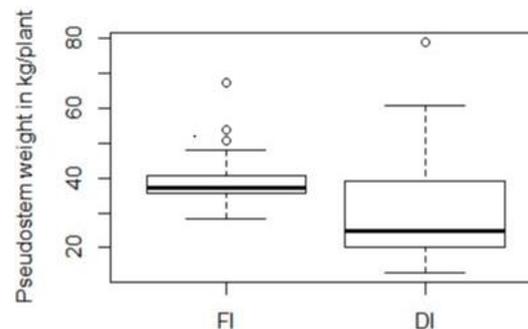(b) Plant height at harvest.
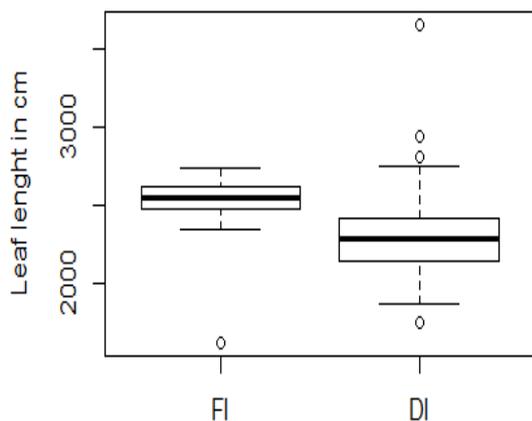
(c) Plant leaf length at harvest.

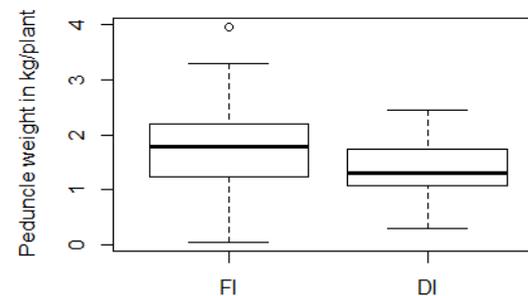(d) Plant leaf width at harvest.
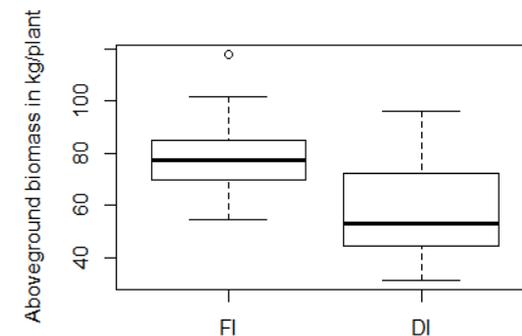
(e) Plant leaf weight at harvest.
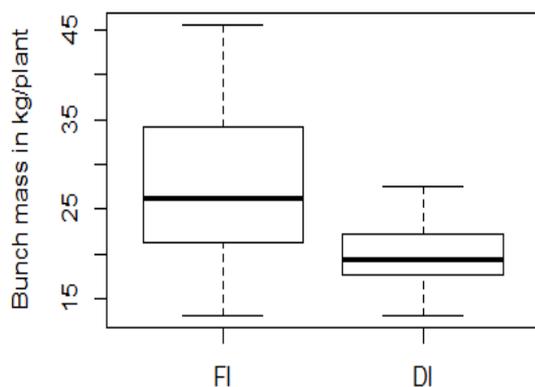
(f) Plant petiole weight at harvest.

(g) Plant pseudostem weight at harvest.

(h) Plant peduncle weight at harvest.

(i) Plant aboveground biomass.

(j) Plant bunch weight at harvest.

Fig. 2. Box plots depict effects of water regimes on the allometric growth parameters and, bunch weight and Aboveground biomass (ABG) measured during destructive sampling at harvest; (a) girth), (b) height, (c) leaf length, (d) Leaf width, (e) Leaf weight, (f) Petiole weight, (g) Pseudostem weight, (h) Peduncle weight, (i) Aboveground biomass, (j) Bunch weight. NB: Above ground biomass (ABG): contains pseudostem, leaves and bunch; Treatments FI: Full irrigation and DI, deficit irrigation.

