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Drip Irrigation Management Increase Growth and Yield of Beetroot in Huye District, Rwanda

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Abstract
Unexpected droughts, short growing season and poorly distributed rainfall, low adoption of drip irrigation system and poor irrigation management are the major constraints to beetroots *(Beta vulgaris*) production in Huye District of Rwanda. Effective drip irrigation management offers an alternative option to reduce beetroots rainfall dependence, to assure an efficient use of irrigation water and to increase growth and yield of beetroots. The objective of the study was to assess the effects of drip irrigation management on growth and yield of beetroots in Huye District of Rwanda. The study was comprised of four treatments: two days irrigation frequency, four days irrigation frequency, six days irrigation frequency compared to the control treatment (rain fed). The experimental design was randomized complete block with three replicates. Number of leaves per plant, plant height, and leaf area were measured at 30, 45 and 60 days after transplanting (DAT). There was a significant increase in number of leaves per plant, plant leaf area and plant height from rain fed, six days irrigation frequency, two days irrigation frequency to four days irrigation frequency at 30, 45 and 60 DAT. Yield component (root length and root diameter) and yield significantly increased from rainfed, six days irrigation frequency, two days irrigation frequency, and were highest in the treatment of four days irrigation frequency. Beetroot yield increased (P<0,001) by 47.03%, 67.80% and 72.30% of the beetroot yield harvested from the rain fed (7.15T/ha), in the 6 DIF, 2 DIF, and 4 DIF, respectively.
The results of this study indicate that 4DIF, 2 DIF and 6 DIF, in decreasing order of effectiveness, have potential to increase beetroot growth and yield. Therefore 4 DIF is recommended by the study for farmers in Huye district and other agro ecological regions similar to Huye district.

Key words: Drip irrigation, Management, Growth, Yield, Beetroot.

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Introduction

Beetroot (*Beta vulgaris* L.) is a member of the Chenopodiaceae family which includes silver beet, sugar beet and fodder beet (Deuter and Grundy, 2004). They are biennials although they are usually grown as annuals and believed to have originated from Germany (Thompson, 2001).

Beetroot produces green tops and a swollen root during its first growing season. It is highly productive and usually free of pests and diseases (Ado, 1999). It is rich in several vitamins, hence is an ideal vegetable for health-conscious people (Deuter and Grundy, 2004). Beetroot crop is gaining prominence in Rwanda due to its high nutritive, medicinal and economic value. Beetroot is advocated as a stimulant for the immune system, as well as a cancer preventative and it has long been considered beneficial to the blood, heart and the digestive system (Nottingham, 2004).

Irrigation frequency is one of the most important factors in drip irrigation scheduling, and a proper irrigation frequency establishes moderate moist and oxygen conditions in the root zone throughout the crop period thus growth and yield increment.

A well-managed irrigation has been reported to improve growth and yield of the crop (El-Askari et al., 2000), but still the majority of Rwandan beetroot growers mostly use rain fed system and very few of them use poorly managed irrigation. That lack of reliable information and recommendations about the irrigation management suited to Beetroot production leads to the misuse of water resources and reduction in growth and yield of beetroots.

The study was therefore aimed at evaluating the performance of treated irrigation frequencies on growth and yield of beetroot compared to rain fed, and identifying the best irrigation frequency in the area among the studied ones.

Materials and Methods

The experiment was conducted during a short dry season of December-Murch 2018 under open field condition at Integrated Polytechnic Regional College of Huye which lies on Latitude and longitude coordinates of -2.586166 and 29.689026 respectively; with the annual precipitation of 1.200 mm, average climate of 19 °C and sandy-loam soil. Experimental Design was a randomized complete block design with four treatments: 2-, 4- and 6-days irrigation frequencies; and control/rain fed; and three replications. The land was disc ploughed using a tractor to a depth of 25cm and 12plots were marked. Plots were 2m × 1.30m in size with 2m wide pathways around each plot to avoid inter-plot treatments effects. Three weeks old seedlings of crimson globe variety of beetroot were transplanted at 25cm x 20cm spacing for a target population of 40 beetroots plants per every plot/replicate.

