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Application of used hydroponic substrate as soil amendment for crop production

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Abstract: Protected soilless culture is a method of crop production whereby resources such as land can be exploited at its best while its main constraint is the disposal of the growing media after use. This study is based on the reuse of disposed hydroponic substrate, namely cocopeat, after its useful lifespan. In order to assess the effect of used hydroponic substrate in open field crop production, an experimental trial was conducted at the University of Mauritius Farm, using tomato (*Solanum lycopersicum* cv. Swaraksha). The treatments were applied at different growth stages and calculated on a weight basis as follows: 0% cocopeat and 100% inorganic fertiliser (T1), 25% cocopeat and 75% inorganic fertiliser (T2), 50% cocopeat and 50% inorganic fertiliser (T3), 75% cocopeat and 25% inorganic fertiliser (T4), and 100% cocopeat and 0% inorganic fertiliser (T5) laid in a randomised block design with four blocks. T2 and T5 produced tallest plants and the greatest stem diameter ($p < 0.05$), while the highest value for percentage dry matter was obtained from T1 and T4 ($p < 0.05$). The most significant difference in nitrogen content in the tomato plants was noted in T3, followed by T1 and T2; while T1 and T5 resulted in significant difference for total plant phosphorus and total plant potassium ($p < 0.05$) as compared to control treatment. Tomato plants under T1 produced the highest fruit yield (27.5 t/ha) followed by T2 (26.4 t/ha). The findings demonstrated that a ratio of 1:3 of used hydroponic substrate to inorganic fertiliser could lead towards sustainable crop production. Hydroponic used substrate mixed with inorganic fertilisers can be used as soil amendments for crop production and a mean to mitigate the disposal problem of used hydroponic substrate.
Keywords: *Solanum lycopersicum*, used cocopeat, inorganic fertiliser, plant height, total nitrogen

INTRODUCTION

Sustainability in agriculture is now a major challenge, and has as three main goals: environmental health, economic profitability, and social and economic equity. Sustainability is based upon the principle that the needs of the present generation must be met, without compromising the capacity of the future one to satisfy their own needs [1]. The future of Mauritius is at present dominated by its large population size which is about 1.3 million people. In Mauritius the current cultivation systems are not efficient and contribute to food insecurity. In our actual system of traditional agriculture, large mass of land are utilised to grow and produce crops while unfortunately climatic conditions are fluctuating causing major loses during weather conditions such as flash floods, cyclones and more resistant pest infestations. To partly mitigate this problem of food insecurity, some farmers of the island are shifting to the soilless crop production.

Protected soilless culture is an amazing way of producing fruits and vegetables by being more environmental friendly compared to the conventional method. The principal advantage of this method of crop production is that resources such as land can be exploited at its best while its main constraint is the disposal of the growing media after use. In Mauritius, compared to other countries, there is a problem of coir disposal; after its useful lifespan of three to four years in greenhouses, the latter is often disposed outside or in dumping grounds.

This research project is based on the reuse of disposed hydroponic substrate, namely cocopeat in order to assess the effect of used hydroponic substrate in open field crop production. The concept is to reduce dumping as the latter is often disposed on landscape, impacting on the visual appearance and also polluting the environment. The use of disposed hydroponic substrate at different regime helps to use less inorganic fertiliser which is a good way towards a more environmental friendly crop production. This method of crop production is very useful as it helps the grower to use less inorganic fertiliser, which implies less money is spent on input and ultimately reducing production cost.

Tomato was used as the test crop and it is an essential high demand vegetable of the Mauritian cuisine. The average annual production is about 13,000 tonnes and the average yield is about 13tha [2]. As recorded in the National annual production by the Food and Agricultural Research Extension Institute (FAREI), production of tomatoes in Mauritius has been fluctuating; since 2006 to 2013, the tomato production sector has faced a drastic decline from a National annual production of 8, 652.3 tonnes in 2006 to 333.6 tonnes in 2013, that is, a decrease of 96%. In 2014, National annual production grew by 79% with a production of 1617.4 tonnes this year as stated by FAREI. The most crucial threats that may impact on tomato production, either it be in greenhouses or in open-field, is the high occurrence of disease outbreaks which may destroy an entire production at a time. To cater for this high demand, planters have moved to its production in soilless medium; cocopeat being the most widely used medium. In Mauritius, this naturally occurring medium which is obtained from coconut has as useful lifespan up to 4 years in hydroponics culture. This method of crop production could be very useful as this will help the crop growers to decrease the use of inorganic fertiliser, thereby reducing the cost of production and synchronously mitigating the problems associated with hydroponic used substrate.

