
Efficiency of a solar-powered automated drip irrigation system in enhancing yield and quality of durian and mangosteen in Eastern Thailand

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Abstract The results demonstrated that irrigation system significantly influenced flowering, fruit set, yield components, and fruit quality in both durian and mangosteen. The solar-powered automated drip irrigation system (SPADIS) produced significantly higher flowering percentages than the conventional sprinkler emitter irrigation system (CSEIS) in durian ($78.40 \pm 1.80\%$ vs. $68.50 \pm 2.20\%$, $P < 0.01$) and mangosteen ($55.80 \pm 2.00\%$ vs. $45.20 \pm 1.60\%$, $P < 0.01$). Fruit set in both durian and mangosteen was significantly enhanced under SPADIS compared with CSEIS. Regarding yield components, SPADIS significantly increased the number of fruits per tree in durian (25.40 ± 2.10) and mangosteen (115.00 ± 10.50). Total fruit weight was significantly higher in mangosteen under SPADIS (52.00 ± 4.20 kg/tree) than under CSEIS (48.00 ± 3.80 kg/tree), while durian yield was also significantly greater under SPADIS (88.00 ± 8.50 kg/tree). In terms of fruit quality, total soluble solids (TSS) were significantly higher under SPADIS in both durian (33.50 ± 0.80 °Brix) and mangosteen (19.50 ± 0.60 °Brix) ($P < 0.01$). In contrast, CSEIS produced significantly firmer durian fruit (14.50 ± 0.90 N), whereas mangosteen fruit firmness was significantly higher under SPADIS (8.20 ± 0.40 N). Linear regression analysis revealed strong positive relationships between irrigation input and flowering under SPADIS in durian ($R^2 = 0.85$, $P < 0.01$) and mangosteen ($R^2 = 0.79$, $P < 0.05$), as well as between irrigation input and total soluble solids (TSS) under SPADIS for durian ($R^2 = 0.89$) and mangosteen ($R^2 = 0.81$). Furthermore, significant interactions between plant species and irrigation system ($A \times B$) were detected for flowering, TSS, and fruit firmness.

Keywords: Automated drip irrigation, Durian, Mangosteen, Precision agriculture, Solar power

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Introduction

In Thailand, durian and mangosteen are economically important fruit crops with durian accounting for a large proportion of export revenue from the eastern and southern regions. However, durian and mangosteen production faces several challenges, including rising input costs, labor shortages, and increasing climate variability. For instance, entering the El Niño stage increased durian production difficulties and cost (Potchanasin, 2013). Distinct rainfall patterns, especially repeated instances of heavy storms and periods of dryness (when a flowering durian tree is expected to establish new blooms after an extended flowering season), had adverse effects on durian flowering and fruit quality. Similarly, variations in rainfall amounts adversely affected mangosteen as it requires consistent maintenance of soil moisture content throughout the year (Suwanseree and Yapwattanaphun, 2015).

Given these impacts, it is very important that good water management practices are adopted. Good water management practices will center on precision irrigation to manage its crops, with technologies like the solar-powered automated drip irrigation system (SPADIS) showing good promise. By automating water delivery and harnessing solar energy, SPADIS addresses both water-use efficiency and the need to reduce energy and labor expenditures. Benedict (2025) introduced a solar-powered automated irrigation system (SPAIS) that integrates soil moisture sensing, IoT, and adaptive control, resulting in significant water savings and improved efficiency, particularly for high-demand crops, with a payback period of 0.92 years compared with gasoline-based alternatives.

Hairudin *et al.* (2023) combined IoT sensors with a solar-powered irrigation system to help address water shortages in durian orchards. Their study showed that the system reduced the need for frequent manual irrigation during dry periods while improving water management efficiency.

In a similar vein, Mohamed *et al.* (2025) introduced a prototype IoT-based system for monitoring water and soil in durian orchards, significantly decreasing management inconsistencies and production costs.

With mangosteen, Jaroensutasinee *et al.* (2024) reported that precise water application delivered by smart irrigation systems stabilized soil moisture, resulting in higher quality yields. This also addressed export-related challenges, such as translucent flesh disorder and internal gumming. Furthermore, maintaining tight control over humidity supported more sustainable and efficient water usage.

To summarize, current literature suggests climate change has significant impacts on both yield and quality of durian and mangosteen agriculture in

Thailand. SPADIS appears to be a particularly useful innovation to reduce those risks. As such, this research aimed to assess the effect of SPADIS on real orchard productivity, and ultimately assess the potential of the innovation and promote widespread adoption within the industry.

