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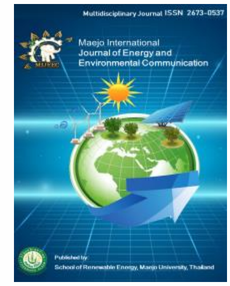

ARTICLE

Energy-efficient irrigation methods and employing polytunnels for sustainable tomato production in Thailand

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A B S T R A C T

The sustainable production of tomatoes (*Lycopersicon esculentum* Mill.) necessitates adopting efficient irrigation methods and protective cultivation techniques to enhance yield and minimize environmental impact. This study investigated the effects of drip irrigation and subsurface irrigation (porous pipe) combined with the use of polytunnels on tomato growth and yield. The experiment employed a three-factorial design with four treatments replicated across four blocks. The treatments included two irrigation systems (drip and porous pipe) and the presence and absence of polytunnels. Results demonstrated that polytunnels significantly increased plant biomass production from the third week onwards and improved overall yield with an average of 77.67 g ± 0.05 compared to no tunnel conditions with 31.06 g ± 0.05. The plant height in polytunnels was 73.48 cm ± 0.05, while in no-tunnel, it was 70.64 cm ± 0.05; however, the difference was statistically insignificant. Drip irrigation outperformed porous pipe irrigation in terms of plant height and yield throughout the growing period. Drip irrigation produced an average plant height of 73.2 cm ± 0.05 and a yield of 81.5 g ± 0.05 per plant, while porous pipe had an average plant height of 69.38 cm ± 0.05 and a yield of 27.28 g ± 0.05. The combination of drip irrigation and polytunnel yielded the highest overall output in this experiment with a 242.63 g ± 0.05 yield, highlighting the potential of combining efficient irrigation methods with protective cultivation to optimize tomato production. These findings offer valuable insights into enhancing the overall efficiency and productivity in tomato cultivation, particularly during the rainy season conditions prevalent in Thailand.

1. Introduction

Sustainable plant production requires appropriate agronomic practices and irrigation methods that improve crop yield and quality while minimizing environmental impacts. Water is essential in agriculture as it fulfills plants' needs (Ariyanto et al., 2019). According to (Wriedt et al., 2008), it is a vital need as it transports nutrients and chemical signals, regulates cellular activities, and is a part of photosynthesis. It is essential in biomass production. Beyond its direct effects on plant growth, it affects soil microbial activity, improving nutrient mineralization, soil health, and fertility (Nguyễn et al., 2024). Improved irrigation aims to provide a high yield per unit area and conserve irrigation water (Dung et al., 2016). Various irrigation techniques are presently employed globally, including sprinklers, drip, furrows, etc. (Rahayu et al., 2021). Direct water application to the root

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zone through drip irrigation is widely recognized as the most efficient method, as it minimizes water loss by evaporation and maximizes water utilization (Kunze et al., 2021). Despite its many advantages, drip irrigation is not a perfect solution for achieving maximum water efficiency, as 100% efficiency cannot be guaranteed (Kunze et al., 2021). In agricultural practice, the efficiency of a drip irrigation system is affected by various factors, including the quality of its setup and the position of the emitters. Aside from technical factors, such as water loss from damaged pipes, planning the correct water application rate is the most crucial aspect that impacts the system's efficiency. The correct crop water requirement (CWR) calculation in drip irrigation is based on crop evapotranspiration (ETc). Based on a sound calculation approach, drip irrigation is a well-established method for irrigation while conserving natural resources, such as groundwater (Rahayu et al., 2021).

Energy-efficient irrigation methods are vital in promoting sustainable agriculture, particularly when water and energy resources are limited (Silva et al., 2017). Subsurface drip irrigation (SDI) is a method that significantly reduces energy consumption by minimizing the need for high-pressure water delivery. By delivering water directly to the plant roots, SDI improves water use efficiency (WUE) and reduces water loss through evaporation, leading to lower overall energy use. Similarly, porous pipe irrigation operates at low pressure, distributing water uniformly along the pipe's entire length, further enhancing WUE while minimizing energy requirements. This system also provides water directly to the root zone, ensuring consistent moisture levels and reducing the energy needed for water transport and application. Integrating these systems with solar-powered pumps can enhance energy efficiency by utilizing renewable energy sources, reducing reliance on traditional energy, and lowering greenhouse gas emissions (Souvannasouk et al., 2021; Thivagaran et al., 2023).