Discussion

Correlations of allometric growth parameters and bunch yield and Aboveground biomass
The correlation coefficients presented in Table 2 and Table 3 indicate that plant growth characteristics were associated significantly with AGB and bunch weight. The pseudostem girth at base, 1m high and mid-height were distinguished to be significantly related with AGB. The bunch weight correlated with pseudostem girth at (base, 1m high and mid-height as well as the height and LAI as presented in Table 2. Also, the bunch weight associated significantly with pseudostem girth at base,1m high and mid-height, pseudostem volume, height and LAI. In other related studies, the allometric growth parameters were correlated with biomass and bunch weight (Nyombi *et al.*, 2009, Kamusingize *et al.*, 2018 and Guimarães *et al.*, 2013). The correlation between bunch weight and pseudostem girth and plant height suggest that the weight of the plant varied directly with the size of the plant. The bunch weight is a generative output like in any plant that bears fruits which basically is a function of resources allocation, meaning the biomass allocated into flowers and fruits relative to plant size

as studied by (Weiner *et al.*, 2009, Bonser and Aarssen,2009) also reported that plants in constrained environmental resources, commence reproduction at small vegetative size as compared with plants in the plentiful resource supply environment, and apportionment to reproduction at the end of the path of reproductive apportionment is directly proportional to the threshold size for reproduction.

The positive association for bunch weight and LAI might be attributed by the functional role of a plant leaf as a factory of converting light energy assimilates into dry matter accumulates.

This finding is interrelated with other studies by (Turner *et al.*, 2007) who reported the size and function of LAI of intercepting light and fix carbon hence increased dry matter accumulation. Despite high LAI providing large surface area for dry matter accumulation, however, a plant characterized by shallow root system increases its susceptibility to water shortage.

Effects of irrigation regimes on growth parameters
The results portrayed a maximum growth recorded in FI, compared with those in DI, had significantly higher growth rates both for Fig. 3. This growth pattern is likely to have been mapped by moisture variability in two trial plots which imposed effects on an overall plant growth trajectory. Most recorded growth parameters exhibited significant variations in growth between FI and DI.

The growth disparity existed between FI and DI suggests that moisture stress significantly had an impact on the growth and performance of plant morphological parts. This results confirm equal findings by (Pramanik and Patra, 2016) who recorded maximum values of banana biometrical characteristics of plant height, pseudostem girth, leaf number, leaf length, leaf width, and leaf area index (LAI) with drip irrigation at 70% cumulative pan evaporation and (Surendar *et al.*, 2013) who found that moisture stress at any stage growth of banana reduced its productivity by 30 to 50%.

Effects of water of irrigation regimes on the bunch yield (kg/plant) and aboveground biomass.

The results for bunch weights were significantly higher at (p<0.001) in FI than DI Table 3 and Fig. 3. The mean maximum bunch weight was 28.3±1.75kg plant^{-1} and 19.06±0.97kg plant^{-1} were recorded for FI and DI, respectively. Related findings for EAHBs were reported across for regions of Uganda under rainfed conditions in with average bunch weight of 19kg for cultivars of Enyeru, Kibuzi, Nakitembe and Nakabululu (Wairegi *et al.*,2009). Similarly, for ABG, the mean maximum weight in FI was 78.81±2.61kg plant^{-1} and in DI it was 59.23±1.06kg plant^{-1}. With respect to estimated yield of the banana bunch/plant and bunch components investigated under FI and DI water levels; plants in FI growth and yield in terms of bunch weight/plant was significantly better compared with plants in DI (Table 3). The results are conforming with the results previously obtained by (Robinson and Alberts,1986) who spotted increased bunch weight from 31.7 to 44.6kg as a result of the increase in crop coefficient from 0.25 to 0.75. Also, (Goenaga and Irizarry,1998) reported a significant increase of bunch components with an increase of water levels from 0.25 to 1.25 in a class A Evaporation pan.

