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Effects of Different Irrigation Rates on Growth and Yield Parameters of Amaranth

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ABSTRACT

Soil water deficit is a principal and biotic factor that limits plant growth and development. Amaranth is very sensitive to water stress. Foregoing research highlighted a reduced amaranth leaf area and dry matter, while others affirmed that water deficit impaired amaranth growth and yield. Although amaranth is recorded as the most important annual crops with higher nutritional value worldwide, higher reduction of amaranth production has been recorded in Burundi, while published information is limited concerning affective irrigation rate for improving amaranth growth and yield in this country. An experiment was carried out in Bujumbura peri-urban zone to evaluate the effective irrigation rate for amaranth cultivation. It was laid out as completely randomized blocs design, consisting of three treatments with different irrigation rates as treatment T1 (10%), treatment T2 (30%) and treatment T3 (60%) with six repetitions for each. During the experiment, growth parameters (number of leaves, stem diameter, plant height, leaf area and root growth) and production attributes (fresh and dry weight of leaves and roots) were measured. The results highlighted treatment T2 of 30% irrigation rate as the most significant and effective treatment. It has significantly improved the number of leaves, stem diameter, plant height, leaf area and root growth. Moreover, this treatment T2 has effectively enhanced the water use efficiency, fresh and dry weight of leaves and roots. It can be used to improve the growth and production of amaranth in Bujumbura peri-urban zone.

Key words: *Irrigation level, Vegetable amaranth, Bujumbura peri urban zone, Growth and yield parameters*.

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1. INTRODUCTION

Amaranth is one of the most important annual crops with higher nutritional value [1-2]. Its Grain has been reported by many researchers as valuable sources of protein and amino acids which are deficient in cereals [1]. Amaranth is also used for the production of healthy food in several world regions [3]. Its phenylalanine performs better profile than cereals like wheat, maize and oat. The amino acid composition of amaranth’s proteins corresponds to the FAO standards for human nutrition. Their unsaturated fatty acid compositions and content are in balanced spectrum. On the one hand, it plays an important role in improving human nutrition through its high nutritional value [4]. Amaranth is rich in vitamins A and B, folic acid, vitamin C and minerals such as calcium, iron, copper, zinc and magnesium [5]. Literature affirmed its protein higher quality than cow's milk protein [6]. Amaranth has extra ordinal nutritional benefits and contains full range of essential amino acids in very balanced amounts [5]. The research of

Wu Leung et al. (1968a, b) revealed 15 to 16% protein and 6.9 to 8.3% lipid in amaranth seeds dry matter and indicated its better calorific value (430 cal / 100 (g) than maize [7- 8]. Despite all these potentialities, amaranth is very sensitive to water stress. It is a plant requiring some water quantity for growth and development. Foregoing research highlighted a reduced amaranth growth due to water deficit [9], while Ejieji and Adeniran (2010) reported a reduced amaranth yield for treatment under water stress [10]. In general, Soil water deficit is a principal biotic factor that limits plant growth and development. Jomo et al (2015) affirmed a reduced amaranth leaf area and dry matter due to water stress [9], whereas Meyers (1996) concluded a reduced amaranth growth and yield due to water deficit [11]. In Burundi, a higher reduction in amaranth production has been recorded while information is limited concerning affective irrigation level for improving its growth and yield [12]. Therefore, there is a need of a study regarding amaranth efficient irrigation rate for enhancing its growth and production in this country. This study aims to analyze the effects of different irrigation levels on amaranth growth and yield parameters in Burundi, at Bujumbura peri-urban zone.

2. MATERIALS AND METHODS

2.1. Experimental Site Localization

The experiment was undertaken in greenhouse of Agricultural Sciences Faculty at Burundi University where the maximum temperature varies between 35 and 37 ° C, while the annual volume of precipitation is always less than 1000 mm with an average of 660mm [6]. The soil characteristics of the experiment are summed up in the following table.