Irrigation facilities consisted of rain water harvesting kit (the kit was there since sometimes before the field experiment to collect water of the precedent rainy season) plus main line, submain line and laterals on which emitters were holed. Each irrigation frequency was equipped with its unique submain line. These last ones were perpendicular to the crop rows with laterals that were parallel to the crop rows and attached at each 30 cm of submain line to keep their emitters at 5 cm away from beetroot plants to avoid root rot problems. The duration of irrigation for one application under all the treated frequencies was thirty minutes with the emitter discharge of 16.7 ml/min. Farm yard manure was applied into planting stations at 20tones ha^{-1} at planting and covered by a layer of soil before beetroot seedlings were placed on the top and its roots covered by the soil. NPK: 17-17-17 was applied at 200kg ha^{-1} into two equal splits at 15 and 30 days after transplanting. Six plants randomly selected from the middle of each plot was used as a sample on which growth parameters were measured at 30, 45 and 60 days after transplanting. At the end, yield component was measured and the treatments yield compared. The data from the study were subjected to analysis of variance (ANOVA) using Genstat Discovery 16th Edition statistical package. Means were separated using ± standard error of the difference where F-test shown significant treatment effects at $P<0.05$.

Results

Season B in the 2018 at IPRC Huye was characterized by low monthly rainfall average of below 100 mm per month and premature end of the season with little rain falling in March when the crop was not yet fully mature (Table 1). Total rainfall in the growing season was 296.85 mm in comparison to 550-750 mm which is normal beetroot water requirement.

Drip irrigation supplemented with 531.831 mm, 254.354 mm and 76.759 mm to the treatment of 2DIF, 4 DIF & 6DIF respectively and that raised the total water used by beetroot crop to 828.681mm, 551.204 mm and 373.609 mm for the treatments under 2DIF, 4 DIF & 6DIF respectively (Table 2).

The number of leaves per plant, plant leaf area and plant height significantly increased in from rain fed, six days irrigation frequency, two days irrigation frequency and were highest in the treatment of four days irrigation frequency at 30, 45 and 60 DAT. Yield component (root length and root diameter) and yield significantly increased from rainfed, six days irrigation frequency, two days irrigation frequency, and were highest in the treatment of four days irrigation frequency. Beetroot yield increased ($P<0,001$) by 67.80%, 72.30% and 47.03% of the beetroot yield harvested from the rain fed in 2DIF, 4 DIF and 6 DIF respectively.

Table. 1 Effective rainfall for the time of experiment

Month	Field treatment	Effective rainfall(mm)
January	Rainfed	116.2
	2 DIF	
	4DIF	
	6 DIF	
February	Rainfed	110.4
	2DIF	
	4DIF	
	6 DIF	
March	Rainfed	70.25
	2DIF	
	4DIF	
	6DIF	
Total effective rainfall		296.85

Table. 2. Total water used per beetroot plants under different treatments

Treatment	Effective rainfall (mm)	Irrigation water (mm)	Total amount of water (mm)	Actual crop water requirement (mm)
2 DIF	296.85	531.831	828.681	550-750
4 DIF		254.354	551.204	
6 DIF		76.759	373.609	
RF		296.85	296.85	

Table. 3. Increment on vegetative part as affected by irrigation frequencies

Period	Treatment	PH (%)	NL (%)	LW (%)	LH (%)
30 DAT	2	39.20	35.04	29.56	33.83
	4	55.20	58.61	55.69	51.39
	6	35.17	27.65	27.72	28.05
45 DAT	2	25.91	24.03	18.70	13.77
	4	36.73	44.76	34.97	32.26
	6	22.15	15.09	11.13	12.53
60 DAT	2	9.07	22.67	15.13	13.27
	4	32.70	36.73	28.73	30.24
	6	21.09	15.74	6.81	10.51

Table. 4. Effects of irrigation frequencies on yield components and yield

Treatment	Increment in root length (%)	Increment in root diameter (%)	Increment in yield (%)
2DIF	23.13	15.76	67.80
4DIF	39.32	24.80	72.30
6DIF	14.78	7.97	47.03

Discussion

This study demonstrated the beneficial effects of drip irrigation management on soil water, beetroot growth and yield in a below-normal rainfall season that ended early in Huye District of Rwanda.

