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Correlation and Regression Analysis of Cucumber (*Cucumis sativus* L) as Affected by Manure teas of Different Sources and Rates in the Sudano-Sahelian ecology of Nigeria

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ABSTRACT

Chemical fertilizers on a regular basis cause serious environmental problems such as nutrient loss, soil deterioration, and groundwater pollution, while manure teas are water extracts from composted animal manures that can be used as organic fertilizers to improve soil fertility. This study investigated the effects of compost tea (CT) and horse manure tea (HMT) on cucumber growth and yield in both open field and net house environments. The experiment comprised of four levels of CT and HMT each (0, 100, 125, and 150 ml/L), which were factorially combined and laid out in a randomized complete block design (RCBD) with four replications. Results revealed that CT significantly ($p < 0.001$) increased vine length, leaf area index, relative growth rate, crop growth rate, and fruit yield compared to HMT. Correlation analysis identified several growth parameters as strong indicators of potential yield, and regression analysis determined optimal application rates for CT and HMT (100-125 ml/L). The findings suggest that both CT and HMT are promising amendments for enhancing cucumber production, with CT showing superior results. Further research is needed to explore the underlying mechanisms and optimize application practices.

***Keywords**:* Cucumber, growth, correlation, yield, regression, manure teas.

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1. INTRODUCTION

The main agricultural input is fertilizer, whose use has increased dramatically in recent decades as a result of the need to feed the world's expanding population (FAO, 2017). The FAO projects that the worldwide fertilizer market will expand by around 2% a year and reach 201.7 Mt by the end of 2020 (FAO, 2019). According to studies, using chemical fertilizers on a regular basis causes serious environmental problems such as nutrient loss, soil deterioration, and groundwater pollution (Hua *et al.,* 2016; Bijay-Singh and Craswell, 2021). In contrast to chemical fertilizers, the green revolution is encouraging the use of biowaste-based products like biofertilizers, which are rich in organic carbon, nutrients, and bacteria and less likely to cause ecological disruptions (*Kumar et al.,* 2019; Chojnacka *et al.*, 2020).

Cucumber is an important worldwide horticultural crop ranking third for vegetable production after tomato and pepper. Major producing countries include China, Turkey, India, Iran, Russia, and the United States. In Africa, Egypt, Algeria, Morocco, and South Africa are major producers. Nigeria grows cucumber in almost all states, mainly in the South West and Northern regions. Cucumber is nutritious and beneficial for human health (Law-Ogbomo and Osaigbovo, 2018).
Cucumber production is currently facing a major threat due to the high cost of synthetic fertilizers (Victor and Julius, 2018; Okafor and Yaduma, 2021). In order to find a suitable solution for this issue, the proposal of using composts derived from organic sources has been put forward.

These composts are known to contain a plethora of beneficial nutrients that are essential for the growth and development of crops (Masters-Clark *et al*., 2020; Signh *et al.,* 2022). A study by Omidire et al. (2015) elucidates the effectiveness of organic manure teas in boosting cucumber yields, aiming to determine the potential of organic materials for a sustainable agricultural system. Manure teas are water extracts from composted animal manures that can be used as organic fertilizers to improve soil fertility (Dadrasnia *et al.,* 2021). Teas can be made from a variety of composts, but poultry litter compost is the most nutrient-rich and popular source for organic liquid fertilizers with lower input costs compared to other animal composts (Manzoor *et al.,* 2024).

The use of correlation in agronomy refers to the study of the relationships, combinations, and correlations of factors affecting crop production and the exploitation of these correlations by the public or the scientific community (Ren *et al.,* 2022). The most commonly used techniques for investigating the relationship between two quantitative variables are correlation and linear regression. Correlation quantifies the strength of the linear relationship between a pair of variables, whereas regression expresses the relationship in the form of an equation (Bewick *et al.,* 2003), while Vakhabov and Hidoyatova (2023) highlighted the various forms of correlation used in predicting relationships between two or more variables. This trial was caried out to study the growth, yield, correlation, and regression of Cucumber as affected by manure teas of different sources and rates.

