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The influence of organic manure formulated from goat manure on growth and yield of tomato (*Lycopersicum esculentum*)

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The influence of organic hydroponic nutrient solution on tomato growth and yield was studied using a randomized complete block design (RCBD) with three treatments (organic nutrient solution, conventional hydroponic fertiliser (as positive control) and plain tap water (as negative control)) replicated three times. Determinate tomato seeds were germinated and transplanted into the 3 treatments. Twenty days after transplanting, vegetative response variables were recorded at fifteen days intervals from each treatment. Vegetative response variables included plant height, number of leaves and stem diameter. The reproductive parameters included number of flowers per plant, number of fruits per plant, average fruit weight (g), yield (kg) per plant and yield (kg) per treatment. Furthermore, the organic nutrient solution formulated from goat manure positively improved plant growth and yield performance of a tomato crop, and provided a technique feasible and alternative to conventional hydroponics. These results open further possibilities for other crops currently grown in hydroponics using conventional fertilisers.

Key words: Organic nutrient solution, growth, yield, goat manure, tomato.

INTRODUCTION

The use of inorganic fertilisers for agriculture is relatively expensive worldwide (Dopler, 1980; Osman et al., 2009) and in particular Africa (Sanchez, 2002). This cost has been particularly pronounced in hydroponic systems which rely on use of the same expensive inorganic fertilisers. Though hydroponics can be an important crop

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production solution in water limited countries like Namibia, not all communities can afford to practice horticulture using conventional hydroponics. This has been the drawback for many even around Henties Bay where this technology has been demonstrated for years to the local community by Sam Nujoma Marine and Coastal Resources Research Centre (SANUMARC). This situation can partly be addressed by development of cheaper, alternative fertilizers such as using manure for hydroponics.

Generally, organic nutrient solution for hydroponics is a fairly new practice despite the similarities in plant growth when either conventional or organic fertilizer is applied on soil (Liang et al., 2014). It was not until the early 1990s when liquid manures for hydroponics were introduced. Challenges emerged such as organic fertilizer being unsuitable to plant growth (Garland et al., 1997; Liedl et al., 2004), because nitrogen in manure is predominantly organic, hence unusable by plants. The forms of nitrogen absorbed by plants are nitrate and ammonium (Strayer et al., 1997). Therefore, the nitrogen in manure requires to be mineralised prior to use by plants hydroponically. Several studies including Garland et al. (1997) and Shinohara et al. (2011) have demonstrated that using microorganisms to degrade organic nitrogen in organic sources such as manure results in nitrates and ammonium production which in turn are used for plant production.

Therefore, the current study investigated the efficacy of an organic hydroponic nutrient solution on plants' performance. The organic nutrient solution was processed from goat manure using a specialized culture of microbes from natural compost.

MATERIALS AND METHODS

Experimental setup

To determine the effect of the organic hydroponic nutrient solution on growth and yield of tomato, hydroponic tables (22.8 × 250 × 150 cm^3) constructed from planks and black sheeting were used in a greenhouse at the Sam Nujoma Marine and Coastal Research Centre (SANUMARC), Henties Bay. Styrofoam that completely covers the hydroponic tables yet float on water in the table was added. Each hydroponic table covered an area of 3.75 m^2. A randomized complete block design (RCBD) with three treatments (organic nutrient solution, conventional hydroponic fertiliser (as positive control) and plain tap water (as negative control)) replicated three times in this experiment. Each replicate was a hydroponic table of 6 plants and served as an experimental unit. Organic nutrient solution was formulated in 2016 at SANUMARC, Henties Bay using natural compost containing ammonia and nitrite oxidising bacteria to convert organic nitrogen into nitrates from goat manure. The control treatment was a nutrient solution made from the conventional hydroponic fertilisers; Calcium Nitrate and Hygrotech. The final nutrient solution made from the 2 fertilisers consisted of: Calcium (Ca) 217 mg/L, Nitrate (N) 225 mg/L, Phosphate (P) 46.5 mg/L, Potassium (K) 372 mg/L, Magnesium (Mg) 58 mg/L, and Sulphur (S) 141 mg/L. Organic nutrient solution had Nitrate (N) 198 mg/L, Phosphate (P) 42.1 mg/L, Potassium (K) 360 mg/L, Magnesium (Mg) 67 mg/L, Sulphur (S) 198 mg/L, and Calcium (Ca) 250.

