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RESEARCH ARTICLE

Bio-efficacy of saflufenacil + dimethenamid-P as pre-emergent herbicide to manage weeds in sugarcane

Simerjeet Kaur*, Gurinder Singh, Tarundeep Kaur, Manpreet Singh and Makhan Singh Bhullar

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ABSTRACT

The growth and productivity of sugarcane is known to be affected by uncontrolled weed competition at crop establishment stage due to reduced availability of resources. During spring season (February to December) of 2018 and 2019, a field study was conducted at Punjab Agricultural University, Ludhiana, Punjab, India using a randomized complete block design with three replications. The objective of the study was to evaluate the effect of pre-emergence application (PE) of different doses of ready-mix saflufenacil 68 g/L plus dimethenamid-P 600 g/L (saflufenacil + dimethenamid-P) on weed control and sugarcane productivity. The premix of saflufenacil + dimethenamid-P at 835 g/ha as PE resulted in 85.2-87.6%, 68.8-70.2% and 72.0-72.9% weed control efficiency of grasses, broad-leaved weeds and sedges, respectively at 60 days after application. The saflufenacil + dimethenamid-P at 835 g/ha application resulted in 20.8-20.9% more millable canes and 62.3-65.2% higher cane yield than untreated control demonstrating its efficacy in managing diverse weed flora at early crop establishment stage resulting in statistically similar cane yield to weed free check. However, there is a need of post-emergence herbicide application in sugarcane after pre-emergence herbicide application to achieve adequate weed control and improved productivity of sugarcane in Indian sub-tropics.

Keywords: Dimethenamid-P, Pre-emergent herbicide, Saflufenacil, Sugarcane, Weed management

INTRODUCTION

Sugarcane is an important cash crop in India, grown over 5.7 million hectares, with total production of 446.4 million tons and an average productivity of 79.0 tons per hectare (MOA 2024). It contributes nearly 78% to the global sugar base and plays a vital role in ethanol production (Gowtham *et al.* 2019, Singh *et al.* 2021). As the second-largest agro-industry in India, after textiles, the sugar industry supports around 6 million farming families (Verma 2015). By 2030, the sugar demand is projected to reach 36 million tons, nearly three times of the current production (12.1 million tonnes) (Ballyan *et al.* 2015). Bridging this considerable gap will require improvements in productivity and sugar recovery from the existing sugarcane area. Sugarcane is a labor-intensive crop, requires approximately 3,300 man-hours for the completion of recommended cultural practices (Arumuganathan 2022). Due to the slow initial growth, the inter-row spaces remain uncovered by the canopy that creates favorable environment for rapid weed growth. Frequent irrigation and fertilizer applications further increase weed population in sugarcane (Krishnaprabhu 2020). Weeds can severely reduce the cane yield by 12% to 83%, while quality and sugar recovery by 25% to 80% (Khan 2015). El-Shafai *et al.* (2010) reported weed competition can cause a 32% reduction in millable stalks, 15% decrease in stalk thickness and 31% reduction in sugar yield over weed-free plots. India suffers a cane yield loss of around 25 million tons annually, equivalent to a loss of 2.5 million tonnes of sugar, which is worth approximately Rs. 1500 crores (Takin *et al.* 2014).

Weed management is a crucial operation in sugarcane cultivation, after selection of variety and irrigation management (Jaiswal *et al.* 2024). Effective and timely control of weeds is essential for achieving higher productivity in sugarcane crop and the most used method is pre-emergence herbicide application, as it ensures a prolonged residual effect and control effectiveness during the critical period of competition with the sugarcane crop (Singh and Kumar 2013, de Castro *et al.* 2024). In northwest part of India, the critical period for crop-weed competition has been identified up to 120 days after planting in sugarcane (Bhullar *et al.* 2008). Weeds in sugarcane can be managed through manual, mechanical or chemical methods (Danawale *et al.* 2012). Three manual

Department of Agronomy, Punjab Agricultural University, Ludhiana Punjab 141004, India