2. MATERIALS AND METHODS

2.1. Site description and Field layout

The experiments were undertaken in both the open field (11'98 N Latitude and 8'426 E Longitude) and the net house (11'98 N and 8'415 E), which were located in the vicinity of the Research and Training Farm of the Centre for Dryland Agriculture (CDA) of Bayero University Kano, which is situated in the Sudan Savannah agro-ecological zone of Nigeria, during the 2020–2021 wet and dry season. The experimental site was prepared by clearing it, tilling the soil, preparing the beds in accordance with the experiment's guidelines, and adding drainage channels. The experimental plots had a gross plot size of 4.5 m 5 m (22.5 m^2) and were made up of six ridges that were each 5 m long. The two inner ridges measuring 1.5 m x 4 m (6.0 m^2) were used as the net plots. For ease of movement, an alley of 0.75 m between each plot and 1.0 m between replications was evenly maintained. Marketer, a tall, slender cultivar with great flavor, spreading, and a dark green skin color, was the cucumber variety used in the research. It had an early maturation potential (75–85 days) and is high yielding. The experiment was a 4 x 4 factorial laid out in a randomized complete block design and replicated four times consisting of four (4) levels of compost tea (0, 100, 125, and 150 ml/L) and four levels of horse tea (0, 100, 125, and 150 ml/L) as experimental treatments.

2.2. Manure teas preparation procedure

The compost manure tea that was utilized in the trials was made by gathering 20 kg of compost, packing it tightly within a jute bag, and then submerging the bag inside a container. The mixture was then mixed twice daily after being added 20 liters of water. By adding 1 liter of dissolved molasses, the microbial activity was activated, and they continued for 3 days. Then, in accordance with the procedures outlined by Igham *et al*. (2013), manure tea was gathered and diluted in a 2:1 ratio (2: clean water and 1: concentrated manure tea). Following the collection of fresh horse droppings, the preparation and extraction of horse tea were conducted using a similar process.

2.3. Cultural practices

By using a 50 cm space between plants in row^{-1}, the cucumber seeds were manually sowed at a depth of 2 cm at a rate of 2 seeds per hole, and afterwards thinned to one plant per stand. Further, at intervals of two weeks, the plots received applications of the compost tea and horse manure teas according to the treatment level. During the course of the trials, timely pest and disease control was carried out by employing appropriate manual, physical, and chemical methods for controlling weeds, insects, and diseases, respectively. When the fruit achieved physiological maturity, it was manually harvested by severing the ripe fruit from the vine with a sharp knife.

2.4. Data collection and Data analysis

In order to collect data, five plants were randomly tagged in the net plot area. The features of the growth and the properties of the yield, such as number of leaves per plant, vine length, leaf area index, net assimilation rate, relative growth rate, crop growth rate and the fruit yield (t/ha) using standard agronomic procedures. The collected data was subjected to an Analysis of Variance (ANOVA) using GENSTAT 17th edition, and significant treatment means were separated using the Student-Newman-Keuls test at 5% probability level.

3. RESULTS AND DISCUSSIONS

3.1. Effect of manure teas on growth and yield of cucumber

Growth and yield characters of cucumber as affected by manure teas are presented in Table 1. Results indicated that vine length and leaf area index (LAI) were significantly ($p <.001$) increased due to the application of CT compared with the control, which resulted in lower values in both the net house and the open field, indicating better plant growth and light interception. The relative growth rate (RGR) in the open field and crop growth rate (CGR) in both environments were significantly ($p <0.001$) influenced by the CT, where the application of 150 ml/l of CT resulted in higher CGR in both environments, suggesting faster plant development and biomass accumulation. Similarly, CT significantly increased cucumber yield in both environments (8.89 and 7.82 t/ha), with the highest yield achieved by the application of 150 ml/L. The increase in VL and LAI might be attributed to higher CGR and NAR that aid in promoting better plant growth and light interception for photosynthetic activities, which ultimately resulted in higher fruit yield. On the other hand, vine length was significantly ($p < 0.001$) influenced by HMT in the open field, where application of 150 ml/L gave longer vines. The number of leaves per plant was significantly increased by the application of 125 mL/L HMT in both locations. The application of 100 and 125 ml/L of HMT significantly resulted in higher CGR at the net house environment, while the application of 125 ml/L and 125 and 150 ml/L resulted in higher fruit yield in both net house and field environments, respectively. While the interaction between CT and HT was not significant for CGR and NAR at both environments, there was a slight interaction effect for other growth characters in both environments. This suggests that the combination of CT and HT may have a synergistic effect on yield under certain conditions. However, findings generally show that because CT has a higher nutrient content than HMT, it is more effective at boosting crop development. This is consistent with the findings of three independent studies on the effectiveness of compost tea in promoting growth and development (Bali *et al.*, 2021; Pilla *et al.*, 2023) as well as the soil properties (Hakimi et al., 2024). The improved nutrient availability, greater soil microbial activity, or hormone stimulation brought on by CT application could all be responsible for the higher CGR. The results further corroborated those of Carrascosa et al. (2023), who reported that compost tea significantly increased purslane shoot biomass, impacted soil chemical properties, and impacted bacterial and fungal community compositions, while inorganic fertilization treatments decreased diversity and predicted bacterial functional pathways. Within the nethouse environment, HMT only had a significant effect on CGR. The best outcomes were observed at a rate of 100 ml/L, but this was comparable to other rates. This raises the possibility that, in contrast to CT, HMT's impact on cucumber development may depend more on several prevailing factors.

