Response of tomato (Lycopersicum lycopersicun, CV UC82B) to drip irrigation and planting conditions

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Studies were conducted in 2007/2008 cropping seasons under a tropical greenhouse (GH) and open field (OF) of the National Horticultural Research Institute (NIHORT) experimental farm. Seeds were sown into the nursery in October, 2007 and January, 2008 for the GH and OF after soil sterilization. Soil samples were analyzed for micro and macro nutrients. Organic manure: Poultry (PM) and horse (HM) wastes and irrigation water were also analyzed using standard laboratory procedures. Drip irrigation and fertilization structures were installed into the GH and OF in 2007 and 2008, respectively. Five week old tomato seedlings were transplanted into the GH in December, 2007 and OF in February, 2008. Organic manure in solution (OMS) was prepared at the rate of 4.2 KgL⁻¹ and NPK at 0.6 KgL⁻¹. Three levels of drip irrigation consisting of water and three levels of fertigation with two separate tanks containing mineral fertilizer (NPK) and poultry manure were investigated for the GH with corresponding water, NPK and HM for OF. Applications were carried out once (W₁), twice (W₂) and thrice per week in both GH and OF conditions using split-plot arrangement fitted into randomized complete block design with three replicates. Plants under PM applied at W₂ gave the highest yield (7.4 ha⁻¹) with significantly higher lycopene formation. Vitamin C was however best under drip irrigation in the GH. B-Carotene was highest under HM for OF. Overall result showed that plants under PM+W₂ in the GH had better yield than others. Likewise, lycopene formation was significantly best under PM in the GH which suggests preference of GH tomato production over OF.

Key words: Greenhouse, open field condition, tomatoes, drip irrigation, fertigation.

INTRODUCTION

Tomato (Lycopersicum lycopersicum, CV UC82B) exhibits medicinal qualities as evident in its flavonoid, carotenoids, Vit. A, Xanthins, lutein, Vit. C and potassium contents (GURA, 1995; AVRDC, 1996; Wener, 2000).

The present world fresh tomato fruit production stands at 100 million metric tons. However, Nigeria ranked the 13th among the fifteen top countries accounting for 1.7% of the world index (FAO, 2010; Shankara et al., 2005) compared with China of production capacity rated 33.9% despite Nigerian’s good weather that accommodates and support vegetables cultivation especially tomato. Generally, tomato production in Africa was 300,000 ha, about 7.7% of the world total and rated the 8th largest exporter of the 10 world leading continents. Strikingly, tomato production in Nigeria appears very low in terms of yield per hectare (20 t/ha) (Balarabe, 2012) compared with Brazil (60.7 t/ha), China (48.1 t/ha), USA (81.0 t/ha) and Italy (50.7 t/ha).

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This trend in Nigeria could possibly be due to unavailability of inputs like improved seeds, fertilizer, irrigation and greenhouse facilities.

George et al. (2009) reported that greenhouse production was an intensive investment, but can be very satisfying and rewarding in view of the relatively small area required compared with field grown crops. Basically, greenhouse structures vary from simple homestead to sophisticated prefabricated structures depending on the objective of the structure coupled with financial resource available. Comparatively, greenhouse structures minimize insect and disease incidence as opposed to susceptibility of open field cultivation to myriads of incidences (Wilson, 1993).

Jagdish et al. (2005) estimated that 50% of human populations depend on open field production resulting into about 83 million metric tons of N. About 50% of this applied N is not assimilated by plants (Tilman et al., 2002; Doberman and Cassman, 2004) thereby contributing to groundwater contamination, eutrophication, acid rain, ammonia deposition, global warming and stratospheric zone depletion with acute environmental pollution (Howarth et al., 1996, Van Drecht et al., 2001). Problems with over fertilization (Jagdish et al., 2005; Fageria and Balligar, 2005) necessitate research in the proper amounts of fertilizer for sustainable production. Organic manure is generally believed to be characterized with slow release of N allowing more effective uptake by plants and reduction of N leaching or denitrification losses (Fageria and Balligar, 2005).

Shoji et al. (2001) and Shoji and Kano (1994) confirmed that slow release of N facilitates reduction in N fertilization rates that contributes to conservation of air and water quality. Studies compared soils of organically and conventional inorganically managed farming systems and confirmed that higher soil organic matter and total N were obtained from organically farming systems with more improved nitrogen used efficiency (NUE) (Irshad et al., 2002; Clark et al., 1998; Chang et al., 1993; Ma et al., 1999).