Table 2.1: Soil characteristics

P^H H_2O	P^H Kcl	C en %	N-NH_4^+ en mg/kg	N-NO_3^- en mg/kg	P Olsen en mg/kg
7,84	7,54	1,17	17,7	25,2	124

2.2. Experiment Design

The experiment was undertaken in pots and has considered three different treatments of irrigation levels as: T1 treatment (10%), T2 treatment (30%) and T3 treatment (60%). These agents were in randomized complete blocks design with 6 replications for each. The rates and frequencies of irrigation are shown in the table 2.

Table 2.2: Treatment rates and frequencies of irrigation

Treatments	Irrigation Levels	Irrigation frequencies
T1	10%	2
T2	30%	2
T3	60%	2

2.3. Data Sampling and Analysis

During the experiment, growth parameters (plant height, number of leaves, leaf area and stem Girth) were measured at 12 d, 19 d, 26 d, and 33 d (**d means the days number after transplanting**) while at harvest, root length, yield and roots fresh weight were recorded as well as the water use efficiency (WUE). However the fresh matter was kept in a forced-air oven at 70°C for two days to get dry weight for analysis.

2.4 Data Analysis

The data were analyzed statistically with applied Excel and Genstat discovery software edition 4. A comparison among treatments were conducted ($P< 0.05$) by using least significant difference (LSD) and Newman-Keuil test at 5% level.

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3. RESULTS AND DISCUSSION

3.1. Effects Irrigation Different Rates on Plant Height

Results for the plant height were summarized in the following table 3.

Table 3.3: Different irrigation level's effects on plant height (cm)

Treatments	12 d	19 d	26 d	33 d
T1	11.76a	11.90a	12.27a	12.41a
T2	12.58a	18.37b	25.97b	33.67b
T3	15.86b	21.77b	28.00b	32.53b

From this table, the plant height changes with the irrigation level and the day of data record. Clearly, at 12 d, the highest value of plant height was observed for treatment T3 (15.86 cm) with significant difference from others. It was followed by treatment T2 (12.58 cm) while treatment T1 (11.76 cm) got the lowest value of plant height. On the 19 d, the same trend was observed. Treatment T3 recorded the first highest value of 21.77cm and significantly differed from treatment T1. The second highest was observed for treatment T2 of 18.37 cm and also differed significantly from the control T1 which got the lowest value of 11.90 cm. Similarly, for 26 d, the treatments T3 and T2 occupied the first two places with plant of 28.00 and 25.97 cm respectively, while treatment T1 was the last with plant of 12.27 cm. On 33rd day after transplantation, the trend changes, treatment T2 (33.67 cm) was the most effective treatment with highest plant. It was followed by treatment T3 (32.53 cm) while treatment T1 (12.41 cm) got the smallest. The improvement of plant growth with applied higher irrigation rate on 12d, 19d and 26d was due to the higher temperature in these days resulting in increased evapotranspiration whence higher irrigation water for compensation to promote transplanted seedlings root system establishment. This supports the results of Zhongping (2013) who found an improved growth due to the use of higher irrigation water during periods of high temperatures [13]. Likewise, these results endorse the outcomes of Leban (2006) which revealed an improved plant height for normally irrigated treatments than those under stress [14]. However, the reduced plant height for treatment T1 could be attributed to limited nutrient uptake as revealed by Wu et al. (2011) who reported decreased crop height due to limited nutrient uptake for treatment under water stress [15]. Likewise, the plant height reduction for T1 could be attributed to the reduced cell turgor which affect cell division and expansion as affirmed by Jomo et al. (2015) [9].

3.2. Different Irrigation Levels Effects On Amaranth Leaf Area

Leaf area is a very important parameter for plant photosynthesis. It is the key mechanism for plant nutrients synthesis. During this study, relate results were displayed in the table below.