The main aim of the project is to assess the effect of cocopeat as a nutrient source complemented by inorganic fertiliser in open field crop production so as to cater for the problem of disposal of used hydroponic substrate and the objectives are:

- to assess the amount of NPK in the hydroponic used substrates;
- to assess the amount of NPK uptake by plant during experiment and;
- to evaluate the effect of different regime of hydroponic used substrates along with incorporated inorganic fertiliser using tomato as the test crop.

MATERIALS AND METHODS

Experimental site and design

The experiment was conducted at the University of Mauritius Farm, at Réduit on a field of size 18 m by 25 m. The experiment was laid in a randomised block design with five treatments and four blocks to assess the effect of different regimes of cocopeat (hydroponic used substrate) along with incorporated inorganic fertiliser at different growth stages.

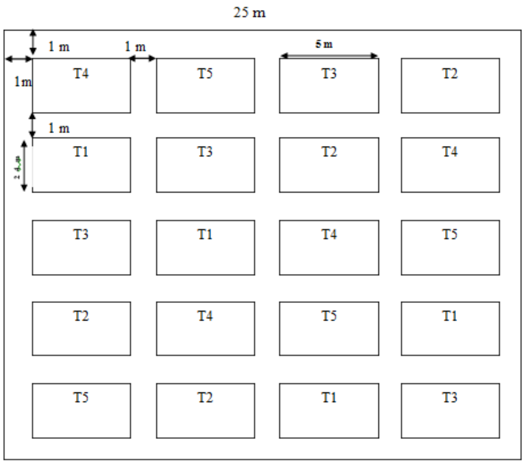

Fig-1: **Field layout**

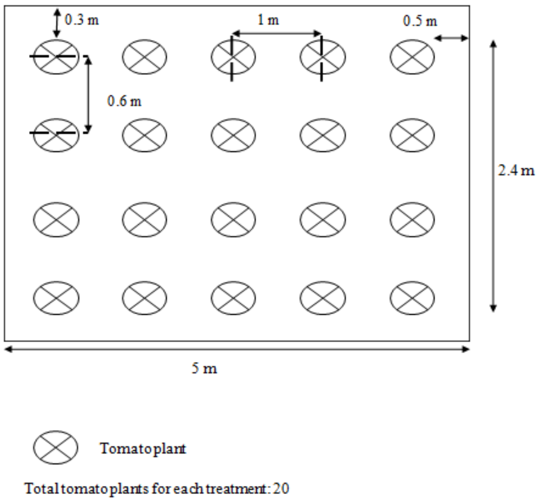

Fig-2: **Plot layout (per treatment)**

Substrates analysis

Before conducting the experiment, soil samples from the experimental site and the used cocopeat were analysed for Total Nitrogen, Available Phosphorus and Available Potassium so that the treatments could be applied with accordance to the plant total nitrogen requirements. Soil samples from the experimental site were analysed and was found to have a pH of 7.00 ± 0.05, electrical conductivity of 0.0032 ± 0.0004 dScm $^{-1}$, total nitrogen 1.58 ± 0.238 g/kg dry matter (DM) , available phosphorus 0.0008 ± 0.0005 g/kg DM and available potassium 0.158 ± 0.0124 g/kg DM. Similarly, the used hydroponic substrates were analysed and their parameters were as follows: pH of 6.93 ± 0.04, electrical conductivity of 0.0023 ± 0.0001dScm $^{-1}$, total nitrogen 8.77 ± 3.39 g/kg DM, available phosphorus 0.0108 ± 0.00065 g/kg DM and available potassium 0.191 ± 0.0127 g/kg DM.

Establishment and management

After preparing the area for the experiment, *Solanum lycopersicum* cv Swaraksha seedlings which were beforehand grown in a greenhouse for 1 month were transplanted in holes with spacing of 1 m between each holes and 0.6 m within each holes. The seedlings were irrigated using the sprinkler irrigation system to meet the crop water requirement and the treatments were applied in accordance to the plant total nitrogen requirement; at transplanting, three weeks after transplant and at flowering stages of growth.