* Corresponding author email: simer@pau.edu

hoeing are recommended at the tillering phase to control weeds below the threshold level (Singh and Kumar 2013,). However, the labor shortage at the critical crop-weed competition period and high labor costs are major constraints that limit the adoption of manual weeding among sugarcane farmers (Pratap *et al.* 2013). The use of herbicides offers an excellent alternative to manual weeding, being both cost-effective and less labor-intensive. In northwest part of India, pre-emergence application (PE) of herbicides such as atrazine 1.0 kg/ha or metribuzin 1.4 kg/ha or diuron 1.6 kg/ha or sulfentrazone + clomazone 0.7 + 0.75 kg/ha can effectively control all annual weeds in sugarcane (Singh *et al.* 2001; Anonymous 2025). For managing *Cyperus rotundus* and *Ipomoea* spp., a post-emergence spray of 2,4-D sodium salt 1.6 kg/ha is recommended. However, continuous use of the same herbicides with similar modes of action can lead to weed shifts (tough to control such as *Brachiaria reptans, Ipomoea nil, etc.*) and the evolution of herbicide-resistant weeds along with potential environmental concerns (Bhullar *et al.* 2008, 2012; de Castro *et al.* 2024). Therefore, the research and commercialization of new alternative herbicides with novel mechanism/mode of action have become increasingly urgent in present scenario. One premix formulation containing saflufenacil and dimethenamid-P was developed for pre-emergence control of weeds in sugarcane, and the field performance of saflufenacil plus dimethenamid-P against complex weed flora in sugarcane needs to be investigated. Therefore, this study was conducted to determine the effective use rates of saflufenacil 68 g/L plus dimethenamid-P 600 g/L (hereafter, saflufenacil + dimethenamid-P) applied as pre-emergent herbicide in sugarcane to manage weeds and improve sugarcane productivity.

MATERIALS AND METHODS

A field experiment was carried out during the spring season (February to December) of 2018 and 2019. The research was conducted at the Agronomy Research Farm of Punjab Agricultural University, Ludhiana, Punjab, India (30°56’N latitude, 75°52’E longitude and at 247 meters above MSL), situated in the northwestern Indo-Gangetic Plains within a subtropical climatic zone. This region is characterized by a semi-arid, subtropical climate, featuring hot, dry summers from April to June, followed by a humid monsoon period between July and September. The winter season starts mildly in October and November and becomes colder through December to February. The area typically receives between 500 and 750 mm of rainfall annually, with nearly 75% of it occurring during the southwest monsoon from July to September. The soil at the test site is sandy loam in texture, with a neutral pH (7.5) and low electrical conductivity (0.13-0.18 dS/m). The organic carbon content is medium (0.39%), while the soil is low in $KMnO_4$-N (223.4 kg/ha), high in Olsen-P (29.9 kg/ha) and high in NH_4OAc-K (337 kg/ha).

The treatments in the field experiment consisted of ready-mix/premix of saflufenacil + dimethenamid-P at 501, 668 and 835 g/ha, saflufenacil 70% WG (hereafter, saflufenacil) at 70 g/ha, dimethenamid-P 720 g/L EC (hereafter, dimethenamid-P) at 600 g/ha, metribuzin 70% WP (hereafter, metribuzin) at 525 g/ha, 2,4-D dimethylamine salt 58% SL (hereafter, 2,4-D dimethylamine salt) at 3500 g/ha, weed-free check and an untreated control. The experiment was laid out in a randomized complete block design with three replications. Sugarcane cv. Co 118 and CoJ 88 were used in the study during 2018 and 2019, respectively. Co 118 is an early-maturing cultivar and CoJ 88 a mid-late maturing cultivar. Both cultivars are frost-resistant. The planting was done on April 22, 2018 and March 1, 2019, at a seed rate of 7.50-8.75 t/ha with 75 cm row spacing using the trench method. Each plot measured 6.0 m × 4.5 m (27 m^2), with six rows. Irrigation was applied on the same day of planting to create optimal moisture conditions for the pre-emergence herbicide application. Herbicides were sprayed using a knapsack sprayer with a flat fan nozzle on April 25, 2018 and March 3, 2019, during the first and second season, respectively. In the weed-free treatment, weeds were manually removed using *khurpa* or mechanically controlled with a *kasuala* or improved wheel hand hoe. The recommended cultivation practices were followed to raise the crop, except weed management. The seedbed was prepared by ploughing once with a disc harrow, followed by two ploughings with a cultivator, with each ploughing followed by planking. The crop was fertilized with 150:30 kg N and P/ha through 325 kg urea/ha and 187 kg single super phosphate/ha, where the full dose of P was applied at the time of sowing. Nitrogen was applied in two splits, *i.e.*, one half dose top dressed alongside the crop rows with first irrigation after emergence and remaining half dose alongside cane rows after one month. To prevent the crop from lodging, earthing up was done at the end of June, before the onset of the monsoon. Crop was prop up in the end of august by using the trash-twist method. The crop was harvested manually on January 2nd, 2019 and February 10th, 2020.

