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ORIGINAL ARTICLE

Growth and Yield of Hybrid Chilli in Response to Diverse Nutrient Management Strategies in a Soil-Based Medium

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Abstract

The economic crisis in Sri Lanka has substantially increased the costs of fertilizers and growing media, thereby posing challenges to affordability for farmers. This study aimed to explore alternative approaches to water-soluble fertilizers and soilless growing media for hybrid chilli cultivation in polytunnels. Chilli grown in a soilless medium with Albert's solution (the current practice) was compared with plants grown in a soil-based medium under inorganic, organic (ONM), and integrated nutrient management (INM) strategies. The experiment was arranged in a completely randomized design with three replicates. Vegetative and reproductive traits of chilli, as well as the pH and electrical conductivity (EC) of the growing media, were evaluated. Although yield differences between the current practice and the ONM and INM methods were not statistically significant ($p>0.05$), the ONM and INM treatments recorded numerical yield increases of 17% and 15%, respectively. In the soil-based medium, ONM and INM significantly ($p<0.05$) increased SPAD values and plant height compared to the current practice. Inorganic fertilizers caused a decline in pH, whereas organic fertilizers maintained optimal pH, and INM maintained EC within desirable ranges. Hence, ONM and INM methods in a soil-based medium present alternatives to the current practice. Limitations of the study include variability in polytunnel conditions and potential challenges in generalizing findings across regions and chilli varieties. Overall, this study demonstrates that soil-based nutrient management strategies, particularly ONM and INM, can reduce reliance on costly soilless media and imported fertilizers, supporting more resilient and sustainable chilli production under the prevailing economic and environmental challenges in Sri Lanka.

Keywords*: Capsicum annuum, Hybrid chilli, Nutrient management, Polytunnel conditions, Soil-based media*

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1. Introduction

The cultivation of chilli (*Capsicum annuum* L.) plays a vital role in global horticultural production, given its economic significance and widespread consumption. It is also an essential ingredient in the Sri Lankan diet, serving as a condiment (Hewage et al., 2022). Although the annual national requirement for dry chilli is approximately 55,000–60,000 tonnes, local production is limited to around 5,000–7,500 tonnes. Consequently, Sri Lanka imports about 50,000–55,000 tonnes of dry chilli annually, incurring an expenditure exceeding SLR 14 billion (Sri Lanka Customs, 2019; DOA, 2020). The Department of Agriculture, Sri Lanka, recommends both open-pollinated and local hybrid chilli varieties (LHCVs) for cultivation. Among these, the locally developed hybrid variety MICH HY1, first released in 2015, has gained popularity due to its higher yield potential, resistance to the chilli leaf curl complex, extended crop duration, and taller plant stature, which facilitates easier harvesting (Hewage et al., 2022). With an average yield of approximately 35 t ha^{-1}, MICH HY1 is now extensively cultivated across various agro-ecological regions of the country.

The cultivation of chilli in protected structures under controlled environments is becoming increasingly popular, offering protection from adverse and variable environmental conditions while maintaining optimal growing conditions throughout the development of crops (McCartney and Lefsrud, 2018). This practice stabilizes crop yields, produces high-quality products free from harmful chemicals, and facilitates market-driven production without seasonal interruptions (Jensen, 2001). Soilless cultivation (growing plants in a medium other than soil) has emerged as a promising strategy for growing various crops, including chilli, within protected environments (Fussy and Papenbrock, 2022), as it allows precise nutrient management, reduces dependency on soil quality, and can enhance growth and yield under controlled conditions. In Sri Lanka, soilless growing media are frequently formulated using coir dust (Perera et al., 2025), either alone or in combination with other amendments such as partially burned paddy husk. Crops in soilless systems are primarily nourished using inorganic nutrient management techniques, which involve synthetic fertilizers containing essential macro- and micronutrients in readily accessible forms, ensuring precise control over nutrient ratios (Sapkota *et al.*, 2021). Previous studies have demonstrated the positive impact of inorganic nutrient management on crop yields, with evidence showing that applying inorganic fertilizers significantly improves both the yield and quality of chilli (Sapkota *et al.*, 2021). However, the excessive and imbalanced use of inorganic fertilizers can result in environmental pollution and nutrient imbalances (Yadav *et al.*, 2019; Sapkota *et al.*, 2021).