Materials and methods

Experimental site and design

The research was conducted during the 2024 production season to evaluate the efficiency of different irrigation systems on tropical fruit crops at two farmer-owned orchards in Phluang Subdistrict, Khao Khitchakut District, Chanthaburi Province, Thailand, a major tropical fruit-producing area. The soil at both sites was classified as well-drained sandy loam. The experiment was arranged as a 2×2 factorial in a randomized complete block design (RCBD) with four replications. Factor A consisted of plant species (durian and mangosteen), and Factor B consisted of irrigation system type: the conventional sprinkler emitter irrigation system (CSEIS) commonly practiced by local farmers (mini-sprinkler system) and a solar-powered automated drip irrigation system (SPADIS).



Figure 1. Representative ‘Monthong’ durian (A) and mangosteen (B) tree specimens at the early production stage during the irrigation trial

The experimental material comprised 40 trees, including durian (*Durio zibethinus* Murr. ‘Monthong’) and mangosteen (*Garcinia mangostana* L.), all at the early bearing stage (approximately 5–6 years old). Trees were planted at a

spacing of 8×8 m (equivalent to 64 m^2 per tree, with one tree per hill), as shown in Figure 1. We selected 40 trees in total—20 per species—to evaluate the four-irrigation treatment. Within each species, 10 trees were randomly assigned to each protocol. To minimize experimental bias, we prioritized specimens with consistent canopy density and trunk circumferences at the start of the trial.

Solar-powered automated drip irrigation system (SPADIS) installation

The SPADIS system was designed to supply irrigation water for durian and mangosteen trees using energy and automated flow control (Figure 2). The system used six 500-W monocrystalline photovoltaic panels to generate direct current (DC) electricity for operating the pump and controller. A variable speed drive (VSD) regulated pump operation according to sunlight intensity during the period from 0800H to 1600H. Water from the system was stored in a 1,000-L high density polyethylene tank to maintain stable pressure within the irrigation lines. Before entering the drip lines, the water passed through a filtration system to reduce emitter clogging and maintain uniform water distribution beneath the tree canopy.

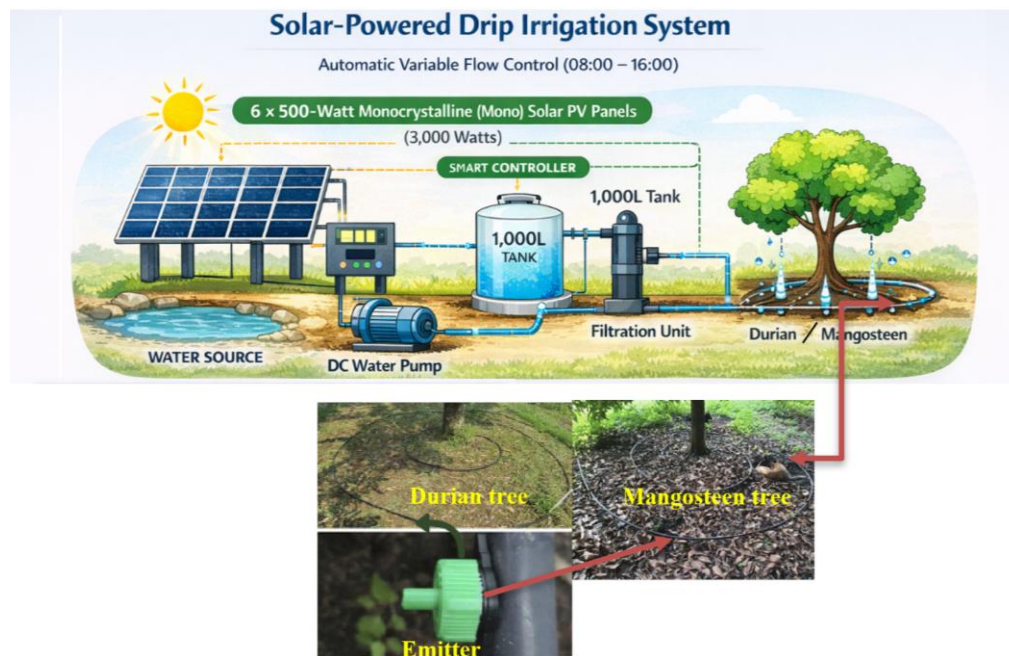


Figure 2. SPADIS layout, which highlights the pump and the control unit configuration and the specific emitter placement (12 emitters per tree) used for both tree test groups

Conventional sprinkler emitter irrigation system (CSEIS) installation

CSEIS was installed as the control treatment for the irrigation practices commonly used in the area (Figure 3). The system used a 20 HP AC centrifugal pump connected to the electrical grid to supply water to the experimental plots. This control unit is equipped with a circuit breaker, magnetic starter, and thermal protection device which was used for system operation and safety. Water was distributed through a 4-inch PVC main pipe connected to 3-inch sub-lines and 1-inch sub-lines to maintain pressure throughout the plots. Lateral distribution was provided using 3/4-inch PVC pipes fitted with one 360° mini-sprinkler positioned 0.5 m below the tree canopy. The system operated on a fixed schedule of the two irrigation events per day, with each session lasting 60 min. The sprinkler treatment applied a larger volume of water over a wider wetting area as compared with the drip irrigation system.

