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Smart Drip Irrigation Maintains Phytosanitary Superiority under Dry Season Conditions in Shaded Cultivation of Celery (*Apium graveolens* L.) in Guyana

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ABSTRACT

Celery (*Apium graveolens* L.) is a commercially important crop in Guyana especially with the advancing of shaded cultivation as part of the national Climate-Smart Agriculture agenda. A companion study evaluating smart drip and sprinkler irrigation during the wet season (April-June 2025) demonstrated that smart drip irrigation significantly reduced foliar disease incidence while maintaining equivalent biomass yields. This study extends the investigation to the dry season (July-October 2025) to determine whether the phytosanitary and yield advantages of smart drip irrigation are sustained. A two-treatment, shade house trial (n= 6 beds per treatment, 504 plants per treatment) was conducted using an automated IoT irrigation system. No statistically significant difference in plant height, leaf length, leaf width or fresh biomass was detected between treatments ($p>0.05$ for all parameters). Smart drip irrigation yielded a disease incidence of 2.8% compared to 9.3% under sprinkler irrigation (Fisher's exact test: $p = 1.30 \times 10^{-9}$ and odds ratio = 0.282). These findings confirm that the phytosanitary superiority of smart drip irrigation is sustained across seasons, supporting its utilization for year-round shade house celery production in tropical contexts.

Key words: Celery, Climate-smart agriculture, Drip irrigation, Dry season, IoT, Shade house.

Global food security concerns and the increasing frequency of climate-related agricultural disruptions have increased interest in precision irrigation technologies, particularly among farmers in tropical countries (FAO, 2015; Wakweya, 2023). The Caribbean region faces challenges of erratic rainfall, high ambient humidity and limited access to affordable agricultural automation (CARICOM Secretariat, 2023). In this context, shade house cultivation of high-value crops such as celery has been prioritised as a component of Guyana's Climate-Smart Agriculture (CSA) strategy (NAREI, 2023).

Traditional irrigation in guyanese shade houses relies predominantly on the manual pump-and-hose system, which is labour-intensive and increases foliar wetness similar to the challenges faced elsewhere (Kumar *et al.*, 2019). This promotes the development of fungal and bacterial pathogens such as *Cercospora apii* (early blight) and *Erwinia carotovora* (bacterial soft rot) (Raghoonanan *et al.*, 2011; Zandstra, 2016). Consumer-grade internet of things (IoT) devices, specifically Wi-Fi-enabled smart switches and solenoid valves, have been proposed as an affordable alternative to expensive microcontroller-based precision irrigation systems (Ghareeb *et al.*, 2023; Kumar *et al.*, 2025).

A companion study conducted during the wet season of 2025 (April-June) evaluated smart drip and sprinkler irrigation systems over a 90-day production cycle under the same shade house conditions described here (Persaud and Persaud, 2026). That study reported fresh biomass yields of 303.4±16.0 g/plant and 308.1±19.1 g/plant for drip and sprinkler systems respectively ($p = 0.55$), but a markedly lower disease incidence of 1.8% under drip irrigation compared to 12.1% under sprinkler irrigation ($p = 1.62 \times 10^{-11}$). The system achieved a 90% reduction in daily labour requirements at a total IoT infrastructure cost of USD 150.

A critical limitation of that initial study was the evaluation of the IoT system to a single wet season. It was unclear whether the phytosanitary advantage of drip irrigation would be observed during the dry season, when

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reduced humidity and lower rainfall might reduce foliar disease especially for the sprinkler irrigation treatment. This short communication addresses this directly by reporting the results of the dry season production cycle (July-October 2025) conducted under identical experimental conditions.

Full methodological details are described in the companion wet season study (Persaud and Persaud, 2026). In brief, this trial was conducted in a shade house located at Bath Settlement, Berbice, Guyana (6°21′36.9″N, 57°35′05.3″W; Datum WGS 84) during the dry season (July to October 2025).

The substrate utilized comprised 60% reef sand, 20% cow manure, 10% rice husk and 10% chicken litter (Table 1). The giant pascal seedlings of celery were cultivated at a spacing of 30 cm in three rows per bed. The experimental design comprised twelve beds each measuring 30 ft by 3.5 ft divided equally between Treatment A (smart drip irrigation-six beds) and Treatment B (smart sprinkler irrigation-six beds) with each bed containing 84 plants or three rows of 28 plants each and 504 plants per treatment. The end rows were located 22.5 cm cm from the edge of the bed while the central row was located 30 cm from either of the end rows. Beds were separted from each other by 1.5 ft drains.