In 2022, Sri Lanka faced a profound economic crisis characterized by inflation, depleted foreign exchange reserves, high debt levels, and various economic imbalances. This crisis led to an increase in the costs of agricultural commodities, such as fertilizers and components for soilless growing media, creating affordability challenges. These circumstances necessitate the exploration of costeffective strategies in protected cultivation by investigating alternative approaches to fertilizers and growing media components, thereby securing profit margins.

Numerous studies have highlighted the benefits of organic nutrient management (ONM), which utilizes natural sources such as compost, animal manure, and biofertilizers, on plant growth and yield. For instance, research by Khaitov *et al.* (2019) revealed that ONM significantly enhanced vegetative growth parameters and the yield of chilli plants compared to conventional methods. The slow-release nature of organic fertilizers provides a steady nutrient supply, improving soil health and reducing nutrient leaching, thereby minimizing environmental impacts (Wang *et al.*, 2021). Moreover, integrated nutrient management (INM), which combines organic and inorganic nutrient sources, has emerged as a promising approach to optimize nutrient availability, improve soil fertility, enhance crop productivity (Srivastava and Ngullie, 2009), and reduce the reliance on synthetic fertilizers. The synergistic effects of INM can mitigate the limitations associated with individual nutrient management methods (Wu and Ma, 2015). Studies, such as those by Kumar *et al.* (2020), have demonstrated the efficacy of INM in improving the growth, yield, and yield parameters of chilli crops.

However, research on the effects of different nutrient management strategies on chilli cultivation under controlled environmental conditions remains limited. Therefore, this study aims to evaluate the effects of organic and integrated nutrient management on the growth, yield, and medium properties of hybrid chilli under soil-based conditions and to compare these strategies with conventional inorganic nutrient management in soilless cultivation.

2. Materials and Methods

This experiment was conducted in a polytunnel at the faculty field of the Faculty of Agriculture, Rajarata University of Sri Lanka, during the 2022–23 *Maha* season. The study site is located at a latitude of 8°34' North, a longitude of 80°38' East, and an elevation of 81 metres above sea level. The experiment comprised four treatments, each replicated three times in a Completely Randomized Design (CRD). The treatments included: coir dust and partially burnt paddy husk (1:1) medium with Albert's solution (Treatment 1 and Control); solely inorganic fertilizers (Treatment 2); Integrated Nutrient Management (INM) (Treatment 3); and Organic Nutrient Management (ONM) (Treatment 4). For Treatments 2, 3, and 4, the chilli plants were cultivated in a growing medium composed of topsoil, compost, and partially burnt paddy husk in a 1:1:1 ratio.

In each replicate, three 28-day-old chilli seedlings of the MICH HY1 variety at an optimal transplanting stage for uniform establishment and growth were individually planted in separate plastic pots with a capacity of 15 litres. Fertilizer application in each treatment adhered to the guidelines provided by the Department of Agriculture, Sri Lanka (DOA, 2022), as outlined in Tables 1 to 5. Table 1 specifies the application rates of Albert's solution for different stages of plant growth, while Table 2 details the weekly application schedule of Albert's solution during distinct periods, including pre-flowering, post-flowering, and post-fruit formation for Treatment 1. Treatment 2 followed the application of inorganic fertilizers as shown in Table 3.

Table 1. The application rate of Albert's solution in Treatment 1

Week	Quantity of Albert fertilizer (g/plant)	Quantity of water to be dissolved (mL)*
1	0.25	250
2	0.375	375
3-4	0.5	500
5-6	0.75	750-100
7-8	1	1000-1500
9-10	1.25	1500
10 onwards	1.25	1500

*The amount of water was adjusted according to the prevailing weather conditions.