Treatment allocation

The treatments applied were as follows: 0% cocopeat and 100% inorganic fertiliser (T1), 25% cocopeat and 75% inorganic fertiliser (T2), 50% cocopeat and 50% inorganic fertiliser (T3), 75% cocopeat and 25% inorganic fertiliser (T4), and 100% cocopeat and 0% inorganic fertiliser (T5). Inorganic fertiliser 13:13:20:2 was applied in split doses at transplant and at flowering stage of growth while 27:0:0 was applied three weeks after transplant.

Table-1: Rate of application of treatments per hole at the three different growth stages

	At transplant		Three weeks after transplant		At flowering	
	Inorganic fertiliser[1] /g	**Cocopeat /g**	**Inorganic fertiliser[2] /g**	**Cocopeat /g**	**Inorganic fertiliser[1] /g**	**Cocopeat /g**
T1	18	-	6.52	-	6.92	-
T2	13.5	55.4	4.89	41.7	5.19	21.3
T3	9	110.8	3.26	83.4	3.46	42.6
T4	4.5	166.3	1.63	125.0	1.73	63.9
T5	-	221.7	-	166.7	-	85.3

[1]13:13:20:2 [2]27:0:0

Parameters assessed

Plant data collection was done at vegetative, at flowering and at fruiting stages of growth; that is, 23 days, 32 days and 67 days after transplant where both chemical and physical plant analyses were conducted. Physical plant parameters assessed were: Shoot diameter, plant height and dry matter content, while chemical plant analysis assessed were: Total Nitrogen, Total Phosphorus and Total Potassium.

Harvest was carried out when fruits have reached maturity. The fresh weight of tomato was recorded and yield was calculated.The tomato experiment trial was conducted in a Randomised Block Design (RBD) with blocks. The parameters (Plant height, Stem diameter, percentage dry matter, total nitrogen, total phosphorus and total potassium) were analysed by ANOVA at a significance level of p=0.05 using MINITAB version 16.0. Mean comparisons were performed using Tukey's test.

RESULTS AND DISCUSSIONS

Chemical analysis of soil and coir

Moisture content

Moisture content is the amount of water contained by a material or substance; and is usually expressed as a percentage. Cocopeat is known for its **excellent** water holding capacity and is appreciated for its ability to retain high amount of moisture content. In this experiment, disposed coconut coir obtained from a previous hydroponic culture of tomatoes, sweet pepper and long chilli, was used and the moisture content was found to be 71.0 ± 3.04 %, which is quite high compared to that obtained for soil which was 23.3 ± 3.19 %. With reference to the findings of Prasad [3]**,** the ideal moisture content for good quality coconut coir should range between 72 to 80 %. It could also be observed that a slight decrease which might be due to the way the used substrates were disposed, that is, in the open field and exposed to the outside the weather conditions of the capital of the island. This lack of moisture might be a result of water evaporation due to exposure to direct sunlight. This observation was in line with the findings of Dyke [4] and Smith [5] who observed that even if the surface of coir appeared to be dry, there was still moisture in the inner part of the substrate. The results have shown similar response to those of Abdelhafeez and Vrherk [6]**,** which demonstrated that a decline in availability of some nutrients was associated with the moisture content of the soil [7].

pH.