3.2. Effects of manure teas on the correlation matrix of cucumber

The results of simple correlation analysis between fruit yield and growth and yield characters of cucumber grown in the open field and screen house during 2020/2021 seasons are presented in Tables 2 and 3. The relationship between fruit yield of cucumber and other growth and yield-related characters is shown in Table 2. Results indicated that fruit yield of cucumber was positive and highly significant ($p<0.001$) with VL ($r = 0.451$), NLP ($r = 0.053$), LA ($r = 0.552$), LAI ($r = 0.464$), DM ($r = 0.714$), and FD ($r = 0.461$), while it was not significant ($p > 0.05$) with NAR ($r = 0.140$) and negatively associated with RGR ($r = -0.192$).

The vine length (VL) was positive and highly significant (p<0.001) with NL (r=0.581), LA (r=0.733), LAI (0.627), DM (0.557), and FRTDMT (r=0.588), while it was not significant (p>0.05) with NAR (r=0.072) and negatively associated with RGR (r=-0.119). On the other hand, the NL was positive and highly significant (p<0.001) with LA (0.522) and LAI (r=0.658), DM (r=0.547), and FRTDMT (r=0.368). The LA and LAI were positive and highly significant with DM (r=0.698 & 0.602) and FRTDMT (r=0.572 & 0.498), respectively. Vitamin C content was positive and highly significantly correlated with fruit yield (r = 0.396), suggesting that higher-yielding cucumbers may have higher vitamin C content.

Table 3 presents the correlation coefficients between fruit yield and various growth characteristics of cucumber plants. Results show that fruit yield was positive and highly significantly (p <0.001) associated with VL (r = 0.464), LAI (r = 0.509), RGR (r = 0.595), DM (r = 0.646), and FD (r = 0.474), while it was significantly correlated with NAR (r = 0.371). However, it was significant (p <0.05) but negatively related with NL (r = -0.283), while it was positive but not significant with LA (r = 0.233).

The strong correlations between yield and growth parameters (VL, NL, LAI, DM) suggest that these parameters can be used as indicators of potential yield (Table 2). The correlation analysis reveals that several growth parameters and nutrient content are significantly associated with cucumber yield. These findings provide valuable insights for developing strategies to improve cucumber production. Vitamin C content (VIT_C) was significantly correlated with yield, suggesting that higher-yielding cucumbers may have higher vitamin C content.

Table 1. Vine length, Number of leaves plant^{-1}, Leaf area index, Relative growth rate, Crop growth rate, and Yield of Cucumber at the Net House and Open field of CDA Bayero University in 2021/ 2022

