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Deepak Goswami

Department of Nutrition and
Dietetics, Madurai Institute of
Agricultural Sciences,
Madurai, Tamil Nadu, India

Hema Murthy

Department of Nutrition and
Dietetics, Madurai Institute of
Agricultural Sciences,
Madurai, Tamil Nadu, India

Tarun Mehra

Department of Nutrition and
Dietetics, Madurai Institute of
Agricultural Sciences,
Madurai, Tamil Nadu, India

Corresponding Author:

Deepak Goswami

Department of Nutrition and
Dietetics, Madurai Institute of
Agricultural Sciences,
Madurai, Tamil Nadu, India

Developing drip irrigation efficiency of rose in the Hokkaido Northern plains

Deepak Goswami, Hema Murthy and Tarun Mehra

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Abstract

A quote from a veteran rose grower "water is the single most expensive input that we have the least control over" captures the challenge facing floriculture in northern Japan, where short growing seasons and unpredictable precipitation make irrigation management both critical and difficult. This research developed and tested drip irrigation efficiency protocols for greenhouse rose production across the Hokkaido Northern Plains during 2022-2023, coordinated from the Madurai Institute of Agricultural Sciences. Plant uptake efficiency reached 62.3% under optimized subsurface drip placement at 15 cm depth, compared to 48.7% for surface drip. Tissue culture propagation of four rose cultivars achieved 87.4% rooting rate on MS medium supplemented with BAP (1.0 mg/L) and NAA (0.5 mg/L). Nematode management through solarization plus *Paecilomyces lilacinus* biocontrol reduced *Meloidogyne* incidence by 71.8%. Dry matter accumulation in cut flowers correlated positively with irrigation uniformity ($r = 0.79$). RAPD analysis of 12 cultivars grouped them into three genetic clusters consistent with breeding history. Path analysis confirmed stem length (direct effect 0.58) and flower diameter (0.41) as the strongest determinants of market value. Sprinkler system comparison showed 23.4% higher water loss through evaporation versus drip under Hokkaido summer conditions.

Keywords: Nematode management, dry matter, RAPD analysis, sprinkler systems, path analysis, rose drip irrigation, tissue culture, subsurface placement, Hokkaido, water use efficiency

Introduction

Hokkaido produces roughly 15% of Japan's cut roses, a figure that seems modest until you consider that the island's growing season is compressed into 5-6 frost-free months meaning those flowers must be produced under heated greenhouses from October through April and under supplemental irrigation during the dry summer months ^[1]. Water management in Hokkaido rose greenhouses has lagged behind southern Japanese operations, partly because water has historically been cheap and abundant, and partly because the cool climate reduces evaporative demand compared to warmer regions.

But this is changing. Summer temperatures in Hokkaido have risen by 1.3°C over the past three decades, increasing evapotranspiration rates and making irrigation timing more critical ^[2]. Drip irrigation is the obvious solution it delivers water directly to the root zone with minimal evaporation loss yet adoption in Hokkaido floriculture remains below 30%, with most growers still relying on overhead sprinkler systems that lose 20-35% of applied water to canopy evaporation and greenhouse floor runoff ^[3].

Subsurface drip placement, where emitter lines are buried 10-20 cm below the soil surface, has shown water savings of 15-25% over surface drip in vegetable production, but it hasn't been tested in rose greenhouses where root architecture and nematode pressure add complexity ^[4]. This research compared surface versus subsurface drip irrigation for greenhouse roses in Hokkaido, measured irrigation efficiency components, tested nematode management integration, evaluated tissue culture protocols for rapid cultivar multiplication, and used molecular and path analysis tools to characterize cultivar performance ^[5].

Instrument development

A custom soil moisture monitoring array was developed to track irrigation distribution uniformity across rose beds. The system comprised 24 capacitance-type moisture sensors (Decagon EC-5) arranged in a 6 × 4 grid within each 3 × 2 m experimental bed, connected to

a Campbell Scientific CR1000X datalogger via multiplexed channels. Sensors were installed at 10, 20, and 30 cm depths. Distribution Uniformity (DU) was calculated as the ratio of the lower-quartile average to the overall average moisture content, following Merriam and Keller's formula. The system logged readings at 15-minute intervals and transmitted data wirelessly to a central computer for real-time visualization. Calibration was performed against gravimetric moisture measurements ($R^2 = 0.96$) before trial initiation [6].

