Original Research Article

Comparative Efficacy of Tembotrione (420 SC) and their Combination for Diverse Weed Flora in Wide Spaced Sugarcane (*Saccharum officinarum* L.) Provides Sustainable Weed Management

ABSTRACT

Widely spaced sugarcane, which is becoming progressively more popular in tropical India to enable mechanization is seriously threatened by weed invasion. Compatibility of tembotrione 420 SC as a tank mix in sugarcane with surfactant (isoxadifen-ethyl), atrazine, metribuzin, and ethoxysulfuron, as well as the residual effects on subsequent crops, were investigated in two consecutive years during the special season June–September in 2015-16 and 2016-17. Application of PoE tembotrione at 120.75 g a.i/ha + surfactant at 1000 ml/ha + metribuzine at 1050 g a.i/ha significantly reduced the weed density and biomass of grasses, broad leaved weeds and this was statistically comparable with tembotrione at 120.75 g a.i/ha + surfactant at 1000 ml/ha + atrazine at 500 g a.i/ha. Herbicidal combination of PoE tembotrione at 120.75 g a.i/ha + surfactant at 1000 ml/ha + metribuzine at 1050 g a.i/ha was recorded lesser dominant grassy and broad leaved weeds *viz*., *Sitaria verticillata* (L.), *Dactyloctenium aegyptium* Beauv., *Dinebra retroflexa* (Vahl) Panzer, *Trianthema portulacastrum* (L.), *Portulaca oleracea* (L.), *Digera arvensis* (Forsk), *Datura fastuosa* (L.) and *Cleome gynandra* (L.) with higher WCE (83.16% & 87.43% at 30 DAA) and cane yield (134.1 t/ha & 136.2 t/ha) in 2015-16 and 2016-17, respectively which was comparable with tembotrione at 120.75 g a.i/ha + surfactant at 1000 ml/ha + atrazine at 500 g a.i/ha of 129.8 t/ha in 2015-16 and 132.1 t/ha in 2016-17, respectively. Yield reduction in the untreated control plots of 46.46% in 2015-16 and 45.57% in 2016-17, respectively. Finally, the combination of tembotrione at 120.75 g a.i/ha + surfactant at 1000 ml/ha + metribuzine at 1050 g a.i/ha at 15 and 30 DAA can maintain a reasonable level of total weed density and dry weight while increasing sugarcane productivity without posing a phytotoxicity risk to either the primary crop or the sunflower that follows.

Keywords: *Atrazine, ethoxysulfuron, 4-Hydroxyphenylpyruvate dioxygenase inhibitor, metribuzin, phytotoxicity, sugarcane, WCE*

1. INTRODUCTION

In India, one of the most significant agro-industrial cash crops is sugarcane (*Saccharum officinarum* L.). Since sugarcane is a long-duration (more than 180 days) crop with slow beginning growth, it provides an environment that is favourable to weed growth and development, which results in a 74% decrease in cane output (Singh et al., 2011; Anusha et al., 2024). Compared to other field crops, sugarcane cultivation presents a very different category of weed problem because sugarcane is sown with comparatively larger row spacing and has very slow initial crop growth. Germination takes roughly 30 to 45 days, and full canopy cover develops in the following 60 to 75 days (Anonymous, 2001). The initial stages of the season, before the sugarcane canopy closes over the middle rows are when weed control is most important. It has been shown that crop weed competition occurs 60–120 days after spring planting and 150 days in autumn season (Patil et al., 1991; Singh et al., 2012). However, the usage of herbicides to control weeds is becoming more popular due to a lack of labour. For sugarcane, a number of herbicides, including atrazine, metribuzin, and 2,4-D, have been suggested. However, only the particular weed species are efficiently controlled by any of these herbicides. Therefore, for broad-spectrum weed control in sugarcane, new herbicide combinations are needed. PoE application is a crucial choice for sugarcane because of escaping weeds. To maximize weed control effectiveness and reduce application costs, challenging pre and post-treatment combinations are now the norm rather than the exception. These issues made the use of herbicides necessary for prompt and efficient weed management as well as a cost-effective substitute for labour-intensive tasks (Bhullar et al., 2006; de Castro et al., 2024).