Treatment	Net house								Open field					
	VL	NLP	LAI	NAR	RGR	CGR	Yield (t ha^{-1})	VL	NLP	LAI	NAR	RGR	CGR	Yield (t ha^{-1})
Compost Tea (CT)														
0	133.5^{c}	30.29^{d}	2.02^{c}	0.091	0.142	14.21^{c}	1.60^{d}	123.4^{d}	28.45^{c}	1.92^{b}	0.047	0.143^{a}	14.84^{c}	1.01^{c}
100	164.2^{b}	44.59^{c}	2.39^{b}	0.081	0.106	22.57^{b}	4.50^{c}	166.3^{c}	42.81^{b}	2.39^{a}	0.059	0.074^{b}	21.42^{b}	3.93^{b}
125	168.8^{ab}	48.85^{b}	2.48^{ab}	0.209	0.121	21.16^{b}	6.07^{b}	173.6^{b}	43.60^{b}	2.42^{a}	0.059	0.073^{b}	19.72^{b}	4.89^{b}
150	175.4^{a}	53.71^{a}	2.57^{a}	0.170	0.094	36.38^{a}	8.89^{a}	185.6^{a}	49.33^{a}	2.54^{a}	0.059	0.053^{b}	35.34^{a}	7.82^{a}
P-value	<.001	<.001	<.001	0.422	0.737	<.001	<.001	<.001	<.001	<.001	0.410	0.002	<.001	<.001
S.E ±	2.80	1.18	0.05	0.06	0.03	0.98	0.37	2.12	1.10	0.05	0.006	0.02	1.54	0.43
Horse Tea (HT)														
0	156.0	39.52^{b}	2.31	0.177	0.102	21.63^{b}	3.89^{c}	154.1^{c}	36.12^{b}	2.31	0.053	0.076	20.87	3.08^{b}
100	160.7	39.52^{b}	2.33	0.179	0.136	26.18^{a}	4.14^{c}	162.0^{b}	37.20^{b}	2.36	0.051	0.111	25.12	3.36^{b}
125	166.2	56.81^{a}	2.39	0.047	0.135	24.10^{ab}	7.54^{a}	162.9^{b}	53.73^{a}	2.38	0.048	0.080	23.16	6.03^{a}
150	158.9	40.30^{b}	2.39	0.149	0.090	22.41^{b}	5.49^{b}	169.9^{a}	36.12^{b}	2.21	0.054	0.076	22.17	5.27^{a}
P-value	0.09	<.001	0.714	0.417	0.673	0.010	<.001	<.001	<.001	0.078	0.919	0.383	0.058	<.001
S.E ±	2.80	1.18	0.051	0.06	0.03	0.98	0.37	2.12	1.10	0.05	0.006	0.02	1.54	0.43
Interaction														
CT × HT	**	**	**	NS	NS	**	**	**	**	**	NS	NS	**	**

Means followed by the same letter(s) are not significantly different at 5% level of probability using SNK Test. NLP= Number of leaves plant^{-1}; LAI= Leaf area index; NAR= Net assimilation rate; RGR= Relative growth rate; CGR= Crop growth rate.

Table 2. Correlation Analysis of Fruit Yield (tha^{-1}) and Growth Characters of Cucumber at the Net House, CDA Bayero University in 2021/ 2022 Rainy season

	F_YLD	VL	NL	LA	LAI	NAR	RGR	FRTDMT	VIT_C
F_YLD	1								
VL	0.451**	1							
NL	0.353**	0.581**	1						
LA	0.552**	0.733**	0.522**	1					
LAI	0.464**	0.627**	0.658**	0.853**	1				
NAR	0.140	0.072^{NS}	0.207^{NS}	0.184^{NS}	0.093	1			
RGR	-0.192	-0.119^{NS}	0.001^{NS}	-0.166	-0.107	-0.155	1		
DM	0.714**	0.557**	0.547**	0.698**	0.602**	0.190	-0.083		
FRTDMT	0.461**	0.588**	0.368**	0.572**	0.498**	0.024	-0.008	1	
VIT_C	0.396**	0.522**	0.392**	0.545**	0.577**	0.103	0.060	0.530**	1

* Significant ** highly significant NS Not significant.

YLD= Fruit yield (t/ha)
VL= Vine length (cm) at 6 WAS
LA= Leaf area (cm^2) at 6 WAS
LAI= Leaf area index at 6 WAS
NAR = Net assimilation rate ($g\ cm^2\ wk^1$) at 6 WAS
RGR = Relative growth rate ($g\ g^{-1}\ wk^{-1}$) at 6 WAS
DM= Dry matter (g) at 6 WAS
FRTDMT= Fruit diameter (mm)

Table 3. Correlation Analysis of Fruit Yield (t/ha) and Growth Characters of Cucumber at the Open Field, CDA Bayero University in 2021/ 2022 Rainy season

	F_YLD	VL	NL	LA	LAI	NAR	RGR	DM	FRTDMT	VIT_C
F_YLD	1									
VL	0.464**	1								
NL	-0.283*	- 0.071^{NS}	1							
LA	0.233^{NS}	0.137^{NS}	0.0740^{S}	1						
LAI	0.509**	0.511**	0.285^{NS}	0.081^{NS}	1					
NAR	0.317*	0.255*	-0.227^{NS}	0.074^{NS}	0.764**	1				
RGR	0.595**	0.625**	-0.193^{NS}	0.153^{NS}	0.777**	0.549**	1			
DM	0.646**	0.477**	0.350**	0.167^{NS}	0.694**	0.545**	0.697**	1		
FRTDMT	0.474**	0.469**	-0.181^{NS}	0.070^{NS}	0.870**	0.684**	0.697**	0.628**	1	
VIT_C	0.474**	0.593**	-0.237^{NS}	0.601**	0.769**	0.440**	0.702**	0.601**	0.660**	1

* Significant ** highly significant NS Not significant.

