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Pre-emergence Herbicide for Controlling Weed in Various Sugarcane Genotypes Grown under Late Rainy Season

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ABSTRACT

Background: Weeds cause a decrease in sugarcane productivity, so the application of pre-emergence herbicides can be used as a solution to control weeds. This study aimed to identify the most effective pre-emergence herbicide for weed management across multiple sugarcane genotypes under late rainy season conditions.

Methods: Split-plot design was used in this study with three replications. Four weed management strategies were assigned as main plots and four sugarcane varieties were assigned as sub-plots. Weed data, including control efficacy, weed biomass, weed density and weed species, were collected at 15-day intervals from 15 to 120 DAA. Plant height and tiller number of sugarcane were measured at 30, 60, 90 and 120 DAA.

Result: The most common weed was *Cyperus rotundus* L. (purple nutsedge), followed by *Indigofera hirsuta* (hairy indigo). Weed control efficiency in diuron and pendimethalin + imazapic treatments was intermediate between hand weeding and weedy (untreated control) with similar patterns observed in overall weed scores from 60 to 120 DAA. Both herbicides reduced weed density and weed biomass between 60 and 120 DAA, with pendimethalin + imazapic being more effective than diuron at 105 DAA. Sugarcane genotypes had no significant effect on weed control efficiency, density, or biomass throughout the experiment. However, pendimethalin + imazapic in KPS01-12 resulted in a higher tiller number at 90 DAA and greater plant height from 90 to 120 DAA. Thus, pendimethalin + imazapic effectively reduced weed presence and supported the growth of certain sugarcane varieties during the late rainy season.

Key words: Diuron, Herbicide efficiency, Imazapic, Initial sugarcane growth stage, Pendimethalin, Weed control.

INTRODUCTION

Thailand, one of the top sugarcane-producing countries, faces major yield constraints from weed competition, with the Northeast region contributing the largest share of production (FAO, 2022; Sukyai *et al.,* 2016; Prasara-A and Gheewala, 2016). Sugarcane cultivation patterns in Thailand show strong regional and varietal dependencies. In particular, planting schedules vary by region: The Northeast typically plants during October-November, while other regions plant from November to February (Manivong and Bourgois, 2017).

Weeds pose a major challenge in sugarcane cultivation, competing for nutrients and reducing yields (Khumla *et al.,* 2022). Sugarcane cultivation employs various weed control strategies that have been used and studied in previous research, including biological control (*e.g.*, mycoherbicides), mechanical tillage (*e.g.*, inter-row cultivation) and chemical applications (both selective (*e.g.*, 2,4-D) and non-selective herbicides (*e.g.*, glyphosate) (Odero and Dusky, 2021; Khumla *et al.,* 2022). Pre-emergence herbicides remain a critical component of integrated weed management in sugarcane cultivation due to their (1) cost-effectiveness compared to manual weeding (saving ~60% labor costs), (2) reliability under large-scale production and (3) ability to control weeds during the critical early growth phase (first 120 DAA) when crop-weed competition is most damaging (Odero and Dusky, 2021). While biological and mechanical controls are available, herbicides offer unique advantages: They prevent yield losses of 15-40% from early weed pressure (Khumla *et al.,* 2022), can be applied rapidly across extensive fields (critical for Thailand's average farm size of 8-12 ha; Prasara-A and Gheewala, 2016) and when used judiciously, reduce soil disturbance compared to tillage (conserving moisture in late rainy seasons). Both pre- and post-emergence applications show efficacy (Raskar, 2004; Odero *et al.,* 2015; Takim and Suleiman, 2018), but pre-emergence treatments are particularly valuable for late rainy-season planting where early weed

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flushes threaten crop establishment (Aekrathok *et al.,* 2021).