Result of analysis carried out (Afolayan et al., 2008) indicated that cow, horse, pig and poultry manures were capable of producing 11.54% CH₄, 5.32% CO₂, 0.06% N₂O; 11.42% CH₄, 16.42% CO₂, 0.14% N₂O; 11.12% CH₄, 16.62% CO₂, 0.13% N₂O and 15.51% CH₄, 7.88% CO₂, 0.14% N₂O, respectively.

These gases when allowed to diffuse into the air could constitute nuisance and aggravated global warming. However, conversion of these wastes into compost has been reported to prevent production of CH₄ and other noxious gases (USEPA, 2003). Similarly, organic manure solution as fertigation is capable of circumventing production of gases in sufficient quantity with reduced effects on global warming. Much work had been done on drip irrigation and fertigation for crop production in developed countries (Hartz, 2005; Sharma and Sharma, 2002; Garcia et al., 2000; Holmes and Schnitzler, 1997), and specifically on vegetables (Alexander et al., 2006; Eunmi et al., 2012) little is reported in Nigeria especially as related to tomato production. This study was undertaken to determine responses of tomatoes to drip irrigation and fertigation in the greenhouse and open field.

**MATERIALS AND METHODS**

The experiment was conducted at the National Horticultural Research Institute (NIHORT) experimental field Ibadan. Ibadan lies between longitude 3° 56’ and 3° 52’ E and latitude 7° 23’ and 7° 28’ N with an altitude of 168 m above mean sea level. Seeds of tomato, CVUC82B, an indeterminate type of tomato variety compatible with both greenhouse and open field productions were planted into the nursery on 27th October, 2007 for the GH experiment and January 3, 2008 for the open field (OF) to ensure similar condition to the greenhouse thereby eliminating the possibility of interruption by rainfall, since cessation of rain effectively occurs between the last week of October and the first week of November at the experimental location. A rectangular shaped greenhouse with effective cropping area of 5.42 m² (58.3 ft²) with ventilated side wall and raised concrete platform was used for this study. The orientation of the greenhouse was skewed to north-east direction and covered with an ultraviolet stabilized medium-density glass film of 4 cm thickness. The cropping area of the greenhouse (GH) was filled with sandy-loamy soil to the depth of 28 cm at 22.4 m³ soil volume and was allowed to stabilize before physical and chemical properties were conducted for nutrients status. The soil was sterilized by subjecting the surface to burning with plant residues for about 10 min and allowed to attain optimum temperature before planting to prevent microbial predators with potentials soil-borne pathogens. The action was repeated for the OF. Irrigation water samples, PM and HM were analyzed following standard laboratories at the university of Ibadan soil analytical laboratory. Drip irrigation and fertigation systems were installed on separate platforms independent of each other in the GH and OF on 14th December, 2007 and 15 January, 2008, respectively. The gravity propelled drip irrigation and fertigation systems were mounted on 2 m elevated prefabricated slabs as head capable of injecting 20 mm depth of water. Drip lines were made of non-pressure compensating drippers and kept at low length and connected with 4 mm adaptors.

The arrangement was made to ensure slow release of water directly to the root zones of the seedlings thereby soaking the root zone before any noticeable evaporation or run off could take place. This method thus guarantees minimum water coverage within the cropping area thereby controlling weed infestation and excess moisture on the plants with resultant effect of disease incidence. The drip lines were flushed and cleaned with water to ensure clog-free drippers. Emitter (dripers) discharge was determined by placing empty containers at discharge points operated at 45° throttling of water valve and run for 60 s at three replications of 1.72 and 2.7 lha for GH and OF, respectively. The PM used for fertigation in the GH and HM for OF fertigations were dissolved in water and sieved with B540 standard sieve size (150 cm) until a soluble solid content of 4.2 kg was achieved. One thousand litre plastic storage tanks were used in all cases in accordance with greenhouse specifications (Richards, 2010).

Tomato seedlings were transplanted into the GH on 17th December, 2007 and OF in February, 2008, five weeks after sowing (WAS) arranged in split-plot fitted randomized complete block design (RCBD) with three applications. Plant spacing was 0.3 by 0.75 m plot size of 5.42 m² transplanting to twenty four plants, an average of four seedlings per plot. Drip irrigation and fertigation
Table 1. Meteorological elements of the experimental period (2007/2008).