Irrigation was automated using Kasa ® Wi-Fi-enabled smart switches and US solid solenoid valves controlled via the Kasa ® mobile application. Scheduling was stored on device firmware to ensure operational continuity during network interruptions. Fertigation was conducted using a venturi injector system with triple super phosphate-62 kg/ha, week 1 (MAFAS Ltd. 2017), 15-15-15 NPK-61 kg/ha, week 3 (Zandstra, 2016) and urea 80 kg N/ha, fortnightly thereafter.

Phytium spp. and *Rhizoctonia solani* were controlled using Shield 30 SL (Caribbean Chemicals Guyana Limited- CCGL) containing mefenoxam and hymexazol.

Early blight and bacterial soft rot were managed using Coback 77 WP (CCGL), a copper hydroxide product, Glory 75 WG (UPL Limited), a mixture of mancozeb and azoxystrobin and Bellis ® 38 WG (BASF Corporation), a mixture of boscalid and pyraclostrobin.

Pests were managed using Caprid ® 20 SL (CCGL) containing acetamiprid, Triazophos 40 EC (CCGL), fastac ® SC (BASF Corporation) containing α-cypermethrin and cure 1.8 EC (CCGL) containing abamectin.

All chemicals were made up to a volume of 20 L and applied as per manufacturer's instructions. Chemical application was conducted weekly using a spray can. Pesticides were applied in the evenings while fertigation was conducted during the day. All chemicals were rotated weekly to minimize the risk of resistance development and applied to both treatments A and B.

The water holding capacity (WHC), pH and electrical conductivity (EC) were all measured in triplicate throughout the cycle using established methods (Nelson *et al.*, 2023; Zandstra, 2016).

Weekly morphometric measurements (plant height, leaf length, leaf width and fresh biomass) were recorded. Five ratoon harvests were conducted at 14-day intervals post-maturity, with the first three harvests included in the statistical analysis. Disease Incidence (DI) was determined by expert visual assessment (Muhamediyeva *et al.*, 2025). Independent samples *t*-tests were used for morphometric comparisons and Fisher's exact test with odds ratio computation (Agresti, 2013) was used for disease incidence analysis, at α= 0.05 using the Microsoft Excel LTSC 2024 software.

Local farmers were consulted to determine the average cost of irrigation. In total, 10 farmers were consulted and the average rate was determined.

The substrate characterization confirmed stable growing conditions throughout the dry season cycle. The mean pH was 6.0±0.1 and 6.0±0.0 for drip and sprinkler treatments respectively, EC was 1.1 mS/cm for both treatments, soil temperature ranged from 27.9-28.1°C and WHC was 23.1±0.5% and 22.5±0.4% respectively (Table 2). These values are consistent with those recorded in the wet season (Persaud and Persaud, 2026), confirming that the substrate provided a stable and comparable growth environment across seasons.

Morphometric analysis revealed no statistically significant difference between irrigation treatments for any measured parameter (Table 3). Fresh biomass yields were 311.9±21.4 g/plant for drip irrigation and 311.1±20.2 g/plant for sprinkler irrigation (p = 0.79). These yields represent a marginal improvement in the dry season over the wet season values of 303.4±16.0 g/plant and 308.1±19.1 g/plant.

Despite equivalent crop performance, a substantial and statistically significant divergence in phytosanitary outcomes was observed (Table 4). Disease incidence was 2.8% (n = 14) under drip irrigation compared to 9.3% (n = 46)

Table 1: Composition and functional rationale of the engineered substrate mix.

Component	% Composition	Purpose
Reef sand	60	Primary growth medium
Cow manure	20	Source of organic matter
Rice husk	10	Increase aeration and porosity
Chicken litter	10	Nitrogenous source

Table 2: Physical and chemical characterization of the substrate during the dry season.

Parameter	Drip irrigation	Sprinkler irrigation
Electrical conductivity, mS/cm	1.1±0.0	1.1±0.1
pH	6.0±0.1	6.0±0.0
Soil temperature, °C	28.1±0.3	27.9±0.5
Water holding capacity, %	23.1±0.5	22.5±0.4

Table 3: Average morphometric measurements of the plants for the two irrigation methods during the dry season.

Morphometric parameter	Drip irrigation	Sprinkler irrigation	*p-value*
Plant height, *h*/cm	48.1±3.1	47.8±4.3	0.74
Leaf length, *l*/cm	5.1±0.2	5.1±0.2	0.15
Leaf width, *w*/cm	3.2±0.2	3.3±0.2	0.23
Fresh biomass, *g*/plant	311.9±21.4	311.1±20.2	0.79

Table 4: Comparative mortality and marketable survival analysis for the dry season.

