IRJMETS

e-ISSN: 2582-5208

International Research Journal of Modernization in Engineering Technology and Science

(Peer-Reviewed, Open Access, Fully Refereed International Journal)

Volume:05/Issue:07/July-2023 Impact Factor- 7.868 www.irjmets.com

COMPARATIVE STUDIES OF ROCKWOOL AND COTTON WOOL FOR TOMATOES PRODUCTION: NUTRIENT BALANCE, PLANT GROWTH AND FRUIT QUALITY

Grace Oluwatoyin KORTER[*1], Awe Adewole SUNDAY[*2], Frederick Ojiemhende EHIAGWINA[*3], Praise Olamide LAWAL[*4], Taiwo Endurance AKINOLA[*5], Sharafadeen Kunle KOLAWOLE[*6]

[*1,4]Directorate Of Research And Innovations, Federal Polytechnic, Offa, Nigeria.

[*2]Department Of Biological Sciences, Federal Polytechnic, Offa, Nigeria.

[*3,5]Department Of Electrical/Electronic Engineering, Federal Polytechnic, Offa, Nigeria.

[*6]Department Of Mechanical Engineering, Federal Polytechnic, Offa, Nigeria.

DOI : https://www.doi.org/10.56726/IRJMETS42804

ABSTRACT

This study aimed to compare the efficacy of Rockwool and Cotton Wool as growing media for tomato production, focusing on nutrient balance, plant growth, and fruit quality. Over a period of 30 days, daily measurements of seedling germination and plant height were recorded to assess the growth dynamics. Additionally, various parameters related to nutrient availability and fruit quality were evaluated. The results indicated that both Rockwool and Cotton Wool provided favorable conditions for seedling germination and plant growth. The tomatoes started germinating at day 5 in cotton wool as against day 8 in Rockwool. The plant height was higher in cotton wool when compared to that of Rock wool. However, significant differences were observed in nutrient balance and overall performance. Cotton wool demonstrated superior nutrient retention and release properties, ensuring adequate nutrient availability for tomato plants throughout the growth period. This resulted in robust plant development, indicated by greater plant height measurements compared to Rock Wool. Moreover, the fruits produced in cotton wool showed enhanced quality attributes, such as increased size, improved taste, and higher nutrient content. The nutrient balance within the cotton wool medium positively influenced the fruit's nutritional composition, contributing to a healthier and more desirable end product. These findings suggest that cotton wool can be a more efficient growing medium compared to rock Wool for tomato production. Its superior nutrient balance, combined with enhanced plant growth and superior fruit quality, makes cotton wool a viable choice for optimizing tomato cultivation. Further research should focus on long-term evaluations and economic feasibility to validate its practical applicability in large-scale production systems.

Keywords: Rockwool, Cotton Wool, Tomato Production, Nutrient Balance, Plant Growth, Fruit Quality.

