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Vegetative growth of banana as influenced by deficit irrigation and irrigation interval

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ABSTRACT

Water is a limited source with no known substitute. The decrease in precipitations leads to less and less soil water available to crops, hence, proper management of agricultural water is of utmost importance. This study assessed the effects of three irrigation levels (IL) and three irrigation intervals (II) on the vegetative growth of East Africa Highland Banana (*Musa* spp., AAA-EAHB), cv Ng'ombe. The experiment involved a rain-shelter experiment comprising a randomized complete block design (RCBD) plots. Three levels of water applications (100%, 90% and 80% of evapotranspiration) at 4, 6 and 8 days as irrigation intervals were applied. FAO-CROPWAT 8.0 model was used to calculate irrigation water requirements based on crop, soil and climate data of the study area. Data collected over a period of 12 months were analyzed and showed that water application could be reduced to 90% of optimal water requirement at 4 days irrigation interval without significantly affecting the important vegetative growth parameters at a level of significance of $\alpha \leq 0.05$. The important vegetative crop parameters considered and their measurements in mid-stage are girth of the stem at the base (70.6±0.9 cm), leaf area (5587.9±84.4 cm^2) and plant heights (297.3±4.2 cm). Local Climate Estimator software (New_LocClim) was used to provide approximations of climatic conditions because actual data required were not available on the site. Deficit irrigation combined with short irrigation intervals on banana cultivation is a way of saving water without affecting vegetative growth and most probably without any significant reduction of the yield. Reducing irrigation water in banana plantations will save the amount of water used in agriculture especially in areas that receive low precipitations.

Keywords: Deficit irrigation, banana, growth parameters, CROPWAT

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1 Introduction

Worldwide, there is an enormous challenge to meet the demand of food and other agricultural products which were projected to increase by 50% between 2012 and 2050 (FAO, 2017). This has to be achieved with less water, due to increasing population, pressure from growing urbanization, industrialization, deforestation and climate change. Climate change threatens to decrease the availability of the limited water resources, increase food insecurity and hold back economic growth (Lasco and Boer, 2006; Mpyisi et al., 2003). Agriculture is a major sector to the national economies in East Africa accounting for 30% of the GDP (FTF, 2018). It is dominated by smallholder farmers who contribute up to 90% of agricultural production (Salami et al., 2010).

In East Africa, one of the major crops affected by climate variability is banana, which is an important food and income generating crop (Smale and Tushemereirwe, 2007), it suffers from soil moisture stress in most of the major growing areas. Ng'ombe cultivar belongs to the dominant grown group called 'East African Highland Banana' (*Musa* spp. AAA-EAHB) representing 80% of the cultivars in the region (Taulya, 2015). Van Asten et al. (2004) stated that in the East African Highlands areas, soil moisture stress causes up to 60% banana yield loss and farmers mention moisture stress among the main causes for yield reduction (Nyombi, 2013). Since limited water available to plants are not used efficiently to improve agricultural production (Nyombi, 2013; Van Asten et al., 2004; Prasad et al., 2008) and moisture stress (drought) is a repeated phenomenon that crops face in their growth stages, effective soil moisture regimes, taking into account water use efficiency, have to be given more attention in agricultural research. Crops with yield response factors greater than one (Ky>1), like banana (1.2–1.35), are classified as very sensitive to water depletion and any decrease of soil moisture below the ETc requirements will negatively affect yield, however shortening irrigation interval can be very effective in supressing moisture stress and improve overall production (Steduto et al., 2012). In this study, two techniques were combined. Those ones are, deficit irrigation which is an application of water below crop water requirement (evapotranspiration) without decreasing significantly the yield (Enchalew et al., 2016) and shortening irrigation interval in order to save irrigation water.

