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The Effect Of Water Application Timings On Agro-Morphological Traits Of Roma Tomato VF Cultivar Grown Under Plastic Bottle Drip Water Irrigation System In Nyagatare District, Rwanda

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Abstract – The present study was aimed to assess the effect of water application timings on agro-morphological traits of Roma Tomato Vf cultivar grown under plastic bottle drip water irrigation system in Nyagatare District, Rwanda. Four treatments were used for the experiment, replicated four (4) times and arranged in Completely Randomized Design (CRD). Each replication plot contains 4 experiment units and 64 experiment units for entire experiment field of 4 plots. The results showed that for all treatments; the overall average mean plant height recorded was found to be 100.30±25.57 cm, 11±4.34 branches, 7±5.102 flowers and 48±10.462 fruits. The highest yield of 69.125 Kg/m^2 and WUE of 1.040 Kg/m^2/mm were recorded by T4 (Morning – Day – Evening) while the T3 (Evening) recorded the lowest yield of 65.03169.125 Kg/m2 and WUE of 0.979 Kg/m^2/mm. It is therefore concluded that the use of plastic bottles under greenhouse structures in applying trickle irrigation and plastic bottles is efficiently and effectively productive and water saving for Roma tomato plant cultivation because of no water loss due to environmental factors including wind speed. It is recommended that the emitter placement around the plant (sparing between dripper and plant) should be varied to study its effects on root development, physiological plant and tomato yield components that will ultimately affect plant yield and water use efficiency

Keywords – Water Application timings, Drip Irrigation, Greenhouse, Roma Tomato

I. Introduction

Tomato (Solanum Lycopersicum L.) is one of the most produced, popular, and nutritious crops worldwide (Padayachee *et al.*, 2017, Sturm & An, 2014). It provides a nutrient needed for human health and contains antioxidants like lycopene that play a crucial role in preventing cancer and cardiovascular diseases (Heber, 2000, Zhang *et al.*, 2015).Tomato is among the most popular vegetables produced in Rwanda and it is sold on the domestic market both in fresh and in processed form. Domestic demand is increasing because of tomato processors. Tomatoes are produced in many districts of Rwanda (Nshizirungu & Kitinoja, 2019). Production has increased from 135,000 tonnes in 2010 to 154,000 tonnes in 2014 (Nshizirungu & Kitinoja, 2019). Yields have increased since MINAGRI reports in 2008, but they were still relatively low at about 20 tonnes/ha (last reported data is for 2014) (Nshizirungu & Kitinoja, 2019). Two-thirds of Rwanda's tomatoes are produced in the Eastern Province, with the rest shared almost equally between the Western and Southern Provinces (Nshizirungu & Kitinoja, 2019).

Due to tomato fruit's nutritional and health benefits, tomato producers are much more interested in enhancing its quality and production (Gruda, 2005, Flores *et al.*, 2010). The fast increasing population has forced an increase in agricultural production that may be attained by consuming more water, thus making water resources run out (Giuliani *et al.*, 2010). Water is one of the main factors influencing crop yield under water-scarce conditions. The crop yield depends on water consumption during the reproductive stage (Merah, 2001, Kato *et al.*, 2008). Reducing the quantity of water used for irrigation can increase urban and industrial water use (Naseri *et al.*, 2009). Thus, the primary research objective concerning sustainable agricultural development and agricultural-ecological balance is to enhance water use efficiency (WUE) (Beltrano *et al.*, 1999, Shabbir *et al.*, 2012).

Water is the most dominant limiting factor for crop diversification and production. Because of urbanisation and increasing population, the competition for limited water resources for domestic and industrial needs is increasing considerably. it is therefore essential to formulate an efficient, reliable, and economically viable irrigation management strategy to irrigate more land area with the existing water resources (Imtiyaz *et al.*, 2000, Hamdy *et al.*, 2003). Drip irrigation system, in Rwanda, a relatively new method is being used to raise vegetable crops including tomato. Because of the reduced water need and potential increase in production, it has piqued interest (Neeraj *et al.*, 2000). The technology has proven to be superior than other traditional irrigation methods. This is especially true when it comes to irrigating fruit and vegetable crops because it allows for precise and direct water delivery in the root zone while saving fertilizer and water. It also has the potential to boost agricultural yields even when irrigation water is used less often (Fekadu & Teshome, 1998).

