A New Pre-emergent herbicide formulation for weed control in sugarcane

G.A.A. Chathuranga[1*], L.M.J.R. Wijayawardhana[1], A.L.C. De Silva[1] and W.R.G. Witharama[1]

[1]*Sugarcane Research Institute, Uda Walawe, Sri Lanka*

**Corresponding author: amilacga@gmail.com*

ABSTRACT

Continued application of the same chemicals as herbicides could develop resistance of weeds to the herbicides. Hence, screening of newly developed herbicide formulations is essential to find out more effective herbicides for controlling weeds in sugarcane at different growth stages of the crop and the weeds. An experiment was conducted to find out the efficacy of a new herbicide formulation, Diuron 46.8 % + Hexazinone 13.2 % (DI+HEX), in controlling weeds in sugarcane as a pre-emergent and early-post emergent application. The identification of the effective dosage of the chemical in the observational field experiment and the replicated field experiment of controlling weeds were done at the Sugarcane Research Institute, Uda Walawe in 2016/17. A pilot project of application of effective dosage of DI+HEX in 0.5 ac of sugarcane field was conducted in a farmer's field at Lanka Sugar Company (Pvt) Ltd, Sevanagala. The effect of DI+HEX on weed knock-down, residual activity, and phytotoxicity on sugarcane was evaluated in all experiments. It was identified that the application of a new herbicide formulation, DI+HEX, at the rate of 3.0 kg/ha is effective and better than the application of recommended herbicide, Diuron 80 WP, at the rate of 3.5 kg/ha in controlling grass and broadleaved weeds at the pre-emergent stage. However, DI+HEX is not effective in controlling sedges, particularly Cyperus rotundus. Therefore, the application of DI+HEX at the rate of 3.0 kg/ha mixed with 400 litres of water at the pre-emergent stage is recommended to control grass and broadleaved weeds in sugarcane.

Keywords: Diuron, Herbicide, Hexazinone, Pre-emergent, Sugarcane, Weed Control

INTRODUCTION

Weeds contribute to substantial yield losses in sugarcane ranging from 6 % to 75%, and in some instances, up to total crop failure depending on the type of weed, degree, and duration of the competition (Witharama, 2000). As the early growth of sugarcane occurs at a fairly-slow rate, it takes about 3-4 months to develop a good canopy to cover the ground under irrigated conditions, and this period could be extended up to 4-5 months under rain-fed conditions in Sri Lanka. Thus, to raise a successful crop, weeds in sugarcane plantations have to be controlled until the crop develops a full canopy cover. Several options, such as manual, mechanical, cultural, and chemical methods, are available to control weeds in sugarcane. However, the adoption of integrated weed management is the best solution for controlling weeds in sugarcane (Bakker, 1990). Within integrated weed management systems, herbicides are essential (McMahon *et al*., 2000), and different types of herbicides that are effective in controlling weeds under diverse field conditions must be made available for this. Mainly two types of herbicides, i.e., Pre-emergent and Post-emergent herbicides, are used for controlling weeds in sugarcane (Bakker, 1990). Pre-emergent herbicides are

applied to the soil before weed and crop emergence, and post-emergent herbicides are applied 2-3 weeks after planting when the crop and the weeds emerge from the soil.

Diuron is a systemic herbicide easily taken up from soil solution by the root system of plants and rapidly translocates into stems and leaves by moving primarily via the xylem (Hess and Warren, 2002). Diuron inhibits the Hill reaction in photosynthesis, limiting the production of adenosine triphosphate (ATP) used for various metabolic processes. This process prevents CO_2 fixation, production of ATP, and other high-energy compounds that are needed for plant growth (Hess and Warren, 2002). Hexazinone inhibits photosystem II in the photosynthesis process of plants (WSSA-Herbicide Handbook, 1994). Hexazinone is absorbed from the soil solution by plant roots and translocated upward in the conductive tissues to the leaves, where it blocks photosynthesis within the chloroplasts (Ghassemi *et al.,* 1981). Most of the pre-emergent herbicides should be applied to soil when there is adequate soil moisture. Because free soil moisture is critical to the performance of most pre-emergent herbicides since pre-emergent herbicides that rely on root uptake will be less available in soil solutions with low soil water content (Congreve and Cameron, 2014).