Additionally, automated irrigation systems, equipped with sensors and controllers, optimize water delivery by applying water only when needed, further conserving water and energy. Using energy-efficient water pumps and variable frequency drives (VFDs) also reduces energy consumption by adjusting pump operation based on demand. By adopting these energy-efficient irrigation techniques, farmers can achieve significant resource savings while maintaining or even improving crop yields, contributing to agriculture's overall sustainability and economic viability (Gammatantrawet et al., 2023; Susawaengsup et al., 2022).

To further improve efficiency, drip irrigation is often used as subsurface drip irrigation, where the irrigation pipes are buried below the surface or introduced into a dam to reduce evaporation. More recently, porous pipe irrigation has been used in subsurface irrigation. It is an example of a type of subsurface irrigation that applies water directly to the root of the plant uniformly. It operates at low pressure, and the entire pipe body acts as an emitter, creating minimal differences in water content along its length (Kunze et al., 2021). Being buried beneath the crop row minimizes evaporation, theoretically enabling a 100% water use efficiency (WUE). As water is delivered directly to the plant roots, WUE is higher in porous pipe irrigation than drip irrigation (Kunze et al., 2021). Despite their advantages, porous pipes are not widely adopted in irrigated agriculture due to deterioration and the requirement for high-quality water and permanent subterranean installation. Combining crop irrigation and fertilization can enhance WUE, increasing yields (Phuntsho et al., 2011) and improving nutrient efficiency (Isah et al., 2014.)

Tomato (*Lycopersicon esculentum* Mill.) is an essential vegetable crop worldwide (Siliva et al., 2017). The production of tomatoes in Thailand has increased in recent years due to the rising demand for fresh and processed tomatoes domestically and in export markets (Rugchat, 2021). To ensure the long-term sustainability of tomato production, it is crucial to implement suitable farming practices, including irrigation strategies. These help enhance yield and reduce environmental detrimental effects (Heiba et al., 2023). Furthermore, the choice of these practices must be guided by the specific needs of the tomato plants, the local climate conditions, and the available resources. This holistic approach ensures a balance between productivity and sustainability, contributing to Thailand's more resilient and efficient agroecosystem. As a result, it is crucial to have a reliable irrigation system. Irrigation is a critical aspect of agriculture, notably where rainfall may not support crops. Thailand faces significant challenges due to water constraints, especially during the dry season when water supplies are scarce.

Tomatoes have a high water requirement and respond well to a sufficient water supply with high biomass formation while only moderately tolerant to drought (Zheng et al., 2013; Karlberg et al., 2007). Therefore, suitable irrigation methods should be able to supply water efficiently in short intervals at a sufficient rate. Water is particularly crucial during crop establishment, flowering, and fruit formation. It influences various attributes such as plant height, leaf count, and branch numbers (Rahayu et al., 2021). Xiukang and Yingying (2016) stated that increased irrigation levels boosted tomato yield and fertilizer rate but decreased WUE.

In contrast, reduced water availability often diminishes growth and physiological components. Still, it may enhance certain aspects of fruit quality, such as acid composition or the formation of secondary metabolites, such as lycopene (Jumawati et al., 2014). However, Helyes et al. (2012) reported that irrigated plants yielded significantly more tomatoes, and a better water supply resulted in a higher sugar content (°Brix) yield than rainfed ones.

In Thailand, approximately 60-70% of all tomatoes are sold in the fresh market. The primary tomato-growing regions are situated in the north and northeast of the country, with the highest yields reported in Chiang Mai, Sakon Nakhon, Nakhon Phanom, and Nong Khai (Thailand, 2020). Open-field and greenhouse methods are utilized for tomato cultivation in Thailand, with open-field cultivation being prevalent due to the country's favorable climate (Rosset et al., 2021). In the open field, tomatoes are primarily grown during the dry season. During the rainy season, high disease pressure and the impact of water and wind on the plant make open-field cultivation nearly impossible. However, as Thai tomato farmers face the challenges of market globalization, shrinking cultivable lands, and climate change, protected cultivation emerges as a promising option for achieving high yields. This technology, which involves controlling the climate around the plant to shield the crop from adverse conditions, is gaining traction in tropical countries for high-value flower and vegetable cultivation (Maitra et al., 2020). In terms of water supply, protected cultivation is most suitable for tomato production, as it supplies the plants with water and nutrients to the roots.