Table 2. The weekly schedule for applying Albert's solution

Day	Before flowering	After flowering	After fruit formation
1	Albert's solution	Albert's solution	-
2	Albert's solution	Albert's solution	Albert's solution + 0.2 g/plant Calcium Nitrate
3	Albert's solution	Albert's solution	-
4	Water only	Albert's solution	Albert's solution
5	Albert's solution	Albert's solution	Albert's solution + 0.2 g/plant Calcium Nitrate
6	Albert's solution	Albert's solution	Albert's solution + 0.2 g/plant Calcium Nitrate
7	Water only	Water only	Water only

Table 3. The application rate of inorganic fertilizers (g/ plant) in treatment 2

Basal dressing	8g/ plant TSP and 4g of micronutrient mix	
Top dressing Up to 3 weeks of planting (weekly interval)	Urea MOP	1.0 g/plant 0.75 g/plant
4-7 weeks (weekly interval)	Urea MOP	1.5 g/plant 1 g/plant
7 weeks onwards	Urea MOP	1.5 g/plant 1.5 g/plant

Table 4. The application rate of compost for treatment 4

Basal dressing	Compost	400 g/plant (P-based)
Top dressing Up to 3 weeks of planting (weekly interval)	Compost	100g/plant (N-based)
4 weeks onwards	Compost	150 g/plant (N-based)

Table 5. The INM in treatment 3

Basal dressing	4g/ plant TSP and 2g of micronutrient mix + 200 g compost		
Top dressing Up to 3 weeks of planting (weekly interval)	Urea MOP	0.5 g/plant 0.375 g/plant	50 g/plant compost
4-7 weeks (weekly interval)	Urea MOP	0.75 g/plant 0.5 g/plant	75 g/plant compost
7 weeks onwards	Urea MOP	0.75 g/plant 0.75 g/plant	

In Treatment 4, compost application rates were determined based on either the P (for basal dressing) or N (for top dressings) requirements of the DOA's inorganic fertilizer recommendations for chilli (Table 4) and applied in split doses at weekly intervals. Treatment 3 involved an integrated fertilizer application at half the rate used in Treatments 2 and 4 (Table 5). Basal dressing in Treatments 2, 3, and 4 were supplemented with a micronutrient mix known as NUTRIMAX®, which contains Magnesium oxide (MgO) - 6%, Calcium oxide (CaO) - 10%, Zinc (Zn) - 3%, Iron (Fe) - 1%, Manganese (Mn) - 0.75%, Copper (Cu) - 0.15%, and Sulphur (S) - 7%.

The compost used in the study was analyzed for its nitrogen content using the Kjeldahl method (Bremner and Mulvaney, 1982) and for available phosphorus content using the Olsen method (Watanabe and Olsen, 1965). The analysis indicated that the compost contained 1% nitrogen and 2% P_2O_5.

The height of two selected observational plants from each replicate was measured weekly for six weeks after transplanting (WAT) using a measuring ruler, and the average plant height for each treatment was calculated. Relative leaf chlorophyll content was assessed weekly for eight weeks using a hand-held SPAD-502-Plus leaf chlorophyll meter (Konica Minolta Sensing Inc., Japan). SPAD values were recorded from five distinct points on two selected leaves from the third leaf layer, counting from the top of the canopy. The average of these readings was calculated as the SPAD value.

At the first harvest, the number of pod-bearing branches was counted in two observational plants per replicate, and the average was calculated. The mean number of fruits harvested per plant was determined based on the total green mature fruit yield (g/plant) collected from two observational plants per replicate at each harvest. The total chilli yield (g/plant) was then calculated by summing the yields from two harvests.

For each harvest, pod length and diameter were measured in five randomly selected green pods from each replicate, and the average pod length and diameter were calculated. Additionally, growing media samples were collected weekly up to eight weeks after transplanting (WAT) from a depth of 10 cm from two observational pots per treatment before the application of fertilizers. The pH (1 part medium: 2.5 parts water) and Electrical Conductivity (1 part medium: 5 parts water) of air-dried media samples were analyzed.