Tembotrione 2-[2-chloro-4-(methylsulfonyl)-3-[(2,2,2 trifloromethoxy) methyl] benzoyl]-1,3-cyclohexanedione is a unique herbicide acts well against a variety of grassy and broad-leaved weeds, particularly those that emerge POST-emergence. Photosystem II (PS II) inhibitors halt electron flow within the photosynthetic electron transport chain, thereby leading to increased oxidative stress. As a result, their addition to mesotrione, which inhibits carotenoid biosynthesis by inhibition of the enzyme 4-hydroxyphenylpyruvate dioxygenase (HPPD), is complementary (Karthikeyan et al., 2024). It prevents the enzyme 4-hydroxyphenylpyruvate dioxygenase (HPPD) from catalyzing the conversion of 4-hydroxyphenylpyruvate to homogentisate, which results in the loss of carotenoids and the non-development of chloroplasts in developing foliar tissue, which causes it to appear stunted and bleached (Hawkes, 2007). Special season sugarcane remains on the field for a year or

more and the 90 cm gap between rows gives plenty of opportunity for weeds to grow, which depletes the soil of moisture and nutrients and lowers cane yields. In sole sugarcane/intercropping systems, weeds were predicted to cause yield losses of 26-75% (Patil et al., 1991; Srivastava et al., 2005). In considering their effectiveness and costs in sugarcane, pre and post-emergence herbicides will be the best way to manage weeds. To prevent undesired weed shift, continuous use of herbicides with comparable modes of action must be limited (Kamboj et al., 2008; Murali Arthanari et al., 2017). These tactics are also a valuable tool for preventing herbicide resistance issues, but they need some background knowledge to help farmers choose the right herbicide and dosage based on the floristic conditions. In order to provide broad-spectrum weed control in sugarcane without compromising growth and cane yield, the current study was conducted to determine the most effective herbicidal solutions (especially post-emergence) for weed control in sugarcane.

2. MATERIALS AND METHODS

2.1. Experimental site and initial soil characteristics

A field study was carried out in the Eastern Block Research Farm (Field No. 74), Tamil Nadu Agricultural University, Coimbatore, India, during the two-year special season (June–September). The experimental farm was situated at an elevation of 426.7 meters above mean sea level in the Western Zone of Tamil Nadu, at latitude 11^{o}29"N and longitude 77^{o}08"E. Clay loam soils with modest drainage made up the experimental fields. Both experimental fields soil fertility status are categorized as having low levels of accessible nitrogen, medium levels of phosphorus, and high levels of potassium.

2.2. Treatments, experimental design and herbicidal doses

Treatments were arranged in a randomized complete block design with three replications. Herbicides included in the study were tembotrione (420 SC), atrazine 50% WP, metribuzin 70% WP, ethoxysulfuron 15% WG and surfactant (isoxadifen-ethyl). New molecule of herbicide combination of tembotrione (420 SC) was applied as PoE herbicide on 10 to 15 DAS (Table 1). Herbicides were sprayed using a hand operated knapsack sprayer with a flat fan type nozzle (WFN 40) with a 500 liters per hectare spray volume.

Table 1. Treatments, dosage and formulation of the herbicides

T.No.	Treatments	Herbicide Doses	
		g (a.i./ha)	Formulation (g or ml/ha)
T_1	Tembotrione 420 SC + Surfactant	75.6 +1000 ml surfactant	180 + 1000
T_2	Tembotrione 420 SC + Surfactant	96.6 +1000 ml surfactant	230 + 1000

T_3	Tembotrione 420 SC + Surfactant	120.75 +1000 ml of surfactant	287.5 + 1000
T_4	Tembotrione 420 SC + Surfactant + Atrazine 50% WP	120.75 + 1000 ml surfactant + 500	287.5 + 1000 + 1000
T_5	Tembotrione 420 SC + Surfactant + Ethoxysulfuron 15% WG	120.75 + 1000 ml surfactant + 60	287.5 + 1000 + 400
T_6	Tembotrione 420 SC + Surfactant + Metribuzin 70% WP	120.75 + 1000 ml surfactant + 1050	287.5 + 1000 + 1500
T_7	Tembotrione 420 SC	120.75	287.5
T_8	Atrazine 50% WP	500	1000
T_9	Ethoxysulfuron 15% WG	60	400
T_{10}	Metribuzin 70% WP	1050	1500
T_{11}	Hand weeding twice at 30 and 60 DAP	-	-
T_{12}	Untreated control	-	-