Metric	Drip irrigation	Sprinkler irrigation
Total population	504	504
Transplant deaths	4	7
Effective population	500	497
Disease incidence[a], %	2.8 (*n* = 14)	9.3 (*n* = 46)
Pathogenic mortality, %	0.8 (*n* = 4)	4.2 (*n* = 21)
Marketable survival rate, %	97.8	91.8

[a]Fisher's exact test: $p = 1.30 \times 10^{-9}$, odds ratio = 0.282, 95% CI.

under sprinkler irrigation. Fisher's exact test confirmed this difference was highly significant ($p = 1.30 \times 10^{-9}$, OR = 0.282, 95% CI). Pathogenic mortality was 0.8% under drip irrigation versus 4.2% under sprinkler irrigation. The marketable survival rate was 97.8% for drip-irrigated plants and 91.8% for sprinkler-irrigated plants.

The results of the dry season trial corroborate and extend the findings of the companion wet season study (Persaud and Persaud, 2026). While studies such as Jahantigh and Amiri (2020) demonstrate that reducing irrigation during critical growth periods reduce the yield per plant, by maintaining optimal and uniform soil moisture conditions, we ensure that potential drought-induced yield reductions are avoided. In both seasons, smart drip and sprinkler irrigation resulted in statistically equivalent growth and fresh biomass yields, confirming that the irrigation method does not directly influence yield when irrigation volumes and nutrient inputs are standardized. The dry season biomass values of approximately 311-312 g/plant compare favorably with reported yields for shade house cultivation of celery in the region (NAREI, 2023) and represent a marginal seasonal improvement.

Notably, the results confirmed the sustained phytosanitary advantage of drip irrigation over the sprinkler irrigation during the dry season. Although disease incidence under sprinkler irrigation was attenuated relative to the wet season (9.3% versus 12.1%), it remained more than three times greater than observed under drip irrigation (2.8%). The Odds Ratio of 0.282 indicates that plants irrigated using the sprinkler system were approximately 3.5 times more likely to develop disease than those irrigated using the drip system during the dry season, compared to approximately 7.6 times more likely during the wet season (OR = 0.132; Persaud and Persaud, 2026). This seasonal attenuation is possibly due to reduced ambient humidity and lower rainfall during the dry season which are noted to reduce the foliar wetness suppressing spore germination and mycelial proliferation of *Cercospora* spp. (Wilson *et al.*, 2024; Raghoonanan *et al.*, 2011).

This finding has direct practical implications since farmers in Guyana cannot rely on seasonal conditions to offset the disease pressure associated with sprinkler irrigation. Smart drip irrigation is therefore recommended for shade house celery production throughout the year, regardless of the season.

The economic impact of IoT system remains unchanged across seasons. The total system cost of USD 150 which includes smart switches and solenoid valves with no recurring subscription fees was offset within a single production cycle by the labour savings generated, however the adaptation of these systems may be hindered as farmers would require training and experience or even reluctant to adapt modern technology as highlighted by Kwatra *et al.* (2026). Daily irrigation management was reduced from approximately one hour of manual labour to five minutes of remote smartphone-based monitoring, representing a saving of approximately 90 labour-hours per season. The labour hours are calculated based on the current local farming practices, where one hour per day is dedicated for irrigation and is subdivided into two 30 minutes sessions, one in the morning and one in the afternoon over a period of 90 days. Using a cost of 10 USD to conduct irrigation, this saving substantially exceeds the capital cost of the system (900 USD over a season or 1800 USD for the year versus 150 USD investment cost). The combined evidence across two seasons demonstrates that these economic efficiencies are not a wet-season artefact but a consistent feature of the smart system under varying meteorological conditions.

This study also has some limitations as it was conducted within a controlled shade house environment using a single variety of celery. Future research should evaluate the performance of low-cost IoT irrigation across a broader range of crops and different ecological zones in Guyana and explore the integration of a weather station to enhance scientific rigor.

CONCLUSION

This short communication confirms that the smart drip irrigation is superior compared to the sprinkler irrigation regardless of climatic conditions. Disease incidence under drip irrigation remained low at 2.8%, compared to 9.3% under sprinkler irrigation, while fresh biomass yields were statistically equivalent between systems (p= 0.79). The evidence supports the recommendation to implement smart drip irrigation for year-round shaded cultivation of celery in Guyana. The low infrastructure cost of USD 150

and the substantial labour savings achieved confirm that this technology is economically accessible and practically viable for farmers seeking to adopt Climate-Smart Agriculture practices in the Caribbean region.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

Not applicable. This study involved only plant material and did not require ethical approval.

Conflict of interest

The authors declare no conflict of interest.

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