Data of plant height at 60 DAA, number of tillers at 60 DAA, cane length, number of millable canes and cane yield at harvest were recorded. Data on weeds was recorded with quadrat (50 × 50 cm) from two locations in each plot at 20 and 60 days after application (DAA). Bio-efficacy in terms of weed control was recorded by taking observations of weed density and biomass. Species wise weed density was recorded at 20 and 60 DAA while biomass of weed species was observed at 60 DAA only. To analyse and interpret weed density and biomass, the average of both quadrats was converted into numbers per square meter (no./m^2) and grams per square meter (g/m^2), respectively. Weed control efficiency was calculated based on weed biomass observed in untreated check at 60 DAA. Weed control efficiency was calculated using the formula suggested by (Mani *et al.* 1973), as shown below:

$$\text{Weed control efficiency (\%)} = \frac{\text{WBc} - \text{WBt}}{\text{WBc}} \times 100$$

where, WBc is the weed biomass in untreated control and WBt is the weed biomass in treated plot. Analysis of variance was performed to assess the efficacy of ready-mix of saflufenacil + dimethenamid-P against complex weed flora in sugarcane. Data were analysed using the General Linear Model (GLM) procedure in IBM SPSS Statistics 22. To normalize the variance of weed data, square root transformation was conducted before performing ANOVA. To determine significant differences between means, the Fisher's Least Significant Difference (LSD) test was employed at a 5% probability level (p=0.05).

RESULTS AND DISCUSSION

Effect on weeds

During both the years of study, the experimental field was infested with complex weed flora comprising of grasses such as: *Echinochloa colona, Eleusine indica, Dactyloctenium aegyptium, Digitaria sanguinalis, Acrachne racemosa;* sedges such as *Cyperus rotundus* and broad-leaved weeds such as *Ipomoea nil, Trianthema portulacastrum, etc.* There were no weeds prior to pre-emergence application. Density of grasses, broad-leaved weeds and sedges at 20 and 60 DAA were significantly influenced by weed control treatments over untreated control. At 20 DAA, saflufenacil + dimethenamid-P 501 to 835 g/ha and standard herbicides (saflufenacil 70 g/ha and dimethenamid-P 600 g/ha) significantly controlled all grasses and broad-leaved weeds over untreated control during both the years of study (**Table 1**). All the herbicidal treatments recorded 100% weed control efficiency for grasses and broad-leaved weeds at 20 DAA. The density of *C. rotundus* was significantly lower with saflufenacil + dimethenamid-P 668 to 835 g/ha as compared to its lower dose of 501 g/ha at 20 DAA. Saflufenacil 70 g/ha, dimethenamid-P at 600 g/ha and metribuzin at 525 g/ha were not effective on *C. rotundus* while 2,4-D dimethyl amine salt at 3500 g/ha resulted in significantly lower density over other herbicide treatments (**Table 1**). The growth of newly germinated weed seeds or seedlings may be inhibited with the application of ready-mix pre-emergence herbicides due to their synergistic effect of the combined molecules. Therefore, during the initial

Table 1. Effect of weed management treatments on weed density (no./m^2) at 20 DAA in sugarcane