In contrast, the shoots are protected from contact with water to which tomato plants are susceptible. However, given the high cost of modern greenhouses, many Thai farmers need help to use protected cultivation. Polytunnel cultivation is a simple form of protected cultivation that does not include complete control of the production climate. Still, it offers several benefits, including opportunities for season extension, improved yield and quality, crop risk reduction, and intensive production capabilities on limited land areas (Waterer, 2003; O'Connell et al., 2012; Drost and Wytsalucy, 2014). It has proven to be a viable alternative to open-field tomato production. Adequate water and sunlight are crucial in tomato production, as they directly impact yield. Technology presents a feasible solution for farmers seeking to cultivate tomatoes year-round without fearing excessive rainfall or temperature fluctuations (Badimo, 2020). The present study examines the impact of irrigation methods and polytunnels on tomato growth and yield. It aims to determine how the Eber variety responds to the use and the absence of polytunnel, as well as to determine the optimal irrigation system and best treatment combination for Thai farmers during the rainy season.

2. Material and methods

2.1 Experimental site

This study was conducted during the rainy season from June 2022-August 2022 at the organic research field of the International College, Maejo University, Chiang Mai, Thailand (18°54'54.0"N 99°03'25.7" E). The soil is a sandy loam with a pH of 6.98, Organic matter of 2.03%, available phosphorus of 96.10 mg/kg, and exchangeable potassium of 63.38mg/kg. Pest and disease monitoring was done daily through visual assessment. In response to pest infestation, neem oil, and surfactant were significantly applied throughout the planting season. Trichoderma was also used on the field three weeks after transplanting to the open field, and this was done once. Pest and disease management was uniformly applied to all experimental blocks. Hand weeding was done once weekly, and Staking was done two weeks after transplanting.

2.2 Plant material

The tomato variety in this experiment was an organic variety known as "e-ber" (อีเบ๋อ), a local variety common in Thailand. It is a determinate type. The fruit they are small in size and has a sour taste; its color usually ranges from red to orange. The harvesting period is usually 60-70 days after transplanting. The seeds were obtained from the Maejo organic farm and were first planted in the nursery. They were allowed to grow for 4 weeks with proper nursery management practiced. Hardening off was done one week before transplanting to the open field. Transplanting of seedlings into the open field was done on the 16th of June 2022.

2.3 Poly tunnels

Furthermore, the polytunnels used were steel and covered with polyethylene plastic. They were semi-circular, with a width of 6 m and a length of 12 m. Some bamboo sticks were used to support the tunnels.

2.4 Irrigation systems

This study compared two irrigation systems: porous pipe irrigation and drip irrigation. Figure 1 shows the setup of the porous pipe irrigation system. The porous pipes were buried 15 cm into the soil. The system was operated at a pressure of 0.6 bars, as the entire body of the pipes emits water.

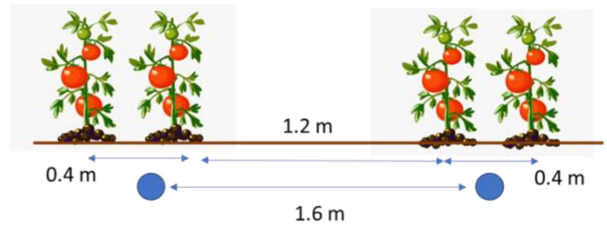

Figure 1. Row spacing and placement of the pipe in porous pipe irrigation

Figure 2 shows the setup of the drip irrigation system. Drip irrigation included drip lines were mounted as laterals. Emitter spacing was 30 cm, and water was also discharged at a pressure of 0.6 bars.

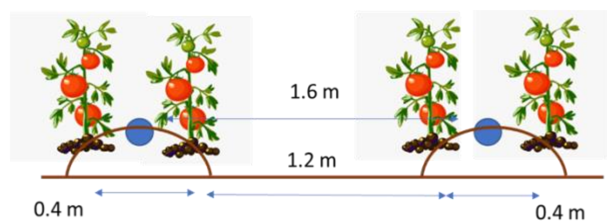

Figure 2. Row spacing and placement of the pipe in drip irrigation

To ensure good water quality, a disc filter was used as the primary filter at the inlet, and a mesh filter was installed as the secondary filter at the irrigation system's inlet and outlet.

2.5 Water requirement and irrigation planning

The initial irrigation scheduling was based on the assessment of long-term climate data provided by the Food and Agricultural Organization of the United Nations (FAO) on the CLIMWAT database (FAO, 2022). Monthly data are supplied on maximum air temperature (T_{max}), minimum air temperature (Tmin), mean relative humidity of the air (RH_{avg}), wind speed (u), and mean daily sunshine (R). Based on the data available, reference evapotranspiration (ET_0) was calculated using the modified FAO Penman-Monteith equation (Allen et al., 1998). Figure 4 shows the initial estimation of ET_0. Weather data for the experimental period were obtained from the weather station of the Field Crop Research Center of the Agricultural Service of Chiang Mai Province. Available data were Tmax, Tmin, and RH. ET0 was estimated based on the Hargreaves method (Hargreaves, 1982). The resulting estimation of ET0 was used to adjust the irrigation in the experiment (Figure 3).

