Can urban farmers depend on biochar substrate (soilless) for growth and yield of lettuce cultivation?

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Abstract

The need to increase food production to meet up with the urban growing population coupled with the limited access to land and soil fertility challenges in Nigeria have called for an alternative agricultural innovation to complement conventional and soil-based food production system. One of such alternatives is the use of Biochar Substrates Hydroponics for cultivation of crops. Whether this innovation could enhance the growth and yield of crop especially at the small-scale level is uncertain. Thus, the paper assesses the response of lettuce to Biochar substrate so as to determine the growth and yield. Experimental research was carried out to establish whether or not there is significant difference between soil based and substrate farming using the same lettuce seed type. Data of plant diameter, width and leave number were collected from lettuce grown in both soil and biochar substrate systems. 3 lettuce plants were randomly selected to measure yield rate. Data collected were analyzed using Design Expert and subjected to a variance test. The result revealed a P-value of = 0.15 indicating no significant growth and yield of the lettuce planted on biochar substrate and soil based in leave production. However, there was significantly difference of yield mass with P-value of 0.038, signifying the biochar substrate-based lettuce was found to be higher than that of the soil-based cultivation. The study concluded that biochar substrate (soil-free) cultivation of lettuce provides weighted or higher massed lettuce than soil-based lettuce cultivation and recommends a larger scale experiment among others to determine if urban farmers can depend on it for increase yield and growth of Lettuce.

Key words: Biochar, soil-free, soil-based, substrate, lettuce, yield, growth

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1.0 INTRODUCTION

The peculiarity of the urban farming system requires innovative process to enhance the yield and growth of food crops to meet up with the growing demand for food due to urban population explosion and amidst urban land scarcity and soil degradation challenges. According to Okpala, (1990), the population of Nigeria doubles every 22 years at a rate of 3.75%/year and this, in addition to high value of and lesser availability of urban land and other agricultural resources should be a major concern to all. In an exclusive interview with the president of the African Development Bank (AfDB), Dr Akinwumi Adesina in the World Government Summit held in Dubai (March 28-30), 2023, Akinwunmi said there is a yawning gap between the production of food crops and consumption of the growing populations on the continent, which puts the region at risk of food insecurity and necessitates a major expansion of agricultural investments and adoption of new technologies. Thus, the AfDB has incorporated biotechnology called Technologies for African agricultural transformation to help countries fight climate change, greenhouse gas emissions and soil degradation to increase crop production. Beside the need for technology to meet up food production, deterioration of land fertility, sterilization and mismanagement have also made land more inadequate, in addition to climate patterns which have affected the growing seasons, leading to flash floods, draught and consequently reducing the overall availability of productive arable lands substantially. These concerns have raised a lot of research questions that begs for answers that will positively compliment the means of producing food that can support not only households but human livelihood conditions, food security and sustainable development.

With the numerous challenges associated with conventional soil-based management practices in Nigeria, soilless or soil-free cultivation which involves the growing of crops without soil, has been canvassed for. It is modern cultivation system of plants that uses either inert organic or inorganic growing substrates, mostly in combination with nutrient solution to supply nutrients to plants (Annika & Dennis, 2021). The soilless cultivation allows the farmer to control over the composition of the nutrient solution and can adjust it at any time. This type of cultivation system enhances food production in places with suitable sunlight and temperature but no soil, such as deserts, beaches, and deserted islands (Blank, 1999).

One of such soilless cultivation is Hydroponics in which plants are grown in an inert medium such as rocks or coco coir fiber, and are fed with solution containing a perfected mix of primary, secondary and micro-nutrient. Hydroponic systems are broadly divided into the closed/ recovery or the open/ non-recovery systems (Faried, 2021). In the closed system, the nutrient solution used is continuously recycled such that the drained nutrient solution is collected, assessed, adjusted, and recirculated back into the system. It does not require the use a growing media. On the other hand, the open system uses a growing media (e.g., coconut coir, biochar, rocks). This system may either be closed (nutrient solution is recycled) or open system (nutrient solution is provided during each fertigation cycle and discarded). The substrate used in this study is Biochar - a processed,