Table3.4: Effects of irrigation different rates on amaranth leaf area (cm^2)

Treatments	12 d	19 d	26 d	33 d
T1	10.09a	10.6a	9.6a	10.0a
T2	12.51a	26.9b	28.7b	29.5b
T3	14.98a	24.4b	28.0b	28.9b

The outcomes displayed in table 4 showed a no significant difference in the first days after transplanting (12d). However, treatment T3 (14.98 cm^2) was the first effective, followed by treatments T2 (12.51 cm^2) and T1 (10.09 cm2) respectively. Afterwards, a significant difference was observed between treatments. Specifically, at 19 d, the results showed treatment T2 as the most effective with 26.9 cm^2, followed by treatment T3 of 24.4 cm^2, while T1 treatment was the last with 10.6 cm^2. However, T2 and T3 treatments did not show a significant difference between them, but significantly differed from T1 treatment. After 26 d, the same trend was observed, treatment T2 of 28.7 cm^2 was the first effective treatment and showed a higher significant difference ($P < 0.001$) comparatively to treatment T1. The treatment T3 was the second highest with 28.0 cm^2, while treatment T1 of 9.6 cm^2 was the last. Similarly, treatment T2 was the most effective at 33 d with 29.5 cm^2 and highly differed from T1, the last effective with 10 cm^2. This shows that irrigation level of treatment T2 (30%) was the most effective compared to others. These results support those of Pincard, (2000) who reported improved leaf area for irrigated treatments at a medium level comparatively to those under stress [16]. The improved leaf area for treatment T2 could be due to leaf cell division and elongation resulting in leaf area expansion as highlighted by Vurayai et al. (2011) [17].

3.3. Irrigation Different Level's Effects On Leaves Number

The number of leaves is an index of good biomass production and a better supply of water and mineral nutrients. In this study, relate results are shown in the following Table 5

Table 3.5: Irrigation's effects on leaves number

Treatments	12 d	19 d	26 d	33 d
T1	5a	5a	6a	6a
T2	8b	12b	15b	19b
T3	9b	13b	14b	16c

Based on this table 6, the results revealed the effectiveness of treatment T3 in the first days (12 d) with 9 leaves, followed by treatment T2 and both significantly differed (P <0.05) from treatment T1 which was the last of 5 leaves. The same trend was also observed at 19d, where the maximum leaves number was recorded for treatment T3 (13 leaves), followed by treatment T2 (12 leaves), and minimum for treatment T1 (5 leaves). At 26 d, the trend changes, the treatment T2 was the most effective with higher leaves number of 15 and showed higher significance difference (P <0.001) from the control T1 of 6leaves. Similarly, at 33d, the treatment T2 of 19 leaves per plant was the first having higher leaves number and showed significant difference (P< 0.05) from others. T3 treatment of 16 leaves per plant was the second while T1 was the last with 6 leaves per plant. These outcomes revealed significant effects of T2 treatment as compared to T1 and T3. They are in accordance with the results of Pincard (2000) and those of Kramer and Boyer (1995) who both affirmed an increased leaves number for normally irrigated treatments than those under stress [16-18]. In addition, these results endorse those of Bouchabke et al. (2006) who reported an increased leaves number for irrigated treatments than those under stress [19].

3.4. Influences Of Irrigation Different Levels On Amaranth Stem Girth

The outcomes on stem girth evolution due to applied irrigation treatments are summarized in the following figure.

