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Comparison of flowering rate and cumulative leaf numbers of banana cv. mchare (Huti Green) under full and deficit irrigation conditions in Northern highlands, Tanzania

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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) cvmc hare-Huti Green (HG) cultivated under drip irrigation remain unavailable in the study area. The objective of this study was to compare the effects of water regimes on flower emergence and cumulative leaf numbers 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 flowering. The results exhibited significant differences within and between treatments of most tested variables. A good number of plants in FI flowered earlier as compared to those ina DI. The mean leaf length in FI was (2571.71 ± 43.18 plant^{-1}) and DI (2144.11 ±72.23 plant^{-1}) at ($p<0.001$. Similarly, the mean leaf width FI (827.7 ± 11.95 plant^{-1}) and DI (724.8± 18.43) at ($p<0.001$) respectively. Understanding the banana growth characteristics in different water regimes is of great importance due to ongoing threats of global change. Prudential use of this information can assist in management decisions concerning irrigation, water use and productivity.

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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 (Economic, 2014, Ortiz Swennen, 2014). Research evidence shows that between 400 – 500million 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 50million smallholder farmers, with a yearly production value of US$ 4.3 billion, corresponding to nearly 5% of the region's overall domestic product (Economic, 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). Growing plant tissues as emerging leaves, flowers and growing fruits are amongst the first to be affected, and leaf emergence rate is even considered the most sensitive indicator of drought stress (Robinson, 1996; Turner *et al.*, 2007). As leaves are among the first tissues to be affected by drought (Turner and Thomas, 1998; Turner *et al.*, 2007; Surendar *et al.*, 2013), the study of cumulative leaf formation is a significant indicator for stress and might guide irrigation. 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, molua, 2007). Bananas need high rainfall of 1400mm for high banana productivity (Nyombi, 2010) and yield lossesmay 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). Under drought-prone areas, plants tend to invest fewer resources in reproduction comparative to vegetative growth, largely because flowering is water demanding (Bonser Aarssen, 2001, She *et al.*, 2017, Xie *et al.*, 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 flowering and cumulative leaf formation. 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) compare the rate of banana flowering grown under two water regimes. (ii) assess the influence of water stress on banana plant leaves attributes.

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 mountmeru 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 (60cmol$_c$/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.

Plantmaterials

In vitro, banana cv.mchare-Huti Green (HG) EAHB was used as planting material. mchare Huti Green was planted on 3may 2017. Plants were spaced 2x3m (row x line) in holes with dimensions of 60cm width x 60cm length x 60cm 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).

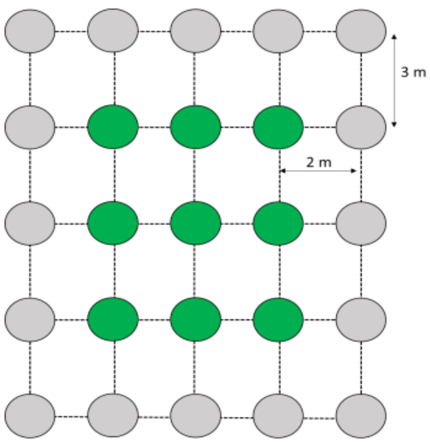

Fig. 1. Part of field layout showing continuous sampling plants (Green) and border line in (Grey).

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 30-cm long TDR probes installed vertically, reading soil moisture at two soil depths, one at the outermost layer of soil (0-30cm) 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 asmg S (16%mgO, 32% SO_3) (200kg ha^{-1}yr^{-1}). During the rainy season, mineral fertilizers were applied every month and every 2months in the dry season, while TSP (46% P_2O_5) (200kg ha^{-1}yr^{-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 dates of flower apex and hermaphrodite emergence were collected from the second cycle of banana cv.mchare (Huti Green) for six months on a weekly basis. Leaf numbers were recorded on a weekly basis and during destructive sampling at harvest. A total of 54 plants were used for data collection.

Statistical analysis

From raw data of growth parameters (leaf length, leaf width) conversion were done through simple mathematical calculations prior to doing direct analysis. 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.

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

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

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)

$$LAI = \frac{laf}{area} \sum_{i=1}^{n} (li \times wi \times ni) \quad (4)$$

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). A paired t-test was used to compare means of variables between treatments using Origin Pro 2015 software. Bar charts were constructed by Excel software. Fisher's least significance was used to compare means at the p=0.05 level of significance.