YLD= Fruit yield (t/ha)
VL= Vine length (cm) at 6 WAS
LA= Leaf area (cm^2) at 6 WAS
LAI= Leaf area index at 6 WAS
NAR = Net assimilation rate ($g\ cm^2\ wk^1$) at 6 WAS
RGR = Relative growth rate ($g\ g^{-1}\ wk^{-1}$) at 6 WAS
DM= Dry matter (g) at 6 WAS
FRTDMT= Fruit diameter (mm

This result is consistent with the findings of Yeshtila *et al.* (2023), who found significant positive associations between leaf area, leaf breadth, branch number, leaf number, and grain yield of amaranth. On the other hand, results from Table 3 suggest that several growth characteristics are important determinants of cucumber fruit yield. A high leaf area index, net assimilation rate, relative growth rate, dry matter, and fruit dry matter are all positively correlated with higher yields. These findings highlight the importance of optimizing plant growth and photosynthetic efficiency for maximizing cucumber production. This result corroborates those of Li *et al*. (2016), who reported that NAR was strongly and positively associated with area-based photosynthetic rate and leaf nitrogen content. While the number of leaves did not show a strong correlation with yield, it's possible that other factors, such as leaf quality or leaf distribution, might play a role. This aligns with the findings of Rowland *et al.* (2020), who stated that photosynthesis contributed strongly to vegetative biomass and sugar content of fruits but had a negative impact on fruit yield of tomatoes. Similarly, Okoh *et al.* (2021) reported that the removal of leaves of the African eggplant, either consciously or otherwise, would not negatively impact the yield and quality of the fruit. Overall, this analysis provides valuable insights into the factors influencing cucumber fruit yield and can inform breeding programs, cultivation practices, and management strategies aimed at increasing productivity.

3.3. Regression attributes of cucumber as affected by manure teas

Figure 1 and 2 show the regression analysis of compost tea manure against yield in the net house and open field, respectively. The regression graph shows an increase in the fruit yield of cucumber from increase in the amount of compost tea manure applied up to the highest level of compost manure tea applied. Therefore, an optimum compost manure tea application rate for maximum attainable yield could not be reached. The results suggest that compost tea manure can be a beneficial amendment for increasing cucumber yield, as reported by Aderibigbe *et al*. (2023) on the use of organic tea to increase the growth and yield of cucumber in Owo, Nigeria

Figure 3 and 4 show the regression analysis of horse tea manure against yield in the net house and open field, respectively. The regression graph shows an increase in the fruit yield of cucumber from increase in the amount of compost tea manure applied up to a certain point before it starts to decline. The optimum yield was observed between the application rates of 100 ml m and 150 ml m. This implies that at lower application rates, there is a positive correlation between horse tea manure and cucumber yield. Beyond a certain point, increasing the application rate of horse tea manure leads to diminishing returns or even a decrease in yield. Hence, the optimal application rate for maximizing fruit yield of cucumber appears to be between 100 ml/m^2 and 125 ml/m^2. These results suggest that while horsetail manure can be beneficial for increasing cucumber yield, excessive application can have negative consequences. However, the optimal application rate may vary depending on factors such as soil fertility, climate, and cucumber variety. Although excessive application of horsetail manure may lead to nutrient overload in the soil, which can be detrimental to plant growth, and this aligns with the findings of Rayne and Aula (2020) on the impact of livestock manure on soil health, which is directly linked to salt buildup in the form of ammonium, calcium, magnesium, potassium, etc. and sometimes causes nutrient imbalance.

