Scientific Research Publishing

Agricultural Sciences, 2026, 17(8), 820-827
https://www.scirp.org/journal/as
ISSN Online: 2156-8561
ISSN Print: 2156-8553

Application of Potassium Nitrate and Mono Potassium Phosphate Foliar Following Prolonged Water Stress on the Yield of Longan in Cambodia

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How to cite this paper: Var, S., Cheang, H., Men, S., Tho, K.E., Khun, K.K. and Sao, S. (2026) Application of Potassium Nitrate and Mono Potassium Phosphate Foliar Following Prolonged Water Stress on the Yield of Longan in Cambodia. *Agricultural Sciences*, **17**, 820-827.
https://doi.org/10.4236/as.2026.178047

Received: June 30, 2026
Accepted: August 18, 2026
Published: August 21, 2026

Abstract

Water deprivation effectively shifts longan (*Dimocarpus longan* L.) from vegetative to reproductive development, but induces nutrient deficits that impair yields. However, these issues could be mitigated through the application of certain foliar fertilizers containing potassium. This research was conducted to evaluate the comparative efficacy of foliar-applied potassium nitrate (KNO_3) and monopotassium phosphate (MKP) on floral induction, leaf macronutrient dynamics, and yield components of water-stressed longan in Kampong Cham, Cambodia. Uniform six-year-old trees were subjected to a 28-day water deprivation protocol and treated twice immediately after drought relief and at 14 days after anthesis (DAA) with either KNO_3 or MKP (1500 ppm K_2O). Both foliar K interventions significantly increased initial fruit set, and harvested fruits per cluster and total yield compared to the control ($P < 0.05$), while only KNO_3 significantly improved flowering twigs. Additionally, both potassium treatments decreased physiological fruit drop due to potassium's function as inorganic osmotic regulator in plant cells. Consequently, MKP and KNO_3 treatments dramatically improved final fruit weight and total tree yield, with MKP producing the heaviest fruits (10.27 g). Leaf analysis at 14 DAA revealed that internal potassium concentrations showed an inverse trend; treated trees exhibited significantly lower foliage reserves than the control. This demonstrates a crop-load-driven dilution effect, where mobile K^+ was rapidly translocated from leaves into developing reproductive organ to optimize economic yield.

Keywords

Dilution Effect, Floral Induction, Fruit Drop, Water Deficit, Kompong Cham

1. Introduction

Longan (*Dimocarpus longan* L.) grows and develops optimally in warm, humid regions with high rainfall. The cultivation area of longan in Cambodia exceeded 12,000 hectares in 2021 and continues to steadily increase [1]. Water regulation or controlled water deprivation is an effective physical method to induce mild stress, which triggers a shift from vegetative growth to reproductive development by altering hormone balances and increasing energy compounds within plant tissues [2] [3].

Under water deprivation conditions (water deficit stress), nutrient absorption by the roots is obstructed, and nutrient movement within the soil matrix is disrupted, driving mild-to-severe nutrient deficiencies in crops. This includes deficiencies in potassium (K), an essential element required to regulate stomatal opening and closing, and to sustain gas exchange for photosynthesis, especially under water deprivation and high-temperature conditions [4]. Additionally, potassium promotes apical meristem development, new leaf growth, and root system expansion. It is also crucial for stabilizing cellular pH, optimizing the absorption and assimilation of nitrogen (N) and phosphorus (P), and directly increasing fruit weight, fruit size, and total crop yield [5].

Studies on different potassium sources indicate distinct efficacies in mitigating specific physiological stresses caused by water deficits. Foliar sprays of potassium nitrate (KNO_3) have shown high potential for inducing flowering and increasing fruit quantity in mangoes. Applying KNO_3 to leaves enhances protein synthesis because K^+ ions actively participate in metabolic pathways by controlling stomata, maintaining gas exchange capacities alongside nitrogen to stabilize chlorophyll, and assisting tRNA binding to ribosomes during cellular development under stress conditions [6] [7].

Conversely, monopotassium phosphate (MKP) possesses a low salt index and safely supplies phosphate (P), which is critical for sustaining energy synthesis (ATP) and enzyme functions when soil phosphorus cannot be fully absorbed by roots. Therefore, this study was designed to evaluate the direct influences of foliar-applied KNO_3 and MKP on the floral induction and yield components of longan under field conditions within a commercial orchard in Kampong Cham province, Cambodia.