The results in DI are matched with (Turner *et al.*, 2007, Alvarez *et al.*, 2001 and Ravi *et al.,* 2013) who reported moisture stress to considerably reduced banana productivity due to closure of stomata, an organ responsible for controlling dry matter production and yield in plants. Likewise (Fahad and Bajwa, 2017) also reported reduced fruit fresh and dry weights which lessened banana bunch weight due to decreased photosynthetic rate and soil moisture content at times of stress. Better growth parameters and bunch yield and bunch attributes detected in FI compared with those in DI could have been attributed by stable available water to rhizosphere throughout its growth phases, steady and uniform availability of nutrients for plant uptake. Suboptimal water balance in banana plants do alter the reproductive phase and its effect begins with bunch components mainly fingers and hands which are easily affected by the water stress, especially at the flowering time.

Conclusion

The variation in banana growth characteristics and reproductive yield (bunch weight) and aboveground biomass (AGB) for HG were significantly affected by moisture stress. Therefore, our results signify the importance of moisture on banana plant growth. The results in this study for EAHBs cv. Mchare Huti Green (AA diploid subgroup) indicated a significant variation of allometric growth parameters and bunch weight between treatments of FI and DI. This variation calls for integrated soil water management in banana production to ensure the optimal level of available moisture for better performance from the vegetative phase to the generative phase. This work has worked on the use of drip irrigation which precisely supplies water to the banana plant hence reduce water losses. However, we suggest more studies be done by incorporation with other agronomic practices like use mulch materials and intercropping.

Acknowledgements

Conflicts of interest
No opposing interests reported by authors.

References
Adhikari U, Nejadhashemi AP, Woznicki SA. 2015.Climate Change And Eastern Africa: A Review Of The Impact On Major Crops. Journal Of Food And Energy Security. Vol. 4, No. **2,** PP. 110-132.

Alvarez CE, Ortega A, Fernández M, Borges AA. 2001. Growth, Yield And Leaf Nutrient Content of Organically Grown Banana Plants In The Canary Islands.Journal of Fruits. Vol. 56, No. **1,** pp. 17-26.

Bonser SP, Aarssen LW. 2009. Interpreting Reproductive Allometry: Individual Strategies Of Allocation Explain Size-Dependent Reproduction In Plant Populations. Perspectives In Plant Ecology, Evolution And Systematics. Vol. 11, No. **1,** pp. 31-40.

Brown A, Tumuhimbise R, Amah D, Uwimana B, Nyine M, Mduma H, Talengera D, Karamura D, Kuriba J, Swennen R. 2017. Bananas And Plantains (*Musa* Spp.), In Genetic Improvement of Tropical Crops. Springer. P. 219-240.

Fahad S, Bajwa AA, Nazir U, Anjum SA, Farooq A, Zohaib A, Sadia S, Nasim W, Adkins S, Saud S. 2017. Crop Production Under Drought And Heat Stress: Plant Responses And Management Options. Journal Of Frontiers In Plant Science. Vol. **8,** No. pp. 1147.

Fermont A, Benson T. 2011. Estimating Yield of Food Crops Grown By Smallholder Farmers. International Food Policy Research Institute, Washington Dc. Vol. No. pp. 1-68.

Goenaga R, Irizarry H. 1998. Yield Of Banana Grown With Supplemental Drip-Irrigation On An Ultisol. Experimental Agriculture., Vol. 34, No. **4,** pp. 439-448.

Guimarães Bvc, Donato Slr, Mais V, Aspiazú I, Rodrigues M, Marques, PRR. 2013. Simple And Multiple Linear Regressions For Harvest Prediction Of Prata Type Bananas. African Journal of Agricultural Research. Vol. 8, No. **48,** pp. 6300-6308.

Kamusingize D, Majaliwa JM, Komutunga E, Tumwebaze S, Nowakunda K, Namanya P, Kubiriba J. 2018. Allometric Relationships And Carbon Content For Biomass-Carbon Estimation of East African Highland Bananas (Musa Spp. Aaa-Eahb) Cv. Kibuzi, Nakitembe, Enyeru And Nakinyika. African Journal of Agricultural Research., Vol. 13, No. **36,** pp. 1865-1873.