According to the Food and Agriculture Organisation of the United Nations, the FAO's database on the crop information for tomato [20], indicated that a growing media with a pH level ranging from 5 to 7 was preferred for production of tomato; whereas, Nonneche, [8], in his book stated that the evident safe pH level was from 5.5 to 7.5. pH is a very important chemical characteristic of the planting media, either be in open field or under protected conditions in greenhouses as it has a great impact on the availability of nutrients. It has been observed by the International Plant Nutrition Institute (IPNI), Fall [18], No. 2, that nitrogen, potassium and sulphur were the major plant nutrients that have appeared to be less affected directly by soil pH compared to many others, but still are to some extent. However, phosphorus was very sensible to pH values above 7.5 that was in alkaline conditions and have the tendency of forming less soluble compounds. Optimally, nutrients appeared to be available in slightly acidic environment, that is, 6.5 to 6.8. In a study conducted on pH optima for crop growth done with six species by the Department of Agriculture at The University of Queensland in Australia, Islam, [9] tomato was found to show symptoms similar to mild nitrogen deficiency at pH 3.3 to 4.0 while maximum yield was attained at pH 5.5 and no significant positive growth responses were observed above this pH value. Moreover, it was also observed that low pH values had a damaging effect on root growth. Likewise, several short term studies have shown large effects of pH on the rate of uptake of various cations. In the experiment of Islam *et al.*, [9], it was observed that above pH 7, growth was superior to that in Arnon and Johnson study [10], which might be probably due to an improved control of phosphorus nutrition achieved under flowing culture conditions. Conversely, over the pH range 4 to 6.5, better growth was obtained in Arnon and Johnson's study [10], partly because of insufficient nitrogen and magnesium uptake at lower pH values in the study done by the University of Queensland. Arnon and Johnson, [10], attributed much of their growth reduction below 5 to inadequate calcium absorption. From the analyses made, the soil used for the field trial was found to have a mean pH of 7.00 ± 0.049 which indicated a neutral soil pH and follows the recommendations as stated by FAO for tomato production in open-field. Likewise, coir is slightly lower than the neutral pH, that is, 6.93 ± 0.041 which also falls in the recommended range. As a conclusion, both disposed coconut coir and soil were appropriate for crop production.

Electrical Conductivity

Electrical conductivity (EC) is referred to as a quantitative value indicating the amount of ions that are present in a solution and are capable of conducting an electrical charge. From findings of this experiment, a statistically significant difference ($p < 0.05$) between the EC values of soil and coir was observed. It can therefore be assumed that soil, having a higher EC, might be containing more dissolved ions compared to coir. A higher EC value might lead to higher risk of root injury and eventually stunted growth. A too high EC value could be resolved by treating the substrate before use, this would decrease the excess salt content, thus could be more suitable and less harmful for future use.

Total Nitrogen

Total nitrogen content in soil and coir were significantly different ($p < 0.05$). This clearly indicated a large difference in the nitrogen content of the two samples. It has been observed that total nitrogen content in coir was much higher compared to that of soil. This might be certainly due to its previous use in greenhouse where hydroponic solutions A and B were allowed to flow through it. Some of the nutrients have been retained in the coconut coir leading to this high value for total nitrogen content. This is an advantage as it can be used as soil mixes and can be complemented by inorganic or even organic fertiliser so as to meet the nitrogen requirement of the crop grown. This is a good solution to the disposal of hydroponic used substrate.

Available phosphorus

Coir contained 0.0108g/ kg DM of mean total phosphorus which was equivalent to 0.00108% phosphorus, on the other hand, soil was found to contain 0.0008 g/ kg DM of total phosphorus which in turn was equivalent to 0.00008% of phosphorus which was very low compared to coir. This big difference might be due to the previous activity in which the substrate was subjected. Hydroponic solution A and B was comprised mainly of the essential nutrients required by the plant. During the hydroponic activity, fertigation was practiced, that is, irrigation together with fertilisation at the same time. When the cocopeat bags were disposed, some of the nutrient solution was retained along with the concentrated salt already present due to the evaporation of water at the surface of the substrate. This might explain the higher phosphorus content in coir. This is a helpful characteristic of disposed hydroponic substrate as it can be used in soil mixture to improve the soil texture and at the same time its nutrient content.

Available Potassium

The total potassium content was found to be 0.158 g/kg DM in soil, that is, 0.0158 % and 0.191 g/ kg DM in coir, that is, 0.0191 %. A statistically significant difference between the two potassium contents was found ($p<0.05$). Higher potassium content was noted in coir. It has been observed in a UK trial, Adams, [19], high levels of potassium have shown to result in high yield of tomato. Also, it is known that tomato has a relatively high potassium requirement. By making use of disposed hydroponic substrate, this would help growers to reduce their excessive use of inorganic fertiliser and would be more favorable to maintain soil fertility [21].

