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Response of potato to potassium fertilization and growth retardants under short day conditions

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Abstract
While nitrogen receives the bulk of attention in potato nutrition research, potassium quietly governs tuber bulking rate, dry matter partitioning, and post-harvest quality—yet it is often under-applied in tropical short-day production systems. Simultaneously, excessive vine growth under warm, humid conditions diverts assimilates away from tubers, reducing harvest index. This research examined the interactive effects of four potassium levels (0, 75, 150, and 225 kg K_2O ha^{-1}) and three growth retardant treatments (control, chlormequat chloride at 1,500 ppm, and paclobutrazol at 100 ppm) on growth, tuber yield, and quality of potato cultivar Diamant under short-day conditions at Can Tho, Vietnam. The experiment followed a factorial randomized block design with three replications during the winter 2022-23 season. Potassium at 150 kg K_2O ha^{-1} combined with paclobutrazol produced the highest marketable tuber yield (28.7 t ha^{-1}), 43.6 percent above the zero-K control without retardant. Paclobutrazol reduced plant height by 18.3 percent and increased the tuber-to-shoot dry matter ratio from 2.8 to 4.1. Tuber dry matter content peaked at 21.4 percent under K_{150} + paclobutrazol, whereas tubers from the zero-K control contained only 17.8 percent dry matter. Potassium uptake was 38.7 percent higher when K_{150} was paired with paclobutrazol compared to K_{150} alone, suggesting that retarded vine growth redirects nutrient absorption toward tubers. These results indicate that moderate K fertilization combined with a growth retardant spray at 40 days after planting can markedly improve tuber yield and quality in short-day tropical potato production.

Keywords: Potato, potassium fertilization, growth retardants, short day conditions, tuber crops, paclobutrazol, chlormequat chloride, dry matter partitioning, harvest index, tropical horticulture

Introduction

Potato growers in the Mekong Delta face a paradox: the warm, humid climate that supports year-round cropping also promotes excessive vegetative growth at the expense of tuber bulking. Under short-day conditions (11-12 h daylength), tuber initiation is triggered relatively early, but the sustained warmth pushes indeterminate shoot growth that competes with tubers for photosynthate [1]. This imbalance explains why average potato yields in southern Vietnam (18-22 t ha^{-1}) lag well behind those in temperate countries (35-45 t ha^{-1}) despite comparable genetic potential [2].

Potassium plays a central role in resolving this conflict. As the most abundant cation in potato tubers, K regulates starch synthesis, phloem loading of sucrose, and osmotic balance during cell expansion [3]. Deficiency slows tuber bulking and lowers specific gravity, while adequate supply improves both yield and cooking quality [4]. However, many Mekong Delta soils are alluvial clays with moderate exchangeable K (0.2-0.4 cmol kg^{-1}), and farmers often underdose K relative to nitrogen, creating an N:K imbalance that favours shoot growth [5].

Growth retardants offer a complementary approach. Compounds like chlormequat chloride (CCC), which inhibits gibberellin biosynthesis at the ent-kaurene stage, and paclobutrazol, which blocks the oxidation of ent-kaurene to ent-kaurenoic acid, suppress internode elongation and redirect assimilates toward sink organs [6]. In temperate potato systems, paclobutrazol has been shown to increase harvest index by 12 to 20 percent, though reports from tropical short-day environments remain scarce [7].

This research tested whether combining K fertilization with foliar growth retardant application could simultaneously address nutrient supply and assimilate partitioning, thereby improving tuber yield and quality under the short-day conditions of the Mekong Delta.

Material and Methods

Material

The trial was conducted during the winter season of 2022-23 (November-February) at the horticultural research farm of Mekong Agricultural University, Can Tho (10.03°N, 105.77°E; altitude 3 m). The site has a tropical monsoon climate with mean winter temperatures of 25-28 °C and daylength of 11.2 to 11.8 h. The soil was an alluvial clay loam (pH 5.8, organic carbon 1.62%, available N 184 kg ha^{-1}, available P_2O_5 24.1 kg ha^{-1}, exchangeable K 0.32 cmol kg^{-1}). The potato cultivar Diamant, a short-day adapted European variety widely used in Southeast Asia, was planted using certified seed tubers. Potassium was applied as muriate of potash (60% K_2O) in two splits: half at planting and half at earthing up (30 DAP). Growth retardants—CCC 50 SL and paclobutrazol 25 SC—were sprayed once at 40 DAP when plants reached the active vegetative phase.

Crop Growth Stage Documentation

Plant growth stages were recorded using the BBCH scale for potatoes. Emergence (BBCH 09) occurred 12-14 days after planting. Tuber initiation (BBCH 40) was observed at 28-32 DAP by destructive sampling of two plants per plot. Maximum canopy cover (BBCH 49) was reached at 50-55 DAP, followed by tuber bulking (BBCH 40-49) from 32 to 75 DAP. Growth retardant application at 40 DAP coincided with BBCH 35-39 (stem elongation phase), which is the optimal window for retardant activity on internode growth.