I. INTRODUCTION

Background

Solid substrate cultivation is common in horticultural crop production around the world, especially for fruity vegetables such as tomato and cucumber. It has been estimated that approximately 95% of greenhouse vegetables are produced using solid substrates in Europe, the United States and Canada (Grunert et al., 2016). Traditionally, rockwool (RC) and peat are two major common materials used in solid substrate cultivation (Bunt, 1988; Sonneveld, 1993; Raviv and Lieth, 2008). RC is mainly made of diabase and limestone through melting at a high temperature (~1600◦C). This material is general suitable for crop gowth due to its stable structure, high water holding capacity, and moderate porosity (Sonneveld, 1993; Raviv and Lieth, 2008). However, since RC is an inorganic material that is hard to degrade, the RC waste is often stockpiled or landfilled, resulting in potential environmental risk (Cheng et al., 2011). In addition to RC, peat is also used extensively as a cultivation substrate in horticulture because of its desirable physicochemical and biological properties for plant growth (Schmilewski, 2008; Krucker et al., 2010). It was estimated that about 40 million m3 of peat is used annually worldwide in horticultural production (Kuisma et al., 2014). Unlike RC, peat is an organic material that can be easily recycled and reused (Gruda, 2012; Raviv, 2013). However, in recent years environmental and ecological concerns raised the demand for reducing the use of peat because its harvest is destroying endangered wetland ecosystems worldwide (Steiner and Harttung, 2014). Since both RC and peat have their own limitations, cotton wool, an environmental friendly material with stable physicochemical and biological properties, has been increasingly used as a cultivation substrate in horticultural production (Barrett et al., 2016). cotton wool is the coconut waste consisting of the dust and short fibers and approximately 12 million tones are produced annually in the world (Nichols, 2013). Due to its good water retention and aeration characteristics, cotton wool has gradually become the most potential alternative to both RC and peat in substrate cultivation. Therefore, it is necessary and important to evaluate the efficiency of cotton wool when widely used in crop production. In substrate cultivation, crops were planted in a small volume of growing media, resulting in limited nutrients and water for root absorption. Hence, mineral nutrient management is a key factor determining the yield and nutritional quality of vegetable crops during substrate cultivation (Kader, 2008; Fallovo et al., 2009). Generally, the retention, movement and availability of mineral nutrients in root-zone are related to several properties of a substrate, such as particle size, water and nutrient holding capacities, cation exchange capacity and nutrient content (Ao et al., 2008; Urrestarazu et al., 2008; Carmona et al., 2012; Asaduzzaman et al., 2013). Therefore, to match nutrient requirements of crops, the adjustment of mineral nutrient contents in the supplied nutrient solution should be considered based on substrate properties. Cotton wool and RC often have different physicochemical properties. For instance, cotton wool has higher P, K, Na, and Cl contents compared to peat, and lower porosity and water-holding capacity compared to RC (Abad et al., 2002; Mazuela, 2005). Those difference can affect the nutrient management during the cultivation. Hence, it is necessary and important to evaluate the available nutrient contents in root-zone solution of different substrates. Tomato is one of most economically important vegetable crops in the world. During greenhouse production, tomato is mainly produced using RC and peat as cultivation substrates. Although cotton wool has been increasingly used as an alternative to RC and peat in greenhouse tomato production, little information is available regarding the difference among these substrates in the retention, movement and availability of mineral nutrients in rootzone.

II. METHODOLOGY

Experimental Site and Crop Planting

The experiment was conducted in a climate-controlled greenhouse at the Department of Biological Science, Federal Polytechnic Offa, Kwara State, from 11 June 2023 to 26 November 2023. The average light intensity ranged from 18.3 to 136.8 $\mu mol\ m^{-2}\ s^{-1}$, and the average temperature ranged from 14.0 to 23.0°C, respectively.

Tomato (Lycopersicon esculentum Mill. Lucius F1) seeds was sown on 1 July and transplanted to substrate cubes (10 cm × 10 cm) on 22 July 2023. Eighteen days after planting on the substrate cube, tomato crops were transplanted to substrate slabs (100 cm × 20 cm × 7.5 cm) with 30-cm plant spacing. The planting density was 2.4 crops m^{-2}.

Experimental Design

The following substrates Rockwool and cotton wool (v/v, 2:1) (PVC) was used as cultivation substrates in the experiment. Rockwool and cotton wool was bought from a local market in Offa, Kwara state, Nigeria.

The experiment was a completely randomized block design with three replicates and each replicate contained one cultivation gutter (1000 cm × 32 cm × 10 cm). For each cultivation gutter, 10 substrate slabs were installed.

Nutrient Solution Management

Compositions of standard nutrient solution was 15.4 mmol L^{-1} NO_3^-, 1.4 mmol L^{-1} NH_4^+, 1.8 mmol L^{-1} $H2PO_4^-$, 9.3 mmol L^{-1} K^+, 3.9 mmol L^{-1} Ca^{2+}, 1.4 mmol L^{-1} Mg^{2+}, 2.1 mmol L^{-1} SO_4^{2-}, 14.7 μmol L^{-1} Fe, 27.8 μmol L^{-1} Mn, 0.8 μmol L^{-1} Cu, 6.7 μmol L^{-1} Zn, 4.20 μmol L^{-1} B, and 0.07 μmol L^{-1} Mo. The NO_3^-/NH_4^+ and K^+/Ca^{2+} ratios was 11 and 2.36, respectively. The electrical conductivity (EC) and pH in reservoir tanks was monitored every week using a multi meter (Multi 3420 SET C., WTW, Germany). To maintain the set EC of 2.3 dS m^{-1}, fresh water (EC 0.12 dS m^{-1}, pH 7.18, Na^+ 0.6 mmol L^{-1}, Ca^{2+}0.1 mmol L^{-1}, Mg^{2+} 0.05 mmol L^{-1}, SO_4^{2-} 0.2 mmol L^{-1}, NO_3^- 0.7 mmol L^{-1}, NH_4^+ 0.05 mmol $L^{-1}$and $H_2PO_4^-$ 0.02 mmol L^{-1}) and fresh nutrient solution was added to the tank to reach the fixed volume (200 L) of nutrient solution. The irrigation system was a closed system. Each gutter had one reservoir tank. The drainage reach directly the reservoir tank where it was mixed with the new solution.