In Thailand, post-emergence herbicides like ametryn and paraquat have been used to control common weed species during tillering stage (Aekrathok *et al.,* 2021), but limited studies have evaluated pre-emergence herbicides across sugarcane genotypes during the late rainy season. Though hand weeding is effective, it is labor-intensive and costly. Herbicide use enhances efficiency, reducing time and cost. The duration of weed control varies significantly among herbicides: Diuron and ametryn provide effective control for approximately 30 days (Esqueda, 2005; Niz *et al.,* 2018), while pendimethalin and imazapic maintain efficacy for 80-90 days (Shaner *et al.,* 2014; Ulbrich *et al.,* 2005). Standard pre-emergence herbicides like atrazine (early rainy season) and metribuzin (dry season) are well-documented (Carbonari *et al.,* 2016; Congreve and Cameron, 2023), but late rainy season plantings present distinct challenges: higher weed diversity, herbicide wash-off risks and delayed canopy closure. Despite demonstrated efficacy of diuron and pendimethalin+ imazapic in controlled conditions (Odero *et al.,* 2015), their performance across cultivars under variable late-season field environments remains poorly understood, particularly regarding interactions between herbicide persistence, rainfall patterns and varietal growth traits (Khonghintaisong *et al.,* 2018; Pringgani *et al.,* 2023). This study aims to identify the most effective herbicide for diverse sugarcane cultivars during this period, optimizing weed management and improving sugarcane productivity.

MATERIALS AND METHODS

Site description, cultural practices and experimental details

This experiment was conducted at the Agronomy Field Crop Stations, Khon Kaen University, Khon Kaen, Thailand (16.4592°N, 102.8120°E; 179 m elevation) from December 1, 2022, to April 18, 2023, covering the late rainy season to early summer. A split-plot design with three replications was used, comprising a total of 48 experimental plots. Weed control methods were the main plots and sugarcane cultivars were the sub-plots. Each experimental plot measured 5 m × 6 m (width × length) and contained five 6-meter-long rows spaced 1.5 m apart, with 0.5 m between plants within rows. Four weed management strategies were applied: (1) hand weeding (weekly), (2) weedy control (no intervention), (3) diuron (280 g a.i. rai^{-1}; 1,750 g ha^{-1}) and (4) pendimethalin (280 g a.i. rai^{-1}; 1,750 g ha^{-1}) + imazapic (12 g a.i. rai^{-1}; 75 g ha^{-1}), mixed and sprayed.

Four Thai commercial sugarcane varieties-KK3, UT-12, KPS01-12 and UT-13-were used in this experiment, differing in canopy coverage. UT-13 and UT-12 have small or slow canopy cover, KPS01-12 has a large or fast canopy cover and KK3 has moderate canopy cover (Pringgani *et al.,* 2023).

Sugarcane setts were planted directly in the field and fertilized with 50 kg ha^{-1} of N and P and 25 kg ha^{-1} of K. The soil, classified as siliceous, isohypothermic, Oxic Paleustults (Yasothon series; WRB: Arenosols), had a sand content of 84.93%, clay content of 5.07% and silt content of 10.0%. The soil's pH was 5.51, with a cation exchange capacity of 3.09 c mol kg^{-1}. It contained 0.85% organic matter, 0.03% total nitrogen, 32.28 mg kg^{-1} of available phosphorus, 30.41 mg kg^{-1} of exchangeable potassium and 214.23 mg kg^{-1} of exchangeable calcium. Following Thai sugarcane cultivation practices, sugarcane was planted using residual soil moisture from the late rainy season, which was sufficient for herbicide activation and germination without additional irrigation during the drought period (Khonghintaisong *et al.,* 2018). In this study, soil moisture content prior to planting was set to field capacity, defined as 12% volumetric water content at a soil depth of 0-30 cm.

Data collection

Weed data were collected at 15-day intervals from 15 to 120 DAA (Days After Application). Growth characteristics, including plant height and tiller number, were recorded at 30, 60, 90 and 120 DAA. Weed counts were conducted in each plot using four 0.25 m^2 quadrats-small, square sampling frames used to standardize area and ensure consistent weed sampling-placed diagonally to represent field variation. Weeds within each quadrat were identified by species and counted. The totals from four quadrats were summed and averaged per plot across three replications to determine weed density and species composition. Weed density was measured for all herbicide treatments, while weed biomass was assessed per 1 m^2. Samples were separated by weed type (broadleaf/narrowleaf/sedge), then dried at 80°C for 72 hours prior to weighing. Herbicide efficacy was visually assessed every 15 DAA for each species and overall weed control, using a scale from 0 (no control) to 100 (complete control), following the protocol by Frans and Talbert (1997). Weed species were identified through random sampling in each plot, following methods from Noda *et al.* (1994).

Weed species density percentage was calculated by counting the number of each weed species found in each plot every 15 days (from 15 to 120 DAA). Each weed species count was then divided by the total number of weeds found and multiplied by 100 (Nedeljkovic *et al.,* 2021).