Continued application of the same chemicals on the same site as herbicides could develop resistance of weeds to the herbicides, and application of herbicides with different modes of action will prevent the development of herbicide resistance (Mahmood *et al.,* 2014). Recently, the government of Sri Lanka banned the application of Glyphosate, a widely used effective herbicide in sugarcane fields (DOA, 2015). Hence, screening of newly developed herbicide formulations is essential to find out more effective herbicides for controlling weeds in sugarcane at different growth stages of the crop and the weeds. Therefore, the Sugarcane Research Institute (SRI) conducts studies to screen new herbicides to find out efficacious and economical herbicide treatments for weed control in sugarcane at different stages of crop and weed growth.

The experiments reported below were conducted to evaluate the effects of the new herbicide, Diuron 46.8 % + Hexazinone 13.2 % formulation (DI+HEX), for controlling weeds in sugarcane in terms of knock-down effect, residual activities, and crop safety. The optimal dosages of the herbicide and the appropriate time of application of herbicide for effective weed control in sugarcane were also investigated.

MATERIALS AND METHODS

The new herbicide

The new herbicide used for the study was a formulated product with Diuron and Hexazinone (DI+HEX). It contains 46.8 % Diuron and 13.2 % Hexazinone as active ingredients. The new product is a pre-emergent systemic herbicide, absorbed through roots and translocate within plants. It kills the plants by inhibiting the photosynthesis process and provides residual effects for controlling weeds.

Experimental procedure

Experiments to evaluate the herbicide were conducted in three different experiments during 2016 and 2017 at the Research Farm of SRI, Uda Walawe, and in sugarcane farmers' fields at Sevanagala. Initially, three herbicide treatments were chosen based on the dosages recommended by the

manufacturer. Treatments were tested by spraying in observational plots at pre-emergent and early post-emergent stages of weeds. Based on the results of the observational experiment, three different doses of herbicide were subsequently tested in replicated experiments for detailed investigation on weed knock-down, residual activity, and crop damage by spraying at pre-emergent and early-post-emergent stages of weeds. The final experiment was conducted as a pilot project with three replicates in farmers' fields at Sevanagala to confirm the findings of the replicated experiments.

Description of the experimental sites

The experimental locations belonged to the Agro-Ecological Region, DL1a and DL1b (Punyawardane *et al.,* 2003). The soil in the area is predominantly well-drained Reddish Brown Earth (RBE) with a sandy clay-loam texture (Mapa *et al*., 2009). The area receives 1,300 mm average annual rainfall with 75 % expectancy, and about two-thirds of the annual rainfall is received from October to February (*Maha* season-second inter-monsoon and the Northeast monsoon). There is a small peak of rainfall from March to May (the first inter-monsoon and the start of the southwest monsoon). The ambient air and soil temperature are high and range from 28 °C to 32 °C. Considerably heavy weed growth with dominating grass and broadleaved weeds was observed in the experimental locations.

Observational experiment

Based on the manufacturer's recommendation, three different dosages of the new herbicide, DI+HEX, were selected to evaluate at pre-emergent and early-post emergent stages of weeds (Table 1). These three treatments were tested against the standard, Diuron 80 WP at the rate of 3.5 kg/ha and the non-weeded treatment in 100 m² plots. Spraying of herbicide was done after planting and before weeds or crop emergence at the pre-emergent stage. For the early-post-emergent stage, herbicide spraying was done at the 2-3 leaf growth stage of the weed and 10-12 days after sugarcane planting.

Table 1: Tested treatments at pre-emergent and early post-emergent stages in the preliminary experiment

Treatment No	Treatment Details	Dosage
1	DI+HEX	3.00 kg/ha
2	DI+HEX	3.25 kg/ha
3	DI+HEX	3.50 kg/ha
4	Diuron 80 WP	3.50 kg/ha
5	Control/Non weeded	-