Data were analyzed using SAS software (SAS Institute, 2002), version 9.0. Vegetative traits, reproductive traits, and medium properties were subjected to analysis of variance (ANOVA). The count data were log-transformed before analysis to ensure homogeneity of variance and normality of residuals. Comparisons among treatment means were performed using the least significant difference (LSD) test at a 0.05 significance level.

3. Results and Discussion

3.1 Yield and yield attributes

3.1.1 Pod yield

The results presented in Fig. 1 reveal a significant difference in pod weight among treatments for both the first and the second harvest, highlighting the effectiveness of the applied methods. Treatment 1, which utilized Albert's solution in a medium of coir dust and partially burnt paddy husk, recorded the highest initial chilli pod weight. However, this difference was not statistically significant compared to the yield achieved with organic nutrient management (ONM). The ONM method involved weekly split applications of compost and a growing medium consisting of a 1:1:1 ratio of topsoil, compost, and partially burnt paddy husk. Treatment 2, which employed a growing medium of topsoil, compost, and partially burnt paddy husk in a 1:1:1 ratio with inorganic fertilizers, exhibited a significantly lower chilli pod yield. Meanwhile, the pod yield in integrated nutrient management (INM) was not significantly different from that of ONM.

In the second harvest, Treatments 3 (INM) and 4 (ONM) produced significantly higher chilli pod yields compared to the control. Among these, Treatment 3 (INM) in a soil-based medium achieved the highest pod yield of 197.11 g/plant. Pod yields in Treatments 1 and 2 were significantly lower compared to Treatments 3 and 4, with reductions of 28% and 43%, respectively, in comparison to Treatment 3 (Fig. 2).

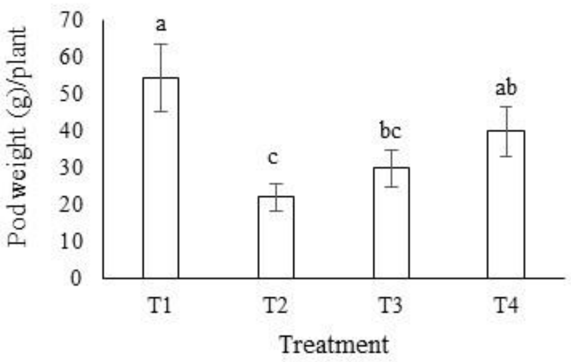

Figure 1. Effect of inorganic, INM and ONM on green chilli yield in harvest no. 1 (Treatments; 1- Coir dust + partially burnt paddy husk (1: 1) medium with Albert's solution; 2- Topsoil + compost + partially burnt paddy husk (1:1:1) medium with inorganic fertilizers; 3- Topsoil + compost + partially burnt paddy husk (1:1:1) medium with INM; 4- Topsoil + compost + partially burnt paddy husk (1:1:1) medium with ONM)
Bars sharing the same letter are not significantly different ($p < 0.05$)

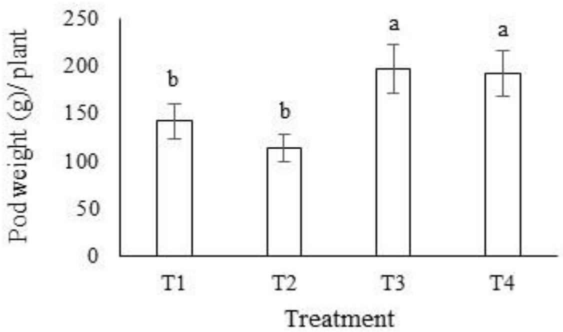

Figure2. Effect of inorganic, INM and ONM on green chilli yield in harvest no. 2 (Treatments 1- Coir dust + partially burnt paddy husk (1: 1) medium with Albert's solution; 2- Topsoil + compost + partially burnt paddy husk (1:1:1) medium with inorganic fertilizers; 3- Topsoil + compost + partially burnt paddy husk (1:1:1) medium with INM; 4- Topsoil + compost + partially burnt paddy husk (1:1:1) medium with ONM)
Bars sharing the same letter are not significantly different ($p < 0.05$)

The cumulative pod yields from the first and second harvests showed significantly higher yields in Treatments 1, 3, and 4 than in Treatment 2, which relied solely on inorganic fertilizers. When cultivating chilli plants in a growing medium composed of topsoil, compost, and partially burnt paddy husk in a 1:1:1 ratio, INM increased pod yield by 15%, while ONM resulted in a 17% increase compared to the use of Albert's solution in a soilless growing medium (Table 6).