In banana plants, vegetative growth is associated with yield. More girth of the stem, height and leaf area are desired characters because they correlate positively with the banana bunch size. Hidoto (2018) in his study revealed that banana yield per hectare was associated positively and highly significantly with growth parameters including pseudo stem girth and number of effective leaves with R^2 value of 0.80 and 0.67, respectively. Another study by Karuna and Kameswara (2016) stated that leaf area (LA) is an important parameter responsible of dry matter accumulation and crop yield. In banana plants, height and more girth are desired as these parameters are positively linked to banana bunch size and other associated characters (Mahendran et al., 2013). Higher growth parameters imply higher biomass according to studies on allometric relationship of East Africa High land Banana, which revealed that the trend of above ground biomass (AGB in kg dry matter) and girth (cm) in the vegetative stage, at flowering and at harvest were highly correlated: AGB = 0.0001 $(\text{girth})^{2.35}$ (R^2 = 0.99), AGB = 0.325 $e^{0.036(girth)}$ (R^2 = 0.79) and AGB = 0.069 $e^{0.068(girth)}$ (R^2 = 0.96), respectively. The same study revealed that girth at flowering was also a good parameter for predicting yields of this group of banana (R^2 = 0.7, cv Mbwazirume) (Nyombi, 2010). The objective of this study was to determine the effect of deficit irrigation and irrigation intervals on vegetative growth of East Africa Highland Banana (*Musa* spp., AAA-EAHB), cv Ng'ombe.

2 Materials and Methods

2.1 Study area and field data

The study was conducted at the Kenya Agricultural and Livestock Research Organisation (KALRO) centre in Kisii County, located at 0°41′ N latitude and 34°47′ E Longitude (Fig. 1) and at an altitude of 1493 m above sea level. Before setting up our experiment, soil and water samples were collected for analysis in order to determine their characteristics in the study area. Soil samples were collected diagonally by auger pits using traverse method and subsequently were analysed. Water samples were collected and tested for irrigation water quality criteria according to Bauder et al. (2014).

2.2 Field preparation

The experimental area was ploughed and then harrowed. Holes of 0.6 m × 0.6 m × 0.6 m were dug; and tissue cultured seedlings (3 months old) of banana cv Ng'ombe, were planted at a spacing of 3 m × 3 m. Well decomposed organic manure (20 kg wet weight) plus 125 g of NPK 17:17:17 were mixed and applied in each hole before planting (Wairegi et al., 2016).

2.3 Experimental design and layout

A complete gravity drip irrigation unit operating from a tank placed at 2 m height was used to generate the required flow. A water tank of 5,000 L capacity was placed on a timber platform and main pipe- line (25 mm in diameter) was connected to it using a tank connector and a filter to prevent the emitters from