Note: DI+HEX; Diuron 46.8 % + Hexazinone 13.2 % formulation

Replicated experiments

Two identical experiments, one for pre-emergent application just after planting sugarcane and the other for early post-emergent application at 12 days after planting (DAP) of sugarcane, were conducted in the 2016/2017 *Maha* season. Based on the observations made at the preliminary experiments, three dosages of the herbicide formulation were selected to test in the replicated experiments for detailed investigations (Table 2). Diuron 80% WP at the rate of 3.5kg/ha was applied as a standard treatment and un-weeded treatment was included as a control. The experiment was laid out in a randomized complete block design with three replicates, and the plot size was 9 m long, with six cane rows with 1.2 m row spacing. Spraying of herbicide was done after planting and before weeds or crop emergence at the pre-emergent stage. For the early post-emergent stage, herbicide spraying was done at the 2-3 leaf growth stage of weed and 10-12 DAP of sugarcane.

Table 2: Tested treatments at pre-emergent and early post-emergent herbicide application in the replicated experimen

	Pre-emergent application		Early post-emergent application	
Treatment No	Treatment Details	Dosage	Treatment Details	Dosage
1	DI+HEX	2.0 kg/ha	DI+HEX	2.5 kg/ha
2	DI+HEX	2.5 kg/ha	DI+HEX	3.0 kg/ha
3	DI+HEX	3.0 kg/ha	DI+HEX	3.5 kg/ha
4	Diuron 80 WP	3.5 kg/ha	Diuron 80 WP	3.5 kg/ha
5	Control/Non weeded	-	Control/Non weeded	-

Note: DI+HEX; Diuron 46.8 % + Hexazinone 13.2 % formulation

The experiment conducted in farmers' fields

Three farmers' fields in the Sevanagala rain-fed area, each with an extent of 2 ac, were selected for the study. Sugarcane was planted in the *Yala* season of 2017. Application of DI+HEX at the rate of 3 kg/ha at the pre-emergent stage of crop and weeds was identified as the most effective treatment based on previous experiments. Therefore, the above treatment was further tested on a pilot scale under farmer management conditions. Land preparation, planting, and crop management practices were carried out by the farmers. DI+HEX was applied at the rate of 3.0 kg/ha in half of the plot, and Diuron 80% WP was applied at the rate of 3.5 kg/ha in half of the plot as the standard treatment.

Establishment and maintenance of the experiments

Land preparation, planting, and crop management were carried out as per SRI recommendations (SRI, 1991). Seedbeds were prepared by making ridges and furrows with a tractor-mounted ridger with 1.2 m spacing between two rows. Three budded stem cuttings of variety Co 775 were planted in furrows and maintained under supplementary irrigation.

Herbicide application

Herbicides were applied by a hand-operated knapsack sprayer fitted with a single poly-jet nozzle. In the pre-emergent experiment, herbicides were sprayed on both ridges and furrows by a walking operator on the ridges. In the early-post emergent experiment, herbicides were sprayed only on ridges by a walking operator on the ridges. The swath width (45cm above the ground) was 1.5m. Spraying pressure was approximately 2-3 bars. The sprayer was calibrated before spraying, and the application rate was 400 L/ha. The herbicide treatments were applied when the soil was adequately moist.

Assessments

The effects of herbicide treatments on weed knock-down, residual activity and crop phytotoxicity were evaluated by visually and counting live weeds. The visual assessments made on weed control and crop damage were graded on a scale of 0 to 100 (Table 3). Live weeds present before and at regular intervals after introducing herbicide treatments were counted to estimate the effect of the treatments on weed knock down and residual activity. In the observational experiments, emerged weeds were counted in two months after spraying (MAS) of herbicide by placing a 40 x 40 cm quadrat in ten random places on the

ridges of each treatment plot. In the case of the replicated experiment, the visual assessment was done at 2, 6, and 12 weeks after spraying (WAS), to find the effect of herbicide treatments on weed knock-down, residual activity, and crop phytotoxicity. The residual activity of the treatments was assessed in terms of their effect on weed control in comparison with the untreated control at 6 and 12 WAS. Each rating was the average of the minimum of three scores assigned by three different assessors. Also, weeds that appeared in each treatment plot at 2, 6, and 12 WAS were identified, counted, and recorded by placing 40 X 40 cm quadrat in a minimum of ten places selected randomly in each treatment plot. The number of sugarcane shoots that emerged in the inner four cane rows one month after planting (MAP) was recorded to measure germination. The number of tillers in four inner rows was counted at 2.5 and 3.5 MAP to estimate tiller production. The TVD (Top Visible Dewlap) height of 30 tillers selected randomly from the inner four cane rows in each treatment plot was recorded at 3.5 MAP to measure the tiller height. In the experiment conducted at farmers' fields, weed control was assessed both visually and by counting live weeds at 1, 2, and 3 months after spraying of herbicide treatments. The same procedures that were followed to give visual ratings and counting live weeds in the replicated experiments were followed in the farmer field experiments. Emerged weeds were counted in thirty random places for each treatment in each allotment in the experiment conducted in the farmers' field.