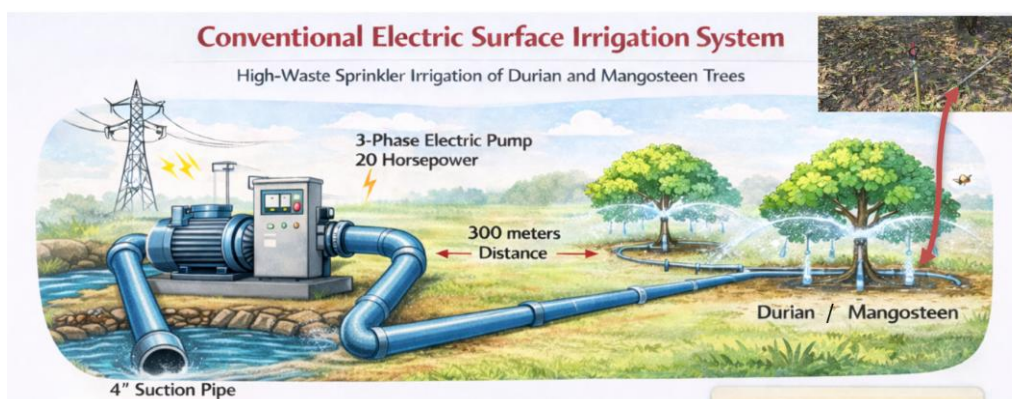


Figure 3. CSEIS layout (the control) which highlights the grid-powered centrifugal pump and electrical control unit, and the distribution network that features a single 360° mini-sprinkler per tree

Data collection

Flowering, fruit set, yield, and fruit quality were monitored for both durian and mangosteen throughout the study period. Flowering and fruit set percentages were determined by randomly counting flowers and fruits on index branches selected from the four sides of each tree. At harvest, fruit yield was recorded as total fruit weight (kg/tree) and number of fruits per tree. Fruit grading followed Codex Alimentarius and ASEAN standards and classified the fruits into Extra, Class I, and Class II categories. For durian, grading was based on fertile locule number (≥ 4 for Extra Class), fruit shape, and dry matter content (Codex Alimentarius, 2014). For mangosteen, grading considered calyx appearance, peel

condition, absence of latex stains, and maturity stage based in the 0–6 color index (Codex Alimentarius, 1997; ASEAN Secretariat, 2008). Only fruit free from pests and visible defects were included in the higher grades. Fruit quality was evaluated at the commercial ripe stage using physical and chemical measurements. Total soluble solids (TSS) were measured using a digital refractometer at 3–5 days after harvest for durian and at maturity stages 4–5 days after harvest for mangosteen. Fruit firmness was measured using a digital firmness tester with an 8-mm plunger for durian pulp and a 6-mm plunger for mangosteen peel hardness. Results were recorded in Newtons (N). Mangosteen fruits were also cut open and inspected for translucent flesh and gamboge disorder.

Meteorological data

On-site data loggers were used to record monthly air temperature, relative humidity, and rainfall during the study period. In both years, the highest temperatures were recorded in April and decreased after the beginning of the rainy season. The dry season in 2024 was slightly warmer than that in 2023 (Figure 4). Relative humidity was lowest during March and April and increased during the rainy season months (Figure 5). We have distinguished these periods—the dry season (March–April) and the rainy season (May–October)—within the figures to provide seasonal context for the irrigation data. Rainfall during the dry season was marginally higher in 2024 than in 2023 (Figure 6). Annual mean meteorological characteristics of the experimental site are summarized in Table 1.