Based on the climate data, the crop water requirement (CWR) was calculated based on Equation 1:

$$ET_{c\ tomato} = ET_0 * k_{c\ tomato} \qquad \text{Equation 1}$$

where ET_{c_tomato} is the potential crop evapotranspiration of a tomato crop, which was considered equivalent to CWR. According to Allen et al., 1998, the crop coefficient ($k_{c\ tomato}$) was assumed to be 0.2 for the initial phase after transplanting (initial stage) and 1.6 after full development of the tomato crop after 60 days (mid-stage). A linear increase for the time of crop development was assumed, resulting in the CWR values for the experimental period displayed in Figure 4.

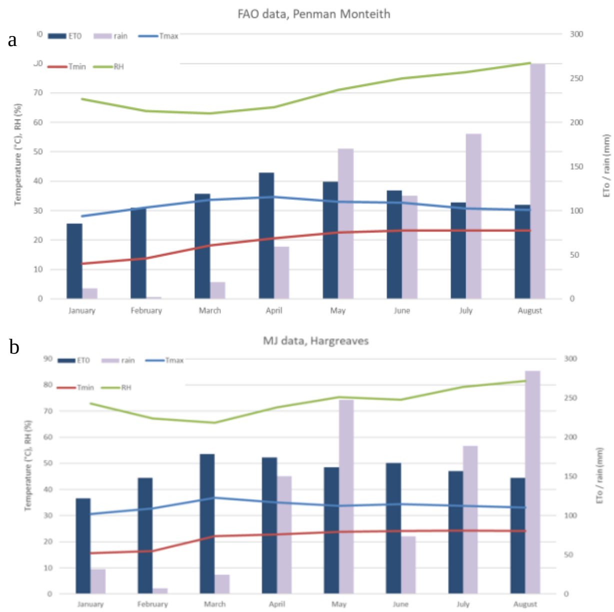

Figure 3. (a) Initial assessment of CWR based on FAO data; (b) Irrigation schedule based on data of the MJU meteorological station.

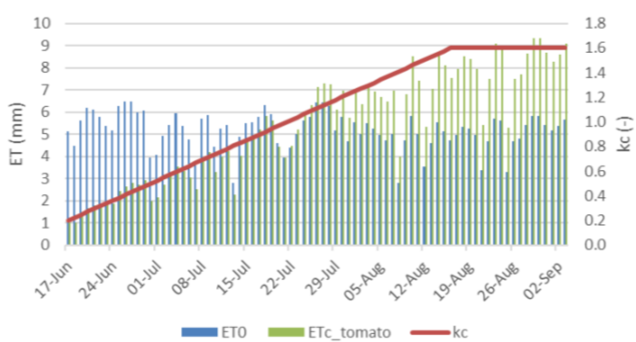

Figure 4. Evapotranspiration (ET_o), Crop Water Requirement of tomato (ET_c), and tomato crop coefficient of tomato during the experiment

2.6 Experimental setup

The experiment was a 2-factorial design with four treatments. The factors used were two irrigation systems (drip irrigation and porous pipe irrigation), polytunnels, and the absence of polytunnels. The experimental field was divided into 4 blocks. Two had drip irrigation, and the other had porous pipe irrigation. Each block was split into two halves, one with polytunnel and the other without polytunnels. Treatments were arranged in a partially randomized design within the four blocks. The tomato variety was randomly placed into two plots on each half, so all treatments were replicated once. Each plot had 3 rows of tomatoes. The two outer rows had the outermost plants, which served as a border for the plants in the central row. The central row had 8 plants per plot, used as the experimental units. Thus, a total of 16 plants were analyzed in a plot. Table 1 shows water applied under the different irrigation treatments.

Table 1. Water application under the different irrigation treatments.

	Polytunnel		No polytunnel
	Drip	Porous pipe	
Irrigation (mm)	159.5	161.6	0.0
Rainfall (mm)	0.0	0.0	503.1
Total water applied (mm)	159.5	161.6	503.1
ET_c	428.3	428.3	428.3

2.7 Data collection

The plant height measurement of the tomato variety was done every week (every Friday) using a measuring tape, which was done in centimeters (cm). The measurement was taken from the soil surface to the tip of the highest leaf. The collected plant height data was used to analyze the plant's growth rate. When Tomatoes reached ripeness, they were manually harvested; the first harvest was seen on the 2nd of August 2022; the harvested tomatoes were counted and weighed using a digital balance with the weight recorded in grams (g) and classified into marketable fruits.