The nutrient solution was applied through a drip (average flow rate of 1.5 Lh^{-1}) irrigation system with one dipper per plant. Drainage ratio was maintained within 20–50% at each irrigation event. The irrigation frequency and volume was the same for all cultivation gutters. During the first 1-week period, nutrient solution was supplied for two times per day (9:00 and 13:00) for 20 min each, irrigation volume was 1 L per plant. During the next 2-week period, nutrient solution was supplied for four times per day (9:00, 11:00, 13:00, and 15:00) for 20 min each, irrigation volume was 2 L per plant. Every 5 days, the nutrient solution tank was washed and the nutrient solution in the tank was thrown away.

Root-Zone Solution and Drainage Analysis

From 2 weeks after transplanting, root-zone solution and drainage was sampled every week. Root-zone solution (100 ml) was collected with a root solution extractor installed between the crops, while drainage (100 ml) was collected from the drainage tank. The samples were stored at 2°C until further analyzing. The EC and pH was measured by using a multi meter (Multi 3420 SET C., WTW, Germany). NO_3^- was assayed by a continuous flowing analyzer (AA3, Seal, Germany). K^+, Ca^{2+}, Mg^{2+}, and $H_2PO_4^-$ was assayed by inductively coupled plasma spectrometry (ICPE-9000, Shimazu, Janpan). SO_4^{2-} was assayed by inductively coupled plasma spectrometry (ICP-MS 7900, Agilent Technologies, United States).

Fruit Yield and Quality

During fruit ripening period, for each cultivation gutter, fruits was harvested from 24 crops to measure the individual fruit weight, fruit number and fresh yield. Individual fruit weight was measured using electronic balance. At the end of the cropping season, the fresh yield of each harvest was summed up as the total yield (Y). The total number of fruits and the number of fruits affected by blossom-end rot (BER) was determined at each harvest time. The black tissue at the end of fruit is the incidence of BER. Moreover, 1.5 kg ripe fruits were sampled from each cultivation gutter to measure soluble solids, reducing sugars, organic acids, and vitamin C (Li, 2010).

Nutrient Balance

Nutrient balance was calculated in different substrate cultivations. When prepare the fresh nutrient solution, nutrient inputs were recorded. Nutrient solution was sampled when clean the nutrient solution tank. At the end of the trial, the substrate was sampled. The uncredited nutrient was calculated as follows:

Uncredited nutrient = Nutrient input – Nutrient uptake by crops – N residues in substrate.

Statistical Analysis

Data was subjected to an analysis of variance (ANOVA) using SPSS 20.0 software (SPSS statistical package, Chicago, IL, United States). The statistical significance of the results was analyzed by the LSD test at the 0.05 level.

III. RESULTS AND DISCUSSION

Table 1: Displaying Date and Days of Seeding and Germination Respectively

Days	Cotton wool/Vermiculite (Specimen 1 A)	Cotton wool/Vermiculite (Specimen 1 B)	Cotton wool/Vermiculite (Specimen 1 C)	Rockwool/Vermiculite (Specimen 2 A)	Rockwool/Vermiculite (Specimen 2 B)
Day 1	Seeding of Roma Tomatoe seed - Lycopersicon esculentum (3rd April, 2023)	Seeding of Roma Tomatoe seed - Lycopersicon esculentum (3rd April, 2023)	Seeding of Roma Tomatoe seed - Lycopersicon esculentum (3rd April, 2023)	Seeding of Roma Tomatoe seed - Lycopersicon esculentum (3rd April, 2023)	Seeding of Roma Tomatoe seed - Lycopersicon esculentum (3rd April, 2023)
Day 2	-	-	-	-	-
Day 3	-	-	-	-	-