2. Materials and Methods

2.1. Study Site

The field experiment was conducted at a private farmer's orchard located approximately 66 meters above sea level in Kampong Cham province (12˚19′18.96″ N, 105˚15′46.66″ E), Cambodia. During the experimental period, temperatures fluctuated between 23˚C and 34˚C with an atmospheric relative humidity ranging from 65% to 85%. The soil physical and chemical properties of the experimental site including texture, pH, organic matter, and major nutrient levels are summarized in Table 1.

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

EC	pH	P (ppm)	K ($cmol_c\ kg^{-1}$)	N (%)	SOM (%)	Soil Texture			
						Clay (%)	Silt (%)	Sand (%)	Class
38.0	5.9	9.70	1.18	0.01	1.38	25.3	19.2	55.5	Sandy Clay Loam

Source. Analyses results conducted by Soil Laboratory, Faculty of Agricultural Science, 2021.

2.2. Experimental Design and Field Management

The experiment utilized uniform, 6-year-old longan trees spaced at 5 m × 5 m, arranged in a Randomized Complete Block Design (RCBD) with three replications (27 trees total, 9 trees per treatment). All trees received a uniform baseline soil fertilization (400 g N, 300 g P_2O_5, and 700 g K_2O per tree) and were irrigated every 3 days until completing two successive vegetative flushes. At full maturity of the second flush, a 28-day water deprivation protocol was enforced, during which the 5 m × 5 m ground area beneath each canopy was sealed with plastic sheeting to exclude moisture.

Following the water deprivation period, three foliar treatments were evaluated: an untreated K (control), potassium nitrate (KNO_3; 13-0-46), and monopotassium phosphate (MKP, 0-52-34). Both nutritional interventions were calibrated to deliver 1500 ppm K_2O (1.5 g L^{-1} K_2O). The solutions contained 3.26 g L^{-1} of KNO_3 and 4.41 g L^{-1} of MKP was applied as a full-canopy spray at a standardized volume of 5 L per tree. No surfactant or adjuvant was used. Treatments were applied twice: immediately after the 28-day water deprivation period to stimulate flowering, and 14 days after anthesis (DAA).

2.3. Data Collection

2.3.1. Reproductive Phenology and Yield Characteristics

- *Percentage of flowering twigs* (%): Fifty fully unfolded shoots were randomly select per tree and tagged for monitoring. The percentage of flowering twigs was calculated as follows:

$$\text{Flowering Twigs}(\%) = (\text{Number of Flowering Twigs}/\text{Total Number of Twigs}) \times 100 \quad (1)$$

- *Flower Count* (Flowers $cluster^{-1}$): Cumulative flowers per cluster was quantified at the end of blooming cycle. Five sampled, enclosed panicles per tree were harvested within their mesh bags, and total flowers were calculated as:

$$\text{Total Flowersper Cluster} = N_{\text{dropped}} + N_{\text{attached}} \quad (2)$$

where $N_{dropped}$ and $N_{attached}$ represent the number of abscised and remaining flowers, respectively.

- *Fruit set count* (Fruits cluster^{-1}): Initial fruit set was evaluated exactly 14 days after full anthesis (DAA) by temporarily removing the micro-perforated mesh bags from the five tagged panicles per tree and counting the swelling, fertilized ovaries.
- *Harvest fruit count* (Fruits cluster^{-1}): The number of viable fruits per clusters was recorded at harvest (120 DAA) from the same five tagged clusters.
- *Fruit dropped* (%): Cumulative fruits dropped per cluster was calculate using the following equation:

$$\text{Fruit Drop}(\%) = \left[\left(F_{fruitset} - F_{harvestfruit}\right)/F_{fruitset}\right]\times 100 \tag{3}$$

where $F_{fruitset}$ is the fruit set at 14 DAA and $F_{harvestfruit}$ is the number of harvested fruits.

- *Individual fruit weight* (g): Ten fruit from each sample cluster was randomly selected and weight individually.
- *Total yield* (kg tree^{-1}): Total yield was determined by weighing all harvest cluster per tree.