The formulated organic hydroponic nutrient solution was therefore compared with the conventional nutrient solution according to the method by Shinohara et al. (2011) and the negative control. Determinate tomato seeds were germinated on coconut husks in polystyrene trays on 23 February 2017 and transplanted into 3 treatments (conventional fertiliser and organic nutrient solution and plain water) on 24 March, 2017.

Twenty days after transplanting, vegetative response variables were recorded at fifteen days intervals from each treatment (Liu et al., 2014).

Vegetative growth

Response variables included plant height (cm) measured from the ground to the main apex, number of leaves and stem diameter measured 10 cm above the root level.

Reproductive growth

The reproductive parameters included number of flowers per plant, number of fruits per plant, average fruit weight (g), yield (kg) per plant and yield (kg) per treatment. In order to determine yield, tomato fruits were picked and weighed when they had reached full maturity at harvest time (Mehdizadeh et al., 2013).

Statistical analysis

Means comparisons analysis were applied whereby a One-way Analysis of Variance (ANOVA), followed by mean separation by Least Significant Difference (LSD) was used when ANOVA determined that the effects of the treatments were significant ($p < 0.05$ for F-test).

RESULTS

Vegetative growth

Vegetative plant growth was measured as plant height, number of leaves, and stem diameter. Figure 1 shows that tomato plant height increased over time and was high in plants growing under manure nutrient solution and under the conventional hydroponic fertilisers compared to plants grown under the negative control. ANOVA results indicate that at $P<0.05$, there were significant differences in tomato plant height between the three treatments. The LSD further shows that the significant difference ($P=0.000$) was between the negative control and the other 2 treatments, whereas there was no significant difference ($P = 0.249$) in plant height between manure nutrient solution and the conventional hydroponic nutrient solution.

Figure 2 shows that vegetative growth in terms of the number of leaves followed the trend: conventional fertiliser nutrient solution, manure nutrient solution, and lastly tap water. Therefore, tomato plants produced more leaves when grown under the conventional hydroponic solution ($P=0.009$) than under manure nutrient solution which in turn produced more leaves than plants grown

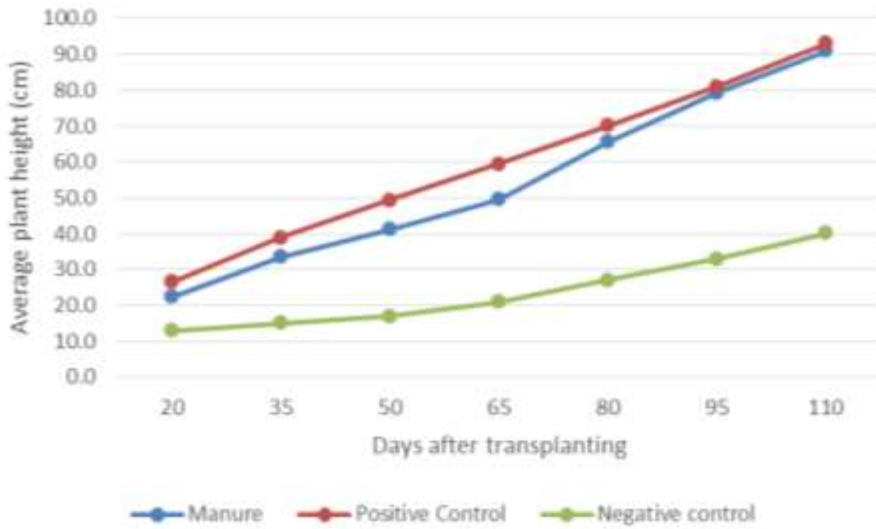

Figure 1. Effect of different nutrient solution on growth of tomato plant height.

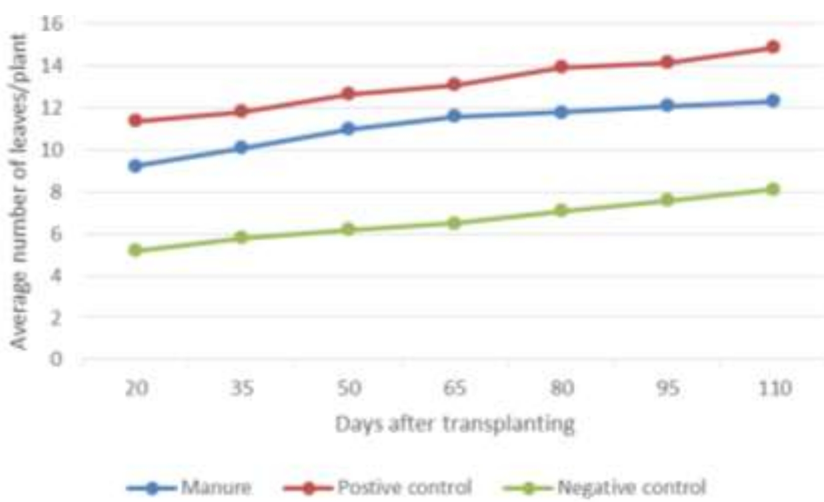

Figure 2. Effect of different nutrient solutions on the number of leaves produced by tomato plants.

under plain tap water (P=0.000).

