Journal of Agricultural Science and Technology A 16 (2026) 108-112
doi: 10.17265/2161-6256/2026.02.005

Effect of Drought Application on Flower, Yield and Leaf Mineral Content of Durian (cv. Monthong) in Cambodia

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Abstract: While synthetic plant growth regulators (PGRs) like paclobutrazol and chlorate compounds are conventionally used to suppress gibberellic acid and induce flowering, their chronic application results in chemical residues, strict export phytosanitary violations, and tree dieback. Water deficit (water stress) presents a sustainable alternative by naturally mimicking chemical retardants to trigger reproductive shifts. However, the exact physiological mechanisms underlying this transition remain incomplete. This study addresses this gap by investigating the dynamic fluctuations of critical macronutrient (N, P, and K) alongside leaf-tissue carbon balances during water deficit to induced flowering. the duration of induced drought stress significantly regulates both the reproductive performance and internal foliar nutrient dynamics of the crop. Prolonged moisture deficit over 28 days markedly optimizes reproductive phenology, driving a significant increase in floral density ($P = 0.012$), which directly enhancements in fruit-set ($P < 0.001$) and harvested fruit count ($P < 0.001$). Consequently, total crop yield per tree significantly increased by roughly 30.7%, without altering individual fruit weight or fruit drop percentages. Physiologically, these reproductive advancements are accompanied by significant alterations in leave macronutrient status; as drought duration extends to 28 days, leaf nitrogen and phosphorus concentrations significantly decline to minimum thresholds of 1.69% ($P = 0.006$) and 0.146% ($P = 0.009$), respectively, whereas potassium and total carbon levels remain unaffected. This drives a significant upregulation of the leaf C/N ratio from 25.78 to 30.13 ($P = 0.007$), identifying this physiological carbon-nitrogen balance as a critical operational mechanism underlying drought (water deficit) mediated floral induction and enhanced yield productivity.

Key words: Flower induction, fruit drop, leave carbon level, Mondulkiri.

1. Introduction

Over the past two decades, the global fruit industry has undergone a major shift, primarily driven by the tightening of sanitary and phytosanitary (SPS) health regulations alongside significant advancements in logistics and transportation infrastructure. Consequently, between the years 2000 and 2021, global fruit production experienced an expansion of approximately 54%, ultimately reaching a yield threshold of nearly 930 million metric tons per annum [1]. Durian (*Durio zibethinus* L.) is a highly value and broadly known fruit among Southeast Asia region. The fruit is considered a delicacy by many consumers. It is one of the leading cultivated fruits after mango, longan, banana, it is the fourth largest fruit species in area production in Cambodia [2]. The production gain popularity and exponentially increased, however, most producers faced difficult time to successfully induce flower due to unpredicted rainfall and uneven rejuvenate for the tree. Fruit crop productivity was heavily relied on the quantitative and qualitative success of floral induction. Consequently, effective floral induction management and post-anthesis canopy maintenance were widely recognized as vital prerequisites for optimizing yields, enhancing productivity, and mitigating production costs in fruit

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crop cultivation. Within the core principles of sustainable pomological production, implementing specific management techniques to establish the environmental and physiological prerequisites for flower bud initiation, phenological cycling, and subsequent canopy management represents an essential economic cornerstone. The physiological mechanism governing floral initiation in fruit trees involves a complex interplay of multiple physiological and environmental factors, including phytohormone profiles, carbohydrate reserves, plant water relations, nutrient status, and the physiological maturity of reproductive structures [3]. Within modern horticultural technologies, ensuring the physiological maturity of vegetative flushes is primarily achieved via the suppression of gibberellic acid (GA_3) levels and the elevation of non-structural carbohydrate status. This is conventionally managed through the application of synthetic plant growth regulators (PGRs) capable of inhibiting vegetative vigor, among which chlorate compounds (e.g., potassium chlorate, sodium chlorate) and paclobutrazol (PBZ) are widely utilized global benchmarks [3, 4]. However, a substantial of scientific literature indicates that the chronic and repetitive application of these synthetic compounds leaves chemical residues and induces phytotoxic consequences. These include complete floral inhibition in subsequent phenological cycles, or atypical root and shoot distortions that can eventually lead to tree dieback. Consequently, the FAO mandates strict phytosanitary monitoring for export commodities, prompting importing jurisdictions to enforce strict maximum residue limits (MRLs) capped at 0.05 mg kg^{-1} [5].