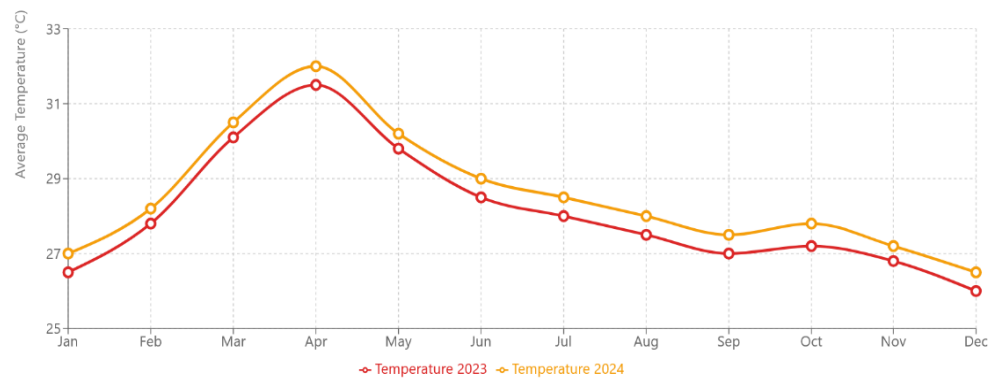


Figure 4. Comparing the monthly average temperature for the years 2023 and 2024

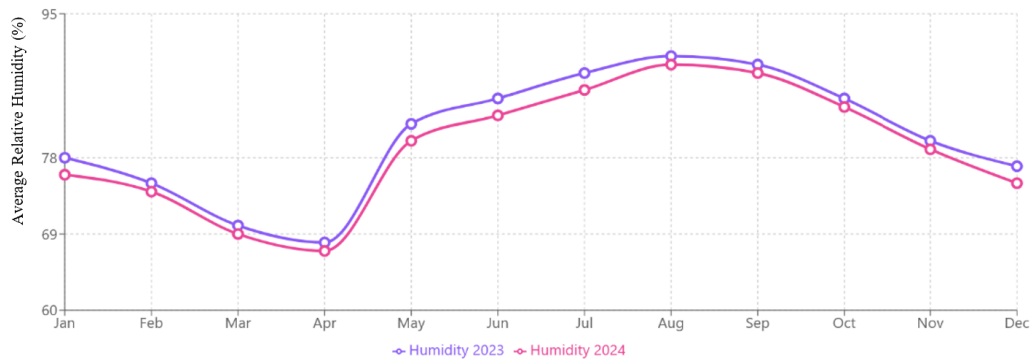


Figure 5. Comparing the monthly average relative humidity for the years 2023 and 2024

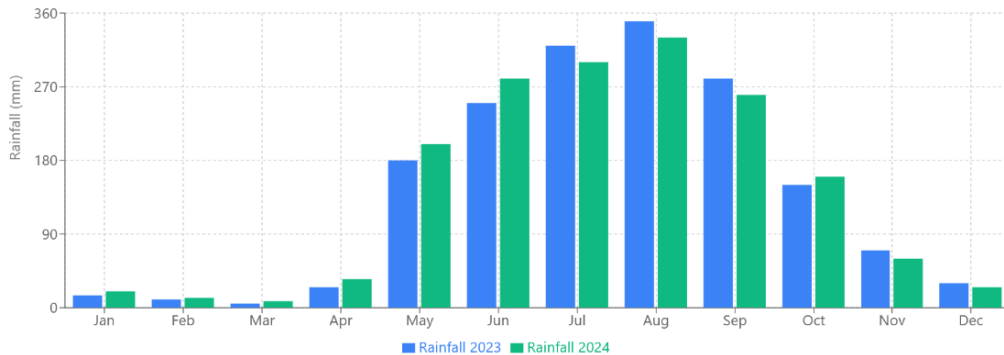


Figure 6. Comparing the monthly rainfall for the years 2023 and 2024

Table 1. Summary of meteorological data in the experimental plot (annual average)

Meteorological data	Unit	Year 2023	Year 2024
Average temperature	°C	28.1	28.7
Average relative humidity	%	80.5	79.9
Total rainfall	mm	1,770	1,790

Statistical analysis

All data were analyzed according to a 2×2 factorial arrangement in RCBD using two-way analysis of variance (ANOVA) appropriate for factorial experiments to evaluate the main effects of plant species and irrigation system, as well as their interaction effects. Mean comparisons were conducted using Duncan's Multiple Range Test (DMRT). The F-test was applied at significance

levels of $P < 0.05$ and $P < 0.01$. In addition, linear regression analysis was performed to examine the relationships between irrigation volume and physiological and quality-related responses.