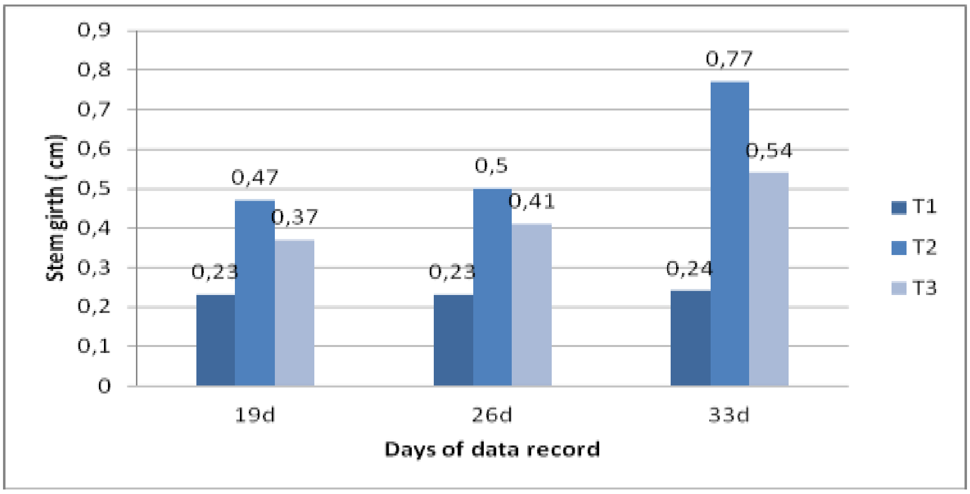

Figure3. 1: Effects of irrigation different levels on amaranth stem girth (cm)

Considering this figure 2, treatment T2 was the most effective compared to others. For all tested dates, this treatment recorded the highest stem girth of 0.47 cm, 0.68 cm, 0.77 cm at 19d, 26d, and 33d respectively. Moreover, it showed significant differences (P <0.05) compared to other treatments. The second highest value was recorded by treatment T3, which was followed by treatment T1 with a minimum value of 0.23 cm; 0.238 cm and 0.042 cm at each tested date respectively. The effectiveness of T2 treatment

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on stem girth was due to the moderate irrigation level applied for this treatment resulting in a good nutrients dissolution and absorption by the plant, whence improved stem girth and other growth parameters. This was due to the stem cell division and elongation as revealed by Vurayai al. (2011) [17]. These results are in agreement with the outcomes of Imana et al. (2010) who highlighted increased stem diameter for adequately irrigated treatments than those with reduced irrigation water amount [20].

3.5 Influences Of Irrigation Levels on Root Length (Cm)

The roots length (RL) was effectively influenced by irrigation levels (Figure 2)

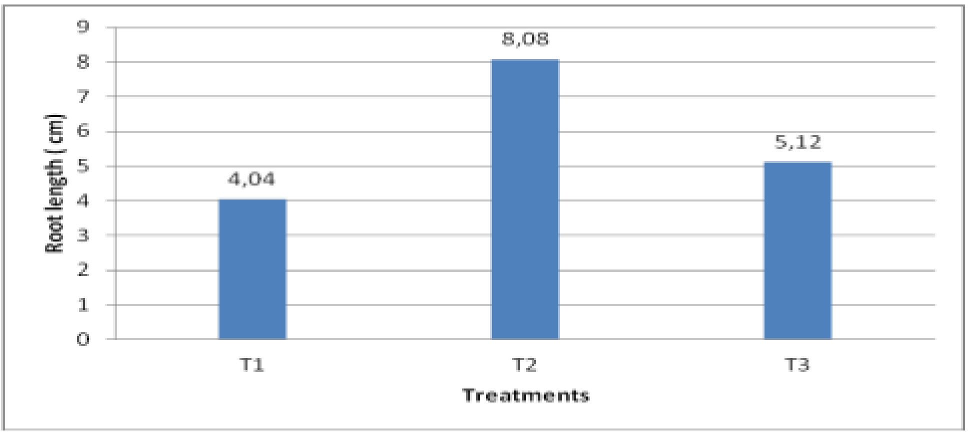

Figure 3. 2: Response of roots length to irrigation levels (cm)

As it can be seen in this figure 2, the results highlighted treatment T2 as the most effective treatment in enhancing the root length per plant comparatively to others. It recorded the highest value of 8.08 cm and significantly differed from others with P <0.05. It was followed by treatment T3 with 5.12 cm, whereas T1 of 4.04 cm got the shortest roots. Increased root length due to medium irrigation level has also been reported by Gajri et al.(1991) [21]