Treatment	*Echinochloa colona*		*Eleusine indica*		*Dactyloctenium aegyptium*		*Digitaria sanguinalis*		*Acrachne racemosa*		*Cyperus rotundus*		*Ipomoea nil*		*Trianthema portulacastrum*	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Saflufenacil + dimethenamid-P 501 g/ha	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	2.44 (5)	2.47 (6)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Saflufenacil + dimethenamid-P 668 g/ha	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.82 (2)	1.89 (3)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Saflufenacil +dimethenamid-P 835 g/ha	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.39 (1)	1.41 (1)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Saflufenacil 70 g/ha	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	3.55 (12)	3.66 (13)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Dimethenamid-P 600 g/ha	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	3.65 (12)	3.69 (13)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Metribuzin 525 g/ha	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	3.51 (11)	3.53 (12)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
2,4-D dimethyl amine salt 3500 g/ha	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	0.67 (1)	1.27 (1)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Weed free check	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Untreated control	3.00 (8)	2.64 (6)	2.31 (4)	2.44 (5)	3.87 (14)	3.65 (12)	3.55 (12)	3.46 (11)	2.44 (5)	2.38 (5)	3.87 (14)	3.74 (13)	1.99 (3)	2.23 (4)	2.00 (3)	2.23 (4)
LSD (p=0.05)	0.10	0.11	0.07	0.12	0.07	0.12	0.13	0.08	0.12	0.07	0.23	0.20	0.15	0.13	0.01	0.13

*Data is subjected to square root transformation ($\sqrt{x+1}$). Figures in parentheses are means of original values in round figures DAA = days after herbicide application period of crop growth, total weed density was significantly less as compared to untreated control. Bhullar *et al.* (2008) observed the synergistic effect of pendimethalin with metribuzin/atrazine on weed control in spring planted sugarcane.

Later at 60 DAA, weeds started emerging in all experimental plots receiving herbicides. However, application of saflufenacil + dimethenamid-P at 835 g/ha resulted in 66.7% and 65.6%, 48.6% and 45.9%, 63.2% and 60.0%, 72.4% and 70.0%, 36.8% and 38.4% lower grass weeds, *viz. E. colona, E. indica, D. aegyptium, D. sanguinalis* and *A. racemose*, respectively, and 40.9% and 39.9%, 66.2% and 65.4% reduced density of broad-leaved weeds, *viz. I. nil* and *T. portulacastrum*, respectively over untreated control during first and second year, respectively (**Table 2**). Further, density of sedges at 60 DAA in plots treated with saflufenacil + dimethenamid-P 835 g/ha was 34.4% and 33.2% less than untreated control during 2018 and 2019, respectively which was statistically similar to 2,4-D dimethyl amine salt at 3500 g/ha. Earlier researchers also reported that integrated weed control methods comprising of pre- and post-emergence herbicides with mechanical weeding resulted in the long-term weed control efficiency as compared to alone pre-emergence herbicide application (Raskar 2004, Singh *et al.* 2008, Bhullar *et al.* 2012, Pratap *et al.* 2013). The pre-emergence application of ready-mix of saflufenacil + dimethenamid-P was also labeled for its residual control of several annual grasses, broad-leaved weeds, and sedges in crops such as grain sorghum, soybean and field corn (BASF 2025). Pratap *et al.* (2013) reported the lowest density and biomass of total weeds in sugarcane ratoon with hand weeding thrice at 30, 60 and 90 days after planting which was at par with integrated treatment of metribuzin at 0.88 kg/ha as pre-emergence followed by one hand weeding at 45 days and spray of 2,4-D Na salt 0.75 kg/ha at 2-4 leaf stage of broad-leaved weeds. Further, saflufenacil at 70 g/ha and dimethenamid-P at 600 g/ha at 60 DAA were found to be less effective when compared to their pre-mix herbicide in this study. Bhullar *et al.* (2008) also reported that tank-mix of pendimethalin 0.75 kg/ha either with metribuzin 0.875 kg/ha or atrazine 0.75 kg/ha than standalone application of pendimethalin 1.125 kg/ha and atrazine 1.0 kg/ha were very effective for control of *Brachiaria reptans* in spring sugarcane. In Brazil, tank-mix of indaziflam 120 g/ha + tebuthiuron 900 g/ha or sulfentrazone 750 g/ha or diclosulam 110 g/ha was the safest option for managing *Rottboellia exaltata* and *Ipomoea quamoclit* in plant sugarcane (de Castro *et al.* 2024).