Table 6. Effect of organic, inorganic and INM on the yield sum of two harvests of green chilli

Treatment	Yield (g/plant) Harvest 1 + 2
1	205.5± 22 a
2	144.4± 16 b
3	235.8± 26 a
4	241.0± 26 a
P- value	0.0029

3.1.2 Secondary branches

Secondary branches in chilli plants significantly influence yield and overall productivity. Treatment 1 exhibited the highest number of secondary branches, followed by Treatments 3 and 4. Conversely, Treatment 2, which employed inorganic fertilizers in a medium composed of topsoil, compost, and partially burnt paddy husk in a 1:1:1 ratio, recorded the lowest number of secondary branches (Table 7).

3.1.3 Pod numbers

The number of pods per chilli plant, a critical determinant of productivity, varied significantly across treatments. During the first harvest, Treatment 1 recorded the highest pod count, followed by Treatment 4, with no statistically significant difference between these two treatments. In contrast, Treatments 3 (INM) and 2 (inorganic fertilizers) displayed significant reductions in pod numbers, with decreases of 34% and 42%, respectively, compared to Treatment 1 (Table 7).

In the second harvest, Treatment 3 (INM) recorded the highest pod count, which was not significantly different from that of Treatment 4 (ONM). Treatments 1 and 2 ranked third and fourth, respectively, with pod counts reduced by 35% and 45% compared to Treatment 3 (Table 7).

Table 7. Yield attributes as influenced by different nutrient management approaches

Treatment	No. of branches	No. of pods	
		1st harvest	2nd harvest
1	22.1±1.6 a	11.3±1.5 a	28.1±4.5 bc
2	11.8±0.9 c	6.5±0.9 c	23.8±3.8 c
3	16.6±1.2 b	7.5±1.0 bc	43.1±6.9 a
4	16.1±1.2 b	9.7±1.3 ab	34.5±5.5 ab
P- value	0.0001	0.0052	0.0095

3.2 Plant height and SPAD value

3.2.1 Plant heights

Significant variations in plant heights were observed across treatments. Treatments 3 and 4, which involved a growing medium comprising topsoil, compost, and partially burnt paddy husk in a 1:1:1

ratio using INM and ONM, respectively, produced significantly taller plants. In contrast, Treatment 2 resulted in the shortest plants. Interestingly, there was no significant difference in plant height between Treatments 1 and 2 (Fig. 3).

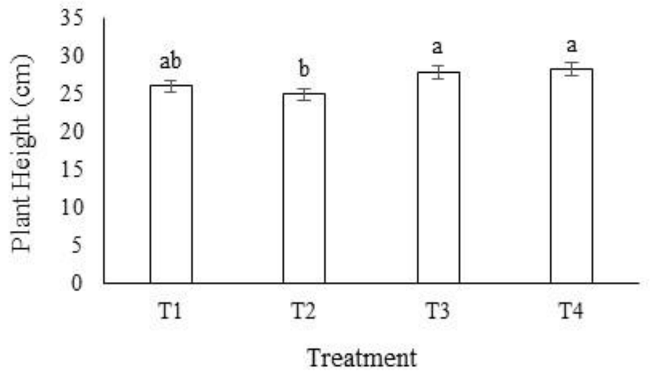

Figure 3. Effect of inorganic, INM and ONM on the height of green chilli

Bars sharing the same letter are not significantly different ($p < 0.05$)

3.2.2 SPAD Values

The interaction between treatment and weeks after transplanting significantly influenced SPAD values. Albert's solution in coir dust and partially burnt paddy husk (1:1) medium showed the lowest SPAD value, which increased over the cropping period. Treatments 2 and 3, which used a 1:1:1 mixture of topsoil, compost, and partially burnt paddy husk with inorganic fertilizers and INM, respectively, displayed the highest SPAD values, with fluctuations observed throughout the cropping period. Treatment 4 (ONM) showed no significant differences in SPAD values from weeks 1 to 8 after transplanting (Table 8).