Statically analysis

The data analysis of variance was used according to the experiment design to examine differences in treatment effect including weed control efficacy, biomass and density. The data were subjected to statistical analysis using Statistix® 10 (1985-2013) program (Analytical Software, Tallahassee, FL, USA) and treatment mean differences were separated using the LSD at 0.05% probability.

RESULTS AND DISCUSSION

Meteorological conditions

The experiment included total rainfall of 52.2 mm, with peaks of 25.6 mm at 113 DAA and 17.8 mm at 118 DAA.

The minimum daily air temperature ranged from 11.0 to 29.0°C and maximum temperature ranged from 24.5 to 42.0°C. Humidity has ranged from 58.0 to 96.0% during the growing season (Fig 1). The late-rainy season is the most common sugarcane production system in Thailand (Khumla *et al.,* 2022). The experimental site experienced a water deficit for more than two months during the study period (Khonghintaisong *et al.,* 2018), representing typical late rainy-season conditions where pre-emergence herbicide efficacy may be compromised by limited soil moisture. The majority of pre-emergent herbicides need to be treated on soil while there is sufficient soil moisture (Chathuranga *et al.,* 2023). Pre-emergent herbicides require adequate soil moisture for effectiveness, as root-absorbed herbicides perform poorly in low soil water conditions (Congreve and Cameron, 2023).

Weed species density percentage

At 15 DAA, seven weed species were observed. However, the number of species increased from 30 DAA to 120 DAA, reaching a total of 15 species. The most common species were recorded at 45, 60 and 90 DAA, while numbers decreased at 105 and 120 DAA. The predominant species included *Cyperus rotundus* L. (24.7%), *Indigofera hirsuta* Harvey (15.2%) and *Ipomoea pes-tigridis* L. (11.4%), each representing over 10% of the total species (Fig 2).

Weed control efficiency of sugarcane cultivars under various weed management strategies

The four weed control methods-hand weeding, weedy, diuron and pendimethalin + imazapic-varied in efficiency across sugarcane cultivars. Weedy plots, where no weed control is applied, serve as controls to assess the full impact of natural weed competition on crop growth and yield (Mathukia *et al.,* 2018). Broadleaf scores differed significantly at 45-120 DAA. At 45 DAA, diuron and pendimethalin + imazapic were more effective than hand weeding and weedy treatments. Broadleaf scores were consistent across cultivars, except for UT13, which scored higher at 60 DAA.

Narrowleaf weed control efficiency varied significantly between 60 and 120 DAA. At 60 and 90 DAA, hand weeding significantly outperformed diuron, pendimethalin + imazapic and the weedy control, which showed similar scores. From 90 to 120 DAA, hand weeding remained most effective, followed by pendimethalin + imazapic and diuron, while the weedy plots were least effective.

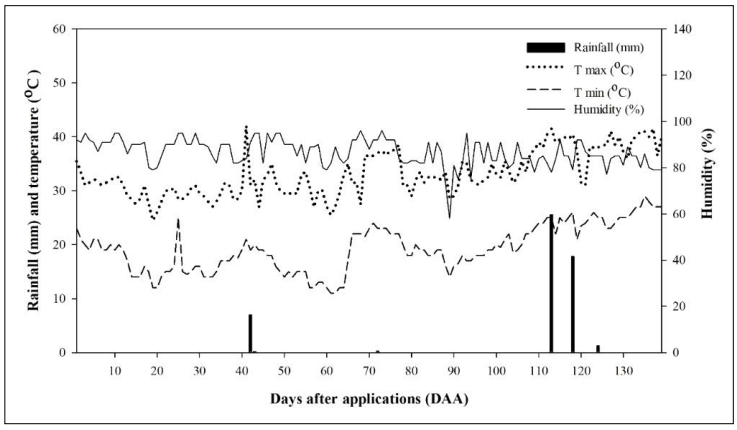


Fig 1: Rainfall (mm), humidity (%), maximum and minimum temperature (°C) of four sugarcane cultivars under four weed controls during early growth stage.