At 60 DAA, significantly lower biomass and higher control efficiency of grass weeds were observed with saflufenacil + dimethenamid-P at 835 g/ha as compared to its lower doses and other standard herbicides (**Table 3**). Ready-mix of saflufenacil + dimethenamid-P at 835 g/ha recorded 63.9% in first year and 61.9% in second year higher control of grasses weed biomass as compared to untreated control. There was lower biomass of broad-leaved weeds and sedges in plots treated with of 2,4-D dimethyl amine salt at 3500 g/ha and recorded 84.6% and 81.4% higher control of broad-

Table 2. Effect of weed management treatments on weed density (no./m^2) at 60 DAA in sugarcane

Treatment	*Echinochloa colona*		*Eleusine indica*		*Dactyloctenium aegyptium*		*Digitaria sanguinalis*		*Acrachne racemosa*		*Cyperus rotundus*		*Ipomoea nil*		*Trianthema portulacastrum*	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Saflufenacil + dimethenamid-P 501 g/ha	2.89 (7)	2.97 (8)	3.31 (7)	3.41 (11)	3.55 (12)	3.76 (13)	3.21 (9)	3.31 (10)	3.61 (12)	3.75 (13)	5.94 (34)	5.99 (35)	3.74 (13)	3.91 (14)	4.43 (19)	4.56 (20)
Saflufenacil + dimethenamid-P 668 g/ha	2.64 (6)	2.68 (7)	2.83 (7)	2.94 (8)	3.31 (10)	3.33 (10)	2.86 (7)	2.91 (8)	3.00 (8)	3.17 (9)	5.48 (29)	5.55 (30)	3.31 (10)	3.41 (11)	4.04 (15)	4.04 (15)
Saflufenacil + dimethenamid-P 835 g/ha	2.45 (5)	2.53 (5)	2.65 (6)	2.76 (7)	3.05 (8)	3.18 (9)	2.51 (5)	2.64 (6)	3.00 (8)	3.05 (8)	5.20 (26)	5.31 (27)	3.11 (9)	3.24 (10)	2.94 (8)	3.01 (8)
Saflufenacil 70 g/ha	2.89 (7)	2.97 (8)	2.89 (7)	3.00 (8)	3.51 (11)	3.62 (12)	3.82 (14)	4.01 (15)	3.00 (8)	3.17 (9)	6.30 (39)	6.38 (40)	3.16 (9)	3.31 (10)	2.14 (4)	2.40 (5)
Dimethenamid-P 600 g/ha	2.58 (6)	2.64 (6)	2.71 (6)	2.82 (7)	3.21 (9)	3.33 (10)	2.71 (6)	2.76 (7)	2.89 (7)	3.02 (8)	6.14 (37)	6.22 (38)	3.46 (11)	3.60 (12)	4.68 (21)	4.64 (21)
Metribuzin 525 g/ha	2.89 (7)	2.92 (8)	2.77 (7)	2.88 (7)	3.11 (9)	3.28 (10)	2.77 (7)	2.84 (7)	3.16 (9)	3.27 (10)	6.08 (36)	6.15 (37)	2.44 (5)	2.70 (6)	2.08 (3)	2.23 (4)
2,4-D dimethyl amine salt 3500 g/ha	3.74 (13)	3.84 (14)	3.41 (11)	3.50 (11)	4.47 (19)	4.37 (18)	4.35 (18)	4.34 (18)	3.60 (12)	3.65 (12)	5.13 (25)	5.26 (27)	1.14 (0)	1.50 (1)	1.00 (0)	1.21 (1)
Weed free check	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Untreated control	4.00 (15)	4.09 (16)	3.55 (12)	3.64 (12)	4.86 (23)	4.88 (23)	4.51 (19)	4.58 (20)	3.70 (13)	3.82 (14)	6.38 (40)	6.46 (41)	3.96 (15)	4.11 (16)	4.86 (23)	4.94 (23)
LSD (p=0.05)	0.19	0.15	0.21	0.23	0.28	0.29	0.35	0.27	0.23	0.18	0.21	0.17	0.26	0.30	0.34	0.23