|                        | 2007  | 2008  | 2007  | 2008  | 2007  | 2008  | 2007  | 2008  | 2007  | 2008  | 2007  | 2008  |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Total rainfall (mm)   | 16.9  | 68.5  | 237.1 | 222.8 | 255.3 | 138.7 | 286.3 | 245.4 | 132.3 | 34.7  |       |       |
| Air temp (%)          | 29.1  | 29.1  | 28    | 26.4  | 25.2  | 25.1  | 26    | 27    | 27.4  | 27    |       |       |
| Max temp (%)          | 40    | 35    | 33    | 31    | 30    | 29    | 31    | 32    | 33    | 34    |       |       |
| R. humidity (%)       | 86    | 89    | 90    | 91    | 91    | 92    | 91    | 91    | 87    |       |       |       |
| Evaporation (mm)      | 6.3   | 6.1   | 5.2   | 5.3   | 4     | 4     | 4.3   | 5     | 4.1   | 4.7   |       |       |
| 2008 (rainfall)       | 88.8  | 181.8 | 234.4 | 372.8 | 250.7 | 221.4 | 401.1 | 273   | 27.2  | 20    |       |       |
| Rainy days            | 4     | 6     | 17    | 20    | 20    | 19    | 20    | 16    | 3     | 2     |       |       |

|                        |       |       |       |       |       |       |       |       |       |       |       |       |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|

Table 2. Physiochemical properties of water and manure.

| Chemical properties | Treatment | PH | Ca  | Mg  | Na  | K   | C   | N   | P   | Cu  | Zn  | Fe  | Mn  | SO_4^{2-} | Cl^- | HCO_3^- | CO_3^{2-} |
|---------------------|-----------|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----------|------|----------|-----------|
|                     | Water 1   | 6.5| 1.35| 0.28| 19.78| 3.01| Nd  | Nd  | 5.05| 0.09| Nd  | Nd  | 1.05| 35.27     |       |          | 0.5       |
|                     | Poultry   | 5.3| 38.75| 7.64| 9.46 | 3.76| 30.4| 1.64| 48.83| 57.85| 1.23| 21.25| 3.15| Nd         | Nd    | Nd       | Nd        |
|                     | Water 2   | 7.0| 11.33| 5.99| 21.93| 10.75| Nd  | Nd  | 3.44| 6.0  | Nd  | Nd  | Nd  | 17.55| 69.16     | 208   | 0.4      |
|                     | Horse     | 7.5| 12.4 | 8.99| 16.77| 16.13| 33.57| 1.68| 16.38| 0.75 | 0.75| 21.40| 1.56| 3.56       | nd    | nd       | nd        |
Table 3. Physiochemical properties (residual) of experimental soils.

| Treatment | PH | Ca (mol/100 g H+) | Mg | Na | K+ (mol/100 g H+) | H+AL | ECEC | Base Sat C (%) | N (%) | AvP (ppm) | Cu | An | Fe (mg/kg) | Mn (Mg/kg) | HCO3⁻ | CO₃²⁻ |
|-----------|----|-------------------|----|----|------------------|------|------|---------------|------|----------|----|---|----------|-----------|------|-------|
| Water 1   | 6.3| 16.35             | 0.94| 1.42| 6.62             | 0.08 | 19.41| 99.59         | 2.27 | 0.17     | 25.0 | 0.34 | 23.24    | 21.05     | 78.47 | nd    |
| PM        | 6.4| 17.46             | 0.83| 1.38| 0.68             | 0.09 | 20.44| 99.59         | 2.59 | 0.25     | 44.9 | 0.99 | 25.25    | 26.20     | 79.61 | nd    |
| NPK 1     | 5.6| 17.95             | 0.69| 1.62| 0.93             | 0.1  | 21.3 | 99.48         | 1.95 | 0.4      | 47.35| 0.49 | 20.89    | 39.20     | 7512  | nd    |
| NPK 2     | 5.5| 4.68              | 1.04| 0.56| 0.25             | 0.08 | 6.61 | 98.79         | 0.49 | 0.16     | 31.15| 0.53 | 3.77     | 5.80      | 15.77 | nd    |
| Water 2   | 6.9| 5.08              | 1.43| 0.56| 0.21             | 0.06 | 7.34 | 99.18         | 0.51 | 0.15     | 32.50| 1.21 | 4.88     | 8.25      | 15.15 | nd    |
| HM        | 6.2| 6.59              | 2.08| 0.49| 0.25             | 0.07 | 9.58 | 99.27         | 0.52 | 0.17     | 21.25| 1.93 | 2.71     | 7.90      | 17.17 | nd    |

Water 1 = Irrigation water for the greenhouse, Water 2 = Irrigation water for the open field; NPK 1, NPK 2 – fertilizer in GH and OF respectively; nd= not detected.