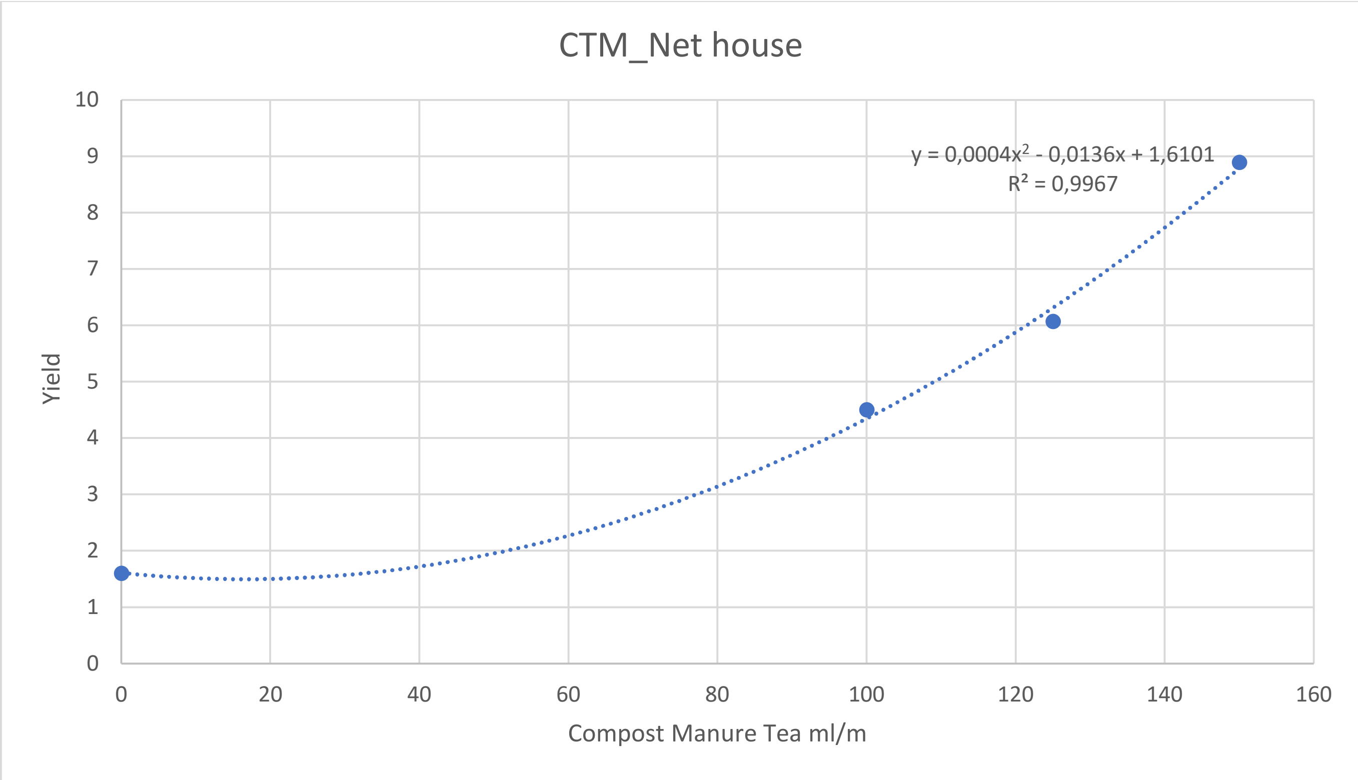

Figure 1. Regression analysis of compost tea manure against yield in the net hous