Applied at weeds are of 2-4 leaf stage except T_8 - to be applied as PE (1-2 DAP)

2.3. Selection of cultivar, sowing and agronomic practices

In each year, sugarcane (Variety - CO 86032 with the duration of 10-12 months) was planted in the special season (June-September). Seven months old cane nursery (short crop) obtained from Bannari Amman Sugars Ltd., was used for the preparation of setts and 75,000 two budded setts/ha were used. Prior to sowing, the setts were treated with Azospirillum (2000 g/ha) for 15 minutes after being immersed in a fungicide (Carbendazim 0.1% + 2.5 kg urea in 250 liters of water) for 15 minutes. Setts were continuously placed in the middle of the furrows after the plots had been irrigated, with the buds remaining lateral and gently pressed into the soil. After ploughing, farm yard manure was added at a rate of 12.5 t/ha, incorporated, and levelled. The experimental plots were applied with inorganic fertilizers as per blanket recommendation (275:62.5:112.5 kg N, P_2O_5, K_2O/ha). Using DAP, the full amount of P was applied as a base. At 30, 60, and 90 DAP, the remaining nitrogen was applied in three equal splits as urea and potassium as muriate of potash.

2.4. Weed flora, weed density and dry weight of the experimental field

The species-wise weeds identified in the treatment plots during the periods when they were most noticeable, which were 15, 30, and 45 DAA, were noted in order to account for the overall weed flora of the experimental field. The experimental site's weed flora was documented by species. Four randomly chosen locations within each plot were used to record the species-wise weed count using a 0.5 m × 0.5 m quadrant. The weeds that fell within the quadrant's frames were recorded and the mean values were expressed in number per m^2. At 15, 30, and 45 DAA, the number of weeds per m^2 as well as the density of grasses, sedges, and broad-leaved weeds were measured. At 15, 30, and 45 DAA, the number of weeds per m^2 as well as the density of grasses,

sedges, and broad-leaved weeds were measured. The weeds that fell inside the quadrant's frames were gathered, divided into grasses, sedges, and broad-leaved weeds, shade-dried and then dried for 72 hours at 80 degrees Celsius in a hot-air oven. At 15, 30, and 45 DAA, the dry weight of grasses, sedges and broadleaved weeds was measured independently and reported in g per m^2.

2.5. Weed control efficiency

The method provided by Mani et al. (1973) was used to calculate weed control efficiency (WCE).

$$WCE\ \% = \frac{WD_c - WD_t}{WD_c} \times 100$$

Where,

WCE - weed control efficiency (per cent)

WD_c - weed biomass (g m^{-2}) in control plot

WD_t - weed biomass (g m^{-2}) in treated plot

2.6. Weed index

Weed index (WI) was calculated as per the method suggested by Gill and Vijaya Kumar (1969).

$$WI = \frac{X - Y}{X} \times 100$$

Where,

X = yield from the minimum weed competition plot (kg/ha)

Y = yield from the treatment plot (kg/ha) for which WI needs to be calculated.

2.7. Cane yield

The yield measured in t/ha, was determined by weighing the harvested canes from the net plot.

2.8. Visual phytotoxicity rating

Following the application of the herbicide, the plants were examined in order to determine the effects of phytotoxicity. The experiment's weed management and phytotoxic signs (yellowing, chlorosis, stunting, and scorching) in the sugarcane crop were visually scored on days 3, 5, 7, and 10. A 0–10 scale was used to score the herbicide injury indicators, with 0 denoting no harm and 10 denoting total devastation.

2.9. Statistical analysis

According to the guidelines for randomized block design provided by Gomez and Gomez (2010), the data for sugarcane was statistically analyzed. According to Snedecor and Cochran (1967), the data relevant to weeds and germination was transformed to square root scale and examined. A crucial difference occurred at a 5% probability threshold whenever a significant difference existed. Treatments that had differences that were not statistically significant were designated as NS.