For growth parameters; (plant height, Number of Leaves and leaf area); all the time of measurement, the tallest individual beetroot plant with big number of widest and longest leaves was found in the treatment under 4 days irrigation frequency with 551.954 mm of water along the growing season. While the shortest beetroot plants with shortest and narrowest leaves was observed in the treatment of rainfed.

The plant under four days irrigation frequency was 55.20 %, 36.73% and 32.70% taller than that under rainfed treatment at 30, 45 and 60 days after transplanting respectively.

The highest increment in plant growth was observed in the treatment of 4DIF where at 30 DAT, the number of plant leaves, leaf width and leaf length were 58.61%, 55.69% and 51.39% respectively higher compared to the number of plant leaves, leaf width and leaf length of the plant under rainfed treatment. At 45 DAT the increment was at 44.76%, 34.97% and 32.26% in number of plant leaves, leaf width and leaf length respectively for the treatment under 4 DIF compared to that of rainfed. And finally at 60 DIF, the increment was at 36.73%, 28.73% and 30.24% in number of plant leaves, leaf width and leaf length respectively for the treatment under 4 DIF compared to that of rainfed.

That superiority observed in 4 DIF was due to the supplement of water from irrigation that raised rainfall regime from 296.85 mm to 551.204 mm which is the optimum beetroot crop water requirement. That led to the crop water satisfaction, the situation under which the crop expresses its fully genetic potentiality in terms of growth. With optimum water, soil mineral nutrients were easily dissolved and up taken by the crop for accelerated growth. The role of water in plant cells turgidity, division, elongation and enlargement positively influenced plant height, number of leaves and leaf size.

That helped the crop under 4 DIF to be ahead of others in photosynthetic area, light interception and carbon dioxide fixation, ground cover, water use efficiency, dry matter accumulation and consequently in overall growth, while for rainfed treatment it was opposite.

Similarly, Boutraa et al., 2010 said that water stress is considered to be one of the most important environmental factors that limit plant production. Same for Fischer (1980), Kriedemann and Barrs (1981) who confirmed that water stress leads to growth reduction, which was reflected in plant height and other growth functions. As well as to Abayomi (2002) who indicated that leaf growth showed high sensitivity to soil water deficit.

Also, Kiziloglu et al. (2006) indicated that the deficit in the irrigation practices significantly decreased root and leaf. Lu and Neumann, 1998 also reported poor leaf bearing for plants under water stress as mechanism to reduce transpiration and survive under that condition.

The insufficient of water in rainfed and in six days irrigation frequency didn’t allow enough cell turgidity, elongation and enlargement. That reduced plant growth through reduced photosynthetic area, reduced light interception, reduced stomatal opening and carbon dioxide fixation and reduced dry matter accumulation. That delayed ground cover and favoured more weeds, soil water evaporation and inefficient use of water by the crop; all of which contributed to the small roots (in length and diameter) and to the low yield compared to the treatment of 4 DIF.

Similarly, Topak et al. (2011) found that root yields of sugar beet significantly decreased by the increasing water deficit. Borivoj et al. 2011; the yield of sugar beet was significantly higher in irrigated than in rainfed conditions (Ali et al., 2010; Pidgeon et al., 2001) found that drought stress is a major cause of yield loss.

Conclusion and Recommendation

All 6-, 2- & 4-days irrigation frequencies proved their potential to reduce the danger caused by beetroots rainfall dependence, and to increase growth and yield of the crop compared to total rainfall dependence; and they are ranked in increasing order as follow: 6, 2 & 4 DIF. The study therefore recommends to beetroots growers to supplement the available rainwater with four days frequency drip irrigation in short dry season (early season B) providing the crop with 550-750mm throughout the crop growth cycle to increase the resilience of crop production systems against droughts that are predicted to increase in frequency and severity because of climate change.

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