Table 8. SPAD value as influenced by different nutrient management approaches

The week after transplanting (WAT)	Treatment 1	Treatment 2	Treatment 3	Treatment 4
1	29.0±0.8 o	40.4±1.1 mn	43.7±1.2 lm	45.5±1.2 kl
2	40.2±1.1 n	54.4±1.4 cd	53.5±1.4 c-f	47.2±1.2 jk
3	43.2±1.1 l-n	54.5±1.4 cd	49.3±1.3 h-j	48.2±1.3 i-k
4	47.6±1.3 i-k	53.7±1.4 c-e	52.4±1.4 d-h	49.8±1.3 g-j
5	49.8±1.3 g-j	58.4±1.5 a	58.3±1.5 ab	52.6±1.4 d-g
6	47.9±1.3 i-k	54.8±1.4 b-d	55.9±1.5 a-d	50.7±1.3 e-i
7	48.2±1.3 i-k	48.0±1.3 i-k	53.1±1.4 c-g	50.2±1.3 f-j
8	49.0±1.3 h-j	56.5±1.5 a-c	58.3±1.5 ab	53.1±1.4 c-f
P- value				
Treatment (TRT)			<.0001	
The week after Transplanting (WAT)			<.0001	
TRT*WAT			<.0001	

Treatments; 1- Coir dust + Partially burnt paddy husk (1: 1) medium with Albert's solution; 2- Topsoil + compost + partially burnt paddy husk (1:1:1) medium with inorganic fertilizers; 3- Topsoil + compost + partially burnt paddy husk (1:1:1) medium with INM; 4- Topsoil + compost + partially burnt paddy husk (1:1:1) medium with ONM

Means followed by the same letter within each column are not significantly different ($p < 0.05$).

3.3 pH and EC of the growing medium

3.3.1 pH

At the start of the study, the pH of all growing media was within the optimal range of 5.8–6.8 for plant growth. This range was maintained across all treatments during the first four weeks. However, by the eighth week after transplanting, pH levels declined in Treatments 2 and 3, which utilized a growing medium of topsoil, compost, and partially burnt paddy husk in a 1:1:1 ratio with inorganic fertilizers and INM, respectively. Treatment 2 recorded a pH of 5.5 by the eighth week, whereas Treatment 4 (ONM) maintained a pH of 6.7 (Fig. 4).

3.3.2 Electrical conductivity (EC)

Treatment 1, which utilized a coir dust and partially burnt paddy husk (1:1) medium with Albert's solution, exhibited the lowest EC values. The EC values of the other three treatments remained within the optimal range of 1000–1500 µS/cm for a standard growing medium (Singh *et al*., 2010). Treatment 3 (INM) consistently maintained EC values within this range throughout the cropping period (Fig. 5). Treatments 1, 2, and 3 displayed similar trends, while Treatment 4 (ONM) showed a decreasing trend in EC from weeks 2 to 8 after transplanting. Treatment 2, which used inorganic fertilizers, recorded the highest EC values, whereas Treatment 1 displayed the lowest (Fig. 5).