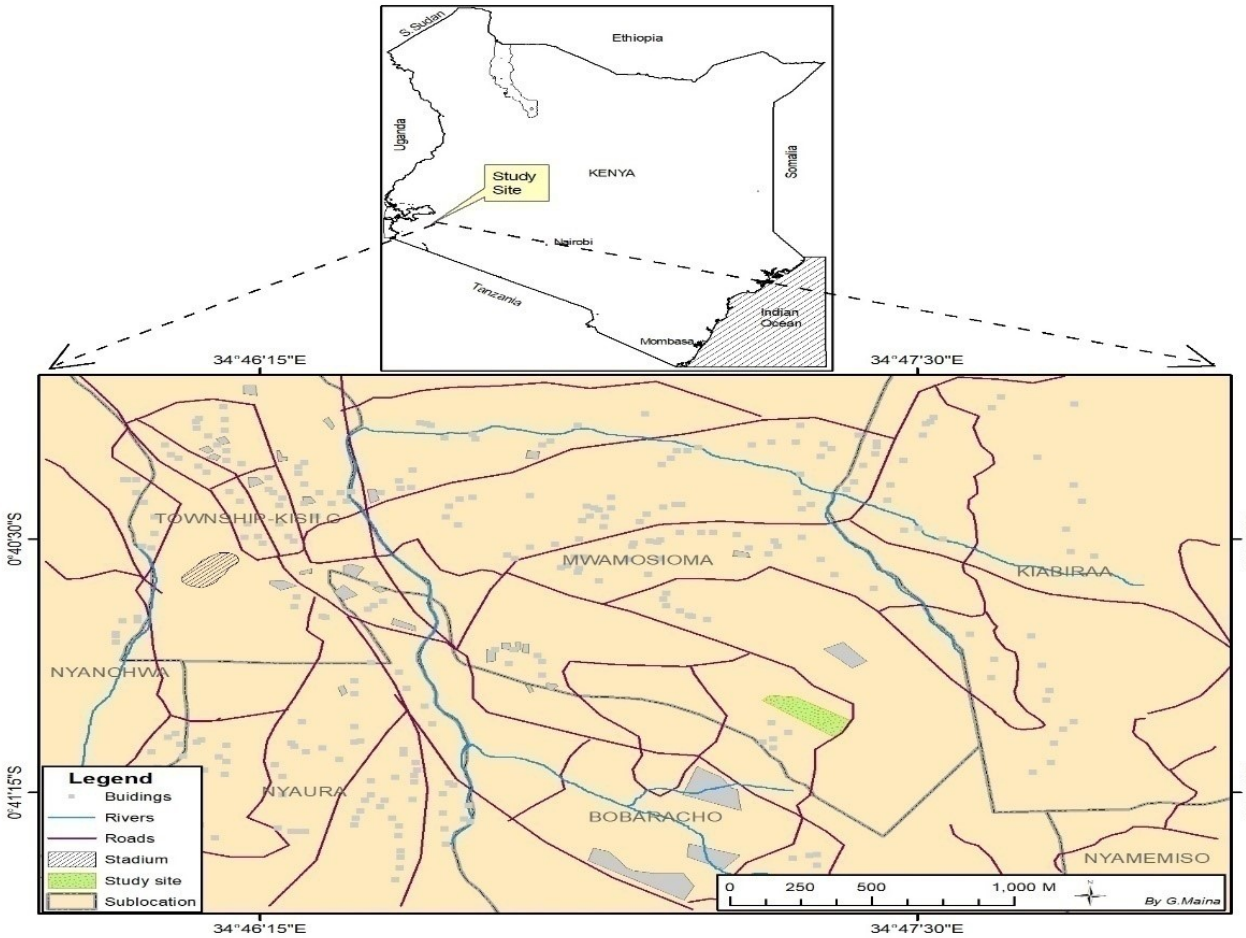

Figure 1. Location of the study site

clogging. The drip lines were of diameter of 16 mm, with two pressure-compensated emitters per plant at a distance of 0.5 m between them (Al-khalifa et al., 2013). Drip irrigation system was the only source of water; therefore, rainfall was eliminated by covering the area (676 m^2) with a rain shelter made of 4 m high wooden framework covered by a clear polythene sheet of 150×10^{-6} m of thickness. A thick polythene (200×10^{-6} m) sheet was placed at a depth of 1.2 m to surround the entire rain shelter in order to prevent potential lateral water infiltration towards the plants roots.

Irrigation was applied straightway after planting and was the sole source of water since rainfall was restricted. Six months after planting one sucker was left with the mother plant, thus making a total number of 2 plants per mat. Recommended agronomic practices including weed control, pruning, mulching, desuckering and removal of male bud were carried out. A water regime of 3 levels of water amounts and 3 levels of irrigation intervals was used in the experiment throughout the whole growing period. Treatments were coded as IL80.D4, IL90.D4, IL100.D4, IL80.D6, IL90.D6, IL100.D6, IL80.D8, IL90.D8 and IL100.D8. Irrigation levels correspond to 80, 90, and 100% of ETc whereas irrigation intervals correspond to 4, 6 and 8 day, irrigation scheduling calculations were made using FAO-CROPWAT 8.0 model (FAO, 2006).

To control water flow every drip irrigation treatment contained a 13 mm valve. Treatments were replicated three times in a complete randomized block design (CRBD) with each experimental plot comprising two plants. Disease and pest management, weed control and fertilizer application were done as per standard agronomic guidelines.

2.4 Calibration of CROPWAT

The weather data required for CROPWAT model to operate were provided by New _LocClim – the local climate estimator of FAO (Grieser et al., 2006). Soil input data including total available soil moisture (Deference between field capacity and permanent wilting point), infiltration rate (mm d^{-1}) and initial soil moisture as percentage of total available soil moisture (TAM). Crop factor (Kc) adjusted as recommended (Allen et al., 1998), growth stages duration data, rooting depth, critical depletion fraction and yield response factor were also used to calibrate the model.