Figure 3 displays that growing tomato plants under manure nutrient solution and conventional nutrient solution increased the plant stem diameter more than when grown under tap water. ANOVA indicates that this difference between the negative control and the other treatments is significant, whereas there is no difference in stem diameter between plants grown under manure nutrient solution and the conventional nutrient solution.

Reproductive growth

Reproductive plant growth was measured as the number of flowers, number of fruits, and yield (fruit weight). Figure 4 indicates that tomato plants grown under conventional hydroponic nutrient solution and under manure nutrient solution produced more flowers compared to those grown under tap water. ANOVA shows that this was a significant difference (P=0.000) and that there is no significant difference in the number of flowers produced by tomato plants grown under manure and conventional nutrient solution (P=0.018).

Figure 5 indicates that there were more fruits produced by tomato plants grown under conventional hydroponic nutrient solution than those grown under manure nutrient solution and tap water. ANOVA results uphold the observed trend in Figure 5, by indicating that these

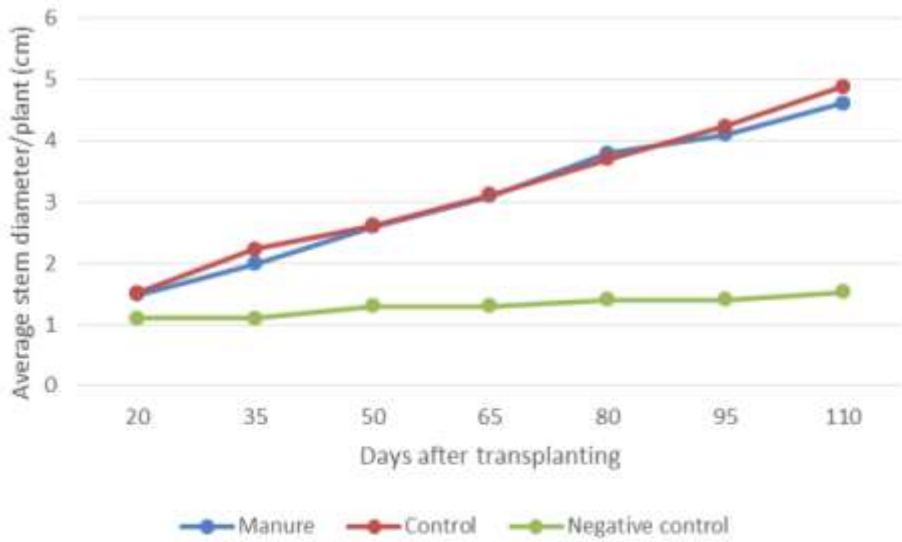

Figure 3. Effect of different nutrient solutions on stem diameter of tomato plants.

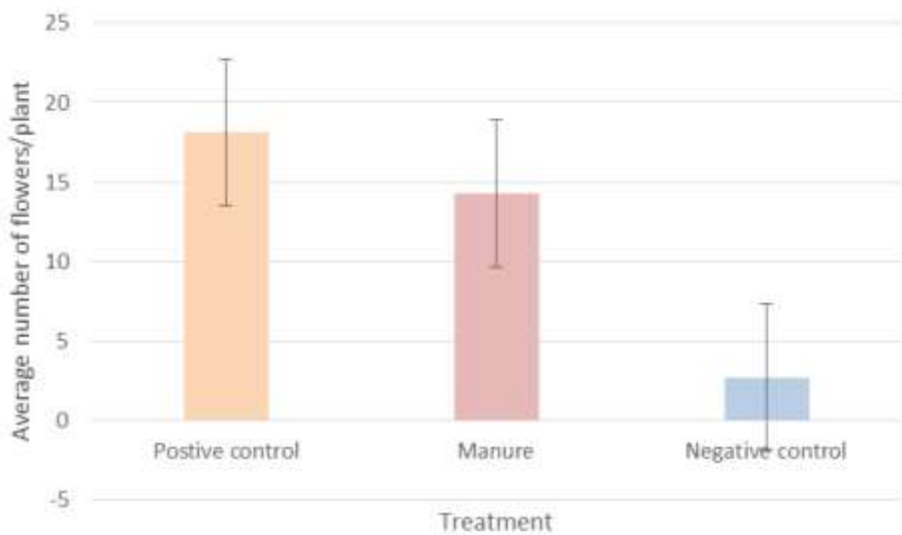

Figure 4. Average number of flowers produced by tomato plants according to different treatments.

differences are significant (P=0.000).