Furthermore, either naturally occurring or artificially induced abiotic stress conditions specifically controlled water deficit or deficit irrigation exert a regulatory influence on vegetative growth control, effectively driving successful floral induction and abundant flowering in multiple fruit tree species [6, 7]. Empirical findings demonstrate that managed water deficits lead to a significant decline in endogenous GA_3 concentrations effectively mimicking the physiological mechanisms of synthetic chemical retardants while concurrently upregulating the synthesis of specific stress responsive proteins and free amino acids following prescribed periods of moisture deprivation. Under Controlled drought stress (moisture deficit) or low soil moisture tension, the subterranean uptake of essential nutrients required to sustain vegetative development is restricted, particularly nitrogen (N), which consequently triggers a shift in the plant's physiological state towards the reproductive stage [8, 9].

Conversely, comprehensive investigations regarding the dynamic fluctuations of critical macro-nutrients directly linked to plant vegetative to reproductive shifts namely nitrogen, phosphorus, potassium, and the leaf carbon balance remain inadequately characterized in current literature.

2. Materials and Methods

2.1 Study Site

Experiment was carried out under farmer's field condition from August 2021 to August 2022 at Mondulkiri province (12°28'27" N, 107°12'33" E). The site was 650 meters above the sea level with average temperature between 20 to 33 °C and relative humidity of 60-90% upon the research conducted. Chemical and physical of the field was described in Table 1.

Table 1 Soil physical and chemical properties analysis of experiment site.

EC	pH	P	K	N	SOM	Soil Texture			
		ppm	$cmol_c\ kg^{-1}$	%	%	Clay	Silt	Sand	Class
38.0	4.20	0.1	0.42	0.29	5.07	22.3	35.3	42.4	Clay Loam

Analyses result conducted by soil laboratory, Faculty of Agricultural Science, 2021.

Table 2 Reproductive and yield characteristics under different structural durations of induced drought stress.

Drought	Floral Density (Flower.m^{-1})	No. Fruit		Fruit Drop (%)	Fruit Weight (kg $fruit^{-1}$)	Yield (kg $tree^{-1}$)
		Fruit-Set (Fruit.$tree^{-1}$)	Harvest Fruit (Fruit.$tree^{-1}$)			
0 day	100.04 b	32.26 c	19.33 c	40.53 a	3.17 a	58.46 b
14 days	164.96 a	36.30 b	21.85 b	39.79 a	3.01 a	65.63 ab
28 days	202.11 a	42.44 a	25.70 a	39.63 a	3.02 a	76.41 a
$LSD_{0.05}$	*64.75*	*2.58*	*1.06*	*2.78*	*0.56*	*13.07*
Pvalue	*0.012**	*0.000**	*0.000**	*0.864^{ns}*	*0.997^{ns}*	*0.020**

Means within a column followed by the same letter are not significantly different according to Least Significant Difference ($LSD_{0.05}$) test. *Indicates significant differences at $P_{0.05}$; ns = indicates non-significant differences.

Table 3 Effect of drought stress duration on leaf macronutrient and physiology.

Drought	N (%)	P (%)	K (%)	C (%)	C/N Ratio
0 day	2.03 a	0.179 a	1.619 a	52.33 a	25.78 b
14 days	1.83 b	0.161 ab	1.564 a	52.45 a	28.59 ab
28 days	1.69 b	0.146 b	1.484 a	50.67 a	30.13 a
$LSD_{0.05}$	*0.19*	*0.02*	*0.288*	*2.86*	*3.14*
P_{value}	*0.006**	*0.009**	*0.328^{ns}*	*0.111^{ns}*	*0.007**

Means within a column followed by the same letter are not significantly different according to Least Significant Difference ($LSD_{0.05}$) test. *Indicates significant differences at $P_{0.05}$; ns = indicates non-significant differences.

2.2 Experimental Design and Field Management

The experiment was arranged in a randomized complete block design (RCBD) with three replications. Treatments consisted of three water management namely: Farmer Practice: Sprinkler irrigation at 3 days intervals, 14 days drought (water deprivation for 14 days) and 28 days water stress.

Uniform, 6-year-old durian trees (*Durio zibethinus* L. cv. “Montong”) planted at a 10m x 10m spacing were selected. Baseline soil fertility was maintained by applying 20 kg compost, 1,000 g N, 800 g P_2O_5, and 2,000 g K_2O per tree. Weeds and pathogens were managed using chemical applications at the manufacturers’ recommended rates to prevent biotic interference.

2.3 Drought Treatment and Irrigation Scheduling

Drought (water stress) conditions were initiated following the complete maturation and deep-green coloration of the third vegetative flush. To exclude natural precipitation during the drought periods, plastic mulch was placed within a 5 meters radius of each tree trunk. Prior to and immediately following the completion of the respective drought durations, surface sprinkler irrigation was restored to a 3 days interval schedule for 40 minutes using under-canopy sprinkler system with a maximum delivery rate of 160 L h^{-1}.