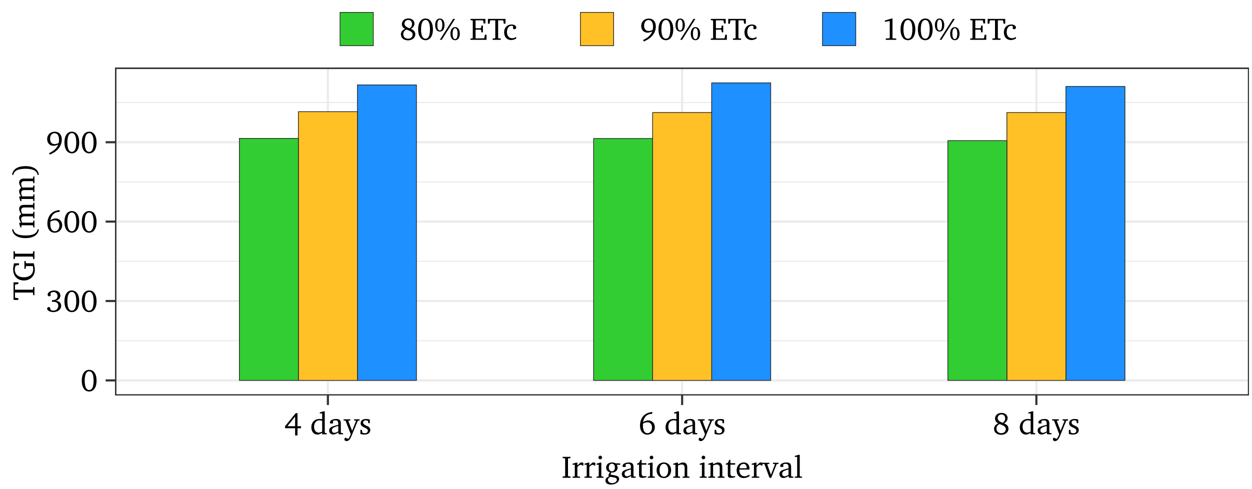

Figure 2. Amount of water applied with different irrigation level and irrigation interval to banana plant

2.5 Data collection and analysis

Data were collected on different growth parameters including plant girth (at base, at 0.5 m and at 1 m), plant height, leaf area (m^2) according to (Kayongo et al., 2016), number of functional leaves and distances between leaves. The distance between leaves were recorded from leaf one (last fully opened leaf) to leaf two (leaf next to leaf one) and from leaf two to leaf three (leaf next to leaf 2). Data on number of functional leaves were not normally distributed and were transformed as recommended by Rangaswami (2013). General linear model (GLM) was performed to evaluate if the effect of treatments on growth parameters was significantly different or not. Data were analysed using Statistical Analysis System package software version 9.2 (SAS, 2010) and the least significance difference test was used to separate means at 5% significance level.

3 Results and Discussion

The crop water requirements were calculated by CROPWAT 8.0 and applied using a time-regulated drip irrigation system (Fig. 2). Deficit irrigation and irrigation intervals effects on different plant growth parameters at initial stage of East Africa Highland Banana (*Musa* spp., AAA-EAHB) cv. Ng'ombe are summarized in Table 1. Significant difference were detected on girth at base, distance from leaf one to leaf two and distance from leaf two to leaf three for all treatments except from IL100.D4 and IL90.D4. There was no significant difference on plant heights, number of functional leaves and leaf area (LA) at this stage. During the development stage (Table 2), changes in reduced growth were reflected on growth parameters including girth of pseudostem, plant height, leaf area (LA) and distance between leaves. Results on mid stage showed treatments were significantly different on all parameters, except the number of functional leaves. Treatments IL100.4 and IL90.D4 were not different for girth at base, girth at 0.5 m, plant height and leaf area (Table 3).

Significant differences on plant height and leaf area could not be detected at initial stage due to recent implementation of deficit irrigation and that responses of banana to soil moisture deficit are gradual (Surendar et al., 2013). For girth at base, there was no significant difference between treatments IL100.D4 and IL90.D4 meaning that applied water could be reduced to 90% of the required amount without affecting this important growth parameter. In the development stage, growth rate decreased with longer irrigation intervals for the reason that reduced plant growth is a reflection of response to soil moisture stress (Surendar et al., 2013).