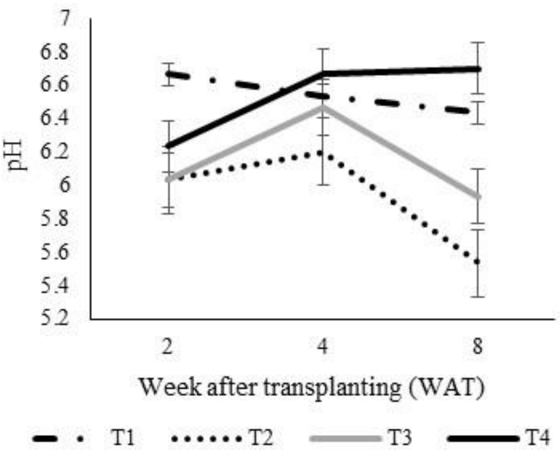

Figure 4. Effect of inorganic, INM and ONM on green pH of growing medium (Treatments; 1- Coir dust + partially burnt paddy husk (1: 1) medium with Albert's solution; 2- Topsoil + compost + partially burnt paddy husk (1:1:1) medium with inorganic fertilizers; 3- Topsoil + compost + partially burnt paddy husk (1:1:1) medium with INM; 4- Topsoil + compost + partially burnt paddy husk (1:1:1) medium with ONM)

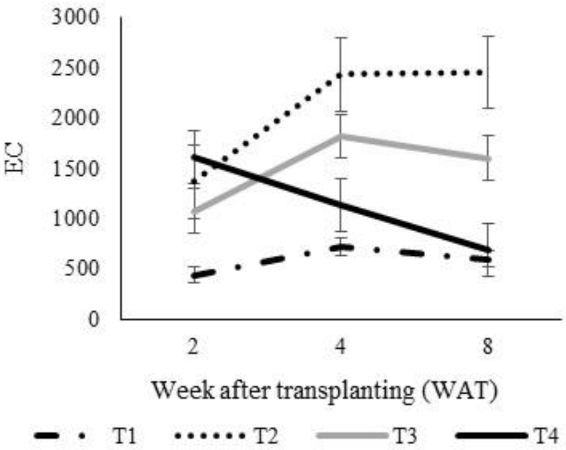

Figure 5. Effect of inorganic, INM and ONM on EC of growing medium (Treatments; 1- Coir dust + partially burnt paddy husk (1: 1) medium with Albert's solution; 2- Topsoil + compost + partially burnt paddy husk (1:1:1) medium with inorganic fertilizers; 3- Topsoil + compost + Partially burnt paddy husk (1:1:1) medium with INM; 4- Topsoil + compost + partially burnt paddy husk (1:1:1) medium with ONM)

4. Discussion

This study demonstrates the significant impact of the growing medium and nutrient management methods on the growth, yield, and yield attributes of green chilli. Additionally, the study highlighted how these approaches influenced the properties of the growing medium, such as pH and electrical conductivity (EC), which are critical for nutrient availability and plant uptake (Olle et al., 2012). The results revealed notable increases in chilli yields under two specific treatments during the first harvest: Treatment 1, where plants were grown in a soilless medium composed of a 1:1 mixture of coir dust and partially burnt paddy husk with Albert's solution, and Treatment 4, where a 1:1:1 ratio of topsoil, compost, and partially burnt paddy husk was used alongside weekly compost applications.

Albert's solution in Treatment 1 is recognized for its well-balanced nutrient composition, which supports vigorous growth across various plant species, including chilli (Szakiel et al., 2011). The combination of coir dust and partially burnt paddy husk likely provided optimal physical conditions for chilli growth and development. Treatment 4, which employed organic manures, aligns with existing research demonstrating that organic materials improve soil fertility and gradually release nutrients to plants, enhancing growth (Adugna, 2016). This finding corroborates literature highlighting the benefits of organic amendments in enhancing soil fertility and moisture retention, thereby supporting crop productivity (Omondi et al., 2016).

In contrast, while inorganic fertilizers can promote plant growth through their high nutrient content, their reduced effectiveness on pod development in this study may be attributed to suboptimal nutrient availability or imbalanced nutrient ratios (Etesami & Alikhani, 2019). Furthermore, splitting compost applications into weekly doses, as opposed to a single application before planting, proved more effective in improving yields.

The increased pod weight during the second harvest was primarily observed in Treatments 3 and 4, likely due to the sustained nutrient release provided by Integrated Nutrient Management (INM) and Organic Nutrient Management (ONM). Organic manures are known for their ability to release nutrients gradually, ensuring a steady supply that supports pod development (Das and Avasthe, 2018). By contrast, Treatment 2 displayed reduced pod weights, potentially owing to the rapid nutrient release characteristic of inorganic fertilizers (Pahalvi et al., 2021). While these fertilizers may boost early growth, they are less effective in sustaining long-term plant development (Steiner et al., 2007).