In comparison to other gravity-driven and pressure-operated irrigation systems, the drip irrigation system has been accepted as the highest water-saving method for the cultivation of tomato and many other horticultural crops(Zhai *et al.*, 2010). However, attempts to look for different and more efficienct approaches are still ongoing. Water pillow irrigation had been compared with drip irrigation and resulted in improved yield, fruit quality, and WUE than drip irrigation (Gerçek *et al.*, 2017). Water deficit irrigation, mainly for horticultural crops, has been studied worldwide for saving water and, hence, improving WUE (Fereres & Soriano, 2007, Rasool *et al.*, 2019).

The national average of tomato yield under farmer's condition is very low as compared to the neighbouring countries. While increasing production of the crop has a great role to strengthen the growing vegetable industries in the country. The low levels of crop productivity noted in Rwanda imply low water use efficiencies (WUE), as available evidence indicates that water at the source is rarely limiting (Fanadzo *et al.*, 2010, Machethe *et al.*, 2004), and in some cases over-application has been noted (Machethe et al., 2004, Lebea *et al.*, 2021). Improving WUE in irrigation is a priority in Rwanda. With the growing scarcity of water, significant increases in water productivity will have to come from improved agronomic practices rather than increasing the area under cultivation (Machethe et al., 2004).

II. Materials and Methods

2.1. Study area

The experiment was conducted under greenhouse growing conditions located at Nyagatare district, Rukomo sector and Rukomo II cell. The site is located 12.59km south west of Nyagatare city and 13.35km from the University of Rwanda, Nyagatare campus and 118km from the capital city of Rwanda-Kigali. It is geographically located on latitude N1.39005^{o} and longitude W 30.25829^{o}. The study site is characterized by short dry season starting from January to mid-March, long rainy season starting from Mid-March to Mid-May, Long dry season starting from Mid-May to Mid-September and short rainy season starting from Mid-September to December**.** The annual average temperature varying between 25.3°C to 27.7°C. Average annual rain falls are both very weak (827 mm/Year) and very unpredictable to satisfy the needs in agriculture and livestock. The predominant soil types in the area are loamy sand and sandy loam.