Table 3: Summary of the scale used for visual rating for weed control and crop damage

Scale	Degree of weed control	Degree of crop damage
0 – 10	No weed control	Minor crop damage
10 – 30	Poor weed control	Less crop damage
30 – 60	Moderate weed control	Significant crop damage
60 – 90	Satisfactory weed control	Severe crop damage
90 – 100	Complete weed control	Complete crop damage

Data analysis

The data were subjected to a normality test, and the data that followed the normal distribution were analysed with the ANOVA technique, and the data which were not followed the normal distribution were analysed with non-parametric techniques (Friedman's test).

RESULTS AND DISCUSSION

Observational experiments

Weed emergence was relatively low in all herbicide treatments applied for the pre-emergent study, and the effect increased with increasing the rate of application of DI+HEX (Table 4). Also, the effect of DI+HEX in controlling grasses and broadleaves was more than the sedges dominated by *Cyperus rotundus*. Moreover, the application of the new herbicide reported a high weed reduction percentage compared to the control and standard herbicide (Diuron 80 WP) application.

Table 4: The density of weeds at two months after pre-emergent application

Treatment details	Rate kg/ha	Weed Densities (Number/m^2)			Degree of weed control* (%)		
		G	S	BL	G	S	BL
DI+HEX	3.00	4	19	1	97	80	98
DI+HEX	3.25	2	14	1	98	85	98
DI+HEX	3.50	2	34	1	98	63	96
Diuron 80WP	3.50	11	6	6	91	94	81
Control		120	92	30	0	0	0

Note: DI+HEX; Diuron 46.8 % + Hexazinone 13.2 %, * Reduction of weed density compared to control, G: Grasses, S: Sedges, BL: Broadleaves

However, when DI+HEX was applied at the early post-emergent stage, weeds were effectively controlled to a satisfactory level for only up to one month (Table 5). Comparatively low weed control percentage was recorded even one month

after application. Therefore, the effectiveness of DI+HEX in controlling weeds at the early-post emergent stage is low compared to pre-emergent application.

Table 5: The density of weeds at one month after early post-emergent application

Treatment details	Rate kg/ha	Weed Densities (Number/m^2)			Degree of weed control* (%)		
		G	S	BL	G	S	BL
DI+HEX	3.00	26	26	13	86	79	76
DI+HEX	3.25	22	23	14	88	82	72
DI+HEX	3.50	22	16	8	88	87	83
Diuron 80WP	3.50	27	9	15	86	93	71
Control		185	126	52	0	0	0

Note: DI+HEX; Diuron 46.8 % + Hexazinone 13.2 %, ***** Reduction of weed density compared to control, G: Grasses, S: Sedges, BL: Broadleaves

Replicated experiment

Pre-emergent application

As per the visual assessment, satisfactory weed control was observed until 6 WAS in all the treatments. However, at 12 WAS, weed control was low in Diuron 3.5 kg/ha treatment. The new herbicide formulation (DI+HEX) 3.0 kg/ha treatment recorded the highest weed control percentage both at 6 WAS and 12 WAS (Table 6).