Results

Flowering and fruit set

Result indicated that plant species (Factor A) and irrigation system (Factor B) significantly affected flowering percentage in both durian and mangosteen ($P < 0.01$) as show in Table 2. In addition, a significant interaction effect ($A \times B$, $P < 0.01$) was observed, indicating that the response of flowering to irrigation system differed between the two species. Across both crops, flowering percentages were higher under the solar-powered automated drip irrigation system (SPADIS) than under the conventional sprinkler emitter irrigation system (CSEIS). In durian, flowering reached $78.40 \pm 1.80\%$ under SPADIS compared with $68.50 \pm 2.20\%$ under CSEIS. Mangosteen also showed higher flowering under SPADIS ($55.80 \pm 2.00\%$) than CSEIS ($45.20 \pm 1.60\%$). The results indicate that the drip irrigation treatment provided more suitable moisture conditions for flowering, particularly in durian.

Table 2. Flowering and fruit set of durian and mangosteen under different irrigation systems

Plant type (Factor A)	Water system (Factor B)	Flowering (%)	Fruit set (%)
Durian	Drip irrigation (SPADIS)	$78.40 \pm 1.80^{a1/}$	5.60 ± 0.40^a
	Sprinkler irrigation (CSEIS)	68.50 ± 2.20^b	4.30 ± 0.30^b
Mangosteen	Drip irrigation (SPADIS)	55.80 ± 2.00^c	10.84 ± 0.50^a
	Sprinkler irrigation (CSEIS)	45.20 ± 1.60^d	9.92 ± 0.45^b
F-test	Plant (A)	**	**
	Irrigation (B)	**	*
	Interaction (A×B)	**	ns

1/: Mean values followed by different lowercase letters within the same column indicate a significant difference at $P < 0.05$; ns = non-significant, * $P < 0.05$; ** $P < 0.01$. Data are presented as mean $\pm$ standard error (SE).

Fruit set was significantly affected by both crop species and irrigation treatment ($p < 0.05$), whereas the interaction between species and irrigation treatment was not significant. Trees irrigated under SPADIS showed higher fruit set percentages than those under CSEIS (Table 2 and Figure 7). Linear regression analysis showed a positive relationship between irrigation volume and flowering in both crops. In durian, the relationship was stronger ($y = 0.92x + 10.5$; $R^2 =$

0.85; $P < 0.05$), indicating that flowering response was closely associated with water availability. The results suggest that the SPADIS treatment improved flowering and fruit set in both durian and mangosteen.



Figure 7. Flowering and fruit set of ‘Monthong’ durian (A) and mangosteen (B) under SPADIS and CSEIS irrigation treatments

Total yield

Both plant species and irrigation system significantly affected total yield parameters, whereas the interaction between species and irrigation system was not significant (Table 3). Trees irrigated with SPADIS produced higher fruit number than those irrigated with CSEIS in both crops. Durian trees under SPADIS produced 25.40 ± 2.10 fruits per tree compared with 20.10 ± 1.80 fruits per tree under CSEIS ($P < 0.01$). In mangosteen, fruit number was 115.00 ± 10.50 fruits per tree under SPADIS and 98.00 ± 8.20 fruits per tree under CSEIS ($P < 0.01$). Mangosteen yield reached 52.00 ± 4.20 kg/tree under SPADIS compared with 48.00 ± 3.80 kg/tree under CSEIS ($P < 0.05$). In durian, yield was 88.00 ± 8.50 kg/tree under SPADIS and 80.00 ± 7.20 kg/tree under CSEIS ($P < 0.01$). Regression analysis showed positive relationship between irrigation volume and yield in both crops. In durian, the relationship was described by $y = 1.12x + 25.4$ ($R^2 = 0.76$; $P < 0.05$). In mangosteen, the regression equation was $y = 0.88x + 12.1$ ($R^2 = 0.82$; $P < 0.01$). Overall, these results indicate that SPADIS effectively increased fruit number and yield weight in both crops.

Table 3. Effect of irrigation treatments on total yield

Plant type (Factor A)	Water system (Factor B)	Yield weight (kg/tree)	Number of fruits (fruits/tree)
Durian	Drip irrigation (SPADIS)	88.00 ± 8.50 ^{a1/}	25.40 ± 2.10 ^a
	Sprinkler irrigation (CSEIS)	80.00 ± 7.20 ^b	20.10 ± 1.80 ^b
Mangosteen	Drip irrigation (SPADIS)	52.00 ± 4.20 ^a	115.00 ± 10.50 ^a
	Sprinkler irrigation (CSEIS)	48.00 ± 3.80 ^b	98.00 ± 8.20 ^b
F-test	Plant (A)	**	**
	Irrigation (B)	*	**
	Interaction (A×B)	ns	ns

1/: Mean values followed by different lowercase letters within the same column indicate a significant difference at $P < 0.05$. ns denotes a non-significant difference. * and ** indicate significant differences at $P < 0.05$ and $P < 0.01$, respectively. Data are presented as mean ± standard error (SE).