Table-2: Chemical analysis of growing media (Based on n=3 replicates)

Chemical properties	Growing media		Comment
	Soil	Coir	
Moisture content/ %	23.3 ± 3.19	71.0 ± 3.04	Moisture content in coir was higher by 47.7 %
pH	7.00 ± 0.049	6.93 ± 0.041	pH was slightly greater in soil; by 0.07
Electrical conductivity/ dScm-1	0.0032 ± 0.00044	0.0023 ± 0.00012	Electrical conductivity was higher by 0.0009 in soil
Total Nitrogen/ g/kg DM	1.58 ± 0.238	8.77 ± 3.394	Total nitrogen was higher in coir by 7.18 g/kg DM
Available Phosphorus/ g/kg DM	0.0008 ± 0.00045	0.0108 ± 0.00065	Available phosphorus was higher in coir by 0.01000 g/kg DM
Available Potassium/ g/kg DM	0.158 ± 0.0124	0.191 ± 0.0127	Available potassium was higher in coir by 0.0321 g/kg DM

Physical plant analysis

Plant height (m)

Table-3: Plant height (m) at different growth stages

Treatments	Growth stage		
	Vegetative	Flowering	Fruiting
0% coir + 100% inorganic fertiliser (T1)	0.436 ± 0.0295*	0.599 ± 0.0522	0.834 ± 0.0151
25% coir + 75% inorganic fertiliser (T2)	0.384 ± 0.0717	0.582 ± 0.131	0.913 ± 0.0125
50% coir + 50% inorganic fertiliser (T3)	0.454 ± 0.0651	0.573 ± 0.0853	0.872 ± 0.561
75% coir + 25% inorganic fertiliser (T4)	0.408 ± 0.0806	0.593 ± 0.0994	0.847 ± 0.0987
100% coir + 0% inorganic fertiliser (T5)	0.338 ± 0.0578	0.554 ± 0.0920	0.825 ± 0.0410

*Standard Deviation (SD); n=4

Diameter of stem

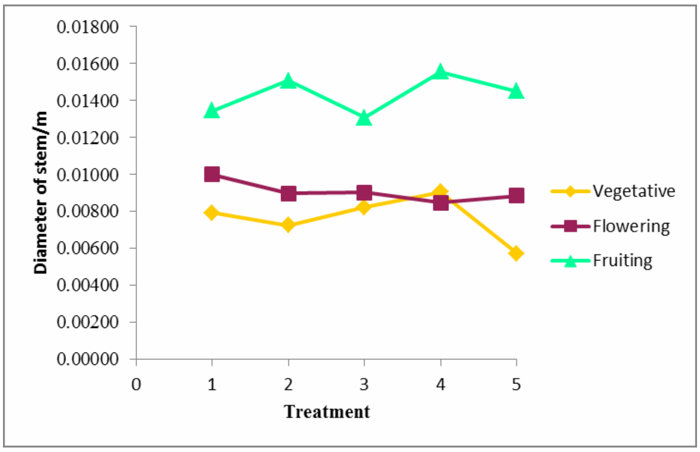

Fig-3: Graph of diameter of stem versus treatment

From the analyses, it has been observed that the stem diameters for the treatments were not statistically different, which means that the experiment has shown that different regime of used cocopeat have no evident impact on the growth and development of tomato plant in terms of height of plant and diameter of stem. A better response in plant height was obtained for T2, that is, 25% cocopeat and 75% inorganic fertiliser, followed by T5, 100% cocopeat and 0% inorganic fertiliser. A smaller value for T1 with 100% inorganic fertiliser was obtained, this is not what was expected but this low value might be due to environmental factor which affected some replicates, leading to this value for T1. Another factor might be due to failure in absorption of the nutrients such as phosphorus and potassium. It has also been observed that the plant height for the different stages of growth have been following an increasing trend; demonstrating that these results have followed the growth curve over time. For stem diameter, a better overall performance was noted for T5; followed by T2, T4, T1 and T3. The trend in stem diameter was almost consistent with the trend in plant height. Greater plant height implies greater surface area for photosynthesis and therefore greater dry matter.