3. RESULTS AND DISCUSSION

3.1. General weed flora of the experimental field

General weed flora of the experimental fields was observed at 60 days after planting. Among the grasses, *Sitaria verticillata* (L.), *Cynodon dactylon* (L.) Pers., *Dactyloctenium aegyptium* Beauv., *Dinebra retroflexa* (Vahl) Panzer were the dominant species and the only one sedge weed are *Cyperus rotundus* (L.). Among the broad leaved weeds, *Trianthema portulacastrum* (L.), *Portulaca oleracea* (L.), *Digera arvensis* (Forsk), *Corchorus olitorius* (L.), *Parthenium hysterophorus* (L.) and *Datura fastuosa* (L.) were the dominant species.

3.2. Total weed dry weight

Significant differences were found between the herbicidal weed management methods in sugarcane with respect to the total weed dry weight (Table 2). During both the years, lower total weed dry weight at 15 and 30 DAA was observed in PoE application of tembotrione at 120.75 g a.i./ha + surfactant at 1000 ml/ha + metribuzine at 1050 g a.i./ha (9.94 & 24.06 g/m^2 in 2015-16 and 4.96 & 17.70 g/m^2 in 2016-17) and it was statistically followed by tembotrione at 120.75 g a.i./ha + surfactant at 1000 ml/ha + atrazine at 500 g a.i./ha (13.54 & 28.48 g/m^2 in 2015-16 and 7.86 & 26.52 g/m^2 in 2016-17), tembotrione at 120.75 g a.i./ha + surfactant 1000 ml/ha + ethoxysulfuron at 60 g .i./ha (14.30 & 37.24 g/m^2 in 2015-16 and 9.04 & 37.10 g/m^2 in 2016-17) and tembotrione 420 SC at 120.75 g a.i./ha + surfactant at 1000 ml (17.58 & 39.52 g/m^2 in 2015-16 and 12.60 & 36.14 g/m^2 in 2016-17). Yadav et al. (2020) found that adding a surfactant (isoxadifen-ethyl) to tembotrione increased its effectiveness against mixed weed flora in maize. PoE application of metribuzine 70% WP at l.00 kg/ha + 2,4-D sodium salt 80% WP as a tank mixed in sugarcane was shown to be much better than the other treatments and to have a reduced weed density and dry weight (Waghmare et al., 2018). The most crucial measure for evaluating weed competitiveness for crop development and productivity is weed dry weight. Compared to dense weeds with lesser dry matter, sparse weeds with more biomass may be more competitive for crops (Sathya Priya et al., 2013). In special season sugarcane, the application of tembotrione at

120.75 g a.i./ha + surfactant at 1000 ml/ha + metribuzine at 1050 g a.i./ha at the 2-4 leaf stage resulted in satisfactory control of all weed types, including grassy, sedge, and broad-leaf weeds.

3.3. Weed control efficiency

During both the years, it was observed that PoE application of tembotrione at 120.75 g a.i./ha + surfactant at 1000 ml/ha + metribuzine at 1050 g a.i./ha resulted the higher WCE of 88.96 & 83.16% in 2015-16 and 93.91 & 87.43% in 2016-17, respectively and it was followed by tembotrione at 120.75 g a.i./ha + surfactant at 1000 ml/ha + atrazine at 500 g a.i./ha (84.96 & 80.06% in 2015-16 and 90.35 & 81.16% in 2016-17) and tembotrione at 120.75 g a.i./ha + surfactant 1000 ml/ha + ethoxysulfuron at 60 g a.i./ha (84.11 & 73.93% in 2015-16 and 88.90 & 73.65% in 2016-17) at 15 and 30 DAA (Table 2). Better performance among different treatments may have turned the pendulum in favor of crops rather than weeds, as seen by higher values of weed control efficiency, which could be attributable to reduced weed numbers and dry weight. Triveni et al. (2017) reported that PoE application of tembotrione at 50 g a.i./ha + atrazine at 500 g a.i./ha was registered higher weed control efficiency (93.6 & 96.9%) over other herbicidal treatments and it was closely followed by hand weeding twice at 20 and 40 DAS (90.1 & 95.6%) in maize. In farmers participatory trial indicated that application of sulfosulfuron at 25 g/ha, sulfosulfuron + metsulfuron (ready-mix) at 32 g/ha, mesosulfuron + iodosulfuron (ready-mix) at 14.4 g/ha (or) pinoxaden at 50 g/ha provided effective weed control efficiency (83 to 97% control of weeds including *Phalaris minor* over the years) in sugarcane + wheat intercropping system (Yadav et al., 2020). In the present study, at 30 DAA, WCE with ranged from 49.62 to 72.33% in 2015-16 and 56.24 to 74.33% in 2016-17, respectively (sole herbicide application); 83.16 to 84.11% in 2015-16 and 87.43 to 81.16% in 2016-17, respectively (new herbicide combination).