Yield quality

The results demonstrated that plant species (Factor A), irrigation system (Factor B), and their interaction ($A \times B$) significantly influenced both chemical quality (total soluble solids, TSS) and physical quality (fruit firmness) of durian and mangosteen fruits (Table 4). Total soluble solids were significantly affected by both plant type and irrigation system, with a significant interaction effect ($P < 0.05$), indicating that the magnitude of the irrigation effect differed between durian and mangosteen. Across both species, fruits irrigated using the solar-powered automated drip irrigation system (SPADIS) exhibited significantly higher TSS values than those grown under the conventional sprinkler emitter irrigation system (CSEIS) ($P < 0.01$). In durian, SPADIS resulted in the highest TSS value (33.50 ± 0.80 °Brix), representing a notable increase compared with CSEIS (31.00 ± 1.10 °Brix). A similar trend was observed in mangosteen, where SPADIS-treated fruits recorded higher TSS (19.50 ± 0.60 °Brix) than those under CSEIS (17.50 ± 0.70 °Brix).

Fruit firmness was significantly affected by both plant species and irrigation treatment, and a significant interaction between the two factors was observed ($P < 0.05$) (Table 4). In durian, fruits from the CSEIS treatment showed higher firmness (14.50 ± 0.90 N) than those from the SPADIS treatment (12.40 ± 1.10 N). In mangosteen, firmness values were slightly higher under SPADIS (8.20 ± 0.40 N) than under CSEIS (7.90 ± 0.50 N). Linear regression analysis showed positive relationships between irrigation level and total soluble solids (TSS) in both crops. The relationship was stronger in durian ($R^2 = 0.89$) than in mangosteen ($R^2 = 0.81$), indicating differences in fruit response to irrigation management between the two species.

Table 4. Effect of irrigation treatments on physical and chemical quality

Plant type (Factor A)	Water system (Factor B)	TSS (°Brix)	Firmness (N)
Durian	Drip irrigation (SPADIS)	33.50 ± 0.80 ^{a1/}	12.40 ± 1.10 ^b
	Sprinkler irrigation (CSEIS)	31.00 ± 1.10 ^b	14.50 ± 0.90 ^a
Mangosteen	Drip irrigation (SPADIS)	19.50 ± 0.60 ^c	8.20 ± 0.40 ^c
	Sprinkler irrigation (CSEIS)	17.50 ± 0.70 ^d	7.90 ± 0.50 ^d
F-test	Plant (A)	**	**
	Irrigation (B)	**	*
	Interaction (A×B)	*	**

1/: Mean values followed by different lowercase letters within the same column indicate a significant difference at $P < 0.05$. Significant differences at the 0.05 and 0.01 levels are marked with * and **, respectively, while all data points represent the mean ± standard error (SE).

Discussion

Flowering

During early bearing stage, water availability is an important factor affecting flowering and fruit development in durian and mangosteen. Compared with sprinkler irrigation, drip irrigation provides water directly to the root zone and reduces water loss from evaporation. The more controlled water application under SPADIS may help maintain more stable soil moisture conditions, which could influence hormonal activity related to floral bud development. Similar observations were reported by Kamariah *et al.* (2011), who found that drip irrigation helped maintain cytokinin balance associated with flowering in longkong.

Linear regression analysis showed positive relationships between irrigation volume and flowering in both crops. In durian, the relationship was stronger ($y = 0.92x + 10.5$; $R^2 = 0.85$; $P < 0.01$), indicating that flowering response was closely associated with irrigation level under the SPADIS treatment. In contrast, the conventional sprinkler system may have provided less uniform water distribution due to evaporation losses and uneven wetting patterns. Our results are consistent with the findings of Ilahi *et al.* (2024), who reported that irrigation based on evapotranspiration (ET_c) requirements improved vegetative growth in durian, including node elongation. Improved vegetative growth under adequate irrigation may contribute to better floral bud development. Reduced water stress under drip irrigation could also help maintain physiological conditions associated with reproductive growth. Drip irrigation also improved fruit set, particularly in mangosteen, which is sensitive to fruit drop and gamboge disorder under fluctuating water conditions. The more continuous water supply provided by SPADIS may have helped maintain more stable plant water status and reduce

stress-related fruit abscission compared with the conventional sprinkler system. Similar observations were reported by Jaroensutasinee *et al.* (2024), who found that stable soil moisture under drip irrigation was associated with improved flowering and fruit quality.