2.4 Data Collection

Fruit harvesting was conducted precisely at 120 days after anthesis (DAA). Leaf tissue samples were collected at full bloom to determine baseline foliar mineral nutrient concentrations. Evaluated reproductive and agronomic yield parameters included flower density per meter branch, fruit set, harvestable fruit count, individual fruit weight, and total yield per tree.

3. Results

3.1 Reproductive Phenology and Yield Characteristics

The duration of induced drought stress significantly influenced the reproductive parameters and final yield profiles of the crop (Table 2). Floral density increased markedly with the extension of the drought period, rising from 100.04 flowers per meter of branch under the well-watered control (0 days) to 164.96 at 14 days, and maximizing at 202.11 flowers per meter branch after 28 days drought (P = 0.012).

This enhanced floral induction directly corresponded with highly significant, stepwise increases in fruit set and harvested fruit count (P < 0.001). The highest number of fruit set (42.44) and harvested fruit (25.70) per tree were recorded under the 28 days treatment, representing a substantial improvement over the control (zero drought).

Consequently, total crop yield per tree was significantly enhanced by prolonged drought duration (P = 0.020), accelerating from 58.46 $kg.tree^{-1}$ (0 days) to a peak of 76.41$kg.tree^{-1}$ (28 days). Conversely, fruit drop percentage (P = 0.864) and individual fruit weight (P = 0.997) exhibited no statistically significant variations across any of the treatments, remaining constant individual friut weight at approximately 39.6% - 40.5% and 3.01 - 3.17 kg, respectively.

3.2 Leave Macronutrient Status and C/N Ratio

Varying the duration of water deficit altered the internal leaf nutritional status and carbon-to-nitrogen ratios significantly (Table 3). Foliar nitrogen (N) concentration declined significantly from 2.03% under control conditions to 1.83% at 14 days and reached its minimum at 1.69% under 28 days of drought (P = 0.006).

Similarly, leaf phosphorus (P) concentration significantly dropped (P = 0.009) from 0.179% (0 days) to 0.146% (28 days).

In contrast, foliar potassium content (P = 0.328) and total leaf carbon concentration (P = 0.111) were not statistically altered by moisture deprivation. Due to the steady carbon accumulation alongside a simultaneous depletion of leaf nitrogen, the carbon-to-nitrogen (C/N) ratio expanded significantly from 25.78 in well-watered plants to 30.13 in the 28 days drought treatment (P = 0.007).

4. Discussion

The physiological driver behind this reproductive success can be traced to the nutrient modifications detailed in Table 3. The significant decline in foliar N and Punder water deficit suggests that restricted soil moisture tension suppressed root-zone nutrient uptake. In perennial fruit trees, a surplus of nitrogen promotes vegetative flushing and gibberellin synthesis, which acts as a powerful antagonist to flower bud initiation. By suppressing leaf N accumulation via managed drought, vegetative vigor is checked, shifting metabolic resources toward reproductive meristem differentiation.

This is further validated by the significant elevation of the foliar C/N ratio, which peaked under the 28-day stress period (30.13). Because total C remained stable across all treatments and the widening of the C/N ratio was significant driven by the reduction of internal nitrogen. This carbohydrate heavy physiological state creates an ideal biochemical environment for starch accumulation in the buds, upregulating signaling pathways that trigger profuse floral induction (as observed in the doubling of floral density in Table 2). According to the classical Kraus-Kraybill rule, a high C/N ratio is a crucial prerequisite for floral transition in woody horticultural crops.

Crucially, from an agronomic parameter perspective, the data shows that the additional sink demand brought on by a higher fruit set fruit have minimal cause structural resource dilution. Because fruit drop percentages and individual fruit weights remained statistically unchanged compared to the control, the trees demonstrated sufficient carbohydrate capacity to sustain the increased fruit load through to harvest. Ultimately, the 28 day drought treatment maximized yield efficiency.

5. Conclusion

This study demonstrates that managed water deficit is a viable, non-chemical alternative to synthetic plant growth regulators for floral induction in durian (*Durio zibethinus* L.). Elucidating the dynamic fluctuations of critical macronutrients (N, P, K) and leaf-tissue carbon balances clarifies the physiological mechanisms driving the vegetative-to-reproductive transition under water stress. Controlled drought restricts subterranean nitrogen and phosphorous uptake, increase C/N ratio, successfully inducing flowering. Consequently, integrating these physiological thresholds into precision irrigation frameworks enables growers to mitigate climate variability, reduce costs, and secure international export compliance. Future work must validate these field-scale protocols across diverse edaphic profiles to standardize the practice globally.

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