Although, in most plants, a drop in the number of leaves is a mechanism of controlling transpiration (Zhang et al., 2018), there was no significant difference in number of functional leaves, instead a reduction of leaf area and distance between leaves was noted. Similarly to the previous stage, at development stage, treatments IL100.D4 and IL90.D4 were not significantly different for parameters including girth at base, girth at 0.5 m, plant height and leaf area. Once more, at mid stage, irrigation water could be reduced to 90% of the crop water requirement without affecting those parameters. At this stage, the difference observed among treatments on different parameters can be explained by the increased effect of deficit irrigation on the plants (Table 3). Our results are in line with those of Surendar et al. (2013). Treatments IL100.D4 and IL90.D4 were superior to other treatments because of greater irrigation water and due to frequent irrigation application. Lahav and Kalmar (1981) found that in banana plantations, short irrigation interval is ben-

Table 1. Effect of deficit irrigation and irrigation intervals on various banana growth parameters at initial stage

Irri Inter.	Irri level	Girth at base (cm)	Plant hei-. ght (cm)	Functional leaves (no.)	Leaf area (cm^2)	1st∼2nd leaf (cm)	2nd∼3rd leaf (cm)
4	80	19.2±0.3 de	61.2±0.7	7.0±0.9	832.5±14.2	7.2 ±0.1 d	9.6±0.1 d
	90	21.7±0.2 a	71.5±1.1	6.0±0.0	1040.2±23.4	8.0±0.1 b	10.6±0.1 b
	100	22.2±0.4 a	72.2±1.2	7.0±0.9	1043.2±23.0	8.4±0.1 a	11.1±0.2 a
6	80	18.1±0.3 f	54.1±1.4	6.5±0.9	689.9±27.9	6.5 ±0.2 f	8.9±0.2 f
	90	20.1±0.4 bc	62.6±1.1	7.0±0.9	860.4±23.4	7.3±0.1 d	9.7±0.1 d
	100	20.3±0.6 b	63.3±1.1	7.0±0.9	868.7±20.9	7.5±0.1 c	10.0±0.1 c
8	80	17.5±0.5 g	51.3±1.5	7.0±0.9	634.1±27.9	6.3±0.1 g	8.6±0.2 g
	90	18.7±0.2 ef	57.9±1.2	7.0±0.9	767.4±23.4	6.8±0.1 e	9.2±0.2 e
	100	19.5±0.3 cd	59.9±2.5	7.0±0.9	774.6±30.5	7.2±0.1 d	9.6±0.2 d
	Mean	19.7	61.5	6.8	834.5	7.2	9.7
	CV (%)	1.7	2.3	4.1	2.8	1.3	1.4
	LSD	0.6	NS	NS	NS	0.2	0.2

Table 2. Effect of deficit irrigation and irrigation intervals on various banana growth parameters at development stage

Irr. inter.	Irr. level	Girth at base (cm)	Girth at 0.5 m (cm)	Girth at 1 m (cm)	Plant hei- ght (cm)	No. func. leaves	Leaf area (cm^2)	1st∼2nd leaf (cm)	2nd∼3rd leaf (cm)
4	80	36.7±0.6 c	17.8±0.3 c	15.1±0.1 d	164.6±2.9 cd	10.8±0.3	2916±60.5 b	14.1±0.2 e	17.6±0.3 d
	90	44.4±0.5 a	21.0±0.3 a	16.6±0.2 b	205.9±2.9 a	11.2±0.8	3747±56.8 a	17.1±0.3 b	21.0±0.1 b
	100	44.7±0.5 a	21.2±0.3 a	17.2±0.1 a	207.6±3.5 a	10.0±0.5	3879±147.0 a	18.3±0.3 a	22.5±0.3 a
6	80	32.2±0.7 e	15.7±0.4 e	14.1±0.2 f	137.4±3.5 f	10.8±0.3	2367±69.0 d	12.2±0.3 g	15.4±0.4 f
	90	38.1±0.6 b	18.2±0.4 b	15.3±0.2 d	170.3±3.3 bc	9.5±1.3	3030±65.3 b	14.6±0.3 d	18.0±0.3 d
	100	38.4±0.6 b	18.4±0.4 b	15.8±0.1 c	172.6±3.4 b	11.7±0.3	3055±56.6 b	15.5±0.3 c	19.2±0.3 c
8	80	30.6±0.9 f	14.9±0.4 f	13.7±0.2 g	128.9±3.7 g	11.3±0.8	2197±74.4 c	11.5±0.3 h	14.6±0.3 g
	90	34.7±0.6 d	16.9±0.3 d	14.6±0.2 d	152.5±3.5 e	11.2±1.4	2674±69.8 c	13.3±0.2 f	16.5±0.4 e
	100	35.0±0.6 d	17.1±0.3 d	15.1±0.2	159.7±8.4	11.0±0.9	2723±101.4 c	14.2±0.2 de	17.6±0.3
	Mean	37.2	17.9	15.3	166.6	10.8	2954	14.5	18.1
	CV (%)	1.6	1.7	1	2.5	7.9	2.8	1.8	1.7
	LSD	1	0.9	0.3	7.2		145.4	0.5	0.5