carbon-rich material made from biomass. Other types of hydroponic are aquaponics which combines both aquaculture (fish farming) and hydroponics (plant growing without soil) and forms a closed- loop recycling fresh water system between fish and plant. There is also aeroponics which involves plants grown in the air or mist environment without the use of soil or an aggregate media, with their roots suspended in a misted nutrient medium. Soilless cultivation has been used globally as a means of growing both food and ornamental plants at both commercial and household levels in time past. But today, it has been used as the standard methodology for plant biological researches in different disciplines (Asoa, 2012). Its application cut across vegetable cultivation to produce safe, healthy and pollution-free green food; flower cultivation for flower markets; medicinal plant cultivation; fruit tree cultivation; seedling cultivation and ornamental decoration of buildings.

There are empirical evidences of the growing of leaf vegetables such as lettuce, Swiss chard and kale using soilless medium in the developed nations. In developing nations, urban smallholder farmers have made lots of efforts and have adopted the soilless innovative technology to increase vegetables production that is driven by substrate and nutrient solution which has great potential to revitalize a lot of abandoned land. However, only limited empirical evidences and data exist in support of the viability and efficacy of soilless agriculture in Nigeria. Onafowora Adebowale (2019), has posited that the adoption of soilless cultivation especially through substrate media can enhance sustainable food production which plays a key role in the achievement of the sustainable development goals. Besides, it promotes improved livelihood through a profitable business that create mutually beneficial relationships among workers and the surrounding.

It is based on this that this study aimed at evaluating the growth and yield characteristics of lettuce (Lactuca sativa L.) using substrate based (biochair) cultivation. Lettuce was chosen because it grows very fast and it is the most consumed salad vegetable all in Nigeria. It is a leafy vegetable from Asteraceae family, and the only member of the Lactuca genus grown commercially (Koike, et al., 2007). It is a good source of different vitamins and minerals especially vitamin A and potassium. As reported by FAO (2010), world production of lettuce in 2010 was more than 23 million tons, and those were primarily from China (53%) and the United States (17%) (Siti , et al., 2015). There are several types of lettuce, but most common are the Leaf, Head and Cos or romaine lettuce, butterhead (Katz & Weaver, 2003).

2.0 METHODOLOGY

2.1: The Study Area

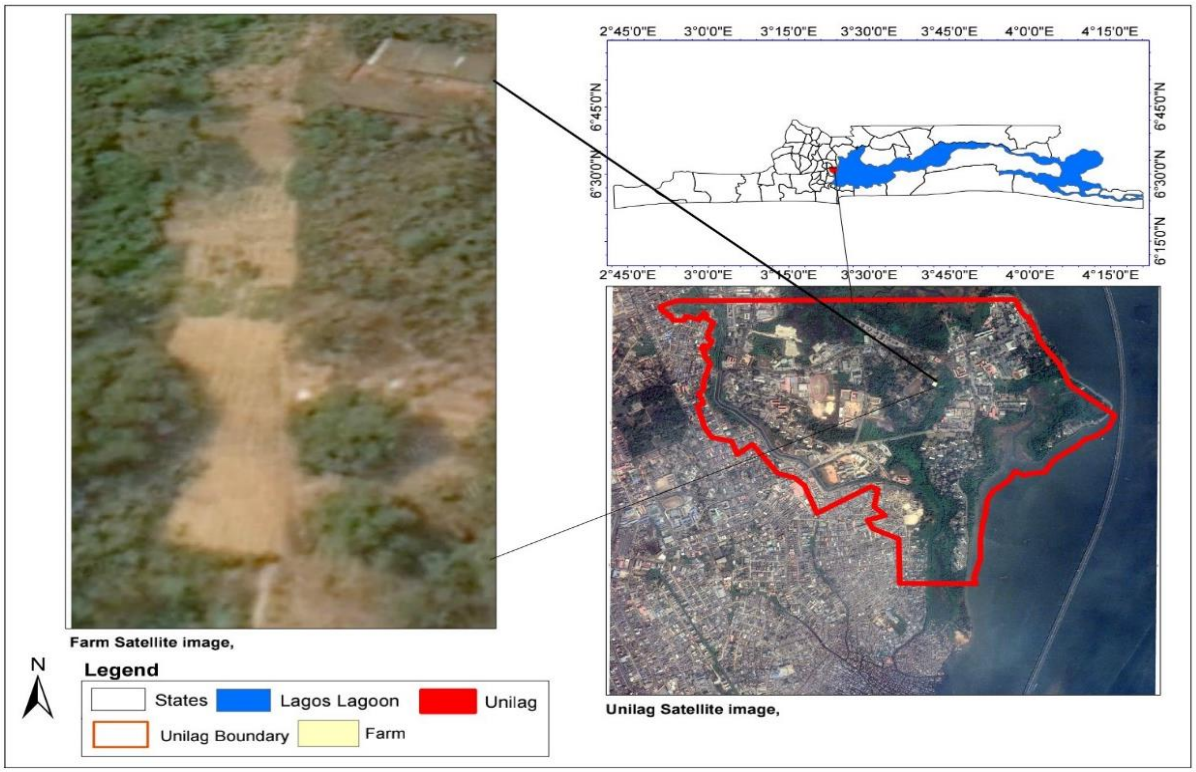
The study was carried out in the Geo-farm, situated at the University of Lagos (UNILAG). Unilag is a federal government university. It is situated within Lagos Mainland LGA of Lagos state and lies between latitude 03.2343^0E – 03.34554^0 E and longitude 06.2135^0 N – 06.4323^0 N (see Figure 1). It is bounded on the north by a swamp which extends to Bariga, at the south by Onike and Iwaya, the east by Lagos Lagoon which extends