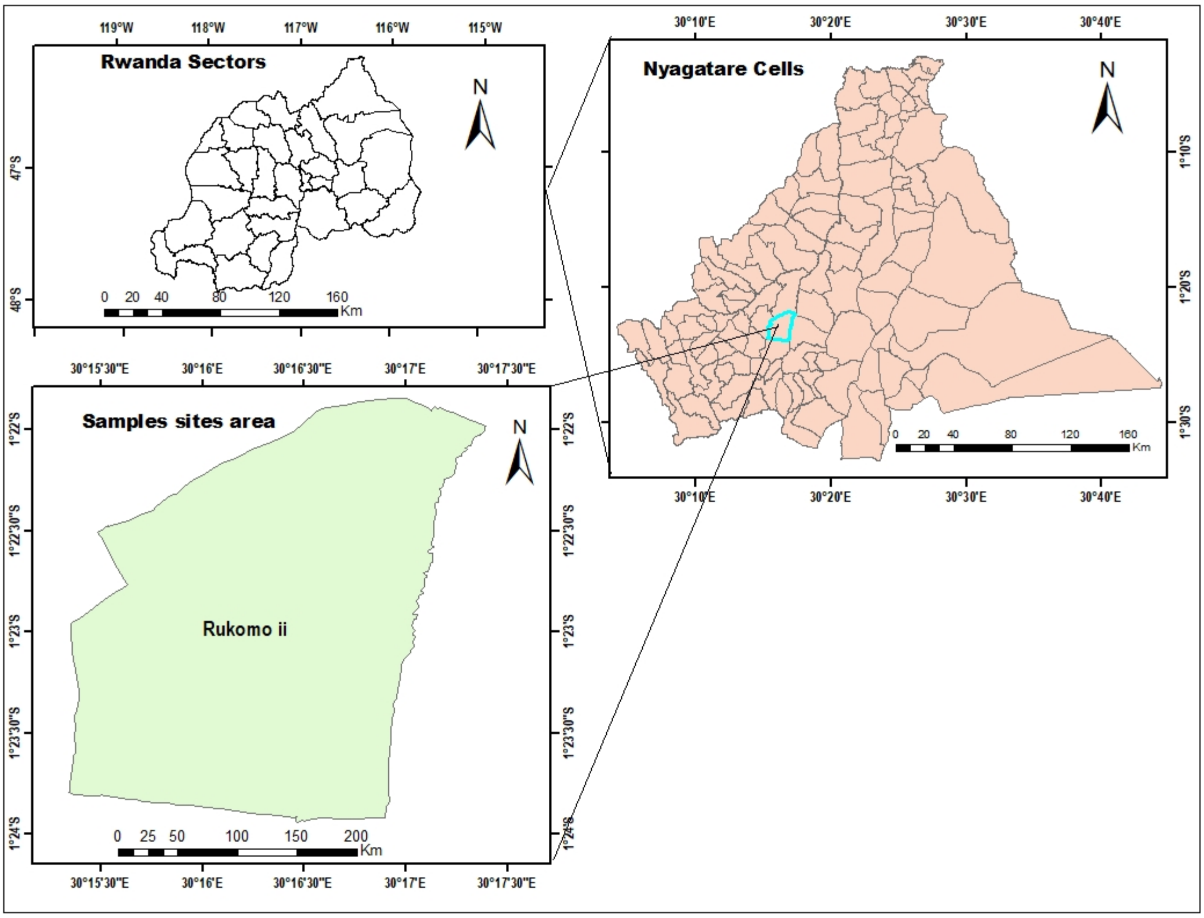

Figure 1: Geographical location of the experimental site
Source: Application of Arc GIS 10.5

2.2. Experimental design and field layout

The field experiment was carried in the dry season. The crop was planted on raised beds (2cm high). Three treatments were used for the experiment, replicated four (4) times and arranged in Completely Randomized Design (CRD). Each replication plot contains 4 experiment units and 64 experiment units for entire experiment field of 4 plots. The total area of experimental field would be 5m x 5m = 25m^2. The separation of two successive plots is 0.5m and 1m between two plots apart. The treatment included: Multiple water application where required amount of water will be applied in multiple equal parts a day during irrigation and two remaining treatments of one complete set (single water application). The multiple water application treatments were the Morning Time (MT), Day Time (DT), Evening Time (ET) and the combination of Morning – Day – Evening time. The daily crop water requirement (ETc) of the crop was calculated for the four stages of growth using the CROPWAT 8.0 software. The Roma tomato VF seeds to be used were sourced from the Agro-Tech Limited, Kigali, Rwanda. Seeds of Roma tomato VF cultivars were sown in the nursery on the 1st July 2021. Before seeding in nursery, Organic manure was mixed with soil in order to provide all the nutrients required by seeds, so as to increases the fertility and productivity of the soil. Water was connected when basic after seeding. After four weeks, on 31st July 2021, the seedlings were transplanted to well get ready beds within the field. Mulching, weeding, insecticidal splashing, staking and other horticultural operations were done when essential.