3.4. Response of cane yield

Cane yield followed all herbicidal treatments ranged from 93.4 to 134.1 t/ha in 2015-16 and 95.7 to 136.2 t/ha in 2015-17, while the untreated control plots yield of 71.8 and 74.13 t/ha in 2015-16 and 2016-17, respectively (Table 2). Among the different treatments, PoE application of tembotrione at 120.75 g a.i./ha + surfactant at 1000 ml/ha + metribuzine at 1050 g a.i./ha recorded significantly higher cane yield of 134.1 t/ha in 2015-16 and 136.2 t/ha in 2016-17, respectively which was comparable with tembotrione at 120.75 g a.i./ha + surfactant at 1000 ml/ha + atrazine at 500 g a.i./ha of 129.8 t/ha in 2015-16 and 132.13 t/ha in 2016-17, respectively. Weed control treatments had a substantial impact on yield characteristics such as milliable cane, cane length, cane girth, and cane weight compared to

the untreated control. Tembotrione prevents the production of carotenoids and their depletion by blocking the enzyme 4-hydroxy phenyl pyruvate dioxygenase (HPPD). Deprives chlorophyll, which is essential for photosynthesis, of its defense against excessive light, leading to chlorophyll oxidation, which bleaches sensitive weeds and eventually reduces the number of weeds, causing plants to appear increasingly white (Akhtar et al., 2015). All the treatments of tembotrione herbicide on control of weeds and consequently reduction in competition for moisture, nutrients and sunlight might have resulted the conspicuous enhancement in cane yield. The highest cane production (89.3 and 98.9 t/ha) was seen in both years when 600 g/ha of PoE halosulfuron + metribuzin was applied. Better sugarcane growth and yield may have been achieved by successfully controlling weeds early in the growth phase (Singh et al., 2017). Weed free environment diverted all the available resources towards crop utilization and resulted in higher cane yield. All the herbicidal treatment plots produced maximum crop growth thereby increasing the accumulation of photosynthates in reproductive parts of plants which ultimately improved the cane yield. The next best treatments, whereas the application of PoE tembotrione at 120.75 g a.i./ha + surfactant at 1000 ml/ha + ethoxysulfuron at 60 g a.i./ha (126.4 t/ha in 2015-16 and 127.6 t/ha in 2016-17) and that of tembotrione at 120.75 g a.i./ha + surfactant at 1000 g a.i./ha (121.7 t/ha in 2015-16 and 124.0 t/ha in 2016-17) registered conspicuously lower cane yield. This study clearly indicated, PoE application of tembotrione at 120.75 g a.i./ha + surfactant at 1000 ml/ha + metribuzine at 1050 g a.i./ha was very effective in reducing the population of BLWs and grasses as compared to sedges, without any phytotoxic effect on sugarcane and its succeeding sunflower. Earlier investigations have additionally shown that pinoxaden, mesosulfuron + iodosulfuron, sulfosulfuron, and sulfosulfuron + metsulfuron are suitable PoE herbicides for controlling weeds in sugarcane + wheat intercropping systems (Kamboj and al., 2008).

3.5. Weed index

The best treatment with the maximum yield was taken as the base to work out the weed index that gives the magnitude of yield reduction due to weed competition in other treatments. In both years, the herbicide combination of PoE application of 120.75 g a.i./ha + surfactant at 1000 ml/ha + metribuzine at 1050 g a.i./ha registered the maximum cane yield; therefore, lower cane yield reductions of only 3.21% and 2.99% were recorded in tembotrione at 120.75 g a.i./ha + surfactant at 1000 ml/ha + atrazine at 500 g a.i./ha (Table 2). This is most likely attributable to better crop growth brought about by efficient weed control and lesser crop weed competition. This resulted in fewer weeds and a reduced dry weight, which allowed the crop to absorb more nutrients. Comparable outcomes support the