to 3rd mainland bridge and at the west by Yaba. The vegetation type in the University of Lagos is mangrove vegetation. It has an undulating terrain, half of which is composed of academic and administrative buildings, with various fresh water channels and creeks passing across at different locations of this area. A large area of mangrove swamps, (roughly 50%) dominates the vegetation. In the north and south east lies the brackish lagoon which supports a typical terrestrial habitat, and experiences less human disturbance while in the south and south west lies the fresh water, where the soil is highly rich and supports a rich flora which is highly favored by climate type and much disturbed by human activities.

According to the Koppen climate classification system, the University of Lagos which is within Lagos Mainland, has a tropical wet and dry climate (Aw). It experiences two rainy seasons, with the heaviest rains falling from April to July and a weaker rainy season in October and November. There is a brief relative dry spell in August and September and a longer dry season from December to March. Monthly rainfall between May and July averages over 400mm, while in August and September it is down to 200mm and in December as low as 25mm. The main dry season is accompanied by harmattan winds from the Sahara Desert, which between December and early February can be quite strong. The highest maximum temperature ever recorded was 38°C and the minimum was 14°C.

The University of Lagos has one of the largest student populations of any university in Nigeria. From a modest intake of 131 students in 1962, enrolment in the university has now grown to over 45,000 students as of 2010. The university's staff strength is 3,365 which consist of 1,386 Administrative and Technical staff, 1,164 junior staff and 813 Academic staff. The University of Lagos Geography Research and learning farm was established on September 2019 by the Department of Geography. The research farm serves for teaching, research and to also provide agricultural community services to the university and its environs. It offers garden services, ornamental flowers, fresh exotic and indigenous vegetables and herbs. The main objective of the research farm is to improve quality of life, minimize the impact of climate change and harmonious ecosystem and also guarantee food security by ensuring that members of the university community and its environs have easy access to freshly healthy foods, and non-synthetic garden inputs.

Figure 1: Study Area Map of Unilag Map



2.2 Data Sources

In this study, data was collected from both secondary and primary sources. Existing works or journals constituted secondary data sources while an experimental research was conducted on the farm to form primary data source.

2.3 Procedure of Research Practical Work

Lettuce seeds were planted in a nursery using a compost mix. After a period of 28days, the plants were transplanting into the substrate hydroponics stand and the growing bags (4pieces) that were filled with well-drained soil. After one week of transplanting, liquid nutrient was applied to the plants. The nutrient used comprises of double components marked solution A and solution B. Solution A contained the following elements in solution: calcium nitrate, monoammonium and phosphate. Solution B components were: Magnesium, Sulphate, copper Sulphate, Manganese Sulphate, Boric acid, Ammonic, Monybolate, Magnesium Nitrate, Iron Chelate and Potassium Nitrate. 7grams of part A and 5grams of part B were dissolved properly in a little quantify of water before pouring into the 20 liters of water then applied to the plants for 5 days. The vegetable growth parameters were observed by measuring leaf diameters, number of leaves and leaf widths weekly under the same climactic condition.