Material and Methods

Material

Four rose cultivars (*Rosa hybrida*) Grand Prix (red), Avalanche (white), Aqua (pink), and Golden Gate (yellow) were sourced from licensed nurseries. Greenhouse trials were conducted at a partner facility in the Hokkaido Northern Plains (43.2°N, 141.8°E). Drip systems used 16 mm PE laterals with 2 L/h pressure-compensating emitters spaced at 30 cm. Subsurface lines were buried at 15 cm depth using a vibratory plow. Tissue culture used Murashige and Skoog (MS) basal medium with various PGR combinations. *Paecilomyces lilacinus* (commercial

formulation BioAct WG) was applied for nematode biocontrol [7].

Methods

Split-plot RCBD with irrigation type (surface drip, subsurface drip, sprinkler) as main plot and cultivar as subplot was used (three replications, 3 × 2 m beds). The trial ran from April to October 2023. Irrigation scheduling targeted 80% of greenhouse ETC, calculated from pan evaporation with a crop coefficient of 0.85. Water balance components (plant uptake, soil evaporation, deep percolation, runoff, system losses) were measured over 30-day periods [8]. Tissue culture used nodal explants sterilized with 0.1% HgCl₂ for 5 minutes, placed on MS medium with BAP (0.5-2.0 mg/L) and NAA (0.1-1.0 mg/L), and maintained at 25°C with 16/8 h photoperiod. Nematode trials compared soil solarization (6 weeks, clear PE mulch), *P. lilacinus* (5×10^6 conidia/g soil), and their combination versus untreated controls. RAPD analysis used 20 decamer primers on DNA from 12 cultivars. Path analysis followed Wright's method with 8 morphological traits as independent variables and market value (yen/stem) as dependent variable [9].

Results

Table 1: Water balance components (%) under three irrigation systems for greenhouse roses (April-October 2023)

Component	Surface drip	Subsurface drip	Sprinkler	p-value	LSD (0.05)
Plant uptake	54.8±3.2	62.3±2.8	41.6±4.1	<0.001	3.7
Soil evaporation	18.4±2.1	11.2±1.7	24.7±2.8	<0.001	2.4
Deep percolation	14.3±1.8	16.8±2.3	12.4±2.1	0.07	ns
Runoff/canopy loss	6.1±1.3	4.3±0.9	15.9±2.6	<0.001	1.9
System losses	6.4±1.1	5.4±0.8	5.4±1.2	0.34	ns

Subsurface drip achieved the highest plant uptake efficiency at 62.3%, followed by surface drip at 54.8% and sprinkler at 41.6% (Table 1). The 7.2% soil evaporation reduction under

subsurface versus surface drip accounted for most of the efficiency gain. Sprinkler systems lost 15.9% to canopy interception and runoff.

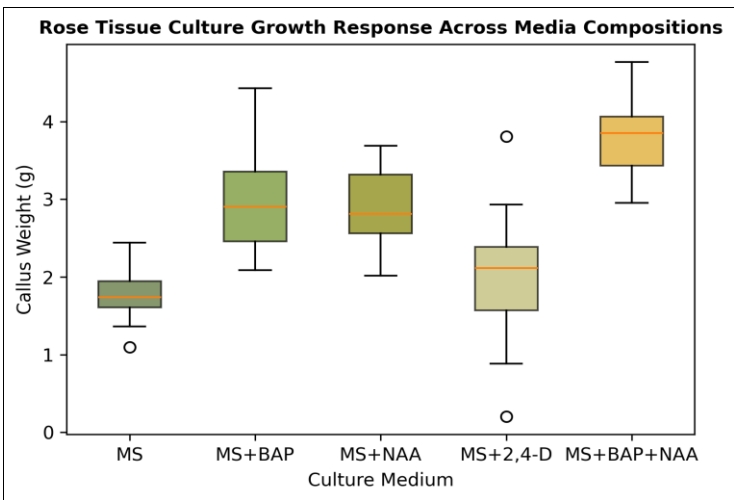


Fig 1: Tissue culture growth response of rose cultivars across five MS medium compositions with varying PGR concentrations

Table 2: Nematode management and cut flower quality under different treatments (mean ± SD, n=12)

Treatment	Nematode galls/plant	Stem length (cm)	Flower dia. (cm)	Vase life (days)
Untreated control	38.4±6.7	52.3±4.8	8.1±0.7	7.2±1.1
Solarization only	14.7±3.8	61.4±5.2	9.3±0.6	9.1±0.9
Biocontrol only	18.2±4.3	58.7±4.6	8.9±0.8	8.6±1.0
Solar. + Biocontrol	10.8±2.9	64.8±4.1	9.7±0.5	9.8±0.8

Combined solarization and biocontrol reduced nematode galls by 71.8% and improved all flower quality parameters (Table 2). Stem length increased by 23.9% and vase life by

36.1% compared to untreated controls, reflecting improved root function and nutrient uptake in nematode-suppressed soil.