*Data is subjected to square root transformation ($\sqrt{x+1}$). Figures in parentheses are means of original values in round figures; DAA = days after herbicide application leaved weeds and 55.9% and 54.8% sedges in first and second year, respectively over untreated control. Among all the herbicidal treatments, application of 2,4-D dimethyl amine salt at 3500 g/ha also registered significantly higher weed control efficiency of broad-leaved weeds (98.2% in first year and 96.7% in second year) and sedges (80.3% in first year and 79.3% in second year). Moreover, ready-mix application of saflufenacil plus dimethenamid-P at 835 g/ha resulted in statistically similar sedges weed biomass and weed control efficiency with 2,4-D dimethyl amine salt at 3500 g/ha during both the years of study.

The new molecule, saflufenacil, a selective herbicide belongs to the pyrimidinedione (uracil) group, and can be used both pre- and post-emergence in certain crops. Once applied and absorbed by plants, saflufenacil primarily translocate through the xylem, with limited movement through the phloem (BASF 2025). This herbicide works by inhibiting the enzyme protoporphyrinogen oxidase (PPO), which is involved in chlorophyll and cytochrome synthesis, leading to plant death. It increases the production of highly reactive singlet oxygen, which causes lipid peroxidation, necrosis and subsequent cell death. Dimethenamid, a chloroacetamide herbicide, inhibiting the synthesis of very long-chain fatty acids helps to prevent the weed growth when applied as pre-emergent herbicide. As a broad-spectrum herbicide, it is used on crops such as corn, soybean, sugarcane and peanut, effectively controlling both grass and broad-leaf weeds (Aulakh 2023). Dimethenamid-P is known for its low toxicity and environmental safety, posing no carcinogenic risks. Its ability to be effective at half the dosage of its racemic mixture further highlights its efficiency.

Application of dimethenamid-P registered effective control of grasses by inhibiting very long chain fatty acids while saflufenacil provided good control of broad-leaved weeds by inhibiting protoporphyrinogen oxidase that provides both contact and soil residual control of broad-leaved weeds (Moran *et al.* 2011). Effective weed control with the pre-emergence application of ready-mix of saflufenacil plus dimethenamid-P was also reported by Odero *et al.* (2014). Moran *et al.* (2011) observed application of saflufenacil plus dimethenamid-P resulted in 95% total weed biomass reduction in maize. In our study, application of ready-mix of saflufenacil plus dimethenamid-P at 835 g/ha was effective on weeds at 60 DAA but weed biomass in this combination was significantly more than weed free that indicated that there is a need of post-emergence weed management option (at 60 days old crop) in sugarcane. Sugarcane, being a long duration crop and heavy infestation of annuals and perennials necessitate the post-emergence cultural and/or chemical weed management option to achieve satisfactory weed control after this pre-emergence herbicide application. Singh *et al.* (2008) reported that pre-emergence application of metribuzin at 0.080 kg/ha or ametryn at 2.0 kg/ha with two hoeings done at 60 and 90 days after planting were most effective against most of the weeds.

Table 3. Effect of weed management treatments on weed biomass and weed control efficiency at 60 DAA in sugarcane