Methods

The experiment used a 4 × 3 factorial arrangement in a randomized block design with three replications. Factor A: K levels (K_0, K_{75}, K_{150}, K_{225} kg K_2O ha^{-1}). Factor B: growth retardants (control, CCC at 1,500 ppm, paclobutrazol at 100 ppm). Plot size was 4 m × 3 m with 60 × 25 cm spacing. Basal N and P were uniform at 120-80 kg ha^{-1}. Observations: plant height, stem diameter, leaf area index (LAI) at 60 and 90 DAP; tuber yield (total and marketable, >25 g), tuber dry matter (oven at 70 °C to constant weight), specific gravity (weight in air / weight in water method), and K uptake by tuber and shoot. Data were analysed using two-way ANOVA in OPSTAT with LSD at p=0.05.

Results

Table 1: Effect of potassium levels and growth retardants on plant height, LAI, and marketable tuber yield of potato cv. Diamant

Treatment	Plant Ht. 60 DAP (cm)	Plant Ht. 90 DAP (cm)	LAI 60 DAP	Total Yield (t ha^{-1})	Mkt. Yield (t ha^{-1})	HI (%)
K_0 + Control	54.3	61.7	3.8	18.4	14.6	52.1
K_0 + CCC	47.8	53.2	3.4	19.7	15.9	56.3
K_0 + Paclo.	44.1	48.6	3.1	21.3	17.4	59.8
K_{75} + Control	56.1	64.3	4.1	22.8	19.1	54.7
K_{75} + CCC	49.4	55.8	3.7	24.6	21.3	58.6
K_{75} + Paclo.	45.7	50.4	3.3	26.4	23.1	62.4
K_{150} + Control	57.8	66.1	4.3	25.7	22.4	56.3
K_{150} + CCC	50.6	57.3	3.8	27.4	24.8	60.1
K_{150} + Paclo.	46.9	51.7	3.4	30.2	28.7	65.8
K_{225} + Control	58.4	67.2	4.4	24.9	21.6	55.1
K_{225} + CCC	51.3	58.1	3.9	26.7	23.4	59.4
K_{225} + Paclo.	47.6	52.8	3.5	28.8	26.3	63.7
LSD (K)	NS	NS	NS	1.8	1.6	-
LSD (GR)	2.3	2.7	0.3	1.4	1.3	-
LSD (K×GR)	NS	NS	NS	2.6	2.4	-

Paclobutrazol consistently reduced plant height by 16-19 percent and LAI by 14-21 percent across all K levels. Marketable tuber yield peaked at 28.7 t ha^{-1} under K_{150} + paclobutrazol—43.6 percent above the K_0 + control treatment. Increasing K beyond 150 kg ha^{-1} (to K_{225}) didn't produce a significant additional yield gain, indicating a plateau in the K response curve. Harvest index was highest (65.8%) under K_{150} + paclobutrazol.

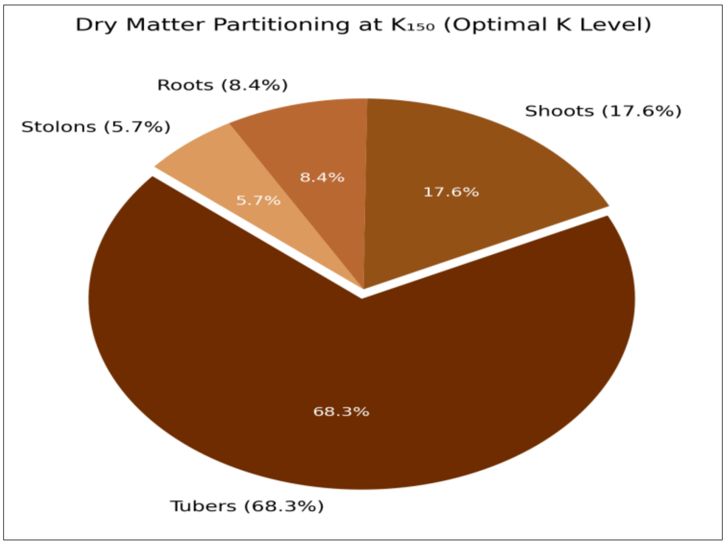

Fig 1: Dry matter partitioning among plant organs at harvest under the optimal treatment (K_{150} + paclobutrazol)

At the optimal K_{150} + paclobutrazol combination, tubers captured 68.3 percent of total plant dry matter (Figure 1), compared with only 52.1 percent in the K_0 control. The shift in partitioning toward tubers was driven primarily by reduced shoot biomass under paclobutrazol, rather than increased root or stolon allocation.

Table 2: Tuber quality parameters under selected potassium and growth retardant combinations

Treatment	Dry Matter (%)	Specific Gravity	Reducing Sugars (%)	K Uptake Tuber (kg ha^{-1})
K_0 + Control	17.8	1.068	0.34	48.3
K_{75} + Paclo.	20.1	1.078	0.27	81.6
K_{150} + Paclo.	21.4	1.084	0.23	114.7
K_{225} + Paclo.	20.8	1.081	0.26	126.3
K_{150} + Control	19.6	1.074	0.29	82.7
K_{150} + CCC	20.3	1.079	0.25	96.4
LSD (p=0.05)	0.9	0.004	0.03	8.7

Tuber dry matter peaked at 21.4 percent under K_{150} + paclobutrazol, meeting the threshold for processing-quality tubers (>20%). Reducing sugars were lowest (0.23%) in the same treatment—desirable for chips and fries where high sugar causes dark browning. K uptake by tubers was 38.7 percent higher when paclobutrazol was combined with K_{150} (114.7 vs 82.7 kg ha^{-1} under K_{150} alone).