2.8 Statistical analysis

Data were recorded and analyzed using SPSS for correlation and regression analysis. Coefficient of Variation (CV) analysis was done with SPSS ver. 16.0. Data was measured using the relative variability of a dataset by calculating the ratio of the standard deviation to the mean, multiplied by 100, to know the significance level of the table data to the research.

3. Result and Discussion

Water was regularly applied for the treatments under the polytunnels, while no irrigation was used outside. Figure 5 represents the temporal distribution of the water allocation. Based on the visual assessment of pests and diseases, bacterial wilt was present in all treatments but more severe in treatments without a polytunnel, resulting in low overall yields. Table 2 shows the difference in plant height between the utilization of polytunnels and non-polytunnels. During weeks 1 and 2 of planting, it was noted that plant height was greater under non-polytunnels. According to Zheng et al. (2023), this is because of light intensity and air circulation. However, a distinct shift occurred in week 3, with plants within the polytunnels displaying greater height.

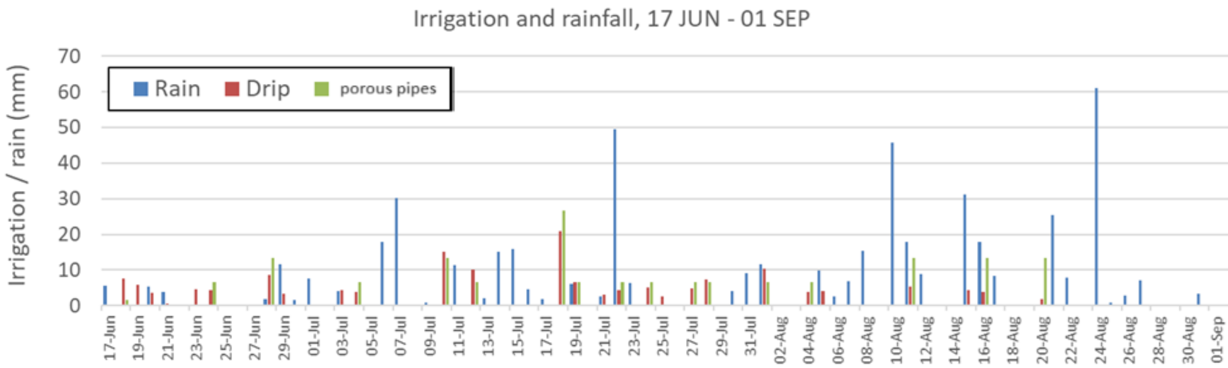

Figure 5. Water supply to the different treatments during the experimental period

Table 2. The effect of the use and absence of polytunnel on plant height and yield

Tunnel	Week1 (cm)	Week2 (cm)	Week3 (cm)	Week4 (cm)	Week5 (cm)	Week6 (cm)	Yield (g)
Poly tunnel	23.09	38.13	53.69	64.65	70.07	73.48	77.67
No Tunnel	25.17	39.78	51.76	62.00	66.15	70.64	31.06
SE±	0.68	1.18	2.00	2.34	2.44	2.51	13.08
CV(P=0.05)	0.26	0.01	0.00	0.01	0.00	0.00	0.00

CV= coefficient of variation, SE±= standard error, P= P value, if cv < 0.05 shows significant difference, if cv > 0.05 show no significant difference

Table 3. The impact of the Irrigation system on plant height and yield

Irrigation	Week1 (cm)	Week2 (cm)	Week3 (cm)	Week4 (cm)	Week5 (cm)	Week6 (cm)	Yield (g)
PP	23.13	36.79	50.09	62.96	66.92	69.38	27.28
Drip	24.84	40.46	54.27	63.22	68.27	73.2	81.51
SE±	0.68	1.18	2.00	2.34	2.44	2.51	13.08
CV(P=0.05)	0.01	0.07	0.04	0.08	0.04	0.02	0.00

PP=porous pipe, Drip= drip irrigation, CV= coefficient of variation, SE±= standard error P= P value, if cv < 0.05 shows significant difference, if cv > 0.05 show no significant difference

Table 4. The interactive effect of irrigation and tunnel on plant height and yield