Table 6: Visual ratings given for weed control at the pre-emergent stage

Treatment details	Rate kg/ha	Degree of weed control* (%)		
		2 WAS	6 WAS	12 WAS
DI+HEX	2.0	93 ±1.0	91±2.4	72 ± 2.6
DI+HEX	2.5	92 ± 1.2	94± 1.8	69 ±10.3
DI+HEX	3.0	98 ±0.7	99 ± 0.3	87 ±5.9
Diuron 80 WP	3.5	89±0.7	84± 2.0	54 ±6.3
Control	-	0	0	0

Note: DI+HEX; Diuron 46.8 % + Hexazinone 13.2 %**,** WAS; Week after spraying, ***** Reduction of weed density compared to control

Effect on weed densities

There is an increase in the emergence of weeds with time for all herbicide treatments, as indicated by estimated live weed densities at 2, 6, and 12 WAS. However, the weed emergence estimated at 2 WAS, was significantly ($p<0.05$) low at the pre-emergent application of 3.0 kg/ha of DI+HEX compared to the control (Table 7). The weed emergence in the plots sprayed with DI+HEX at the rate of 2.0 and 2.5 kg/ha and standard Diuron 3.5kg/ha were not statistically significant compared to the un-weeded control treatment. Further, as estimated at 6 WAS, the least weed emergence was observed in plots treated with DI+HEX at the rate of 3.0 kg/ha. Weed emergence for the new herbicide treatment 3.0 kg/ha was significantly less than the weed emergence in the plots treated with Diuron 3.5kg/ha and un-weeded control plots. However, at the 6 WAS stage, the application rates of 2.0, 2.5 and 3.0 kg/ha of DI+HEX were statistically similar (Table 7).

Table 7: Total weed densities in the field at two weeks, six weeks, and 12 weeks after application of treatments

Treatment	Rate kg/ha	Weed density (Number/m^2)		
		2 WAS	6 WAS	12 WAS
DI+HEX	2.0	41 ^{ab}	68 ^{bc}	124 ^{ab}
DI+HEX	2.5	38 ^{ab}	54 ^{bc}	90 ^{bc}
DI+HEX	3.0	22 ^{b}	41 ^{c}	75 ^{c}
Diuron 80 WP	3.5	41 ^{ab}	87 ^{b}	133 ^{a}
Control		66 ^{a}	160 ^{a}	149 ^{a}
CV %		21.23	13.11	20.54

Note: *Means with the same letter in each column are not significantly different ($p>0.05$) WAS: Week after spraying, DI+HEX; Diuron 46.8 % + Hexazinone 13.2 %

Similarly, at 12 WAS, the least weed emergence was observed in plots treated with DI+HEX at the rate of 3.0 kg /ha. Estimated weed densities in the plots treated with DI+HEX at the rate of 2.5 and 3.0 kg/ha were not significantly different at 12 WAS. The effect of the new herbicide, 2.0 kg/ha dosage rate and standard Diuron 80% WP 3.5 kg/ha treatment were similar to the un-weeded control treatment at this stage (Table 7). Therefore, pre-emergent application of DI+HEX mixture at the rate

of 3.0 kg/ha appears to be the most effective treatment of giving lasting residual weed control in sugarcane.

Effect on different weed species

Similar to the total weed densities, there is an increase in the emergence of different weed types at 2, 6 and 12 WAS for all herbicide treatments. But, the emergence of grasses and broadleaved species was low compared to the un-weeded control treatment (Table 8).

Table 8: Mean weed densities (Number/m^2) of grasses (G), sedges (S), and broadleaved weeds (B) at 2, 6 and 12 WAS

Treatment	Rate kg/ha	weed density (Number /m^2)								
		2 WAS			6 WAS			12 WAS		
		G	S	B	G	S	B	G	S	B
DI+HEX	2.0	0 ^{ab}	40	1 ^{b}	1 ^{b}	65 ^{b}	2 ^{b}	2 ^{b}	119	4 ^{b}
DI+HEX	2.5	0 ^{b}	37	1 ^{b}	0 ^{b}	53 ^{b}	1 ^{b}	2 ^{b}	84	3 ^{b}
DI+HEX	3.0	0 ^{b}	21	1 ^{b}	1 ^{b}	40 ^{b}	0 ^{b}	1 ^{b}	73	2 ^{b}
Diuron 80 WP	3.5	1 ^{ab}	36	4 ^{b}	3 ^{b}	80 ^{ab}	5 ^{b}	6 ^{b}	119	9 ^{b}
Control	-	5 ^{a}	32.	29 ^{a}	9 ^{a}	120 ^{a}	31^{a}	15 ^{a}	95	39 ^{a}
CV %		54.2	39.3	77.6	33.2	24.5	26.7	18.2	63.2	18.4

Note: *Means with the same letter in each column are not significantly different (p>0.05). DI+HEX; Diuron 46.8 % + Hexazinone 13.2 %

However, the emergence of sedges dominated by *Cyperus rotundus* was higher in all treatment plots. This indicates that neither standard Diuron treatment nor the tested rates of DI+HEX were effective enough to control *Cyperus rotundus* in the sugarcane field.