2.4 Data Collection

Growth Characteristics-: Samples of lettuce plants (3 plants) were randomly chosen from each system at the interval of 7 days (weekly) after the transplanting to study the following growth characteristics and plant analysis. Average leave diameter (cm) was measured from the cotyledon node to plant top of the main stem.

i. Average number of leaves was estimated by taking the average number of leaves of 3 plants.
ii. Average width of leaves the samples were estimated by taking the average of 3 plants

Yield parameters-: At the age of 80 days from sowing, lettuce plants were harvested. 3 plants from each cultivation type (substrate based and soil based) were randomly chosen to study the harvest weight.

2.5 Data Analysis.

The data was analyzed using the Levene's test for Equality of variance and mean variance of Statistical Package for Social Science version 15.0 (SPSS) to determine the statistical significance of the identified differences between biochar subtract hydroponic (soilless) and soil-based cultivation of lettuce. an independent sample t-test was carried out for the three parameters (leaves, diameter and width) at confidence interval of 95% (0.05). Tables and histography were use displace the results.

3.0 RESULTS AND ANALYSIS

3.1 The Characteristics of Lettuce Leaves and Growth

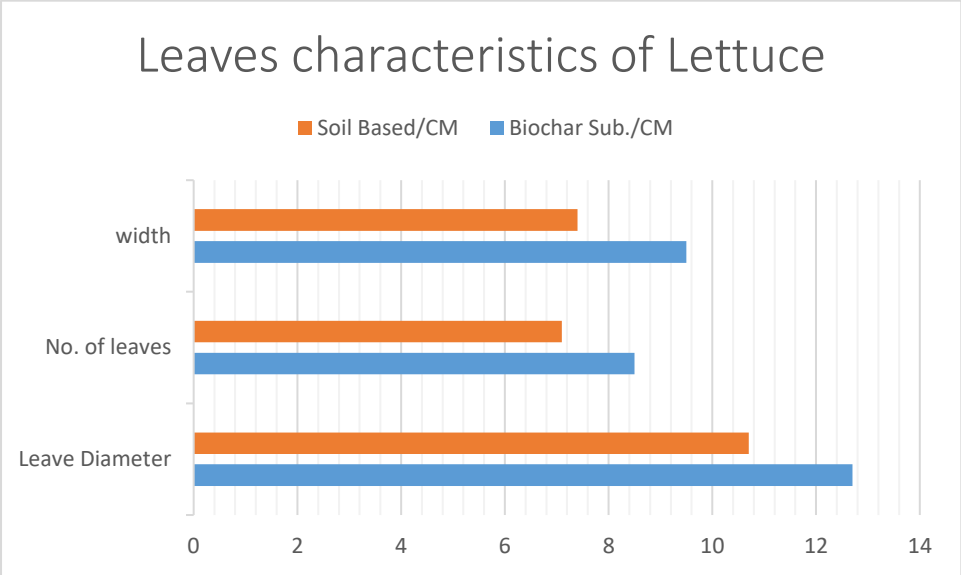
Understanding the features of lettuce leaves goes a long way to depict the way it appeals to a consumer and the premium that consumer can placed on them. According to Kader (2002), appearance has a major influence in choosing the lettuce a product to buy since spots on the leaves and extremities for example can be factors lead to the refusal to purchase such