One characteristic of the SPADIS system is that irrigation occurred during periods of high solar radiation and evapotranspiration demand. This may have helped reduce heat and water stress during reproductive development. In contrast, the conventional sprinkler system operated on fixed schedules, which may have resulted in uneven soil moisture conditions during the day. Linear regression analysis suggested that more controlled irrigation under SPADIS was associated with higher flowering percentages and improved reproductive performance.

Total yield

During the early bearing stage, irrigation management played an important role in the productivity of both durian and mangosteen. In this study, the SPADIS treatment produced higher yields than the conventional sprinkler system. The drip irrigation system reduced water loss from evaporation and runoff by supplying water directly to the root zone. More stable water availability under SPADIS may have supported photosynthesis and nutrient transport during fruit development. Our findings are consistent with previous studies reporting that micro-irrigation can improve the productivity of tropical perennial crop (Kamariah *et al.*, 2011). Drip irrigation supplies water directly to the root zone and reduces water loss through surface evaporation (Netafim, n.d.). This may help maintain more uniform soil moisture conditions and adequate soil aeration, which are important for plant growth and yield. Salakpetch *et al.* (2006) also reported that stable soil moisture is important in mangosteen due to water stress can negatively affect flowering and fruit development.

In durian, linear regression analysis showed a positive relationship between irrigation volume and yield ($y = 1.12x + 25.4$; $R^2 = 0.76$; $P < 0.05$). The results indicate that yield increased with greater irrigation input under the SPADIS treatment. Similar responses to irrigation management in durian have also been reported by Ilahi *et al.* (2024). Although irrigation volume explained a large proportion of yield variation, other factors such as nutrient management and orchard practices may also have contributed to yield differences (Firman *et al.*, 2023).

Mangosteen also showed a positive relationship between irrigation volume and yield ($y = 0.88x + 12.1$; $R^2 = 0.82$; $P < 0.01$). The relatively high R^2 value suggests that water availability was closely associated with fruit production in

this crop. Similar findings were reported by Jaroensutasinee *et al.* (2024), who observed improved crop performance under regulated irrigation during periods of high evaporative demand. Stable water supply under SPADIS may have helped reduce heat and water stress during fruit development.

In addition to increasing yield, the SPADIS treatment may also have improved fruit quality compared with the conventional sprinkler system. Irregular water supply during the dry season can contribute to physiological disorders in durian and translucent flesh disorder in mangosteen. Due to SPADIS supplied water more continuously and according to solar-driven operation, soil and plant water conditions may have remained more stable than under fixed-schedule sprinkler irrigation. Similar improvements in water use efficiency under solar-assisted irrigation systems were reported by Karnib *et al.* (2024) in sugarcane production. These findings suggest that solar-powered automated drip irrigation can support both crop productivity and water management in tropical orchard systems.

Fruit quality assessment

Total soluble solids (TSS) are commonly used as an indicator of fruit quality in durian and mangosteen. In this study, fruits from the SPADIS treatment showed higher TSS values than those from the conventional sprinkler system. Higher water application under sprinkler irrigation may have reduced sugar concentration in the fruit due to increased water uptake. In contrast, the more controlled water supply under SPADIS may have supported greater sugar accumulation in the pulp. These findings are similar to those reported by Cui *et al.* (2024), who observed that reduced water application during the late stage of citrus development increased soluble sugar and antioxidant contents. Previous studies have also shown that stable soil moisture can influence fruit size and internal quality in tropical fruit crops (Kumar *et al.*, 2008). In mangosteen, Jaroensutasinee *et al.* (2024) reported that precise irrigation management helped reduce physiological disorders and improve fruit quality. Linear regression analysis showed positive relationships between irrigation level and total soluble solids (TSS) in both crops. In durian, the relationship was relatively strong ($y = 0.85x + 5.2$; $R^2 = 0.89$; $P < 0.01$), indicating that irrigation management was closely associated with the fruit sweetness. A similar trend was observed in mangosteen ($y = 0.68x + 4.8$; $R^2 = 0.81$; $P < 0.01$), although the response was slightly lower than in durian. These results suggest that regulated irrigation may contribute to sugar accumulation and improved fruit quality in both species.

Our findings are similar to those reported by Syah *et al.* (2013) who found that drip irrigation reduced yellow latex disorder in mangosteen. In addition to

improving fruit chemical properties, the SPADIS treatment was associated with better firmness and more uniform ripening. Due to SPADIS supplied water continuously during periods of high evaporative demand, plant water conditions may have remained more stable than under conventional sprinkler irrigation. More stable water availability may help support normal rind and pulp development during fruit growth.