conclusions of Singh et al. (2011) and Yadav et al. (2012). Yield reduction in the treatment of tembotrione at 120.75 g a.i./ha + surfactant at 1000 ml/ha + ethoxysulfuron at 60 g a.i./ha and tembotrione at 120.75 g a.i./ha + surfactant at 1000 ml/ha were found to be 5.74 and 9.21% in 2015-16 and 6.31 and 8.94% in 2016-17, respectively. Yield reduction in untreated control plots of 46.46% in 2015-16 and 45.57% in 2016-17, respectively. The untreated control had the highest weed index value when compared to the herbicide combination, which showed a very small yield loss because there were no weeds present as long as there were no other limiting factors. Poor growth and yield components under weedy conditions suggest that this is likely caused by competition for nutrients, moisture, and light provided by unregulated weed growth.

3.6. Effect on phytotoxicity symptoms in sugarcane

Phytotoxicity symptoms of herbicides on sugarcane were observed during both the years at 3, 5, 7 and 10 DAA. Phytotoxicity symptoms were observed in the three combination of tembotrione with atrazine, metribuzine and ethoxysulfuron and also higher doses of tembotrione alone, whereas the phytotoxicity symptoms were noticed at early stages of herbicide combination. Double doses of PoE application of tembotrione at 241.5 g a.i./ha + surfactant at 2000 ml/ha + atrazine at 1000 g a.i./ha, tembotrione at 241.5 g a.i./ha + surfactant at 2000 ml/ha + ethoxysulfuron at 120 g a.i./ha and tembotrione at 120.75 g a.i./ha + surfactant at 2000 ml/ha + metribuzine at 2100 g a.i./ha were noticed phytotoxicity symptomps with the rating of three, two and one (injury more pronounced but not persistent, some stand loss, stunting / discoloration) at 3, 5 and 7 DAA (Table 3). There was no phytotoxicity of tembotrione at 120 and 240 g a.i./ha (with surfactant) on maize at 15 and 30 DAT and no residual phytotoxicity on succeeding crop of wheat during both the years (Yadav et al., 2018). The treatment of halosulfuron + metribuzin at varying concentrations did not cause any phytotoxic effects in sugarcane crops, including scorching, necrosis, hyponasty, and epinasty (Srivastava et al., 2005). In this study, combination of herbicides at 10 DAA in sugarcane plants recovered completely from phytotoxicity symptomps and there was not evident thereafter. Phytotoxicity symptoms on sugarcane (in terms of leaf chlorosis, leaf tip burning, leaf necrosis, leaf epinasty and wilting *etc*.,) were observed with combination of tembotrione with double doses of different herbicide combination. Singh et al. (2012) reported that there was no phytotoxicity of tembotrione on maize and succeeding crop of mustard in rotation. Phytotoxicity symptoms were not evident thereafter at 10 DAA in all the double doses combination of tembotrione in sugarcane.

4. CONCLUSION

The findings and interpretation of the present study it could be concluded all among the herbicidal treatments, the individual application of PoE herbicides like tembotrione, atrazine, metribuzin and ethoxysulfuron showed lesser weed control efficacy in the complex weed flora in sugarcane trial during both the years. Addition of surfactant (isoxadifen-ethyl) was realized to attain satisfactory efficacy of tembotrione against mixed weed flora in sugarcane. Herbicide combination of tembotrione 420 SC at 120.75 g a.i./ha + surfactant at 1000 ml/ha (isoxadifen-ethyl) + metribuzine 70% WP at 1050 g a.i./ha applied at 2-4 leaf stage (10-15 DAP) provided satisfactory control of all type of weeds (BLWs and grasses as compared to sedges) in special season sugarcane without causing any crop phytotoxicity on sugarcane and consequently, it resulted into higher cane yield with more profitability.

Acknowledgments

The authors are indebted to the Department of Agronomy, Tamil Nadu Agricultural University, India for providing infrastructural facilities for conducting experiment and M/s. Bayer Crop Science, Pvt. Ltd., Coimbatore (India) for providing necessary funding to accomplish this project.

Funding

There is no funding assistance for conduct of this research experiment.