Table 1: Features of the Soil-based and Biochar Substrate Lettuce Leaves

Soil Based Cultivation (Control)					**Biochar Substrate Based Cultivation**			
First Readings: 2/8/21	Plant 1	Plant 2	Plant 3	Avg	Plant 1	Plant 2	Plant 3	Avg
Diameter	4	4	6	4.7	6	5	5	5.3
No of Leaves	6	6	8	6.7	9	6	7	7.3
Width	2	2	2.8	2.3	2.8	2	2.3	2.4
Second Readings : 9/8/21								
	Plant 1	Plant 2	Plant 3	Avg	Plant 1	Plant 2	Plant 3	Avg
Diameter	11	12	7.8	10.3	9	10	12	10.3
No of Leaves	5	6	4	5.0	5	5	5	5.0
Width	6.5	6.5	3.5	5.5	5.5	5.5	6	5.7
Third Readings: 16/8/21								
	Plant 1	Plant 2	Plant 3	Avg	Plant 1	Plant 2	Plant 3	Avg
Diameter	13.5	11	11	11.8	13	14.5	13.2	13.6
No of Leaves	6	7	7	6.7	7	6	6	6.3
Width	7.5	8	9.5	8.3	9.2	9.2	10.5	9.6
Fourth Readings: 23/8/21								
	Plant 1	Plant 2	Plant 3	Avg	Plant 1	Plant 2	Plant 3	Avg
Diameter	13.8	11	11	11.9	16	18	16	16.7
No of Leaves	6	7	7	6.7	10	10	13	11.0
Width	7.5	8	9.5	8.3	12.5	13	18	14.5
Fifth Readings: 30/8/21								
	Plant 1	Plant 2	Plant 3	Avg	Plant 1	Plant 2	Plant 3	Avg
Diameter	15	15	15	15.0	18.5	16	19	17.8
No of Leaves	10	10	11	10.3	12	16	11	13.0
Width	15	11	12	12.7	14	17	16	15.7

Source: Field Survey 2021

Figure 2: Average difference between Soil-based and Biochar Substrate Lettuce



Source: Field Survey 2021

product or not. Knowing the identity of the leaves and growth of lettuce is also one of the most characteristic biological processes in plant life is their growth. This is because it serves as a good indicator for the compatibility of a plant within varying environmental conditions. For this analysis and as presented on Table 1 and Figure 2, lettuce leaves from biochar substrate was found to be larger and broader than the soil-based lettuce. In order to compare the growth characteristic of lettuce in both the substrate hydroponics and soil-based (conventional) cultivation.

Table 2: Mean of Soil-based and Biochar Substrate lettuce leaves

	Type	N	Mean	Std. Deviation	Std. Error Mean
Leaves	Soil Base	15	7.0667	1.94447	.50206
	Substrate Based	15	8.5333	3.37780	.87214

Source: Field Survey 2021

Table 3: **Levene's test for Equality of Variance of Soil-based and Biochar Substrate lettuce leaves**

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Leaves	Equal variances assumed	6.753	.015	-1.457	28	.156	-1.46667	1.00633	-3.52804	.59471
	Equal variances not assumed			-1.457	22.361	.159	-1.46667	1.00633	-3.55172	.61838

Source: Field Survey 2021

The results show that that soil-based lettuce cultivation have an average mean of about $\bar{x}$=7.0667 leaves on the plants, while the leave found on the biochar substrate have an average mean of about $\bar{x}$=8.5333 leaves on the plant (see Table 2). The Levene's test for equality of variance in Table 3 reveals that there is no significant difference between the lettuce leave density for both plants as the P-value = 0.15. which is > than 0.05.

On the diameter of the leaves, the result shows that the soil-based lettuce had an average of about $\bar{x}$=10.7400 in diameter while for the hydroponics, it has an average of about $\bar{x}$=12.7467 in diameter as indicated in Table 4. For the Levene's test of equality, the P-value = 0.223. since the P-value > 0.05, that means there is no significant difference between the soil base cultivation and the Substrate Hydroponics in terms of their diameter (see Table 5).

Table 4: Mean of Soil-based and Biochar Substrate lettuce leaves diameter

	Type	N	Mean	Std. Deviation	Std. Error Mean
Diameter	Soil Base	15	10.7400	3.73512	.96440
	Substrate Based	15	12.7467	4.80013	1.23939

Source: Field Survey 2021

For the width of the lettuce leaves, the result shows an average of $\bar{x}$= 7.4200 for the width for the soil- based leaves and an average of $\bar{x}$= 9.5667 for the width of biochar substrate hydroponics (see Table 6). Similarly, The Levene's test for equality shows on Table 7 reveals that P-value= 0.075. Since the P-value > 0.05, then there is also no significant difference between the width of the soil base cultivation for lettuce and that of the biochar substrate hydroponics.