Table 4. Proximate analysis of Tomato fruit.

| Treatment | Ca (mg/kg) | Mg (mg/kg) | Cu (mg/kg) | Zn (mg/kg) | Fe (mg/kg) | P (mg/kg) | Na | K | N (%) | Vit.C | Lycopene | B-Carotene |
|-----------|------------|------------|------------|------------|------------|----------|----|---|------|-------|----------|------------|
| Water 1   | 15.57      | 42.71      | nd         | 2.21       | 4.1        | 118.18   | nd | nd| 0.15 | 36.20 | 6.09     | nd         |
| PM        | 25.61      | 60.43      | nd         | 2.27       | 5.06       | 249.64   | nd | nd| 0.14 | 24.50 | 8.84     | nd         |
| NPK 1     | 32.18      | 28.29      | nd         | 2.30       | 4.54       | 113.76   | nd | nd| 0.17 | 32.0  | 5.22     | nd         |
| Water 2   | 18.20      | 54.45      | 50.20      | 400        | 310.9      | 19.30    | 45.56| 2.11| 28.40 | 12.60 | 0.68     | nd         |
| NPK 2     | 17.69      | 46.17      | 14.50      | 8.38       | 11.41      | 533.8    | 18.28| 4.35| 2.02 | 19.20 | 17.00    | 0.51       |
| HM        | 13.78      | 36.99      | 8.30       | 6.28       | 11.53      | 5.34     | 11.28| 38.48| 2.11 | 17.50 | 14.80    | 0.60       |

Results of the macro and micro elements conducted before and after experimentation are presented on Tables 2 and 3. The primary macro nutrients comprising nitrogen (N), phosphorus (P) and potassium (K) concentrations indicated 1.64 meg/100 gN, 48.83 meg/100 P and 3.76 meg/100 g for PM, 1.68 meg/100 gN, 16.38 meg/100 gP and 16.13 meg/100 K for HM. The K and N values in HM were higher than PM suggesting the ability of HM capable of supplying higher nutrients essential for plant physiological growth (Bianw, 1995). However, the available phosphorus in PM was more superior than HM thereby revealing the possibility of plants grown in PM medium exhibiting less susceptibility to restricted root development and stunted growth (Bianw, 1995). The secondary macro elements showed concentrations levels in PM and HM as 38.75 meg/100 gCa, 7.64 meg/100 gMg, 12.4 meg/100 Ca and 8.99 meg/100 gMg, respectively. The concentrations in both PM and HM media were however adjudged sufficient for tomato especially when applied in solid form about two weeks before planting. The micro-elements reflected a similar trend with the macro-elements (Table 2).

Table 3 showed the physiochemical properties of the fertilizers after experimentation. Evidences of effective breakdown of element were noticed in all the brands of fertilizers used which suggested uniform utilization of soluble solids (Table 3). Physiochemical compositions of the tomato products obtained from the effect of drip irrigation and fertigation are presented in Table 4. Mean
Table 5. Effect of GH and OF drip irrigation and fertigation on growth parameters and yield of tomato.

| TRT       | PHT | SD | NB | NFL | YLD t/ha | BM t/ha |
|-----------|-----|----|----|-----|---------|---------|
| G1W1      | 39.5| 2.3| 14 | 3   | -       | 50-5    |
| G1W2      | 94.4| 4.9| 36 | 5   | 6.81    | 83.4    |
| G1W3      | 119 | 6.2| 44 | 6   | 4.31    | 88.8    |
| G2W1      | 96.3| 5.3| 44 | 5   | 3.34    | 83.4    |
| G2W2      | 91.6| 4.8| 28 | 5   | 7.40    | 74.0    |
| G2W3      | 118.3| 7.0| 37 | 6   | 3.75    | 95.7    |
| G3W1      | 78.5| 4.5| 27 | 5   | 1.35    | 70.0    |
| G3W2      | 66.5| 4.0| 24 | 2   | 2.98    | 65.7    |
| G3W3      | 98.8| 5.4| 32 | 3   | 4.94    | 98.6    |
| LSD (5%)  | 21.5| 1.0| 9.9| 3   | 2.92    | 43      |
| F1W1      | 25.9| 7.4| Ng | 6   | 3.3    | Ng      |
| F1W2      | 32.5| 8.2| Ng | 2   | 3.1    | Ng      |
| F1W3      | 45.3| 10.2|Ng  | 21  | 2.8    | Ng      |
| F2W1      | 44.0| 10.4|Ng  | 8   | 3.5    | Ng      |
| F2W2      | 30.0| 8.1| Ng | 7   | 0.03   | Ng      |
| F2W3      | 330 | 7.6| Ng | 9   | 1.67   | Ng      |
| F3W1      | 29.6| 6.0| Ng | 4   | 0.67   | Ng      |
| F3W2      | 26.1| 6.0| Ng | 9   | 3.1    | Ng      |
| F3W3      | 27.9| 5.1| Ng | 7   | 1.0    | Ng      |
| LSD (5%)  | 8.0 | 1.4| Ng | 5   | 3.0    | Ng      |