Results and discussion

Effects of water regimes on banana flowering.

Approximately, more than 75% of the banana plants under FI, flowered earlier in the first two months as compared to approximately 40% of counts of banana planted under DI Fig. 2. However, these results can not lead us to the conclusion that it is only moisture stress or drought stress that contributed to these differences. It is reported in several studies plants that flowering is controlled by several external factors such as photoperiod, temperature, abiotic stresses and internal factors like hormone levels, C/N ratios and age of the plant (Turck *et al.*, 2008, Ortiz and Swennen *et al.*, 2014, Vidal *et al.*, 2014).

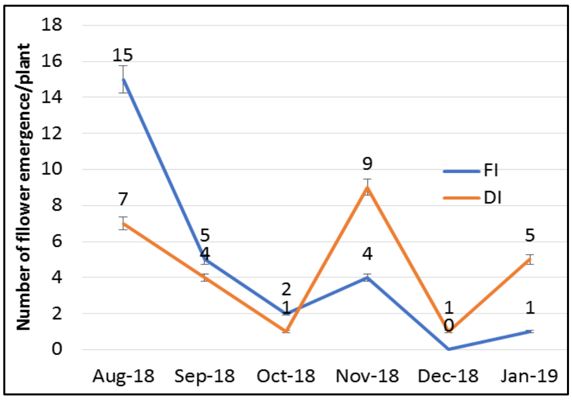

Fig. 2. Effects of water regime on the cumulative flower emergence per plant with time. Vertical bars are a number of flowers recorded per month.

Effects of water regime banana leaf characteristics

Leaf length and leaf width

The results presented in Table 1 and Fig. 3 shows significant differences between both leaf length and leaf width at p<0.001. The variations of leaf length and width recorded in this study are in conformity with what found by (Fahad *et al.*, 2017, Zak *et al.*, 2000) who reported that drought condition for banana plant may render a considerable decrease in leaf dimension, disturbed stomata oscillations, leaf water potential, transpiration rate and number. moisture stress as experienced in DI in relation to what found by (Aroca, 2012) it affects not only leaves by the entire vegetative part of the plant hence upsetting, vegetative allocation

(VA) causing apportionment resources to stem mass fraction and leaf mass fraction reduced significantly.

Due to continuous change in the environment accelerated by global climate change, the knowledge of water plant relations, particularly its leaves, has long been related with understanding the physiological retorts of the plant to soil and atmospheric water. Prudential use of this information can assist in management decisions concerning irrigation, water use and productivity (Turner *et al.*, 2007).

Table 1. Mean differences of banana leaf characteristics between treatments.

Banana leaf characteristics	Leaf characteristics (mean ±SE) (FI)	between treatments (DI)	Mean difference (p-value)
Leaf length (cm)	2571.71 ± 43.18	2144.11 ±72.23***	<0.001
Leaf width (cm)	827.7 ± 11.95	724.8± 18.43***	<0.001
LAI (log)	6.268 ± 0.01	6.179 ± 0.*	0.047
Functional (nr)	8.15± 0.31	7.37 ± 0.*	0.05
Cumulative young leaf (nr)	29.15 ± 0.25	28.89 ± 0.29ns	>0.05
Cumulative old leaf (nr)	22.56± 0.49	20.63 ± 0.38**	< 0.01
Cumulative third leaf (nr)	27.11 ± 0.26	26.19 ± 0.53ns	>0.05

Two tailed t -test summary

Variable	µ1- µ2	Sed	t-value	p-value
Leaf length (cm)	426.59	84.15	5.07	<0.001
Leaf width (cm)	102.89	21.97	4.68	<0.001
Functional leaf (nr)	0.778	0.388	2.00	0.05
LAI	0.089	0.043	2.07	0.047
Cumulative young leaf (cm)	0.259	0.385	0.67	0.504
Cumulative old leaf	1.926	0.628	3.07	<0.01
Cumulative third leaf	0.926	0.593	1.56	0.127

Test of null hypotheses state 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 nr=number.