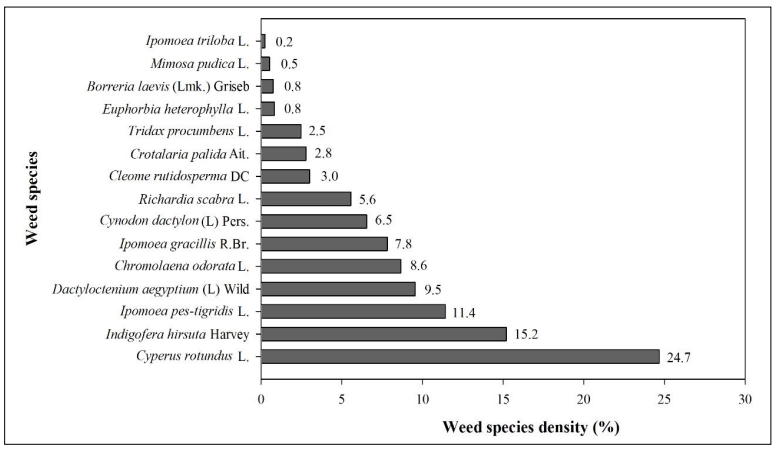


Fig 2: Percentage of weed species density.

Sedge control efficiency varied significantly among the four weed control treatments at 60-120 DAA. Weedy, diuron and pendimethalin + imazapic showed no significant differences in sedge scores at 60 and 90 DAA. Diuron and pendimethalin + imazapic did not differ significantly in sedge scores, while the weedy treatment had the lowest scores at 75, 105 and 120 DAA. The four sugarcane cultivars did not show significant differences in sedge control efficiency overall, but there were notable differences at 15 and 75 DAA. KK3, UT12 and UT13 exhibited high sedge control efficiency at 15 DAA, with UT12 and UT13 showing strong scores at 75 DAA. Weed control efficiency for overall weed scores varied from 60 to 120 DAA. Diuron and pendimethalin + imazapic showed similar overall weed control efficiency, while the weedy treatment had the lowest scores.

From 60 to 120 DAA, hand weeding consistently showed the highest weed control efficiency across all weed types, followed by diuron and pendimethalin + imazapic, while weedy plots were least effective. Although there were some variation points among treatments at specific time intervals, no significant differences or interactions were observed between sugarcane cultivars and weed control methods for broadleaf, narrowleaf, sedge, or overall weed control throughout the experiment (Table 1).

Weed control effectiveness varied in weed density and biomass during the application period. From 60 to 120 DAA, hand weeding consistently reduced weed density and biomass more than weedy, diuron and pendimethalin + imazapic. At 105 DAA, pendimethalin + imazapic reduced weed density and biomass more than weedy and diuron. Although pendimethalin + imazapic showed no significant differences, it trended lower than weedy and diuron at 120 DAA. Weed density and biomass did not vary significantly among the sugarcane cultivars and the influence of weed control treatments was no differences across cultivars (Table 2).

Pre-emergence herbicides vary in effectiveness and persistence in weed control. Diuron translocates *via* xylem, inhibiting photosystem II, with a 90-day field half-life (Shaner *et al.,* 2014). Pendimethalin is absorbed by coleoptiles and roots, disrupting mitosis *via* tubulin inhibition (Shaner, 2014; Hess, 2000), with a 44-day half-life, affected by soil moisture and temperature (Yadav *et al.,* 2019). Imazapic, translocated through xylem and phloem, inhibits acetolactate synthase, with a 120-day half-life, potentially delaying rotational crops (Ulbrich *et al.,* 2005; Shaner *et al.,* 2014).

Weed control treatments showed no significant differences in weed type, density, or biomass during 15-45 DAA. From 60-120 DAA, differences became significant, with hand weeding outperforming pre-emergence herbicides. However, at 60-120 DAA, herbicides provided comparable weed control to hand weeding (Table 1). Diuron achieved up to 92% efficiency, maintaining over 95% control at 30 DAA before declining to 80% at 90 DAA (Esqueda, 2005; Niz *et al.,* 2018). Applied at 3.5 kg ha^{-1} diuron 80% WP effectively controlled grass and broadleaf weeds (Chathuranga *et al.,* 2023). Additionally, pre-plant trifluralin at 1.0 kg ha^{-1} showed effective weed control (Bhullar *et al.,* 2006). At 75, 105 and 120 DAA pendimethalin+imazapic was proven to be more effective in controlling narrow leaf weeds compared to diuron. Pedrinho Junior and Durigan (2001) reported that the application of pendimethalin+ imazapic (1260 g/ha + 1050 g/ha) was proven to control narrow leaf weeds in sugarcane at 126 DAA.