Figure 6 shows that in terms of yield, tomato plants grown under the conventional hydroponic nutrient solution produced more than those grown under manure nutrient solution which in turn, produced more than the plants grown under plain tap water. These are significant differences as provided by ANOVA (P=0.000)

As shown in Figure 7, the average weight of a single tomato fruit was more from tomato plants grown under conventional nutrient solution and manure nutrient solution compared to fruits from plants grown under plain water. The addition of either manure nutrient solution or conventional nutrient solution significantly increased the weight of each single tomato fruit compared to when only plain water was used to grow tomato plants hydroponically.

DISCUSSION

The performance of tomato plants grown in manure nutrient solution was similar to those grown in the conventional nutrient solution and was more than those in the negative control. Similar results have been reported

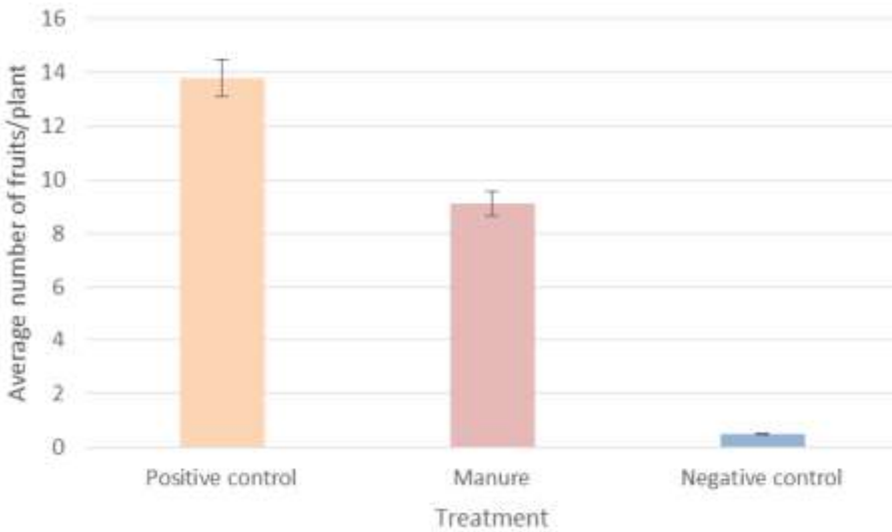

Figure 5. Average number of fruits produced by each tomato plant according to different treatments.

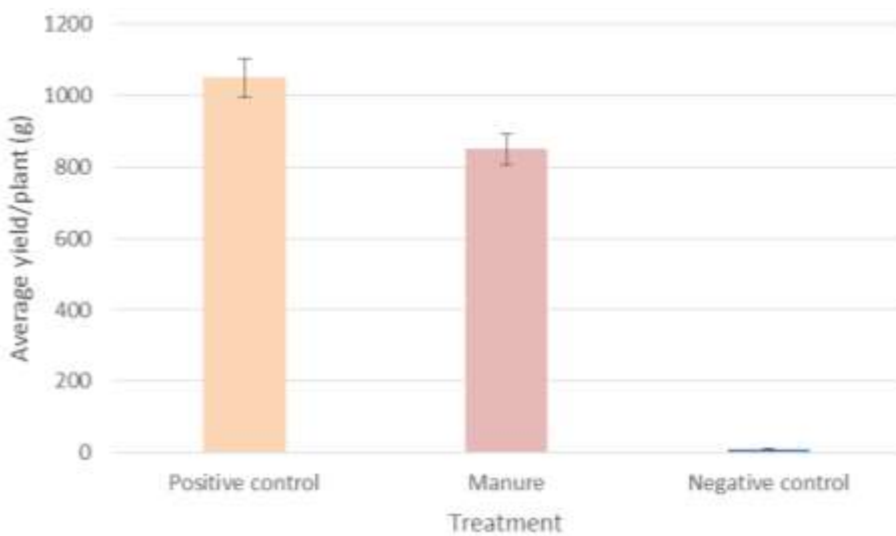

Figure 6. Average yield per tomato plant as influenced by different nutrient solution.