Cumulative leaf numbers

Cumulative young leaf (CumY), cumulative leaf number three (Cum3) and cumulative old (CumO) were assessed under DI and FI, the mean maximum number of leaves attained during destructive sampling at harvest was 29.15±0.25, 27.11±0.26, and 22.56±0.49, respectively. Cumulative old leaf number was recorded to be significantly different at (p<0.01, n=54) whereas cumulative young leaf and cumulative third leaf were tested to be insignificant at (p>0.05,n=54). Similarly, according to (Turner *et al.*, 2007) who reported in his review a total of 30 to 50 or more leaves may be produced on a pseudostem but at any one time only 10 to 14 functional leaves are present during maturity stage.

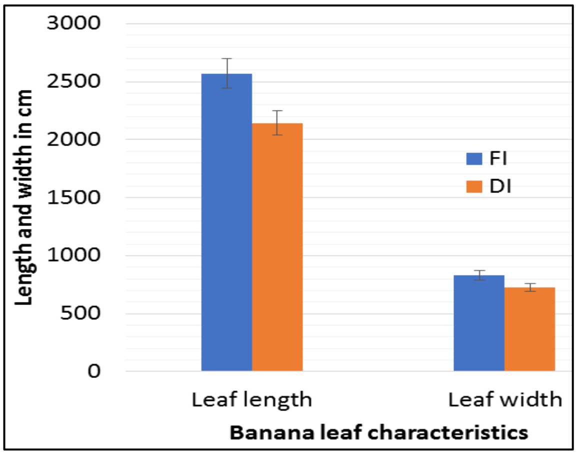

Fig. 3. Effects of water regime on the leaf growth per plant with time. Vertical bars are the dimension of leaf length and leaf width in centimeter recorded during destructive sampling.

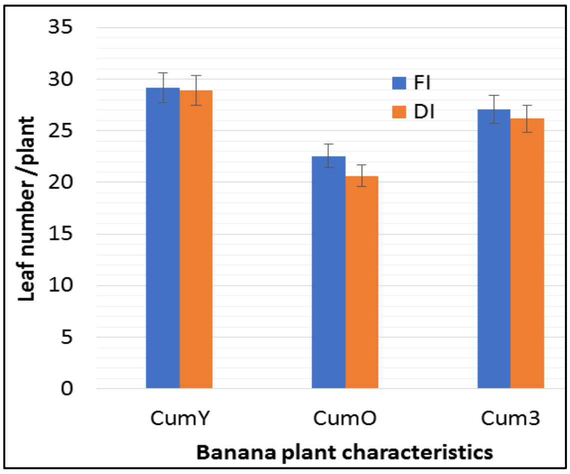

Fig. 4. Effects of water regime on the cumulative leaf number per plant with time. Vertical bars are the number of leaves recorded during destructive sampling.

Functional leaves and LAI

The results presented in Table 1 and Fig. 5 specifies results of comparison of unpruned functional leaves and LAI in two different water regimes of FI and DI.

Both growth parameters exhibited significance differences, for functional leaves at (p=0.05) and LAI at (p=0.047). The result of LAI from this study relates to the findings reviewed by (Turner *et al.*, 2007) who reported commercial plantations with LAI range from 2 to 5.

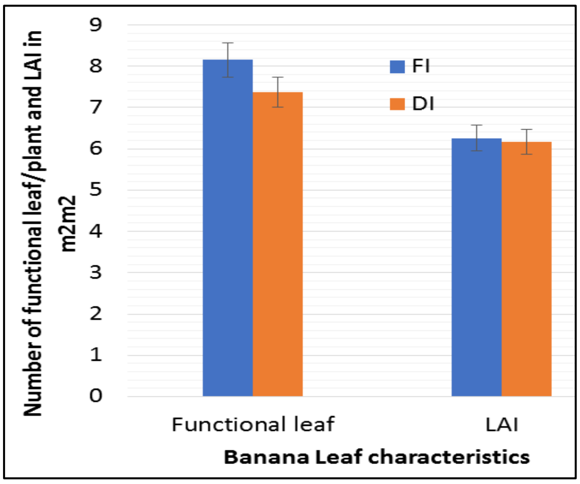

Fig. 5. Effects of water regime on the number of functional leaf and LAI. Vertical bars are Figs for two growth parameters.

Conclusion

The variation in banana growth parameters was significantly affected by moisture stress. Therefore, our results signify the importance of moisture on banana plant growth. 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.

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Conflicts of Interest

No opposing interests reported by authors.

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