At three months after planting, pre-emergence herbicides in sugarcane effectively reduced weed dry weight and controlled key species such as *Cyperus rotundus* L. (Singh *et al.,* 2001). At 105 DAA, pendimethalin + imazapic exhibited greater efficiency than diuron, reducing weed density and biomass. However, no significant difference was observed between the two at 120 DAA (Table 2). Pendimethalin at 2.0 kg a.i. ha^{-1}, combined with brown manuring and hoeing, reduced weed density and dry weight by 85-90% at 90 DAP (Fanish and Ragavan, 2020). The slight reduction in weed density and biomass with pendimethalin + imazapic compared to diuron may be attributed to herbicide wash-off following 25.6 mm rainfall at 113 DAA, as rainfall significantly influences herbicide dissipation, transport and efficacy (Khalil *et al.,* 2019). In sugarcane, post-application rainfall can reduce herbicide efficacy by affecting retention, degradation, interception and leaching, all of which influence weed control (Carbonari *et al.,* 2016; Khalil *et al.,* 2019).

Hand weeding proved to be more effective in controlling weeds compared to herbicide treatments (Pendimethalin+ imazapic and diuron) throughout the experiment. This method is highly effective because it physically removes weeds, preventing competition for resources (Kashyap *et al.,* 2021; Singh *et al.,* 2001). However, hand weeding is extremely labor-intensive, time-consuming, costly and frequent weeding damages superficial sugarcane roots (Prasara-A and Gheewala, 2016). In contrast, herbicide treatments provided comparable weed control results, especially between 60 and 120 DAA (Table 1). Despite being slightly less effective than hand weeding, herbicide treatments significantly reduced weed density and biomass, enhanced sugarcane growth across several cultivars and offers a cost-effective and labor-efficient alternative for managing weeds (Pedrinho Junior and Durigan, 2001; Yadav *et al.,* 2019).

Effect of weed control on sugarcane growth

KK3 exhibited no significant differences in tiller number or height across weed control treatments-hand weeding, weedy, diuron and pendimethalin + imazapic-at all growth stages (30, 60, 90 and 120 DAA). In contrast, KPS01-12 showed higher tiller numbers under pendimethalin + imazapic at 90 DAA and greater height at 90 and 120 DAA compared to other treatments. UT12 displayed significant tiller variations, with hand weeding yielding the highest count at 30 DAA, while pendimethalin + imazapic outperformed other treatments at 60 and 120 DAA. Though no significant height differences were observed across treatments, pendimethalin + imazapic resulted in the

Table 1: Weed control efficiency for broadleaf, narrowleaf, sedges and overall weed scores was evaluated for four weed control methods across four sugarcane genotypes at 15, 30, 45, 60, 75, 90, 105 and 120 days after application (DAA).