for other organic sources of nutrients. Shinohara et al. (2011) reported that tomato vegetative growth in fish-based organic fertiliser mineralised by microorganisms was similar to those in the conventional fertiliser. Kawamura-Aoyama et al. (2014) maintain that vegetative growth can be increased even in other crops such as lettuce when grown in organic nutrient solution degraded by microorganisms. This is because there are sufficient levels of nitrate in nutrient solutions formulated from organic sources such as animal manure, since most vegetable crops prefer nitrate (N) over ammonium (N) (Cruz et al., 2006). As is evident from the current study's levels of nitrate in the organic nutrient solution, it was sufficient to produce vegetative growth in tomato plants similar to when they were grown under conventional nutrient solution, and significantly more improved more than when plants were grown without the addition of either manure or fertilizer.

These results further suggest that the minimum amounts of other nutrients required for tomato plant growth were sufficient in the organic nutrient solution to result in similar growth patterns as those from the conventional fertilizer.

Reproductive growth was significantly high in tomato plants grown in manure nutrient solution compared to the negative control, though lower than those grown in the

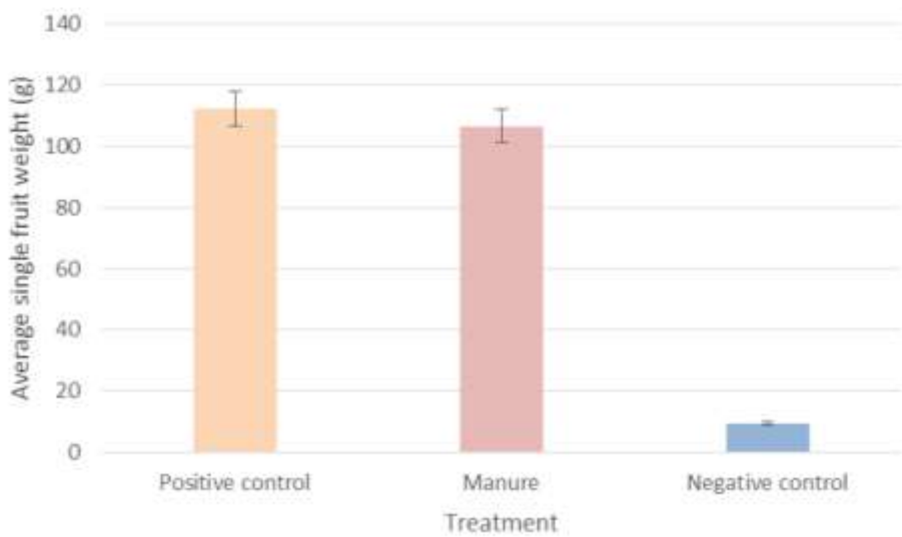

Figure 7. Average weight of a single fruit produced by tomato plants as influenced by nutrient solution.

conventional nutrient solution. Differences in fruit yield in tomato plants grown under manure nutrient solution compared to those grown under conventional nutrient solution are most likely due to differences in nitrate and other nutrient levels between the conventional nutrient solution and manure nutrient solution. These results support those of Muñoz et al. (2008) who indicate that nitrate levels in the nutrient solution influence tomato yield, with higher nitrate levels yielding more. Gore and Sreenivasa (2011) uphold that the levels of nitrogen in liquid manure influence the yield of tomato plants, with higher nitrogen levels yielding more. For the current study, conventional nutrient solution had Nitrate (N) 225 mg/L, Phosphate (P) 46.5, Potassium (K) 372 mg/L; in contrast manure nutrient solution had Nitrate (N) 198 mg/L, Phosphate (P) 42.1 mg/L, and Potassium (K) 360 mg/L. This may also be attributed to the result that tomato yield was significantly high in tomato plants grown under manure nutrient solution compared to the negative control where no nitrates and other nutrients were added other than the content in tap water.

These results are also supportive of earlier findings indicating that manures and other organic sources of plant required nutrients indeed provide sufficient nutrients to promote plant growth and yield (Atiyeh et al., 2002; Ojeniyi, 2008; Mehdizadeh et al., 2013; Wilkinson, 1979).

Conclusion

The organic nutrient solution formulated from goat manure positively improved plant growth and yield performance of a tomato crop, and provided a technique feasible and alternative to conventional hydroponics. This is particularly significant to communities living in Namibian areas where fertilizer access, water or fertile soil are limiting factors to horticultural production in that locally available waste resources can be added value to and used as the main input for horticultural production.

These results open further possibilities for other crops currently grown in hydroponics using conventional fertilisers and being baseline for Africa in terms of organic hydroponics and provided a foundation for further research in this regard.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

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