Competing Interest

The authors declare no competing interests.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

References

1. Akhtar P, Kumar A, Kumar J, Sharma AK and Bharti V. Efficacy of tembotrione on mixed weed flora and yield of spring maize under irrigated sub-tropical shiwalik foothills 25th Asian-Pacific Weed Science Society Conference on “Weed Science for Sustainable Agriculture, Environment and Biodiversity”, Hyderabad, India. 2015. October 13-16, p 266.
2. Anonymous. Controlling weeds in sugarcane. Louisiana State University Ag Center and Louisiana Cooperative Extension Service. 2001. Pub. 2314.
3. Anusha S, Geetha P, Krishnapriya V. et al. Management of diverse weed flora in

widely spaced sugarcane plant crop in tropical India through sequential and tank mix application of herbicides. Sugar Tech. 2024; https://doi.org/10.1007/s12355-024-01515-9

4. Bhullar MS, Kamboj A, Singh GP. Weed management in spring planted sugarcane based intercropping systems. Indian J. Agron. 2006;51(3):183-185.
5. de Castro RA, de Castro SGQ, de Castro SAQ, Piassa A, do Nascimento Soares GO, Tropaldi L, Christofoletti PJ. Optimizing herbicide selection for pre-emergence control of itchgrass and cypressvine morning glory in sugarcane. J. Environ. Sci. Health B, 2024;59(6):350-360.
6. Gill GS, Vijaya Kumar K. Weed Index - A new method of reporting weed control trials. Indian J. Agron. 1969;14:96-98.
7. Gomez KA, Gomez AA. Statistical procedures for Agricultural Research. Wiley India Pvt. Ltd., New Delhi, India. 2010.
8. Hawkes TR. Hydroxy phenyl pyruvate dioxygenase (HPPD) - The herbicide target. In: Kramer W and Schirmer U (Eds.), Modern Crop Protection Compounds, 2007;1:211-220.
9. Kamboj BR, Malik RK, Garg R, Yadav A, Singh S, Goyal NK, Lathwal OP, Malik YP, Mehla OP. Bed planting - A novel technique to encourage multiple land use. Technical Bulletin (29). Directorate of Extension Education, CCS Haryana Agricultural University, Hisar, India, 2008. p.24.
10. Karthikeyan R, Sathya Priya R, Bharathi C, Janaki P, Chinnusamy C, Kandeshwari M, Saranraj T, Balamurugan R. 2024. Triketone derivates of hydroxyl phenyl pyruvate dioxygenase (hppd) as potential herbicides against diverse weed flora in maize: Efficacy, phyto-toxicity, soil residual toxicity impact on succeeding sunflower. International Int J. Plant Soil Sci. 2024;36(8):639-52. https://doi.org/10.9734/ijpss/2024/v36i84894.
11. Mani VS, Mala ML, Gautam, KC, Bhagavandas. Weed killing chemicals in potato cultivation. Indian Farming. 1973;23(1):17-18.
12. Murali Arthanari P, Gowthami S, Chinnusamy C, Sathya Priya R, Hariharasudhan V. Effect of low dose early post emergence herbicide on growth and yield of transplanted rice crop. Chem. sci. rev. let. 2017;6(21):231-236.
13. Patil MP, Naik PL, Metha NJ, Patel HS and Naik BC. 1991. Herbicidal control of weeds in sugarcane. Indian Sugar. 2006. 16;309-312.
14. Sathya Priya R, Chinnusamy C, Manickasundaram P, Murali Arthanari. Evaluation of New Formulation of Oxyfluorfen (23.5% EC) for weed control efficacy and bulb

yield in onion. Am. J. Plant Sci. 2013;4:890-895.