G1W1 = Green house + watering once per week; G1W2 = green house + watering twice per week; G1W3 = Fertigation with NPK once per week in the green house; G2W1 = Fertigation with NPK twice per week in the green house; G2W2 = Fertigation with NPK three times per week; G2W3 = Fertigation with PM three times per week; G3W1 = Fertigation with PM once per week in the green house; G3W2 = Fertigation with PM twice per week in the green house; G3W3 = Fertigation with PM three times per week; F1W1 = open field water application once per week; F1W2 = Open field water application twice per week; F1W3 = Open field water application three times per week; F2W1 - fertigation in the open field with NPK once per week; F2W2 - fertigation in the open field with NPK per week; F2W3 - fertigation in the open field with NPK three time per weeks; F3W1 - fertigation in the open field with horse manure once per week; F3W2 - fertigation in the open field with horse manure twice per week; F3W3 - fertigation in the open field with horse manure three times per week; Ng – Negligible.

same pH range of 5.6 and 5.5. The percent N. composition of 20% in the minerals fertilizers (20-10-10) was sufficient enough to introduce values of Lycopene, B-carotene and Vitamin C indicated 36.2% Vitamin C, 6.09% Lycopene, and B-carotene for PM; 32% Vitamin C, 5.22% Lycopene, and B-carotene for plants under Water 1; 28.4% Vitamin C, 12.60% Lycopene, 0.68% B-carotene for plants under Water 2; 19.2% Vitamin C, 17.0% Lycopene and 0.60% B-carotene and 17.5% Vitamin C, 14.8% Lycopene and 0.60% B-carotene confirming the work of Renata et al. (2013). Vitamin C concentrations were highest in water based drip irrigation with corresponding mean values in PM and HM. The variation in Vitamin C content might possibly depend on environmental conditions as reported by Martinez et al. (2002) that variation in light intensity prior to harvest has a great influence on Vitamin C content.

Obviously, the tomato plants in the GH have the tendency of greater concentration of light intensity compared to the diffused nature typical of OF. However, Lycopene content was highest in NPK2 based fertigation followed by HM based fertigation. This observed trend might not be unconnected with the molecular structure of Lycopene as a liposoluble micronutrient thereby suggesting more tendency to remain in semi-soluble form in NPK than in organic materials like PM and HM, thus affecting the concentrations (Djuric and Powell, 2001). Contrariwise, B-carotene was more superior under HM in OF than others, although confirming the studies of other researchers (Renata et al., 2013; Bourn, 2002; Clinton, 1998).

The superiority of B-carotene in HM might not be unconnected with the degree of exposure of the tomato fruits under HM based fertigation in OF to light, temperature and degree of fruit ripeness thereby stimulating accumulation in accordance with the report of Abuslita et al. (2000). Effects of GH and OF drip irrigation and fertigation on growth parameter and fruit of tomato are presented in Table 5. Plants under GH using drip and watering thrice per week (G1W3) recorded the highest mean plant height, although one of the least fruit yields. This might be due to the difficulty in reproductive ability of
transforming its flowers to fruit resulting from shortage of nutrients typical of ordinary water sample. Strikingly, the highest fruit yield was obtained under NPK combination in combination with watering twice per week (G1W2). This phenomenon is however, expected in view of high mobility of typical mineral fertilizer with little or no constraints in the release of the nutrients for plant growth and fruit set compared to extremely low mineralization and consequent release of active nutrients for plant growth except when applied at least two weeks before planting in confirmation of Montagu and Goh (2012). Overall results showed that mean values of Lycopene and B-carotene formation were superior under HM while fruit yield was best under mineral fertilizer.

Conclusion

Discoveries in the nutrient status of tomato had ranked the crop as a very powerful anti-oxidant that fights against many forms of cancer. Tomatoes are susceptible to various diseases most of which are caused by high humidity and air pollutants. However, water and soil nutrients are regarded as the most two important critical inputs in tomato production. Therefore, the need for in-depth study on drip irrigation and fertigation to optimize its water use efficient. In addition, green house intervention becomes the best alternative to screen off diseases and air borne vectors typical of open field cultivation. In this study, GH production using poultry in solution for fertigation appears more superior to expose open field cultivation and the conventional practice in Nigeria.

Conflict of Interests

The authors have not declared any conflict of interests.

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