IRR and TUN	Week1 (cm)	Week2 (cm)	Week3 (cm)	Week4 (cm)	Week5 (cm)	Week6 (cm)	Yield (g)
PP X Poly	22.55	34.55	49.91	63.00	66.91	68.82	47.82
PP X NoTu	26.85	40.69	55.31	65.00	66.92	69.85	93.85
DripXPoly	28.17	44.00	61.50	68.22	72.00	76.33	242.63
Drip&NoTu	25.70	40.85	53.35	62.73	67.23	71.04	29.54
SE±	0.89	1.33	2.14	2.45	2.58	2.68	21.98
CV (P=0.05)	0.06	0.85	0.12	0.40	0.64	0. 56	0.00

IRR= irrigation, TUN= tunnels, PPxPoly= interaction between porous pipe and use of polytunnels, PPxNotu= interaction between porous pipe and absence of tunnel, DripxPoly= interaction between drip irrigation and use of polytunnels, DripxNoTu = interaction between drip irrigation and absence of polytunnel

This pattern persisted throughout the planting season, with continuous growth in plant height within the polytunnels. This finding is consistent with the study of Rogers & Wszelaki. (2012). Which also recorded higher plant heights with the use of polytunnels. Plant height reached its peak at week 6. A significant contrast was evident when comparing the yield obtained from polytunnels and non-polytunnels, as polytunnels had more yield. This result agrees with Smith & Lee (2020), who reported increased yield using polytunnels.

Table 3 presents the comparative analysis of drip and porous pipe irrigation on plant growth and yield. Our findings reveal the influence of these irrigation methods on plant development. During week 1, a notable difference in plant height emerged, with plants subjected to drip irrigation exhibiting superior height. However, by week 2, no discernible variance was evident between the two irrigation systems. Interestingly, by week 3, a distinct trend emerged, with plants under drip irrigation displaying significantly greater height. This trend persisted through week 4, where no substantial differences were observed.

Notably, from week 5 until the culmination of the planting season, a consistent elevation in plant height was observed under drip irrigation, signifying a significant disparity. Moreover, plant yield between the two irrigation systems revealed a notable contrast, with drip irrigation yielding substantially and significantly higher outputs. This compelling evidence underscores drip irrigation's potential superiority in enhancing plant growth and yield.

Table 4 shows the interactions between various irrigation methods and the use of covers, namely polytunnels and no tunnels, on plant development and yield. When comparing the interaction of porous pipe irrigation with polytunnels against porous pipe irrigation with no tunnels, our findings unveil a consistent upward trajectory in plant height from week 1 to week 6.

However, no significant difference in plant height was discernible between these interactions. Notwithstanding, a notable contrast emerged in yield, with the interaction of porous pipe irrigation and no tunnel yielding higher outputs compared to porous pipe irrigation with polytunnels. Similarly, when scrutinizing the interactions between drip irrigation and cover types (polytunnel and no tunnel), a similar trend in plant height augmentation was observed across both interactions over the six weeks. Nevertheless, identical to porous pipe irrigation, no significant variance in plant height manifested between the interaction of drip irrigation with polytunnels and drip irrigation with no tunnels. Nonetheless, a noteworthy discrepancy surfaced in yield, with higher yields obtained from the interaction of drip irrigation with polytunnels. These findings underscore the nuanced dynamics between irrigation methods and cover types in influencing plant growth and yield, offering valuable insights for optimizing agricultural practices. The interaction of drip irrigation and polytunnels resulted in the highest overall yield.

The irrigation method significantly influenced plant height (Figure 6). Data reveal that drip irrigation performed better in plant height by producing in week 6 an average height of 73.2 cm ± 0.05 compared to porous pipe irrigation, which produced 69.38 cm ± 0.05 during the planting season. This agrees with the findings of (Kunze et al., 2021), who stated in their experiment that plant height was higher in drip irrigation than in eco-tube (porous pipe) irrigation. Also, drip irrigation gives a far better yield than porous pipe irrigation; drip irrigation gave a yield of 85.1 g ± 0.05, while porous pipe irrigation gave a yield of 27.28 g ± 0.05. This is in agreement with the findings of (Yang et al.; 2023), who stated that when drip irrigation is more (100–120%), drip irrigation significantly increases crop yields relative to porous pipe irrigation.