More stable irrigation under SPADIS may have helped improve rind and pulp development and reduce problems such as low dry matter content and uneven ripening. Similar observations were reported by Kim and Kim (2004), who found that irrigation adjusted according to light conditions improved fruit yield and quality. Overall, the results suggest that solar-powered automated drip irrigation can contribute to both fruit quality and production performance in durian and mangosteen.

Comparison of operational efficiency between SPADIS and CSEIS

A comparison between SPADIS and CSEIS showed differences in energy source, irrigation control, and water management (Figure 8). Unlike, the conventional sprinkler system, which depended on grid electricity, SPADIS operated using solar energy. SPADIS also adjusted irrigation flow according to sunlight intensity, whereas the conventional system operated at a fixed flow rate. Similar observations were reported by Azman *et al.* (2025), who identified electricity use as a major operating cost in conventional irrigation systems.

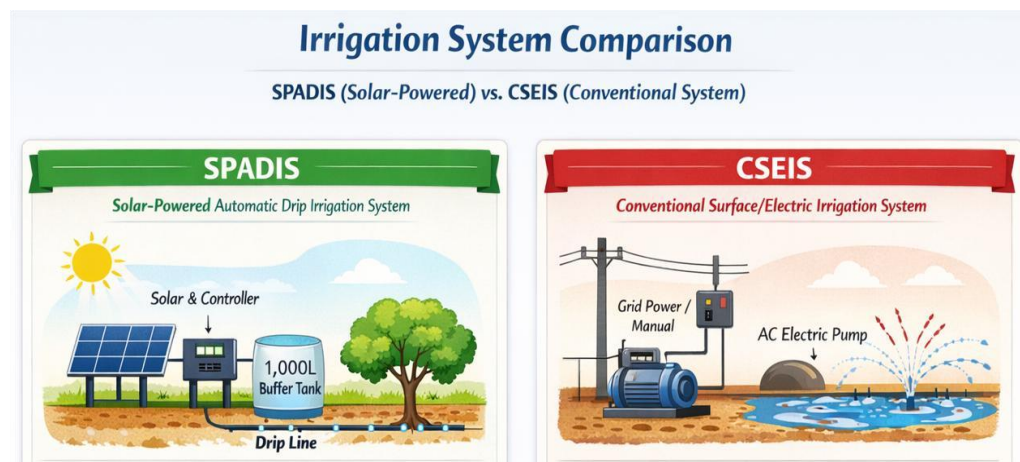


Figure 8. Comparison between SPADIS (Solar-Powered Automatic Drip Irrigation System) and CSEIS (Conventional Sprinkler Emitter Irrigation System/Conventional Surface/Electric Irrigation System)

The SPADIS treatment showed higher irrigation efficiency (90–95%) than the conventional sprinkler system, which is associated with greater evaporative water loss (FAO, n.d.). In addition, SPADIS reduced the need for manual irrigation management. Due to the system operated using solar energy, it also reduced dependence on conventional electricity sources. Similar observations were reported by Thokal *et al.* (2024), who noted that solar-powered irrigation systems may help reduce the environmental impacts associated with diesel- and grid-based irrigation.

Structural comparison of the SPADIS and CSEIS irrigation systems

Benedict (2025) reported an energy efficiency of 23.78% for automated solar-drip systems, which is higher than that of conventional irrigation technologies. These results suggest that solar-based irrigation can improve energy performance while also supporting water conservation in orchard systems such as durian and mangosteen. Using FAO Annex I guidelines, we evaluated irrigation efficiency for both systems. A conveyance efficiency of 95% was assumed for both due to the system used closed piping (FAO, n.d.). However, differences were observed at the application level, where SPADIS achieved higher efficiency (90–95%) than the sprinkler system (70–75%). As a result, the overall efficiency of SPADIS (85.5%) was higher than that of CSEIS (71.25%). Overall, SPADIS performed better than the conventional sprinkler system in terms of flowering, fruit set, and yield during the early production stage. The results indicate that more controlled water delivery may support better reproductive performance under field conditions. Higher total soluble solids (TSS) were observed in both durian and mangosteen under SPADIS compared with the sprinkler system. These results suggest that irrigation management influences fruit sweetness. The results also indicate that irrigation differences can affect fruit quality parameters such as firmness and ripening, although the responses vary between species.

In conclusion, SPADIS reduced reliance on grid electricity and improved irrigation efficiency compared with the conventional system. The results suggest that the solar-powered automated drip irrigation system is a promising option for improving water management in durian and mangosteen orchards. Further studies under different field conditions are needed to confirm its long-term performance.

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Conflicts of interest

The authors declare no conflict of interest.

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