Treatment	Weed biomass (g/m^2)						Weed control efficiency (%)					
	Grass weeds		Broad-leaved weeds		Sedges		Grass weeds		Broad-leaved weeds		Sedges	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Saflufenacil + dimethenamid-P 501 g/ha	13.96 (194)	13.71 (187)	9.78 (95)	10.06 (100)	14.16 (200)	14.26 (203)	62.6	58.2	37.1	37.3	19.0	18.8
Saflufenacil + dimethenamid-P 668 g/ha	11.23 (125)	11.02 (121)	8.99 (80)	9.28 (86)	11.18 (125)	11.31 (128)	75.9	73.1	47.1	46.4	49.9	49.3
Saflufenacil + dimethenamid-P 835 g/ha	8.26 (67)	8.08 (65)	6.70 (44)	7.13 (50)	8.23 (68)	8.40 (71)	87.2	85.6	70.2	68.8	72.9	72.0
Saflufenacil 70 g/ha	16.56 (273)	15.96 (254)	5.58 (30)	6.04 (36)	14.75 (217)	14.85 (220)	47.6	43.3	79.9	77.5	12.0	11.9
Dimethenamid-P 600 g/ha	10.82 (116)	10.57 (111)	10.56 (111)	10.82 (116)	13.82 (190)	13.92 (193)	77.7	75.3	26.4	27.2	21.9	21.7
Metribuzin 525 g/ha	14.18 (200)	13.74 (188)	3.94 (15)	4.60 (20)	14.42 (208)	14.53 (211)	61.4	58.0	90.2	87.3	16.3	16.0
2,4-D dimethyl amine salt 3500 g/ha	19.82 (392)	18.52 (342)	1.90 (3)	2.36 (5)	6.94 (48)	7.17 (51)	24.5	23.5	98.2	96.7	80.3	79.3
Weed free check	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	100.0	100.0	100.0	100.0	100.0	100.0
Untreated control	22.89 (523)	21.19 (448)	12.31 (151)	12.69 (160)	15.75 (148)	15.85 (251)	-	-	-	-	-	-
LSD (p=0.05)	1.00	0.58	0.82	0.96	1.38	1.36	6.8	3.5	7.8	8.9	13.9	13.8

*Data is subjected to square root transformation ($\sqrt{x+1}$). Figures in parentheses are means of original values in round figures. Weed control efficiency was calculated based on weed biomass; DAA = days after herbicide application

Effect on sugarcane growth, yield attributes and cane yield

All herbicidal treatments registered significant impact on the sugarcane's yield attributes and yield but there was non-significant difference in all weed control treatments for plant height of sugarcane at 60 DAA during both the years of study. Saflufenacil + dimethenamid at 501 to 835 g/ha and weed free check treatments recorded statistically similar number of tillers at 60 DAA and was significantly higher over other weed control treatments and untreated control. The cane length of sugarcane did not differ significantly with different treatments during both the years of study. The ready-mix application of saflufenacil + dimethenamid-P at 835 g/ha recorded 20.8% and 20.9% more number of millable canes during first and second year of crop, over untreated control plot.

The highest cane yield was recorded with weed free check and the lowest cane yield were recorded with untreated control plots. The cane yield with ready-mix of saflufenacil + dimethenamid-P at 835 g/ha was statistically similar with weed free check but was significantly higher than other herbicide treatments and untreated control plots. Ready-mix of saflufenacil + dimethenamid-P at 835 g/ha improved the cane yield 62.3 to 65.2% over the untreated control plots, and led to a significant increase in cane yield by 65.2% and 62.3% in first and second year over untreated control plots (**Table 4**). This yield improvement is attributed to the enhanced weed control efficiency and improved yield attributes with herbicidal treatment. By effectively suppressing weed growth at early stages, pre-emergence herbicides reduced competition for essential resources such as moisture, space, light and nutrients, thereby promoting better crop growth and higher productivity. Pre-emergence application of saflufenacil plus dimethenamid-P has the potential to provide effective weed control (>90%) at 42 days after treatment and produced satisfactory corn yield (Odero *et al.* 2014). Further, integrating pre-emergence application of metribuzin 1.25 kg/ha with post-emergence application of 2,4-D 1.0 kg/ha in sugarcane exhibited 65.3% weed control efficiency which was comparable with three hand hoeing at 30, 60 and 90 DAP (Singh and Kumar 2013).