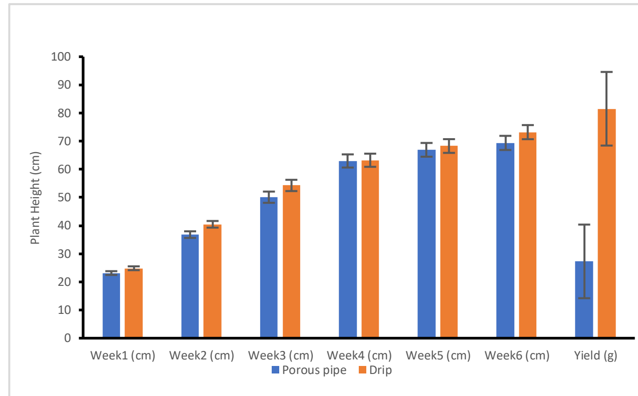

Figure 6. Plant height development and final fruit yield of e-ber tomatoes under drip and porous pipe irrigation

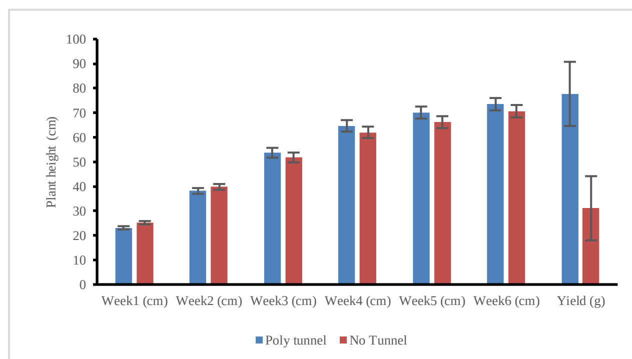

Figure 7. Plant height development and final fruit yield of e-ber tomatoes grown with and without polytunnels

Figure 7 shows the influence of tunnels (using polytunnels or no polytunnels) on plant height and yield. Polytunnels were used to protect the plants against direct rainfall and wind damage and prevent injury from insects and diseases. From the result shown in Figure 7, plant height was consistently higher across all weeks using the polytunnels than those without tunnels. in week 6, the highest average height was 73.48 cm ± 0.05 with polytunnels and 70.64 cm ± 0.05 without the tunnels. The yield was significantly higher with polytunnels at 77.67 g ± 0.05, whereas without polytunnels, the yield was low at 31.06 g ± 0.05. The use of polytunnels in tomato production has been found to increase yield, according to the findings of Rogers and Wszelaki (2012). This increase in yield can be attributed to the reduction of pests and diseases in organically grown tomato plants, as demonstrated by (Baysal et al., 2009). These results suggest that polytunnels can effectively enhance tomato yields, especially in organic farming systems where chemical control of pests and diseases is restricted. Observations during the experiment showed that tomatoes grown without the polytunnels had a higher incidence of pests and diseases due to excess rainfall. These findings highlight the importance of protective structures like polytunnels and adequate water management in mitigating the harmful effects of excess rainfall on tomato crops, ultimately leading to better yields. Moreover, polytunnels have been shown to provide additional benefits beyond reducing the incidence of pests and diseases, such as regulating temperature and humidity, extending the growing season, and protecting plants from adverse weather conditions. Figure 8 illustrates the effect of combining different irrigation systems using polytunnels or no polytunnels on tomato plant height and yield.