Table 3. Effect of deficit irrigation and irrigation intervals on various banana growth parameters at mid stage

Irr. inter.	Irr. level	Girth at base (cm)	Girth at 0.5 m (cm)	Girth at 1 m (cm)	Plant hei- ght (cm)	No. func. leaves	Leaf area (cm^2)	1st∼2nd leaf (cm)	2nd∼3rd leaf (cm)
4	80	56.9±0.9 c	40.9±0.7 c	31.3±0.5 c	235.3±3.8 cd	11.5±2.7	4339±79.10 c	22.2±0.3 e	26.8±0.5 e
	90	70.6±0.9 a	50.9±0.6 a	37.5±0.5 a	297.3±4.2 a	12.2±1.0	5588±84.4 a	27.6±0.5 b	33.0±0.3 b
	100	71.0±0.8 a	51.4±0.7 a	40.2±0.4 a	300.0±4.6 a	11.0±1.0	5614±99.2 a	29.8±0.4 a	35.6±0.4 a
6	80	48.4±1.0 e	34.2±0.8 e	27.1±0.7 e	194.1±4.7 f	12.2±1.4	3508 ±93.0 e	18.7±0.4 g	22.8±0.5 g
	90	59.1±0.9 b	42.2±0.8 b	32.1±0.6 b	243.6±4.2 bc	10.8±2.3	4506 ±84.4 b	22.9±0.4 d	27.7±0.5 d
	100	59.5±1.0 b	42.8±0.7 b	34.3±0.5 b	245.7±4.7 b	13.2±1.3	4532±86.7 b	24.7±0.4 c	29.8±0.5 c
8	80	45.9±1.2 f	32.4±0.8 f	25.7±0.7 f	182.6±4.6 g	13.3±1.5	3278 ±93.2 f	17.6±0.4 h	21.7±0.5 h
	90	53.2±0.9 d	37.9±0.7 d	29.4±0.6 d	216.9±4.4 e	12.5±3.0	3970±88.4 d	20.6±0.3 f	24.9±0.5 f
	100	53.5±0.8 d	38.5±0.8 d	31.4±0.4 d	226.7±12.7 de	12.7±1.8	4006±98.6 d	22.3±0.3 de	27.0±0.5 de
	Mean	51.6	41.2	32.1	238	12.1	4371	23	27.7
	CV	1.6	1.6	1.6	2.4	14.8	1.9	1.5	1.7
	LSD	1.5	1.1	0.9	10		144.1	0.6	0.8

Results with the same letter are not significantly different, NS = not significant eficial, since it decreases temperature of the soil, increases shallow rooting system and diminishes leaching of nutrients. Gul and Ahmad (2004), also, found that growth of Canola plants was much decreased under soil moisture regimes of 6 days irrigation interval as compared to 2 or 4 days irrigation intervals. While morphological distinctions exist between varieties, the triploid East Africa Highland Banana genepool (AAA-EAHB) , to which Ng'ombe belongs, is genetically similar (Kitavi et al., 2016). Banana growth parameters are correlated to yields (Nyombi, 2010), on the same group of banana, Wairegi (2010) confirmed a positive relationship between bunch weight and pseudostem girth at base and 1 mand established linear and power functions between the two. Taulya (2015) also, conducted a study on East Africa Highland Banana and indicated that total dry biomass was positively related to fresh banana bunch weight .

4 Conclusions

Irrigation water can be saved by reducing water to 90% of the crop water requirement at 4 days of irrigation interval. Deficit irrigation combined with short irrigation interval on banana cultivation could be a way of saving water without affecting vegetative growth and most probably without any significant reduction of the yield. Further research is needed to understand more causes that made shorter irrigation intervals to be the best in terms of vegetative growth and to confirm at which extent vegetative growth is associated with yields.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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