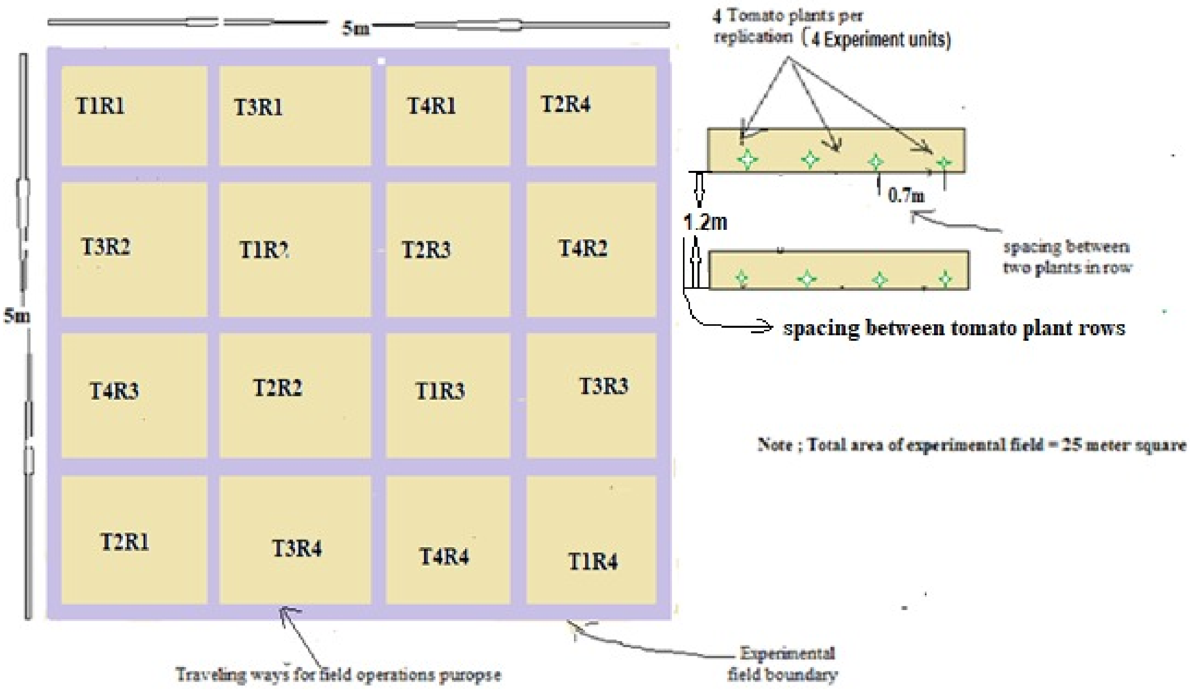

Figure 2: Layout of experiment field design

2.3. Design experiment of Plastic bottle drip water irrigation system

Half litre cool drink plastic bottles with lids were used to store water and provide water to the tomato plants. Small holes were drilled into the cap of the plastic bottles which aimed to discharge water from the holes of approximately 2 litres per hour. The bottom of each bottle were removed to enable the bottles to be filled with water. A hole was dug next to each plant and the bottle buried approximately one-third deep with the bottom facing up.

Figure 3 the photos above shows the current experiment field status

2.4. Quantitative agronomic parameters recorded (plant height, Number of branches, number of fruit and fruit weight)of Roma tomato

Average mean of each specified agronomic parameters information were collected from randomly selection on identified plants from the central row not including, the border rows in different growing stage in each 30 days. The parameters that were considered during information collection are: plant height, number of branches, number of fruit with total fruit weight per plant selected in one replication for each treatment.

2.5. Quantitative data

Mean plant height: Eight tagged plants from the middle row were measured from the soil to the tip of the shoot. This was recorded at thirty (30) days after transplanting using a meter rule.

Number of Branches (NB), Number of Flowers (NF) and **Fruits Number (FN)** : The number of tomato branches, Number of Branches (NB), Number of Flowers (NF) and Fruits Number (FN) were counted and recorded by visual eyes from the first to the end of the stem of tomato plant.

2.6. Data analysis

The collected data were kept in a Microsoft Excel file and later used in STATA 13.0. The overall significance of agronomic parameters like plant height, Number of branches, number of fruit and fruit weight soil samples by treatments were evaluated at the 5% level of probability ($p \leq 0.05$) through Analysis of Variance (ANOVA) one way. The Pairwise comparisons of means with equal variances through LSD (Least Significance Difference) was performed to assess the significance treatment by means comparison. Descriptive statistics like means, median, variance, standards deviation, minimum, maximum and coefficient of variation were used to interpret data.

III. Results And Discussion

3.1. Effect of irrigation timings on tomato agro-morphological traits

Table 1 pertained to mean performance of tomato agro-morphological traits (Quantitative) by treatments which included plant height, number of branches, number of flowers and number of fruits by treaments. The statistical findings showed that the maximum plant height of 107.75 cm was recorded by the T4 (Morning – Day – Evening) while the minimum plant height of 65.0cm was recorded by the T2 (Day) and the overall average mean plant height recorded was found to be 100.30±25.57 cm. The coefficient of variation was found to be 0.255 and the standard deviation of 25.57. The similar findings were found by Anderson (2019) when studying the agro-morphological traits (Quantitative) of the accession CLN3900D under greenhouse in Ghana. It was also found that there were significant differences increase in the number of branches among the treatments applied but not statistical significant at $LSD_{0.05}$. The highest number of branches of 14 was recorded by T4 (Morning – Day – Evening) while the T3 (Evening) with 12 branches, T2 (Day) with 10 branches and T1 (Morning) with 9 branches recorded the lowest number of branches of in their descending order; while the overall average mean number of branches recorded was found to be 11±4.34 branches. The coefficient of variation was found to be 0.385 and the standard deviation of 4.34. Furthermore, the study findings showed that there were significant differences increase in the number of flowers per plant in the various treatments but not statistically significant. The highest number of flowers was found to be 11 recorded by the T4 (Morning – Day – Evening) while T3 (Evening) and T2 (Day) recorded the same number of flowers of 6 flowers. The lowest was recorded by T1 (Morning) with 5 flowers. It was that also the overall average mean number of flowers recorded was found to be 7±5.102 flowers. The coefficient of variation was found to be 0.698 and the standard deviation of 5.102. The similar findings of 6 flowers was recorded by the accessions Tengeru-2010, Nkansah HT, CLN3900D, FMTT1733E and CLN3212C in the research conducted by Anderson (2019)under greenhouse in Ghana. Additionally, descriptive findings showed that also that there were significant differences increase in the number of fruits among the treatments but not statistically significant at $LSD_{0.05}$. The highest number of fruits of 58 was recorded by T4 (Morning – Day – Evening) while the T3 (Evening) with 48 fruits, T2 (Day) with 46 fruits and T1 (Morning) with 43 fruits recorded the lowest number of fruits of in their descending order; while the overall average mean number of fruits recorded was found to be 48±10.462 fruits. The coefficient of variation was found to be 0.698 and the standard deviation of 5.102. It is an implication that there is no statistical significance difference among recorded agro morphological parameters for Roma tomato under plastic bottle irrigation system in greenhouse, and hence these findings are coherent with the study conducted by Antony and Singandhupe (2004) who concluded that different methods of irrigation timings and quantity of water applied has increased instantly the the plant height and number of branches which thereafter affected the numbers flowers and fruit of tomato in greenhouse.