2.3.2. Leaf Macronutrient Status and C/N Ratio

- *Leaf mineral content*: Twenty leaves were randomly sampled from the mid-section of fruiting twigs on the outer canopy at 14 DAA. Samples were washed with distilled water, oven-dried at 60˚C for 72 hours to a constant weight, and pulverized. Total organic carbon (C), nitrogen (N), Phosphorous (P), and potassium (K) concentration (%) were determined using standard analytical methods.
- *C/N Ratio*: The leaf carbon-to-nitrogen (C/N) ratio was calculated as:

$$\text{C/NRatio} = \text{Total Organic Carbon}(\%)/\text{Total Nitrogen}(\%) \tag{4}$$

2.4. Data Analysis

Data were subjected to statistical processing Statistix 10 software (version 10.0, Analytical Software, Tallahassee, FL, USA). Treatment effects were evaluated via a one-way Analysis of Variance (ANOVA), and mean separations were determined using the Least Significant Difference (LSD) test at $\alpha = 0.05$.

3. Results

3.1. Reproductive Phenology and Yield Characteristics

- *Percentage of flowering twigs*: The application of KNO_3 significantly increased the percentage of flowering twigs compared to both the unfertilized control and MKP ($P < 0.05$).
- *Flower Count*: There were no statistically differences observed among the KNO_3, MKP and control treatements regarding total flower count per cluster ($P > 0.05$).
- *Fruit set Count*: Results revealed that monopotassium phosphate and potassium nitrate treatments led to a significantly higher number of fruit set per

cluster compared to control ($P < 0.05$).

- *Harvest Fruit Count*: Among the reatement, monopotassium phosphate treatments produced the highest number of harvested fruit (62.11), performing significanlty better than the KNO_3 (55.44) and control treatment (39.22) ($P < 0.05$).
- *Fruit Drop*: Folair potassium significantly reduced fruit drop under severe drought stress. The untreated tree (control) exhibited the highest rate of fruit drop (52.74%), which decreased to 52.74% with KNO_3 and dropped further to 49.05% with MKP (Table 2).

Table 2. Influence of foliar potassium on yield components under a 28-day water stress period.

Water deprivation	Flowering Twig (%)	Flower Count (No. $Cluster^{-1}$)	Fruit Count		Fruit Drop (%)	Fruit Weight (g $fruit^{-1}$)	Yield (kg $tree^{-1}$)
			Fruit set (No $Cluster^{-1}$)	Harvest Fruit (No. $Cluster^{-1}$)			
Control	64.88 b	290.56 a	91.33 b	39.22 c	57.07 a	7.74 c	52.59 b
KNO_3	78.22 a	301.44 a	116.78 a	55.44 b	52.74 b	9.70 b	62.96 a
MKP	69.77 b	300.67 a	121.89 a	62.11 a	49.05 c	10.27 a	64.47 a
$LSD_{0.05}$	5.66	16.02	5.36	4.52	2.60	0.42	4.42
P_{value}	0.000*	0.203^{ns}	0.000*	0.000*	0.000*	0.000*	0.000*

Note: 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.

- *Individual Fruit Weight*: Foliar potassium applications significantly increased individual fruit weight compared to the control treatment (7.74 g). Both KNO_3 and MKP treatments produced fruits that were approximately 2 to 3 gram heavier than the control, with the MKP treatment (10.27 g) yielding significantly heavier fruits than the KNO_3 treatment (9.70 g).
- *Total Yield*: Foliar MKP application achieved the highest overall crop yield, performing statistically on par with the KNO_3 treatment, whereas the control produced the lowest yield. Although treated trees exhibited a significantly higher fruit drop percentage, their final yield remained superior due to a heavily elevated initial fruit set. This massive initial load intensified intra-cluster competition for maternal resources, triggering increased physiological self-thinning. Nevertheless, the sheer volume of the initial set offset these losses, resulting in a significantly higher absolute number of harvested fruits compared to the control.

3.2. Leave Macronutrient Status and C/N Ratio

- *Leaf Nutrient Dynamics*: For internal leaf concentrations of nitrogen (N), phosphorus (P), total organic carbon (C), and the resulting C/N ratio, no statistically significant differences were observed between the two foliar fertilizers and the untreated control group (P > 0.05), indicating a uniform baseline suppression under water deprivation.

- *Potassium Accumulation*: Foliar treatments significantly altered the accumulation of potassium (K) in the leaves (P = 0.012). However, an inverse physiological trend was observed. The KNO_3 treatment uniquely resulted in the lowest internal leaf potassium concentration (1.366%), dropping significantly below the untreated control (1.476%). The MKP treatment occupied an intermediate statistical position (1.400%) and did not differ significantly from either the control or the KNO_3. This indicates a rapid, crop-load-driven dilution effect, whereas accumulated K^+ is heavily drawn from the leaves to support intense reproductive sink growth (Table 3).