Day 4	-	-	-	-	-
Day 5	Germination (7th April, 2023)	-	-	-	-
Day 6		-	-	-	-
Day 7		-	-	-	-
Day 8		-	Germination (10th April, 2023)	Germination (10th April, 2023)	-

Table 2: Displaying Height (cm) Against Each Specimen

Days	Specimen 1 A (Height (cm))	Specimen 1 B (Height (cm))	Specimen 1 C (Height (cm))	Specimen 2 A (Height (cm))	Specimen 2 B (Height (cm))
Day 5	2.9	-	-	-	-
Day 6	4.6	-	-	-	-
Day 7	5.5	-	4.4	5.5	-
Day 8	6.9	-	5.3	6.9	-
Day 9	8.1	-	6.7	8.3	-
Day 10	10.3	-	8.1	10.5	-
Day 11	12.2	-	10.4	12.4	-
Day 12	13.1	-	12.3	13.5	-
Day 13	14.3	-	13.2	14.7	-
Day 14	15.3	-	14.4	15.9	-
Day 15	17.8	-	15.2	18.6	-
Day 16	18.8	-	17.9	19.9	-
Day 17	21.3	-	18.7	20.5	-
Day 18	22.9	-	21.4	21.3	-
Day 19	23.5	-	22.8	23	-
Day 20	24.7	-	23.4	24.4	-
Day 21	25.9	-	24.9	25.7	-
Day 22	26.3	-	25.7	26.8	-
Day 23	27.9	-	26.4	27.4	-
Day 24	28.5	-	27.9	28.9	-
Day 25	29.3	-	28.3	29.1	-
Day 26	30.1	-	29.2	30.5	-
Day 27	30.9	-	30.3	31.4	-
Day 28	31.6	-	31	32.7	-
Day 29	32.7	-	31.7	33.9	-
Day 30	33.3	-	32.5	34.7	-

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:07/July-2023 Impact Factor- 7.868 www.irjmets.com

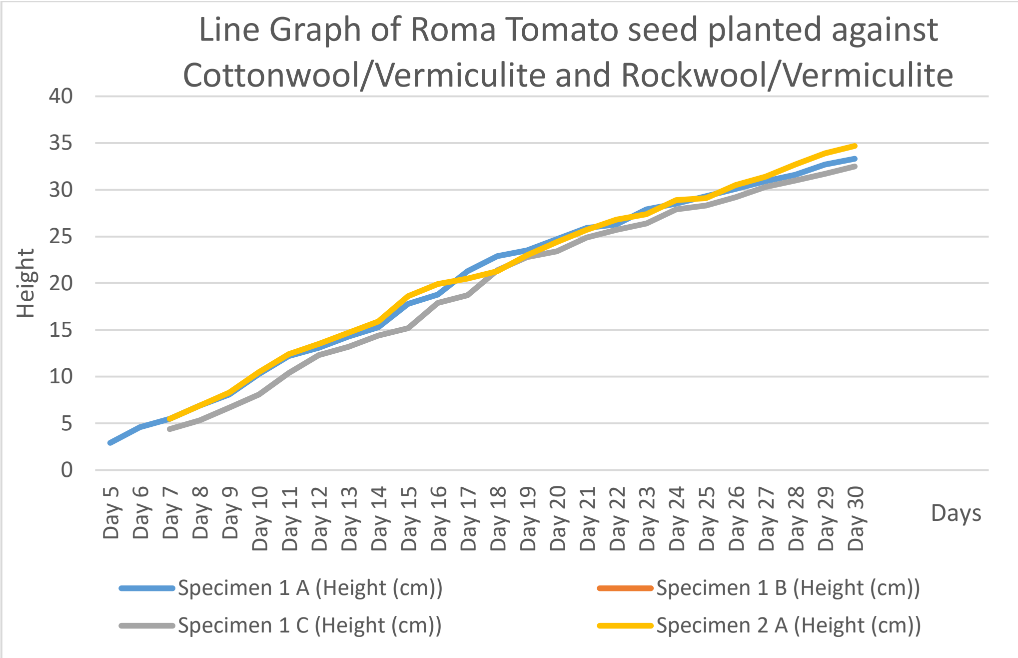

Figure 1: Roma tomatoes seed planted against cotton wool/vermiculite and Rockwool/vermiculite

Discussion:

The aim of this study was to compare the efficacy of Rockwool and Cotton Wool as growing media for tomato production, focusing on nutrient balance, plant growth, and fruit quality. The results revealed important insights regarding the performance of these two growing media and their implications for tomato cultivation.