Table 2: Mean performance of tomato accessions for agro-morphological traits (Quantitative) by treatments

Treatments	stats	Plant Height, cm	Number of Branches	Number of Flowers	Number of Fruits
T1 (Morning)	Mean	98.188	9	5.125	42.688
T2 (Day)	Mean	96.813	10.125	6.438	45.5
T3 (Evening)	Mean	98.438	12.188	6.25	47.563
T4 (Morning-Day-Evening	Mean	107.75	13.813	11.438	57.938
Total overall average	Mean	100.297	11.281	7.313	48.422
	SE(Mean)	3.196	0.543	0.638	1.308
	SD	25.566	4.341	5.102	10.462
	Min	50	3	1	30
	Max	150	22	25	90
	CV	0.255	0.385	0.698	0.216
	N	64	64	64	64
	$LSD_{0.05}$	4.68	2.46	1.48	3.26

Based on previous studies, usuallytomato plants begin developing fruit about six weeks after transplanting, and adequate watering is necessary for the fruit to develop and grow to a proper size. An average of 1.982 to 9.9 liters of water per plant per day will be needed as the fruit continues to grow until the harvesting stage. This comes out to more than 3785.41 of water per week for a high greenhouse structures containing 300 tomato plants. The same findings were agreed by the research conducted by Kere *et al.* (2003) who comfirmed that application of water through drip irrigation techniques increased tomato yield under greenhouse.

Previous studies have shown that, in line with the present findings, deficit irrigation reduces vegetative growth and fruit yield(Agbna *et al.*, 2017, Hooshmand *et al.*, 2019). The explanation for this was thatconsiderably decreased plant photosynthesis reduced the volume and energy of metabolites neededunder water-stressed conditions for proper plant growth(Agbna et al., 2017, Kulkarni & Phalke, 2009). In accordance with the above, the greater percentage of Crop Evapotranspiration (ETc) under plastic drip irrigation regime incaresed the tomato yield gradually as the irrigation timing incaresed by 21.6% of coefficient of Variation (CV). The increase in fruits number lead to increased yield due to precision of water application by emitters from plastic bottles per plant and therefore affect positively the increase in mean unit fresh fruit weight and the number of fruits per plant respectively. Thus these findings are supported by the findings of (Shabbir *et al.*, 2020) who found that the increase in fruit unit fresh weight is due to increased fruit size (fruit diameter and fruit height. As is known, plant vigor has been closely connected to the root system that supplies the shootwith water and nutrients. The reason is that the pattern of root growth and shoot development is strongly correlated, and both increase with emitter density in this study, which may be considered the key factor promoting increased yield (Aguirre & Johnson, 1991).

IV. Conclusion And Recommendations

The use of plastic bottles under greenhouse structures to perform trickle irrigation is efficiently and effectively productive and water saving for Roma tomato plant cultivation because of no water loss due to environmental factors including wind speed. All the plant height, number of branches, number of flowers and number of fruits components showed an increasing trend but not statistically significant (LSD>0.05). Overall, it was seen that one dripper per plant had no significant effects on fruits number and weight which therefore reduced the tomato productivity, and the obtained results were similar under full and deficit irrigation. Rather it reduced water loss within the greenhouse structures. Bearing in mind the trade-off among plant agronomical parameters recorded (Table 1), the T4 (Morning-Day-Evening) irrigation timing per plant was found as the best combination irrigation regime than can boost the development of physiological traits of tomato grown under greenhouse conditions within pots. It is recommended that the emitter placement around the plant (spaing between dripper and plant) should be varied to study its effects on root development, physiological plant and tomato yield components that will ultimately affect plant yield and water use efficiency.

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CONFLICTS OF INTERESTS

The authors declare that there are no conflicts of interest.

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