	15 DAA	30 DAA	45 DAA	60 DAA	75 DAA	90 DAA	105 DAA	120 DAA
Broad leaves								
Weed control (W)								
Hand weeding	86.67	83.33	75.00 B	100.00 A	100.00 A	100.00 A	100.00 A	100.00 A
Weedy	85.83	80.00	75.00 B	69.74 C	67.26 C	66.67 C	60.00 C	66.67 C
Diuron	88.33	86.67	85.00 A	78.63 B	77.69 B	78.33 B	75.00 B	76.67 B
Pendimethalin+imazapic	90.00	88.33	85.83 A	79.17 B	75.00 B	75.00 B	71.67 B	73.33 BC
F-test	ns	ns	**	**	**	**	**	**
Genotypes (G)								
KK3	88.33	85.00	80.00	80.83 b	79.17	79.17	75.83	79.17
KPS01-12	86.67	85.00	80.00	80.88 b	79.96	80.00	75.83	79.17
UT-12	88.33	84.17	80.83	80.00 b	80.83	80.00	76.67	79.17
UT-13	87.50	84.17	80.00	85.83 a	80.00	80.83	78.33	79.17
F-test	ns	ns	ns	**	ns	ns	ns	ns
W × G	ns	ns	ns	ns	ns	ns	ns	ns
Narrow leaves								
Weed control (W)								
Hand weeding	89.17	89.17	90.00	100.00 A	100.00 A	100.00 A	100.00 A	100.00 A
Weedy	85.83	90.00	88.33	85.68 B	74.85 D	75.00 C	65.00 C	66.67 C
Diuron	88.33	90.00	90.00	87.41 B	81.32 C	82.50 B	77.50 B	76.67 B
Pendimethalin+imazapic	90.00	90.00	90.00	90.00 B	87.50 B	84.17 B	83.33 B	77.50 B
F-test	ns	ns	ns	**	**	**	**	**
Genotypes (G)								
KK3	89.17	90.00	89.17	91.67	84.17	85.00	80.00	80.00
KPS01-12	88.33	90.00	90.00	92.27	87.01	86.67	81.67	80.00
UT-12	87.50	89.17	89.17	88.33	87.50	85.83	82.50	80.00
UT-13	88.33	90.00	90.00	90.83	85.00	84.17	81.67	80.83
F-test	ns	ns	ns	ns	ns	ns	ns	ns
W × G	ns	ns	ns	ns	ns	ns	ns	ns
Sedges								
Weed control (W)								
Hand weeding	80.00	80.00	72.50	100.00 A	100.00 A	100.00 A	100.00 A	100.00 A
Weedy	83.33	82.50	75.00	74.44 B	69.74 C	70.83 B	65.83 C	67.50 C
Diuron	83.33	78.33	75.83	76.45 B	75.83 BC	75.00 B	74.17 B	75.00 B
Pendimethalin+imazapic	84.17	81.67	77.50	78.33 B	78.33 B	71.67 B	75.83 B	76.67 B
F-test	ns	ns	ns	**	**	**	**	**
Genotypes (G)								
KK3	83.33 a	79.17	75.00	80.83	79.17 b	77.50	77.50	76.67
KPS01-12	80.00 b	80.00	75.00	82.56	79.74 b	79.17	79.17	80.83
UT-12	85.00 a	81.67	75.83	84.17	84.17 a	79.17	80.00	80.00
UT-13	82.50 ab	81.67	75.00	81.67	80.83 ab	81.67	79.17	80.00
F-test	*	ns	ns	ns	**	ns	ns	ns
W × G	ns	ns	ns	ns	ns	ns	ns	ns
Overall score weed control								
Weed control (W)								
Hand weeding	86.67	84.17	75.00	100.00 A	100.00 A	100.00 A	100.00 A	100.00 A
Weedy	83.33	84.17	75.83	70.85 C	67.86 C	67.50 C	62.50 C	66.67 C
Diuron	85.00	85.00	84.17	79.72 BC	76.26 B	79.17 B	77.50 B	76.67 B
Pendimethalin+imazapic	79.83	87.50	83.33	81.67 B	79.17 B	75.83 BC	75.00 B	75.83 B
F-test	ns	ns	ns	**	**	**	**	**

Table 1: Continue....

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Genotypes (G)								
KK3	86.67	84.17	79.17	81.67	80.00	80.00	77.50	79.17
KPS01-12	76.50	86.67	79.17	82.24	79.96	80.83	77.50	79.17
UT-12	86.67	85.83	80.83	82.50	83.33	80.83	79.17	80.00
UT-13	85.00	84.17	79.17	85.83	80.00	80.83	80.83	80.83
F-test	ns	ns	ns	ns	ns	ns	ns	ns
W × G	ns	ns	ns	ns	ns	ns	ns	ns

**,* and ns indicate significance at p≤0.01, significance at p≤0.05 and non-significance, respectively.

Different uppercase letters indicate significant differences among weed control treatments in each genotype; different lowercase letters indicate significant differences among genotypes in each weed control treatment by LSD at p≤0.05.

Table 2: Weed density and weed biomass was evaluated for four weed control methods across four sugarcane genotypes at 15, 30, 45, 60, 75, 90, 105 and 120 days after application (DAA).