3.6. Impact of Irrigation Different Levels on Yield

The irrigation levels effectively influenced yield with higher significance difference among the treatments. As can be seen in Table 6, a there were significant differences between treatments for fresh yield weight (FWY). Specifically, treatment T2, with 12288kg/ha, got the maximum FWY and highly differed from others with P <0.001. It was followed by T3 of 5605 kg/ha, while the minimum was recorded for treatment T1 with 1059 kg/ha. Similarly, the DYW was effectively and significantly (P <0.05) improved by treatment T2 with optimum weight of 1684 kg/ha, followed by T3 of 1104 kg/ha and lastly T1 with a lowest value of 282 kg/ha. This treatment T2 has also effectively enhanced RFW and RDW with highest value of 933kg/ha and 229 kg/ha respectively, whereas T1 got the minimum of 114 kg/ha and 38 kg/ha successively.

Table 3.6: Impact of irrigation on yield

Treatments	FYW (Kg/ha)	DYW (Kg/ha)	yield ration(%)	RFW (Kg/ha)	RDW (Kg/ha)	root ration	Total fresh weight (Kg/ha)	Total dry weight (Kg/ha)	WUE (Kg/m^3)
T1	1059a	282a	3,755a	114a	38a	0,404	1455a	320a	4,322a
T2	12288b	1684b	7,297b	933b	229b	0,554	14905b	1913b	13,740b
T3	5605c	1104c	5,077ab	588c	74a	0,533	7297c	1178c	3,363a

FYW: Fresh Yield Weight; DYW: Dry Yield Weight; RFW: Roots Fresh Weight; RDW: Root Dry Weight; WUE: Water Use Efficiency

The yield ration under treatment T2 (7.297%) was ranked as the highest, while the one of T1 (3.755%) was the lowest as indicated in table 6. The ratio of root length was also highest in T2 (0.554%) and least under treatment T1 (0.404%). On the other hand, the total yield weight of treatment T2 (14905kg/ha) was highest and significantly exceeded the treatment T1 (1455 kg/ha) and T3 (7297 kg/ha). Likewise, maximum dry weight was observed for T2 with 1934 kg/he and minimum for T1 of 320. Moreover, this treatment T2 has significantly enhanced WUE with highest value of 13.740 kg/m^3, followed by T1 with 4.322 kg/m^3, while T3 was the last with lowest value of 3.363 kg/m^3. The effectiveness of T2 by improving all yield parameters could be ascribed to the applied irrigation level (30%) which could improve nutrient dissolution and absorption resulting in enhanced synthesis of sufficient photosynthases as reported by Di Paolo E and Rinaldi M (2007) [22]. These results are in accordance with those of Xiukang and Yingying (2017) who revealed increased crop yield due to moderate irrigation rate application [23]. The improvement of WUE by T2 was probably due to its ability to supply frequent and sufficient amounts of water. Improved WUE due to appropriate irrigation level has been also reported by Shaozhong et al. (2002) and by Ghulam et al. (1995) [24-25]. Considering each aspect factor, treatment T2 (30%) was the most effective than other treatments. It might be due to the used moderate irrigation level which could supply effective and adequate water during amaranth's growth and development.

4. CONCLUSIONS

The experimental outcomes showed that the amaranth plant growth and yield parameters were significantly increased with the increase of irrigation water to some extent. Treatment T2 with (30 %) was the most effective and could enhance significantly the leaf are, leaves number, stem girth, root length, total fresh and dry yield. This treatment T2 could also effectively improve the ratio of amaranth different parts as well as the water use efficiency. Considering all tested index in this research, T2, (30%), was the most effective treatment in improving the growth and yield parameters of amaranth at Burundi in Bujumbura peri urban zone.

Conflicts Of Interest

I declare that this manuscript has not been submitted anywhere for possible publication. This study was financed by the University of Burundi.

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