There is a reduction of densities of grasses, sedges, and broadleaved weeds compared to un-weeded treatment after application of all tested dosage rates of DI+HEX, and the effect is more than the standard Diuron 3.5 kg /ha (Table 9). Also, the reduction of densities of grasses, broadleaved weeds, and sedges has increased with increasing dosage rates of DI+HEX. However, the reduction of sedges density was less than the reduction of grasses and broadleaved weeds. In contrast, sedges density has increased in the plot treated with DI+HEX at the rate of 2.0 kg/ha and standard Diuron 3.5 kg/ha treatment. This may be due to the release of interference from emerged weeds since the pre-emergent application of the above two treatment have restricted the emergence of grasses and broad-leaved weed species but failed to suppress the emergence of *Cyperus rotundus*. Although DI+HEX was not effective in controlling sedges completely, it reduced the density of sedges significantly compared to the control at 6 WAS if applied at a high dosage rate.

Table 9: Reduction of weed densities at 6 and 12 weeks after application of treatments

Treatment	Rate kg./ha	Reduction in weed density* (%)					
		6 WAS			12 WAS		
		G	S	BL	G	S	BL
DI+HEX	2.0	91	46	94	87	-25	91
DI+HEX	2.5	98	56	97	85	11	92
DI+HEX	3.0	89	67	99	96	24	96
Diuron 80 WP	3.5	73	33	84	62	-25	77
Control	-	0	0	0	0	0	0

Note: G: Grass, S: Sedge, BL: Broadleaves and the minus value indicates that increase of weed density, DI+HEX; Diuron 46.8 % + Hexazinone 13.2 %, WAS: Week after spraying, ***** Reduction of weed density compared to control

Effect of the herbicide on sugarcane growth

There were no phytotoxicity symptoms observed visually in the experiment sprayed with pre-emergent treatments. The average number of emerged shoots at 1 MAP was 6 per meter row length, and there were no significant differences ($p > 0.05$) in the values between different treatments. Also, the tiller production at 2.5 and 3.5 months after planting was not significantly different between plots applied with herbicide treatments. However, tiller production in the un-weeded control treatment was significantly ($p<0.05$) low than the other treatments. (Table: 10) This may be due to suppression of tiller production due to the interference of emerged weeds in un-

weeded control plots. Also, there was no significant difference in plant TVD height recorded at 3.5 MAP between different herbicide treatments. But significantly higher plant height was recorded in herbicide-applied treatments compared to the control. This confirmed that sugarcane growth was not affected due to the application of tested rates of DI+HEX herbicide.

Table 10: Tiller production and plant height at different rates of application of herbicide and time after planting of sugarcane

Treatment	Rate kg/ha	No of tillers/m		Plant TVD height (cm)
		2.5 MAP	3.5 MAP	3.5 MAP
DI+HEX	2.0	11 [a]	10 [a]	97 [a]
DI+HEX	2.5	11 [a]	11 [a]	96 [a]
DI+HEX	3.0	12 [a]	13 [a]	99 [a]
Diuron 80 WP	3.5	11 [a]	10 [a]	98 [ab]
Control	-	6 [b]	6 [b]	81 [b]
CV %	-	14.7	11.4	8.2

Note: *Means with the same letter in each column are not significantly different (p>0.05). DI+HEX; Diuron 46.8 % + Hexazinone 13.2 %, MAP: Month after planting,

Early-post emergent experiment

Visual observations

According to the averages of the ratings given for weed control at 2 WAS, the highest value (73%) was recorded for DI+HEX applied at the rate of 3.5 kg/ha. But the effect on weed control has reduced with time, as depicted by the ratings (58%) given at 2 MAS. Therefore, weed control at 2 MAS of DI+HEX was not satisfied (Table 11). However, the phytotoxicity showed by DI+HEX was minor and negligible.