	15 DAA	30 DAA	45 DAA	60 DAA		75 DAA		90 DAA		105 DAA		120 DAA	
Weed density (g/2.5 m^2) (g m^{-1})													
Weed control (W)													
Hand weeding	36.25	48.67	29.75	0.00	C	0.00	B	0.00	B	0.00	C	0.00	B
Weedy	40.08	46.74	40.58	30.75	B	37.83	A	26.88	A	43.33	A	47.83	A
Diuron	43.67	52.24	55.25	49.17	A	36.92	A	20.33	A	47.08	A	37.67	A
Pendimethalin+imazapic	37.33	49.33	34.58	37.09	AB	33.42	A	20.13	A	25.33	B	33.13	A
F-test	ns	ns	ns	**		**		**		**		**	
Genotypes (G)													
KK3	41.25	57.58	45.67	34.75		31.50		20.33		26.83		32.58	
KPS01-12	43.25	51.66	39.17	27.01		24.42		18.00		32.42		25.67	
UT-12	32.17	44.75	33.83	25.08		24.83		12.67		27.67		25.63	
UT-13	40.67	42.99	41.50	30.17		27.42		16.33		28.83		34.75	
F-test	ns	ns	ns	ns		ns		ns		ns		ns	
W × G	ns	ns	ns	ns		ns		ns		ns		ns	
Weed biomass (g/2.5 m^2) (g m^{-1})													
Weed control (W)													
Hand weeding	6.75	19.60	16.12	0.00	B	0.00	B	0.00	B	0.00	A	0.00	B
Weedy	7.27	22.24	20.42	20.95	A	17.82	A	26.45	A	22.84	A	22.28	A
Diuron	13.98	26.08	23.17	22.26	A	16.31	A	17.29	A	25.88	A	19.22	A
Pendimethalin+imazapic	10.79	19.62	14.26	18.15	A	16.21	A	22.82	A	14.66	A	13.78	A
F-test	ns	ns	ns	**		**		**		**		**	
Genotypes (G)													
KK3	8.87	21.70	21.16	16.51		13.48		17.49		14.65		12.07	
KPS01-12	10.78	24.13	17.84	18.02		11.21		13.72		15.77		16.83	
UT-12	8.87	21.29	16.24	10.83		11.84		17.05		19.33		11.75	
UT-13	10.26	20.41	18.74	15.99		13.82		18.31		13.62		14.62	
F-test	ns	ns	ns	ns		ns		ns		ns		ns	
W × G	ns	ns	ns	ns		ns		ns		ns		ns	

** and ns indicate significance at p≤0.01 and non-significance, respectively.

Different uppercase letters indicate significant differences among weed control treatments in each genotype by LSD at p≤0.05.

greatest height at 60 and 120 DAA (Fig 3). UT13 exhibited significant tiller differences at 90 and 120 DAA, with diuron producing the highest tiller count at 90 DAA and both diuron and pendimethalin + imazapic surpassing hand weeding and weedy treatments at 120 DAA. Height was significantly affected across all treatments, with diuron reducing UT13 height at 30 DAA, whereas diuron and pendimethalin + imazapic resulted in greater heights at later stages (60, 90 and 120 DAA).

There were no significant differences among sugarcane cultivars in terms of weed control efficiency. However, cultivars exhibited varied responses in growth parameters such as tiller number and plant height under different weed control treatments. Weed management had