The cumulative pod weight reflected the benefits of extended and balanced nutrient release associated with ONM and INM strategies, as well as the balanced nutrient profile of Albert's solution, all of which contributed to enhanced productivity (Siedt et al., 2021).

This study also investigated the influence of the growing medium and nutrient management on vegetative growth and branching. Treatments involving Albert's solution with a coir dust and partially burnt paddy husk medium (Treatment 1) and organic manures (Treatments 3 and 4) recorded the highest branching and tallest plants. These findings suggest that these media and nutrient management practices promote vegetative growth and branching. This observation aligns with studies demonstrating the positive effects of organic materials on vegetative growth (Caplan et al., 2017), attributed to their ability to provide a balanced nutrient supply (Gransee and Führs, 2013).

SPAD values, which reflect chlorophyll content and plant health, varied across treatments. Treatment 1 exhibited the lowest SPAD values, potentially indicating plant stress or reduced chlorophyll production. Conversely, Treatments 2 and 3 recorded higher SPAD values, suggesting improved chlorophyll content and reduced stress. The fluctuations in SPAD values during the cropping period for these treatments could be linked to variations in nutrient availability. INM, in particular, has been shown to improve plant health through balanced nutrient availability (Aslam et al., 2022). Meanwhile, Treatment 4 displayed stable SPAD values throughout the cropping period, which could be attributed to the slow nutrient release associated with organic manures, ensuring consistent plant health (Shaji et al., 2021).

Soil pH, a critical determinant of nutrient availability and microbial activity, showed variations during the study. Initially, all growth media had pH levels within the optimal range of 5.8–6.5, conducive to chilli cultivation (Mayfield et al., 2004). By the eighth week, pH declined in Treatments 3 and 4, likely due to organic acid release during compost decomposition or nitrification processes linked to INM (Singh and Amberger, 1997; Graham et al., 2017). Treatment 2, which relied solely on inorganic fertilizers, had a pH of 5.6, slightly below the optimal range, likely due to soil acidification effects of the fertilizers (Barak et al., 1997). In contrast, Treatment 4 exhibited a pH of 6.7, slightly above the optimal range, potentially due to the alkaline properties of organic manures or the neutralizing effect of compost (Chang et al., 2007).

Electrical Conductivity (EC), an indicator of soil salinity and dissolved salt concentration, also varied across treatments. Elevated EC levels can negatively affect plant growth by causing osmotic stress or nutrient imbalances (Bernstein, 1975). The optimal EC range for chilli cultivation is 1000–1500 µS/cm (Singh et al., 2010). Treatment 1 consistently exhibited lower EC values, suggesting the need to adjust nutrient concentrations during key growth stages. Treatments 2, 3, and 4 maintained EC values within the optimal range. Treatment 3, with stable EC levels throughout the study, demonstrated effective nutrient balance. In contrast, the declining EC values observed in Treatment 4 reflected the gradual nutrient release associated with compost (Coppens et al., 2016). Treatment 2 recorded the highest EC values, likely due to the rapid dissolution of salts from inorganic fertilizers (Ahmad et al., 2018).

5. Conclusion

The study demonstrates that both the composition of the growing medium and the nutrient management strategy significantly affect green chilli growth, yield, and yield attributes under polytunnel conditions. Cultivating chilli in a soil-based medium of topsoil, compost, and partially burnt paddy husk (1:1:1) combined with Integrated Nutrient Management (INM) or Organic Nutrient Management (ONM) consistently produced higher pod yield, pod number, plant height, SPAD values, and secondary branching compared to a soilless medium with Albert's solution. INM and ONM also maintained optimal pH and electrical conductivity, supporting better nutrient availability and plant health. Treatments relying solely on inorganic fertilizers showed reduced growth and yield, highlighting the advantages of organic and integrated approaches. These findings support the adoption of INM and ONM as sustainable strategies for improving the productivity of chilli in protected cultivation.

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