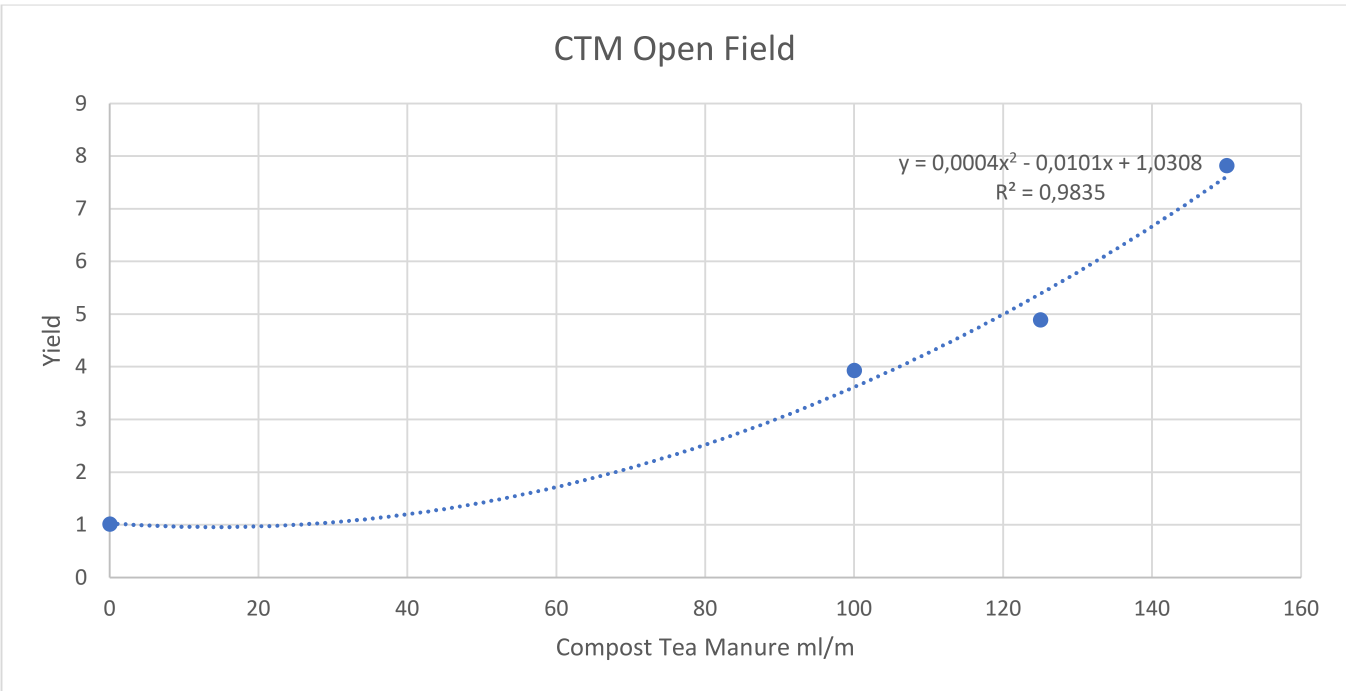

Figure 2. Regression analysis of compost tea manure against yield in the open field