Molua El. 2007. The Economic Impact Of Climate Change On Agriculture In Cameroon. World Bank Policy Research Working Paper Series, Vol. No. pp.

Nelson Sc, Ploetz Rc, Kepler Ak.2006. *Musa Species* (Banana And Plantain). Species Profiles For Pacific Island Agroforestry. Vol. 15, No. **2,** pp. 251-259.

Nyombi K, Van Asten Pj, Leffelaar Pa, Corbeels M, Kaizzi C, Giller Ke. 2009. Allometric Growth Relationships of East Africa Highland Bananas (M*usa* Aaa-Eahb) Cv. Kisansa And Mbwazirume.Journal of Annals of Applied Biology. Vol. 155, No. 3, pp. 403-418.

Nyombi K. 2010. Understanding The Growth of East Africa Highland Banana: Experiments And Simulation.

Okech S, Van Asten P, Gold C, Ssali H. 2004. Effects Of Potassium Deficiency, Drought On Banana Yield And Economic Performance In Mbarara, Uganda. Uganda Journal Of Agricultural Sciences, Vol. 9, No. **1,** Pp. 511-519

Ortiz R, Swennen R, 2014. From Crossbreeding To The Biotechnology-Facilitated Improvement Of Banana And Plantain. Journal Of Biotechnology Advances. Vol. 32, No. **1,** pp. 158-169.

Pramanik S, Patra Sk. 2016. Growth, Yield, Quality And Irrigation Water Use Efficiency Of Banana Under Drip Irrigation And Fertigation In The Gangetic Plain Of West Bengal. World Journal Of Agricultural Sciences. Vol. 12, No. 3, pp. 220-228.

Ravi I, Uma S, Vaganan Mm, Mustaffa, Mm.2013. Phenotyping Bananas For Drought Resistance. Journal Of Frontiers In Physiology. Vol. 4, No. pp. 9.

Robinson J, Alberts A. 1986 Growth And Yield Responses Of Banana (Cultivar 'Williams') To Drip Irrigation Under, Drought And Normal Rainfall Conditions In The Subtropics. Journal Of Scientia Horticulturae. Vol. 30, No. **3,** pp. 187-202.

Salau Or, Momoh M, Olaleye Oa, Owoeye Rs 2016. Effects Of Changes In Temperature, Rainfall And Relative Humidity On Banana Production In Ondo State, Nigeria. World Scientific News. Vol. No. **44,** pp. 143-154.

Surendar Kk, Devi Dd, Ravi I, Krishnakumar S, Kumar Sr, Velayudham K.2013. Water Stress In The Banana-A Review. Bulletin Of Environment, Pharmacology And Life Sciences Vol. 2, No. 6, pp. 1-18.

Turner Dw, Fortescue Ja, Thomas Ds. 2007. Environmental Physiology Of The Bananas (Musa Spp.). Brazilian Journal Of Plant Physiology. Vol. 19, No. 4, pp. 463-484

Van Asten Pj, Fermont A, Taulya G. 2011. Drought Is A Major Yield Loss Factor For Rainfed East African Highland Banana. Agricultural Water Management. Vol. 98, No. 4, pp. 541-552.

Wairegi L, Van Asten P, Tenywa M, Bekunda M. 2009. Quantifying Bunch Weights Of The East African Highland Bananas (Musa Spp. Aaa-Ea) Using Non-Destructive Field Observations. Journal Of Scientia Horticulturae. Vol. 121, No. 1, pp. 63-72.

Weiner J, Campbell Lg, Pino J, Echarte L.2009**.**The Allometry Of Reproduction Within Plant Populations. Journal Of Ecology. Vol. 97, No. 6, pp. 1220-1233.

World Reference Base For Soil Resources 2014. International Soil System For Naming Soils And Creating Legends For Soil Maps. Vol. No. 106, pp.