Table 4. Effect of weed management treatments on growth, yield attributes and yield of sugarcane

Treatment	Plant height at 60 DAA (cm)		Tillers at 60 DAA (no./m^2)		Cane length (m)		Millable canes (x10^3/ha)		Cane yield (t/ha)	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Saflufenacil + dimethenamid-P 501 g/ha	55.8	55.3	14.7	15.6	3.4	3.5	129.4	129.2	58.9	57.9
Saflufenacil + dimethenamid-P 668 g/ha	56.2	55.0	14.9	15.8	3.4	3.5	133.6	134.1	66.4	65.8
Saflufenacil + dimethenamid-P 835 g/ha	56.5	56.3	15.6	15.9	3.4	3.5	137.9	137.7	76.8	79.2
Saflufenacil 70 g/ha	53.9	53.7	12.7	12.7	3.4	3.4	115.3	115.0	57.1	54.2
Dimethenamid-P 600 g/ha	54.6	53.9	12.9	12.8	3.4	3.5	127.1	126.8	66.6	66.3
Metribuzin 525 g/ha	55.0	54.7	12.6	12.2	3.4	3.5	125.3	125.1	65.7	63.4
2,4-D dimethyl amine salt 3500 g/ha	55.2	56.4	12.7	12.4	3.4	3.4	125.0	124.8	60.1	62.5
Weed free check	56.0	56.1	14.8	15.2	3.5	3.6	156.2	155.9	81.1	84.8
Untreated control	54.6	54.1	12.3	12.0	3.1	3.2	114.1	113.9	46.5	48.8
LSD (p=0.05)	NS	NS	1.2	1.6	NS	NS	13.1	12.7	10.4	9.7

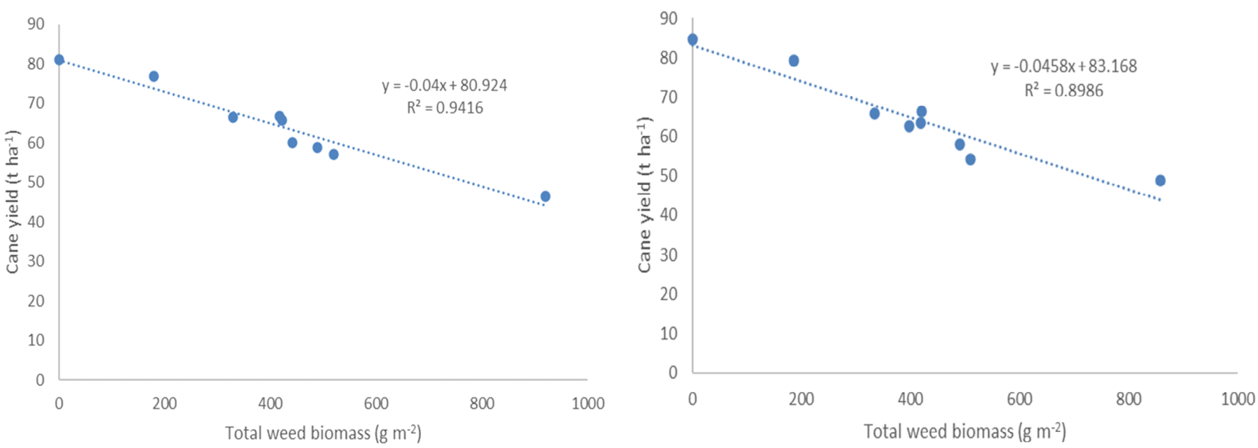

Figure 1. The relationship of cane yield with total weed biomass at 60 DAA during 2018 and 2019

The linear regression analysis illustrates the relationship between total weed biomass and sugarcane yield (**Figure 1**). A strong negative linear correlation (r= -0.97 and -0.95 for 2018 and 2019, respectively) of weed biomass at 60 DAA with cane yield was observed. As total weed biomass increased, sugarcane yield decreased correspondingly. The R^2 values of 0.9416 and 0.8986 indicates that weed biomass accounted for 94% and 90% of the yield variation during 2018 and 2019, respectively. The findings highlighted a significant influence of weed control treatments on both weed biomass and cane yield.

Based on the findings of two-year study, it was concluded that saflufenacil + dimethenamid-P at 835 g/ha as PE effectively controlled wide range of grasses, broad-leaved weeds and sedges, and resulted in cane yield statistically comparable to weed free check. However, it is suggested that for a long duration crop like sugarcane, solo application of pre-emergent herbicide is often inadequate and sequential application of pre- and post-emergence herbicides are crucial for effective weed management to produce more millable canes and cane yield.

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