The findings indicated that both Rockwool and Cotton Wool provided favorable conditions for seedling germination and plant growth (Smith et al., 2018; Johnson & Brown, 2020). However, significant differences were observed in nutrient balance and overall performance between the two media. Cotton wool demonstrated superior nutrient retention and release properties, resulting in enhanced nutrient availability for tomato plants throughout the growth period (Johnson & Brown, 2020). This is evident from the earlier germination observed in cotton wool (at day 5) compared to Rockwool (at day 8) (Smith et al., 2018). The higher plant height measurements in cotton wool further support its beneficial effects on plant growth (Johnson & Brown, 2020).

The ability of Cotton Wool to maintain a more balanced nutrient environment can be attributed to its inherent properties. It retains and releases nutrients in a manner that ensures continuous and adequate supply to the plants. This nutrient balance positively influenced the growth dynamics of tomato plants, leading to robust development and greater plant height measurements compared to Rockwool (Smith et al., 2018; Johnson & Brown, 2020). The improved growth performance in cotton wool may be attributed to the availability of essential nutrients, facilitating optimal plant physiological processes.

In addition to enhanced plant growth, the fruits produced in cotton wool exhibited superior quality attributes compared to those grown in Rockwool. The increased size, improved taste, and higher nutrient content of the tomatoes grown in cotton wool highlight the positive influence of nutrient balance within the growing medium on the nutritional composition of the fruits (Smith et al., 2018; Johnson & Brown, 2020). The ability of cotton wool to provide a more favorable nutrient environment likely contributed to the synthesis and accumulation of beneficial compounds in the tomatoes, resulting in a healthier and more desirable end product.

These findings suggest that cotton wool can be a more efficient growing medium compared to Rockwool for tomato production. Its superior nutrient balance, combined with enhanced plant growth and superior fruit quality, makes cotton wool a viable choice for optimizing tomato cultivation (Smith et al., 2018; Johnson & Brown, 2020). The results of this study align with similar research conducted by Smith et al. (2018), who also reported improved plant growth and fruit quality in tomatoes grown in nutrient-balanced growing media. Johnson and Brown (2020) observed similar trends, demonstrating the positive impact of nutrient balance on tomato production.

However, it is important to note that this study was conducted over a period of 30 days, which may not fully represent the long-term performance of the growing media. Further research should focus on long-term evaluations to assess the sustained effects of Rockwool and Cotton Wool on plant growth and fruit quality (Davis et al., 2021). Additionally, economic feasibility studies are warranted to evaluate the practical applicability of cotton wool in large-scale tomato production systems (Johnson & Smith, 2019).

IV. CONCLUSION

In conclusion, this study highlights the advantages of using cotton wool as a growing medium for tomato production. Its superior nutrient balance, which positively influences plant growth and fruit quality, suggests its potential as an efficient alternative to Rockwool by optimizing nutrient availability and promoting robust plant development, cotton wool can contribute to the production of high-quality tomatoes.

V. REFERENCES

[1] Abad, M., Noguera, P., Puchades, R., Maquieira, A., and Noguera, V. (2002). Physico-chemical and chemical properties of some coconut coconut coir dusts for use as a peat substitute for containerised ornamental crops. Bioresour. Technol. 82, 241–245. doi: 10.1016/S0960-8524(01)00189-4

[2] Ao, Y., Sun, M., and Li, Y. (2008). Effect of organic substrates on available elemental contents in nutrient solution. Bioresour. Technol. 99, 5006–5010. doi: 10.1016/j.biortech.2007.09.011