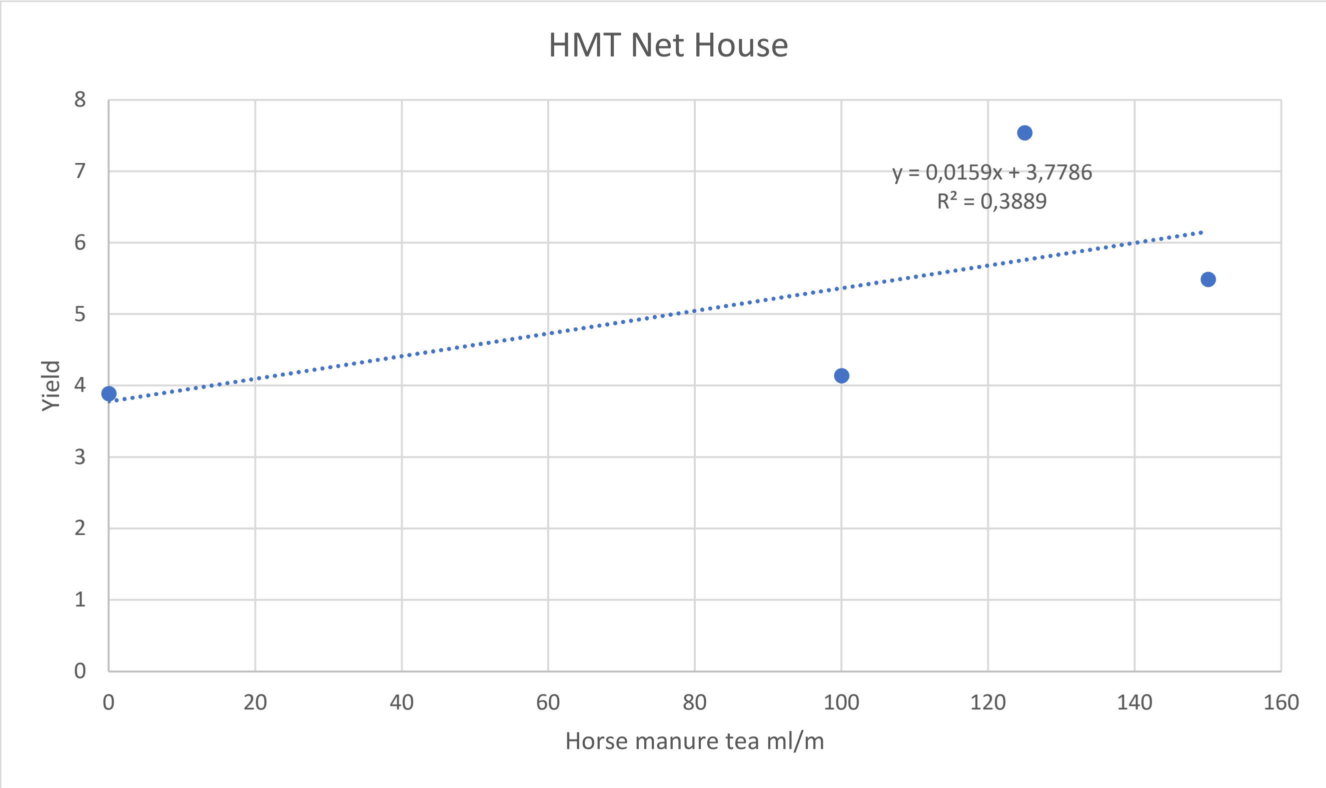

Figure 3. Regression analysis of horse tea manure against yield in the net house

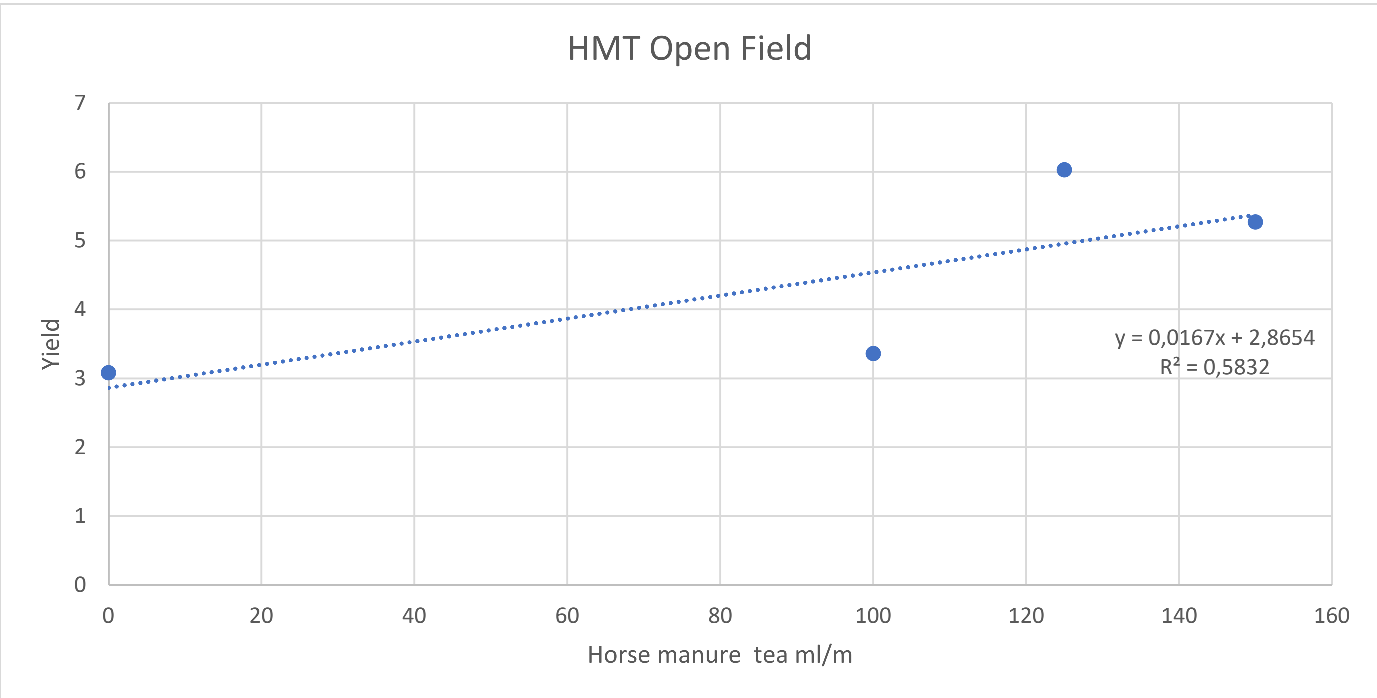

Figure 4. Regression analysis of horse tea manure against yield in the open field

4. CONCLUSIONS

The study demonstrates the effectiveness of compost tea and horse manure tea in improving cucumber growth and yield. CT, in particular, proved to be a valuable amendment for enhancing plant development and productivity. The findings highlight the importance of optimizing plant growth parameters and considering the application rates of manure teas to maximize cucumber production. Based on this finding, the application of 150 ml/L and 125 ml/L could be recommended for compost tea manure and horse tea manure respectively. On the other hand, growers have the potential to enhance cucumber quality and productivity while advancing sustainable agricultural practices by fully utilizing CT and HMT and comprehending their underlying mechanisms.

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