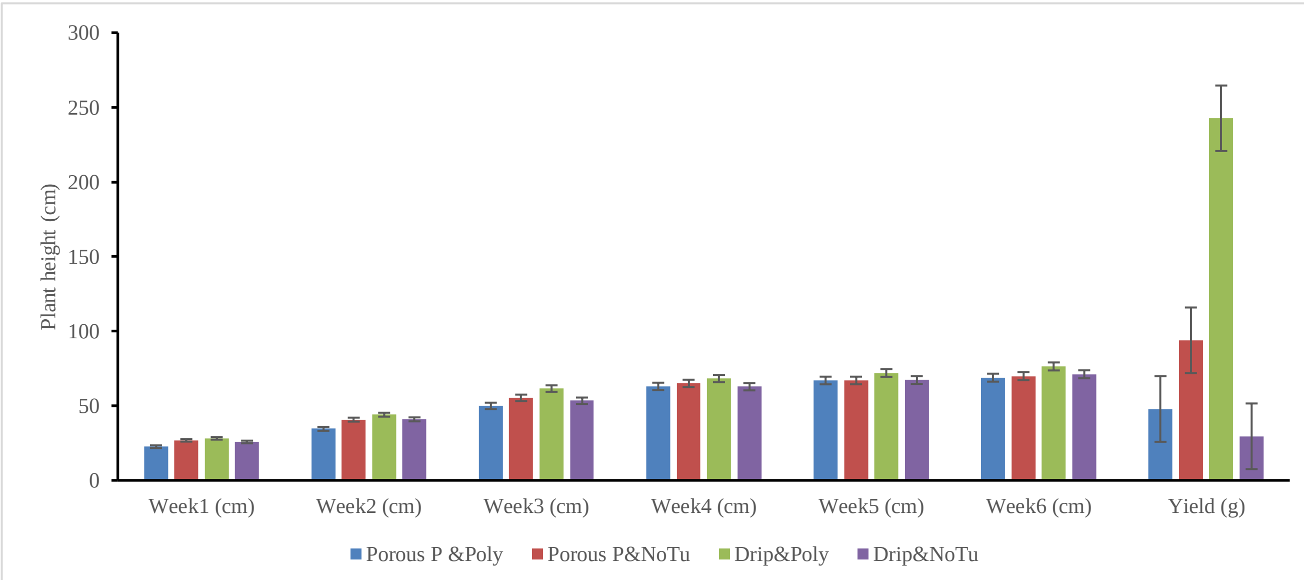

Figure 8. Combined effects of irrigation and the use of polytunnels on plant height development and final yield of e-ber tomatoes.

Comparing the combination of porous pipe irrigation with and without polytunnels, the result indicates that plant height was slightly higher without using polytunnels. Notably, the plants under porous pipe with no tunnels attained a height of 69.85cm ± 0.05 by week 6 compared to 68.82cm ± 0.05 for the porous pipe and polytunnels combination. Although there is a slight variation in height, it is statistically insignificant. However, comparing the yields obtained with porous pipe and no tunnels combination, a significantly higher yield of 93.85g ± 0.05 compared to porous pipe combination with tunnels, which had 47.82g ± 0.05. This significant difference in yield suggests that, while the absence of polytunnels has no significant effect on plant height, it significantly impacts yield, favoring the non-polytunnel design in this situation.

Furthermore, the combination of drip irrigation and polytunnel had a height of 76.33 cm ± 0.05, higher than 71.04 cm ± 0.05 observed with drip irrigation and no tunnels. Although there is a slight variation in plant height, it is statically insignificant; the yield results were notably different as more yields were obtained from the combination of drip and polytunnels 242.63g ± 0.05 compared to a significantly lower yield of 29.54g for the combination of drip and no tunnels. Overall, the best yield was achieved using drip irrigation and polytunnels. This exceptionally high yield in drip irrigation can be explained by the adequate amount of water delivered to the plant root zone and the efficient water saving. Drip irrigation, according to Banik et al. (2004), enhances crop growth and productivity by providing water precisely. According to their study, drip irrigation frequently outperforms other irrigation techniques regarding various growth parameters such as plant height, dry matter accumulation tiller number, and yield. On the other hand, in this research, high rainfall created runoff in porous pipe irrigation, which resulted in water loss and decreased irrigation system performance.

4. Conclusion

The research evaluated the impact of different irrigation methods, specifically drip, eco-tube irrigation, and polytunnels, on Thailand's sustainable tomato production. The findings revealed that drip irrigation was significantly more efficient regarding water use than porous pipe irrigation. This increased efficiency is crucial in Thailand, where water conservation is vital due to varying climatic conditions. The relatively poor performance of the porous pipe irrigation system was attributed to the local soil type and structure. The soil in the test area was prone to compaction after exposure to rainfall, leading to suboptimal water infiltration and root aeration. In the drip irrigation setup, a dam was constructed to lay the drip pipes on top, ensuring better soil aeration during non-irrigation periods. This setup allowed water to infiltrate the dam efficiently, enhancing overall irrigation effectiveness. In contrast, the porous pipe system, which operates as a subsurface irrigation method, has the advantage of reducing evaporation losses and increasing application efficiency. However, during the rainy season, these evaporation losses are minimal, diminishing the benefits of the porous pipe system. Polytunnels, another aspect of the study, were found to have a significant positive impact on tomato yield. By creating a controlled environment, polytunnels mitigated the adverse effects of environmental factors such as temperature fluctuations, strong winds, pests, and diseases. This led to a more consistent and higher yield, particularly in areas with prevalent environmental challenges. Beyond the agricultural benefits, these methods also offer substantial ecological advantages. The controlled use of water in drip irrigation systems helps to minimize water wastage and preserves local water resources, which is especially important in regions experiencing water scarcity. Moreover, combining polytunnels and targeted irrigation reduces the dependency on chemical pesticides and fertilizers. This lowers the environmental footprint of tomato production and contributes to the conservation of local biodiversity and the overall health of ecosystems. In conclusion, the study strongly recommends using polytunnels to enhance tomato production and extend the growing season, particularly during the rainy season when environmental conditions are less favorable. Additionally, it highlights the need for further research to optimize the layout and effectiveness of irrigation systems, ensuring that they can be tailored to specific soil types and environmental conditions for maximum agricultural and ecological benefits.

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