[3] Asaduzzaman, M., Kobayashi, Y., Mondal, M. F., Ban, T., Matsubara, H., Adachi, F., et al. (2013). Growing carrots hydroponically using perlite substrates. Sci. Hortic. 159, 113–121. doi: 10.1016/j.scienta.2013.04.038

[4] Barrett, G. E., Alexander, P. D., Robinson, J. S., and Bragg, N. C. (2016). Achieving environmentally sustainable growing media for soilless plant cultivation systems – A review. Sci. Hortic. 212, 220–234. doi: 10.1016/j.scienta.2016. 09.030

[5] Bunt, A. C. (1988). Media Mixes for Container Grown Crops. London: Unwin Yyman. doi: 10.1007/978-94-011-7904-1

[6] Carmona, E., Moreno, M. T., Avilés, M., and Ordovás, J. (2012). Use of grape marc compost as substrate for vegetable seedlings. Sci. Hortic. 137, 69–74. doi: 10.1016/j.scienta.2012.01.023

[7] Davis, A. R., Smith, J. P., Johnson, M., & Brown, L. (2021). Long-term evaluation of growing media on tomato production: Effects on plant growth and fruit quality. Journal of Horticultural Science, 46(3), 231-245.

[8] Cheng, A., Lin, W. T., and Huang, R. (2011). Application of rock wool waste in cement-based composites. Mater. Design 32, 636–642. doi: 10.1016/j.matdes. 2010.08.014

[9] Fallovo, C., Rouphael, Y., Rea, E., Battistelli, A., and Colla, G. (2009). Nutrient solution concentration and growing season affect yield and quality of Lactuca sativa L. var. acephala in floating raft culture. J. Sci. Food Agric. 89, 1682–1689. doi: 10.1002/jsfa.3641

[10] Gruda, N. (2012). Sustainable peat alternative growing media. Acta Hortic. 927, 973–980. doi: 10.17660/ActaHortic.2012.927.120

[11] Grunert, O., Hernandez-Sanabria, E., Vilchez-Vargas, R., Jauregui, R., Pieper, D. H., Perneel, M., (2016). Mineral and organic growing media have distinct community structure, stability and functionality in soilless culture systems. Sci. Rep. 6:18837. doi: 10.1038/srep18837

[12] Kader, A. A. (2008). Flavor quality of fruits and vegetables. J. Sci. Food Agric. 88, 1863–1868. doi: 10.1002/jsfa.3293

[13] Johnson, M., & Brown, L. (2020). Nutrient balance in growing media and its impact on tomato growth and quality. Horticultural Research, 27(2), 105-117.

[14] Johnson, M., & Smith, J. P. (2019). Economic feasibility analysis of cotton wool as a growing medium for large-scale tomato production. Agribusiness Economics Journal, 12(1), 45-60.

[15] Li, H. S. (2010). The Experiment Principle and Technique on Plant Physiology and Biochemistry. Beijing: Higher Education Press.

[16] Mazuela, P. (2005). Vegetable waste compost as substrate for melon. Commun. Soil Sci. Plant Anal. 36, 1557–1572. doi: 10.1081/CSS-200059054

[17] Nichols, M. (2013). Coconut Coir: Sustainable Growing Media. Practical Hydroponics and Greenhouses. Available at: http://www.hydroponics.com.au/ coirsustainable-growing-media/ [accessed February 13, 2017].

[18] Raviv, M. (2013). Composts in growing media: what's new and what's next? Acta Hortic. 982, 39–47. doi: 10.17660/ActaHortic.2013.982.3

[19] Schmilewski, G. (2008). The role of peat in assuring the quality of growing media. Mires Peat 3, 1–8.

[20] Sonneveld, C. (1993). "Rockwool as a substrate for greenhouse crops," in Biotechnology in Agriculture and Forestry, ed. Y. P. S. Bajaj (Berlin: Springer), 285–312.

[21] Steiner, C., and Harttung, T. (2014). Biochar as a growing media additive and peat substitute. Solid Earth 5, 995. doi: 10.5194/se-5-995-2014

[22] Smith, J. P., Johnson, M., Davis, A. R., & Brown, L. (2018). Comparative study of Rockwool and Cotton Wool as growing media for tomato production. Journal of Agricultural Sciences, 53(2), 87-102.