Chemical analysis of plant
Percentage dry matter

Table-4: Percentage dry matter content at different growth stages

Treatments	Growth stage		
	Vegetative	Flowering	Fruiting
0% coir + 100% inorganic fertiliser (T1)	20.2 ± 3.98	19.7 ± 7.52	23.1 ± 5.21
25% coir + 75% inorganic fertiliser (T2)	28.9 ± 10.4	24.3 ± 9.45	20.0 ± 7.12
50% coir + 50% inorganic fertiliser (T3)	24.0 ± 3.40	26.5 ± 13.5	25.2 ± 5.80
75% coir + 25% inorganic fertiliser (T4)	25.4 ± 7.78	22.7 ± 6.56	26.8 ± 6.12
100% coir + 0% inorganic fertiliser (T5)	32.3 ± 14.4	21.3 ± 5.82	21.8 ± 7.10

From the above table, it can clearly be observed that there was no significant difference between each treatment at vegetative, flowering and fruiting growth stages. There was no significant difference between the different treatments at each stage of growth ($p > 0.05$). This irregularity in the dry matter accumulation for each treatment might be because not the same plant was taken at each stage of growth, but the plant representing the general performance of the treatment. Secondly, there were external factors that could have affected the dry matter accumulation, such as failure of nutrient uptake or deficiencies of certain nutrients.

It has been observed by Hegde and Srinivas [17] dry matter accumulation, in tomato during the initial 30 days after transplantation (DAT) was low, less than 5% of the dry matter produced by the end of the growth cycle. Later, it was expected to have an almost linear increase in dry matter production up to 90 DAT. It would be then expected to reduce, and during the final stages of the life cycle there might even be a slight decline in dry matter due to leaf fall. The rate of dry matter accumulation in the stem and fruit continued to increase until the crop reached full maturity.

Total Nitrogen

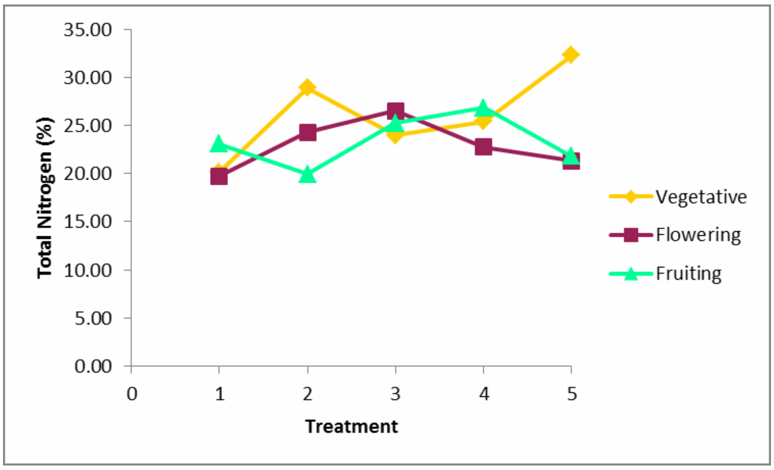

Fig-4: Graph of mean total nitrogen in plant tissues versus treatment

It has clearly been observed that there was no significant difference between each treatment at vegetative and flowering growth stages but a difference was noted at growth stage with the mean total nitrogen content in plant tissue was different for 50% coir + 50% inorganic fertiliser (T3) and this was illustrated by the above graph. These were indicated by means sharing same or different lettering when Tukey's test was performed.

Total Phosphorus

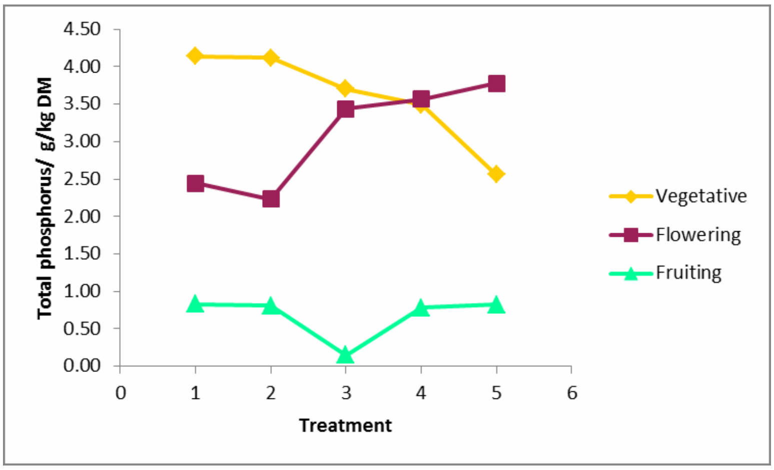

Fig-5: Graph of mean total phosphorus in plant tissues versus treatment

It has been observed that there was no significant difference between each treatment at vegetative and flowering growth stages but a difference was noted at growth stage with the mean total phosphorus content in plant tissue was different for 50% coir + 50% inorganic fertiliser (T3) and this was illustrated by the above graph. These were indicated by means sharing same or different lettering when Tukey's test was performed.