Table 3. Effect of foliar K applications on nutrient concentrations and C/N ratio at 14 DAA.

Water deprivation	N (%)	P (%)	K (%)	C (%)	C/N Ratio
Control	1.683 a	0.136 a	1.476 a	52.92 a	31.46 a
KNO_3	1.697 a	0.142 a	1.366 b	52.57 a	31.00 a
MKP	1.663 a	0.136 a	1.400 ab	53.08 a	31.94 a
$LSD_{0.05}$	0.132	0.019	0.084	1.51	1.54
P_{value}	0.963^{ns}	0.327^{ns}	0.012*	0.661^{ns}	0.303^{ns}

Note: 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.

4. Discussion

Despite differences in their effect on flowering percentage between KNO_3 (78.22%) and MKP (69.77%), both foliar potassium treatments showed a trend toward higher percentages than the control treatment. Potassium salt triggered floral initiation by breaking shoot apical domacy, suppressing vegetative growth, and stimulating the transition of mature terminal buds into floral primordia. Furthermore, potassium (K^+) enhances phloem sucrose loading and carbohydrate translocation from leaf to developing shoots, providing the metabolic energy required for flower bud differentiation under water stress [8] [9].

Although initial flower counts were unaffected by the treatments, foliar potassium (KNO_3, MKP) significantly improved the number of fruit set and harvested fruit per cluster. In addition, both potassium treatments significantly decreased the percentage of fruit drops compared to the control treatment. Severe water stress promotes the synthesis of abscisic acid (ABA) and ethylene, activating cell wall-degrading enzymes in the pedicel abscisic zone that trigger fruit shedding [10]. Meanwhile, potassium (K^+) functions as the principle celluar inorganic osmolyte, regulating stomatal opening and preserving cell turgor under water deficit conditions [9].

Ultimately, foliar potassium interventions drastically optimized individual fruit weight and total tree yield, with MKP exhibiting the most pronounced effect on fruit size. The physiological superiority of MKP is attributed to the synergistic pairing of P and K; phosphorus drives cellular energy transfer (ATP) during rapid fruit development, while concurrent potassium suppresses excessive vegetative flushing and promotes structural flower development [11].

Leaf macronutrient analysis at 14 DAA showed that water deprivation locked N, P, and C concentrations, as well as C/N ratio, into static baselines across all treatments, confirming a uniform suppression of root nutrient uptake under water stress [12].

Conversely, leaf K concentration presented a significant inverse trend. The control treatment retained the highest foliage reserves, while treated plants, particularly under KNO_3, exhibited the lowest. This inverse trend could be explained by a crop-load-driven dilution effect [13]. KNO_3 treatment enhances flowering and fruit set, promoting rapid K^+ translocation from leaf reserves to developing fruits [14]. This demonstrates that under severe water stress, foliar K application did not merely accumulate nutrients in the leaves, but acted as a metabolic catalyst, triggering immediate resource translocation toward economic yield improvement [15].

5. Conclusion

This study demonstrates that applying foliar/canopy sprays of either KNO_3 or MKP is a highly effective physicochemical strategy to overcome the reproduction and nutrient constraints imposed by the 28-day water deprivation protocol in longan cultivation. Both foliar potassium treatments successfully increased the flowering twig percentage, initial fruit set, final harvest fruit number, individual fruit weight, and total yield. Under severe water stress, while foliar application maximized reproductive capacity, it caused a sharp decline in internal leaf potassium concentrations at 14 DAA. This indicates a profound crop-load-driven dilution effect, a physiological mechanism where accumulated K^+ is heavily drawn out of leaves to sustain aggressive reproductive growth. Ultimately, while both fertilizers performed similarly across broad yield parameters, MKP provides a distinct physiological advantage in maximizing individual fruit weight due to the synergistic interaction of phosphorus and potassium during rapid fruit expansion.

Author Contributions

Conceptualization, Var, Sophal.; methodology, Var, Sophal., Cheang, Hong.; software, Tho, Kim. Eang.; validation, Men, Sarom., Khun, Kim. Khuy., and Tho, Kim. Eang.; formal analysis, Var, Sophal.; investigation, Men, Sarom., Khun, Kim. Khuy.; resources, Sao, Sreymom.; data curation, Tho, Kim. Eang., Sao, Sreymom., and Men, Sarom.; writing—original draft preparation, Var, Sophal.; writing—review and editing, Var, Sophal.; supervision, Cheang, Hong. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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