Table 5: Independent Sample Test for Diameter parameters

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Diameter	Equal variances assumed	1.550	.223	-1.278	28	.212	-2.00667	1.57040	-5.22349	1.21015
	Equal variances not assumed			-1.278	26.406	.212	-2.00667	1.57040	-5.23226	1.21893

Source: Field Survey 2021

Table 6: **Mean of Soil-based and Biochar Substrate lettuce leaves Width**

	Type	N	Mean	Std. Deviation	Std. Error Mean
Width	Soil Based	15	7.4200	3.75827	.97038
	Substrate Based	15	9.5667	5.41554	1.39829

Source: Field Survey 2021

4.2 Weight Characteristics of Lettuce.

The weight of lettuce is key to identifying its maturity and value for human consumption hence the weight of the lettuce of biochar substrate and soil-based were determined in this study. The result shows that the average weight of cultivated from biochar substrate and soil based was found to be $\bar{x}$= 0.3667 and $\bar{x}$= 0.1500 respectively (see Table 8). As depicted in Table 9, the Levene's test of equality showed that, the P-value was found to be 0.038. At a confidence interval of 95% (0.05), the Levene's test showed that there is a significant difference between the yield mass (weight) of the biochar substrate hydroponics and the soil-based cultivation as the P-value < 0.05. The result revealed that there no significance difference in the leaves, diameter and width characteristics of the biochar substrate and soil-based lettuce cultivation. Whereas there was only significant difference in weighted mass of the lettuce in the substrate than the soil-based lettuce. This finding is of significant because the only difference feature in this study was the medium through which nutrients was transported into the plant. While soil-based cultivation provided the lettuce plants with nutrients through the soil, the other provided the nutrients through the biochar substrate (soil-free) based medium. The implications of this result could mean that the lettuce plants could have taken directly more nutrients and water without any obstruction through the soil free based growing media than the soil-based lettuce plant.

Table 7: Independent sample test for width parameters

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Width	Equal variances assumed	3.417	.075	-1.261	28	.218	-2.14667	1.70201	-5.63308	1.33975
	Equal variances not assumed			-1.261	24.946	.219	-2.14667	1.70201	-5.65241	1.35908

Source: Field Survey 2021

Table 8: Mean Weight of Biochar Substrate and Soil-based Lettuce

	Biochar Substrate			**Mean**	**Soil-Based**			**Mean**
	Lettuce 1	Lettuce 2	Lettuce 3		Lettuce 1	Lettuce 2	Lettuce 3	
Weight	**0.5**	**0.1**	**0.5**	.3667	**0.1**	**0.15**	**0.2**	.1500

Source: Field Survey 2021

Table 9: Independent sample test for yield Mass (Weight)

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
YIELD MASS	Equal variances assumed	9.260	.038	1.588	4	.187	.21667	.13642	-.16210	.59544
	Equal variances not assumed			1.588	2.187	.243	.21667	.13642	-.32473	.75806

Source: Field Survey 2021

4.0 CONCLUSION AND RECOMMENDATION

This paper attempted to provide answer to the question "can urban farmers depends on biochar substrate (Soilless) for growth and yield of lettuce cultivation? The response to this question might not have a direct answer but can be articulated to have been subjected to partial answers. This is because, the findings revealed that lettuce cultivation under the same procedures with different means of supplying nutrients and water (soil-free (biochar substrate) and soil based) provided only limited response. The outcome of the experiment which reveals relatively higher mass of lettuce plant from soil-free cultivation, outweighs the soil-based lettuce cultivated, while other characteristics like the diameter, width and numbers of the leaves showed the no difference. The strength of the soil free cultivation would have to be subjected to a bigger experiment for more viable conclusions for farmers to understand if they can actually depend on soil-free lettuce cultivation for higher yield, improved income and sustainability. That is, if soil-free cultivation can complement soil-based cultivation in an urban area where the cost and value of land is high. Of course, there are many factors that need to be considered for this conclusion but the paper would recommend a future research focus area that covers:

- An experiment on a larger scale, this will help in reflecting whether the substrate-based cultivation will meet the demand of today and future market.
- A comparative evaluation of the cost efficiency of both soil-free and soil-based cultivation for the immediate, short, medium and long terms
- As assessment of the response of varied species of lettuce to different types of soil-free (substrates) and soils.
- The examination of the lettuce rooting characteristics in substrates and soil cultivation

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