Total Potassium

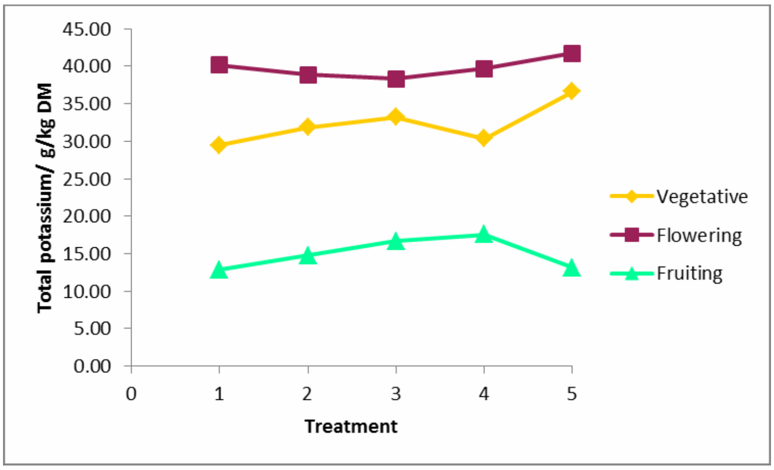

Fig-6: Graph of mean Total Potassium in plant tissues versus treatment

From the findings, for total nitrogen content in the plant tissues, it was observed that there was no statistically significant difference between the different treatments at each stage of growth, similarly, no significant difference was observed between treatment ($p>0.05$). T3 was observed to have a greater assimulation response to the applied treatment as the total nitrogen content in plant tissues at vegetative and fruiting were of higher difference in comparison to the other treatments; followed by T1 and T2, T4 and lastly T5. This decline in total nitrogen content at each stage of growth is due to the absorption of the nutrients by the plant tissue for growth and development.

A significant difference in total phosphorus content in the plant tissues for the different treatment at each stage of growth was observed ($p< 0.05$). A significant difference between treatments for total phosphorus content was observed; indicating that the treatment was effective and that the different treatments gave different results.

No significant difference in total potassium content in the plant tissues was found for the different treatment at each stage of growth ($p> 0.05$). There was also no significant difference for total potassium content in the plant tissues between treatments ($p> 0.05$); indicating that the treatment was not effective for the different treatments.

It has been observed by Stark *et al.* [11], that the average uptake rates of many nutrients varied with the environmental conditions but are not greatly affected by the stage of development after anthesis of the first truss. Total uptake of nitrogen increased with the level of applied nitrogen, but was not greatly affected by the frequency of irrigation. In young plants, the distribution of nutrients depended on the stage of development. For example, in plants that were old, approximately 50% of the potassium absorbed was found in the leaves, 25-30% in the stems and less than 10% in the roots, the rest being in the developing flowers and fruit [12]. A high amount of the nutrients absorbed by mature tomato plants were found in the fruit, for example, 50-53% of the nitrogen uptake in the field [13] and 56% of the nitrogen, 63% of the phosphorus and 63 % of the potassium under glass [14]. It was also found that the proportion of the total nitrogen uptake found in the fruit of field tomatoes declined (54% to 38%) as the rate of applied nitrogen increased [11].