Table 11: Visual ranking for weed controlling in the early-post emergent experiment

Treatment details	Rate kg./ha	Degree of weed control* (%)	
		2 WAS	2 MAS
DI+HEX	2.5	73 ± 7.0	53 ± 1.7
DI+HEX	3.0	70 ± 7.7	60 ± 4.4
DI+HEX	3.5	73 ± 5.1	58 ± 2.0
Diuron 80 WP	3.5	62 ± 1.0	51 ± 2.5
Control	-	0	0

Note: DI+HEX; Diuron 46.8 % + Hexazinone 13.2 %, WAS: Week after Spraying, * Reduction of weed density compared to control

Effect on weed densities

Weed densities of different weed species have not been reduced to a satisfactory level even one month after the application of DI+HEX (Table 12). In contrast, the total weed densities of each treatment have increased with time. Also, at 2MAS, all treatments were statistically similar to the control treatment. This confirmed that the application of DI+HEX at the post-emergent stage is not effective in controlling weeds in sugarcane fields.

Table: 12 Total weed density at different times after spraying for early-post emergent study

Treatment	Rate kg/ha	Weed Density (Number/m^2)		
		Before application	1MAS	2 MAS
DI+HEX	2.5	42	48 [b]	49
DI+HEX	3.0	73	54 [b]	60
DI+HEX	3.5	57	105 [a]	66
Diuron 80 WP	3.5	41	48 [b]	54
Control	-	78	121 [a]	69
CV		ns	62.3	ns

Note: DI+HEX; Diuron 46.8 % + Hexazinone 13.2 %, MAS: Month after Spraying

The experiment conducted in farmer's field at Sevanagala

According to the visual observations made at 1 and 2 MAS, more weed control was observed in DI+HEX applied area compared with the standard Diuron 80 % WP 3.5 kg/ha (Table. 13). Also, the

residual effect of DI+HEX at the rate of 3.0 kg/ha was high. This is because the herbicide treatment has given satisfactory weed control over 2 MAS, and the degree of weed control is more than the standard Diuron 3.5 kg/ha treatment.

Table 13: Visual ranking for weed control at farmer's fields at Sevanagala

Treatment details	Rate kg./ha	Degree of weed control (%)	
		1 MAS	2 MAS
DI+HEX	3.0	90.5 ± 2.1	88.25 ± 1.2
Diuron 80 % WP	3.5	80.75 ± 1.5	64.25 ± 2.2

Note: DI+HEX; Diuron 46.8 % + Hexazinone 13.2 %, MAS: Month after Spraying

There were no significant differences in emerged weed densities between the two treatments at 1 MAS. But, the plots treated with DI+HEX at the rate of 3.0 kg/ha have recorded significantly low weed densities at 2 and 3 MAS (Table 14). Therefore, the residual activity of DI+HEX is significantly higher compared to Diuron 80 WP.

Table 14: Total weed density at 1 MAS, 2 MAS, and 3 MAS in farmer's field at Sevanagala

Treatment details	Rate kg/ha	Weed Density (Number/m^2)		
		1 MAS	2 MAS	3 MAS
DI+HEX	3.0	6	12 ^{b}	19 ^{b}
Diuron 80 % WP	3.5	7	21 ^{a}	30 ^{a}

Note: *Means with the same letter in each column are not significantly different (p>0.05) DI+HEX; Diuron 46.8 % + Hexazinone 13.2 %, MAS: Month after spraying

CONCLUSION

The results of the experiments confirmed that the application of a new herbicide formulation, Diuron 46.8 % + Hexazinone 13.2 % (DI+HEX) at the pre-emergent stage, was effective in controlling grass and broad-leaved weeds in sugarcane fields and the efficacy of this herbicide treatment is better than the standard Diuron 80 WP 3.5 kg/ha treatment. However, this formulation is not effective in controlling sedges, particularly *Cyperus rotundus*. Therefore, the application of DI+HEX formulation at the rate of 3.0kg/ha mixed with 400 L water at the pre-emergent stage is recommended to control grass and broadleaved weeds in sugarcane plantations.

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