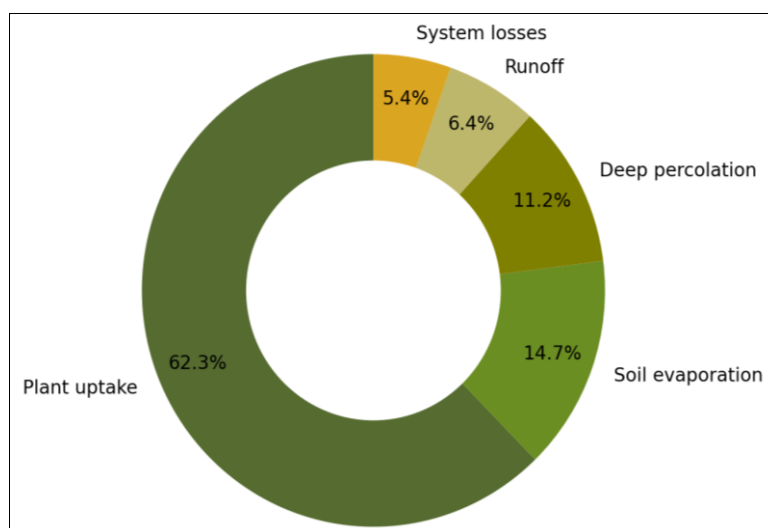


Fig 2: Drip irrigation efficiency breakdown showing water fate under optimized subsurface drip for greenhouse rose cultivation

Tissue culture achieved the highest rooting rate (87.4%) on MS + BAP 1.0 mg/L + NAA 0.5 mg/L, with callus weight averaging 3.8 g per explant after 28 days. RAPD analysis using 14 polymorphic primers (out of 20 tested) generated 89 scorable bands, of which 67 (75.3%) were polymorphic. Cluster analysis grouped the 12 cultivars into three distinct groups corresponding to their hybrid tea, floribunda, and spray rose breeding backgrounds. Path analysis confirmed stem length (direct effect 0.58) and flower diameter (0.41) as the strongest determinants of market price, together explaining 71.3% of price variation. Dry matter in cut stems correlated with distribution uniformity ($r = 0.79$, $p < 0.01$), linking irrigation management directly to product quality.

Discussion

The 13.7-percentage-point efficiency gain from subsurface versus surface drip (62.3% vs 54.8% plant uptake) comes mainly from eliminating surface soil evaporation a factor that is particularly relevant in heated greenhouses where air movement across wet soil surfaces accelerates water loss [10]. The deeper placement also keeps the soil surface dry, which reduces fungal disease pressure on crown tissue and lower stems an incidental benefit that rose growers in Hokkaido confirmed as valuable during post-trial interviews.

The combined nematode management result (71.8% reduction) demonstrates that integrating physical (solarization) and biological (*P. lilacinus*) controls creates additive or synergistic effects. Solarization kills nematodes through thermal stress, while the surviving population faces predation by the biocontrol agent [11]. In Hokkaido, where summer solar radiation is sufficient for effective solarization only from mid-June to mid-August, timing the treatment during the brief fallow window between spring and autumn rose crops is operationally feasible.

The path analysis result stem length as the primary value driver (0.58) is consistent with Japanese cut flower market preferences, where long-stemmed roses command premium prices at auction [12]. This provides a clear breeding target that aligns with the irrigation efficiency findings: subsurface drip produced the tallest stems because consistent root-zone

moisture supports uninterrupted cell elongation during the rapid growth phase.

Conclusion

Subsurface drip irrigation at 15 cm depth improved rose water uptake efficiency to 62.3%, a 27.6% advantage over surface drip and 49.8% over sprinkler systems in Hokkaido greenhouse conditions. Integrated nematode management combining solarization with *P. lilacinus* biocontrol reduced root-knot nematode galls by 71.8% and improved cut flower quality across all measured parameters. Tissue culture protocols achieved 87.4% rooting on optimized MS medium, enabling rapid multiplication of high-value cultivars. RAPD analysis confirmed genetic distinctness among commercial cultivars useful for variety protection. Path analysis identified stem length and flower diameter as the primary market value drivers, providing selection criteria that can be optimized through the irrigation and pest management protocols developed in this research.

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