Yield attributes

Table-5: Yield attributes for each treatment

Treatments	Yield t/ha
0% coir + 100% inorganic fertiliser (T1)	27.5 ± 0.21
25% coir + 75% inorganic fertiliser (T2)	26.4 ± 0.19
50% coir + 50% inorganic fertiliser (T3)	25.2 ± 0.26
75% coir + 25% inorganic fertiliser (T4)	14.9 ± 0.31
100% coir + 0% inorganic fertiliser (T5)	20.6 ± 0.31

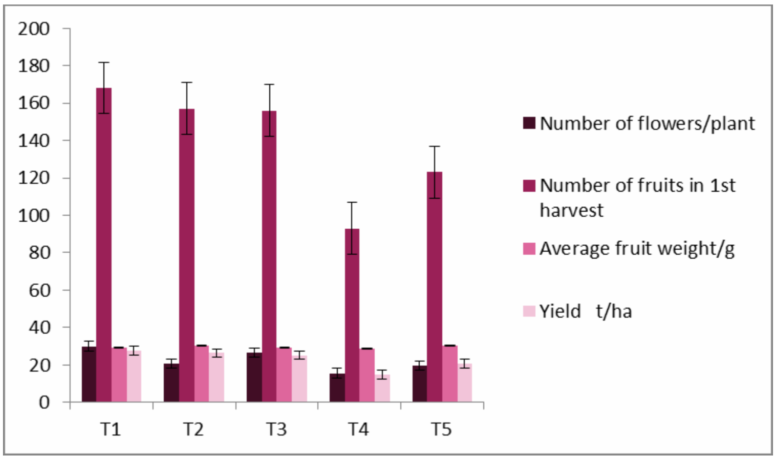

Fig-7: Yield attributes of tomatoes

The growth of tomato plant was expressed by an increase obtained from plant height, stem diameter and dry matter which were relatively good. Difference in growth and development of the plant could be attributed to genetic development of the plant and also to the environmental conditions to which the plant was exposed. In a study conducted by Isah *et al.,* [15], the application of NPK fertiliser improves growth of two tomato varieties, which were expressed by an increase in crop dry matter, plant height and relative growth rate. From this study, it was found that there was a significant difference between the treatments ($p<0.05$). It was also observed that T1, T2 and T3 gave best responses and resulting in higher yields. This could be explained by the availability of nutrients to the plants; provided by the soil and the inorganic fertiliser appeared to be more compared to that provided by the coconut coir. The high yield achieved might be due to the readily available nutrients supplied by the inorganic fertiliser. This was coherent with the other parameters which are related to yield, namely, number of flowers per plant and number of fruits per plant. It has been observed by Benton Jones [16], that one cultural practice to increase fruit size, removal of fruits from the lower trusses increased the size of fruits found from the upper trusses should be promoted. Moreover, to favour fruit production, fruit dry matter can be manipulated indirectly by light, CO_2, temperature, humidity and water availability during cultivation. Cultural practices, such as leaf and fruit pruning, could influence nutrient and biomass partitioning along with rate of photosynthesis. This could also explain the lower yield observed in 100% cocopeat, high temperatures have been experienced during the on-field experiment and this might have affected rate of photosynthesis hence, the production of fruits. It was clearly observed that at least 50 % inorganic fertiliser should be incorporated so as to achieve a good yield of tomato. The ratio 1:3 of the disposed coconut coir incorporated to the inorganic fertiliser could be recommended so as to mitigate the problem of hydroponic waste disposal.

CONCLUSION

With the great concern of food security and self-sufficiency in agricultural sector in Mauritius, new sustainable ways of crop production must be thought of. Hydroponic have been a few years back of great help to the crop production in the country but, thereafter has come the problem of disposal of the used hydroponic bags. From this study, it can clearly be observed that different regime of used coconut coir has definitely an impact on the growth and development of a plant, here, tomato. So, people could be encouraged to reuse disposed hydroponic substrate for field production of crop. This would be more environmental friendly as instead of dumping the hydroponic waste, it can be reused for open-field cultivation, reducing the level of inorganic fertiliser applied and it already contains certain level of nutrients such as nitrogen, phosphorus and potassium.

This result revealed that the hydroponic used substrate can be incorporated together with inorganic fertilisers as soil amendments for crop production. This will eventually help to mitigate the disposal problem of used hydroponic substrate and also to reduce heavy use of chemical fertilisers. A ratio of 1:3 and even 1:1 of used hydroponic substrate to inorganic fertiliser can be recommended which could lead towards a more sustainable method of crop production as they prodsuced almost equal yield when compared to the conventional method. This method of crop production could be very useful as this will help the crop growers to decrease the use of inorganic fertiliser, thereby reducing the cost of production and synchronously mitigating the problems associated with hydroponic used substrate.

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