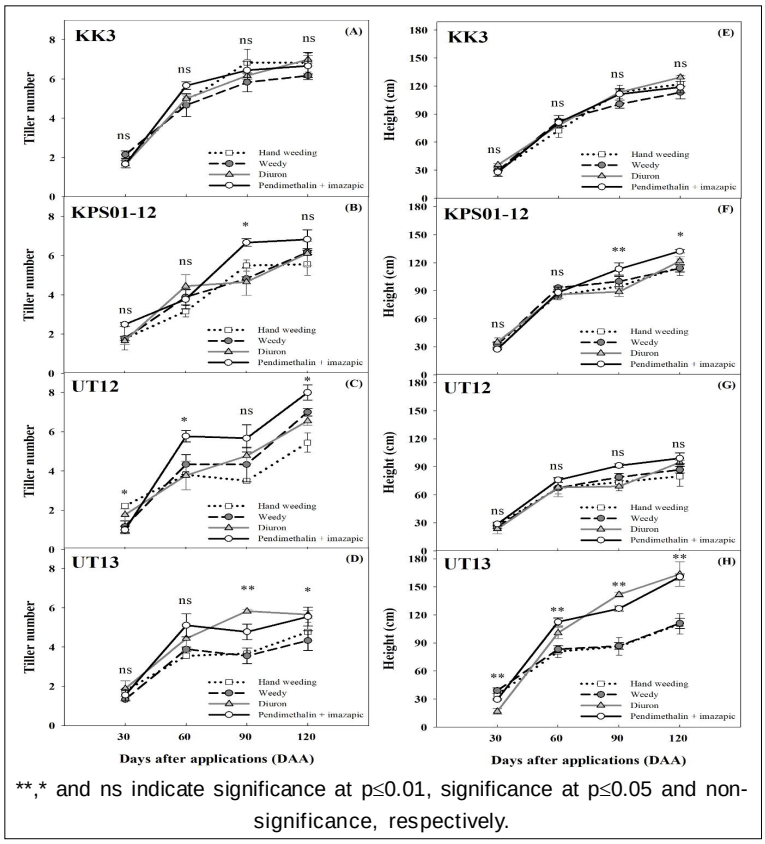


Fig 3: Effect of four weed controls on tiller number and height (cm) of four sugarcane genotypes during 30, 60, 90 and 120 days after application (DAA).

no significant effect on tiller number or height in KK3 throughout the experiment. However, pendimethalin + imazapic increased tiller numbers at 90 DAA and height at 90-120 DAA in KPS01-12, as well as tiller numbers at 30, 60 and 120 DAA in UT12 (Fig 3). Both pre-emergence herbicides improved tiller numbers at 90 DAA and height from 60-120 DAA in UT13. The rapid canopy coverage of KPS01-12 and moderate ground cover of UT13 (Pringgani *et al.,* 2023) contributed to reduced weed competition.

Pendimethalin + imazapic effectively suppressed weeds, reducing competition and enhancing sugarcane growth, aligning with Fanish and Ragavan (2020), who reported weed control effects on sugarcane growth and yield. Weed management increased yield by 8.3-79.0% due to improved cane height, tillering and millable cane (Singh *et al.,* 2001). However, pre-emergence herbicides had minimal effects on shoot emergence at 24-42 DAP, as early growth depends on parent stalk nutrients rather than soil uptake (Viator *et al.,* 2002; Richard, 1989). Additionally, pendimethalin at 2.32 kg ha^{-1} did not impact sugarcane survival (Baucum, 2022). Pre-emergence application of pendimethalin (2.0 kg a.i. ha^{-1}) combined with brown manuring and hand hoeing enhanced sugarcane yield (Fanish and Ragavan, 2020). Pendimethalin and trifluralin provided weed control comparable to manual hoeing (Bhullar *et al.,* 2006). Imazapic, alone or in combination, has also been shown to improve weed suppression in sugarcane (Assis *et al.,* 2021). Imazapyr enhanced sugarcane growth in clay soil (Campbell *et al.,* 2019) and pre-emergence applications of pendimethalin and diuron at recommended rates did not reduce energy cane biomass at 28 and 56 DAA (Odero *et al.,* 2015). Pre-emergence herbicides effectively minimized weed populations, creating a favorable environment for sugarcane seedlings (Baucum *et al.,* 2022). Weed competition during the initial growth phase negatively impacted yield at harvest (Gana *et al.,* 2006), underscoring the importance of early weed management.

CONCLUSION

Pre-emergence herbicides are effective in managing weeds in various sugarcane genotypes during the late rainy season. Diuron and the combination of pendimethalin + imazapic successfully controlled broadleaf, narrowleaf and sedge weeds from 60 to 120 DAA, with pendimethalin + imazapic reducing weed density and biomass more effectively than diuron at 105 DAA. Although hand weeding achieved the highest weed control efficiency, its labor-intensive and costly nature makes herbicide treatments a more practical and economically viable alternative for large-scale sugarcane production during the late rainy season. Sugarcane genotypes showed no significant differences in weed

control efficiency, weed density, or biomass throughout the experiment. Moreover, pendimethalin + imazapic promoted tiller development and plant height in certain genotype, notably KPS01-12, supporting its role in optimizing both weed management and crop growth under late rainy-season conditions.

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Disclaimers

Ayuning Mawar Pringgani Methodology, formal analysis, data curation, writing-original draft preparation, writing-review and editing, Jidapa Khonghintaisong Methodology, formal analysis, data curation, writing-original draft preparation, writing-review and editing, Santimaitree Gonkhamdee Conceptualization, methodology, validation, investigation data curation, writing-original draft preparation, writing-review and editing, supervision, Patcharin Songsri Conceptualization, validation, supervision, Nakorn Jongrungklang Conceptualization, methodology, validation, investigation data curation, writing-original draft preparation, writing-review and editing, supervision, project administration, funding acquisition.

Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University of Animal Care Committee.

Conflict of interest

Authors state no conflict of interest.

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