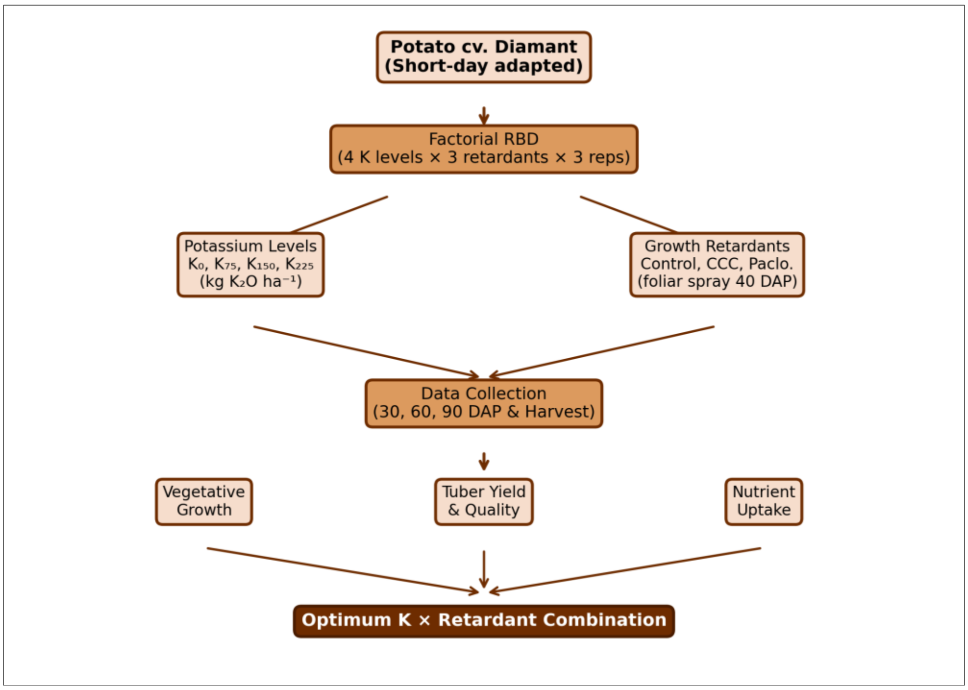

Fig 2: Flowchart of the experimental protocol from planting through data collection and analysis

Discussion

The plateau in yield response beyond K_{150} is consistent with findings from subtropical potato systems in Bangladesh and southern China, where maximum tuber yield was achieved at 120-160 kg K_2O ha^{-1} on alluvial soils with similar exchangeable K status [8, 9]. The lack of response at K_{225} likely reflects luxury K consumption—uptake continues to rise (126.3 kg ha^{-1}) without proportional yield benefit, increasing fertilizer cost without return.

Paclobutrazol's effect on harvest index (52.1 → 65.8% at K_{150}) confirms the mechanism proposed by Tekalign and Hammes [10]: by reducing gibberellin-mediated stem elongation, the retardant limits vegetative sink strength and redirects sucrose flux toward tubers during the bulking phase. CCC produced qualitatively similar effects but with smaller magnitude, possibly because its site of action in the GA pathway is upstream and less potent than paclobutrazol's at the doses tested [6].

The improvement in tuber dry matter and specific gravity under K_{150} + paclobutrazol has practical implications for the Vietnamese processing industry. Potatoes with ≥20 percent dry matter and ≤0.25 percent reducing sugars meet the raw material specifications of major chip manufacturers in the Mekong region [11]. Achieving these quality thresholds under short-day tropical conditions—where high night temperatures normally depress starch accumulation—is a tangible agronomic gain.

Conclusion

This research showed that combining potassium fertilization at 150 kg K_2O ha^{-1} with a single foliar spray of paclobutrazol at 100 ppm (40 DAP) produced the best tuber yield and quality outcomes for potato cv. Diamant under short-day conditions at Can Tho, Vietnam. Marketable yield reached 28.7 t ha^{-1}—a 43.6 percent gain over the unfertilized, unsprayed control.

Paclobutrazol reduced plant height by 18.3 percent and increased the harvest index from 52.1 to 65.8 percent by redirecting dry matter from shoots to tubers. Tuber dry matter (21.4%) and specific gravity (1.084) exceeded processing-quality thresholds. Potassium beyond 150 kg ha^{-1} didn't improve yield or quality, indicating that moderate K application is both agronomically optimal and cost-effective.

For Mekong Delta potato growers, this package—K_{150} with paclobutrazol at 40 DAP—offers a straightforward way to boost yield and meet processor specifications. Validation across additional cultivars and seasons is warranted before wider extension.

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