15. Singh R, Shyam R, Bhatnagar A, Singh VK, Kumar J. Bio-efficacy of herbicides applied at 2 to 4 leaf stage of weeds in sugarcane after second interculture. Indian J. Weed Sci. 2011;43: 145-48.
16. Singh VP, Guru SK, Kumar A, Banga A and Tripathi N. Bioefficacy of tembotrione against mixed weed complex in maize. Indian J. Weed Sci. 2012;44(1):1-5.
17. SinghVP, Pareek N, Singh SP, Raverkar KP, Satyawali K, Bisht N, Joshi N, Kumar A, Kaushik S. Halosulfuron + metribuzin effect on weed control in sugarcane and their carry over effect on succeeding lentil. Indian J. Weed Sci. 2017;49(4):364-369.
18. Snedecor GW, Cochran WG. Statistical Methods. Oxford and IBH Publ. Co., New Delhi. 1967. p.593.
19. Srivastava TK, Chauhan RS and Lal M. Weed dynamics and their management under different preceding crops and tillage systems. Indian J. Agric. Sci. 2005. 75;256-260.
20. Triveni U, Sandhya RY, Patro TSSK and Bharathalakshmi M. Effect of different pre and post-emergence herbicides on weed control, productivity and economics of maize. Indian J. Weed Sci. 2017;49(3):321-235
21. Waghmare PK, Shinde SA, Chenalwad SP, Jadhav AS. Study on weed control and yield of seasonal sugarcane as influenced by application of different herbicides. Int. J.curr. Microbiol. Appl. Sci. 2018;6:930-932.
22. Yadav DB, Chand M, Kamboj BR, Yadav A, Punia SS. Herbicide options for weed management in sugarcane + wheat intercropping system in Indo-Gangetic Plains. Indian J. Weed Sci. 2020;52(1):32-36.
23. Yadav DB, Punia SS and Yadav A. Tembotrione: a new post emergence herbicide for complex weed flora in maize. Proceedings of Biennial conference of Indian society of Weed Science, Thrissur (Kerala). CCS HAU Regional Research Station, Karnal, Haryana. 2012.
24. Yadav DB, Yadav A, Punia SS and Duhan A. Tembotrione for post-emergence control of complex weed flora in maize. Indian Journal of Weed Science. 2018. 50;(2):133-136.

Table 2. Total weed dry weight, weed control efficiency, cane yield and weed index as influenced by different weed management practices in sugarcane

Herbicide treatments	Total weed dry weight (g/m^2), WCE (%), Cane yield (t/ha) & Weed Index (WI)											
	Special season, 2015-16						Special season, 2016-17					
	Total weed dry weight		WCE		Cane yield	Weed Index	Total weed dry weight		WCE		Cane yield	Weed Index
	15 DAA	30 DAA	15 DAA	30 DAA			15 DAA	30 DAA	15 DAA	30 DAA		
T_1 - Tembotrione at 76.5 g a.i./ha + surfactant at 1000 ml/ha	6.65 (42.20)	8.60 (71.96)	53.11	49.62	95.00	29.16	5.91 (32.88)	7.98 (61.61)	59.63	56.24	97.4	28.49
T_2 - Tembotrione at 96.6 g a.i./ha + surfactant at 1000 ml/ha	4.53 (18.50)	6.53 (40.58)	79.44	71.59	113.2	15.59	3.94 (13.52)	6.47 (39.92)	83.40	71.65	114.2	16.15
T_3 - Tembotrione at 120.75 g a.i./ha + surfactant at 1000 ml/ha	4.42 (17.58)	6.44 (39.52)	80.47	72.33	121.7	9.25	3.82 (12.60)	6.18 (36.14)	84.53	74.33	124.03	8.94
T_4 - Tembotrione at 120.75 g a.i./ha + surfactant at 1000 ml/ha + atrazine at 500 g a.i./ha	3.94 (13.54)	5.52 (28.48)	84.96	80.06	129.8	3.21	3.14 (7.86)	5.34 (26.52)	90.35	81.16	132.13	2.99
T_5 - Tembotrione at 120.75 g a.i./ha + surfactant 1000 ml/ha + ethoxysulfuron at 60 g a.i./ha	4.04 (14.30)	6.26 (37.24)	84.11	73.93	126.4	5.74	3.32 (9.04)	6.25 (37.10)	88.90	73.65	127.6	6.31
T_6 - Tembotrione at 120.75 g a.i./ha + surfactant at 1000 ml/ha + metribuzin at 1050 g a.i./ha	3.46 (9.94)	5.10 (24.06)	88.96	83.16	134.1	0.00	2.64 (4.96)	4.44 (17.70)	93.91	87.43	136.2	0.00
T_7 - Tembotrione at 120.75 g a.i./ha	5.58 (29.14)	7.51 (54.46)	67.62	61.87	95.8	28.56	4.98 (22.82)	7.27 (50.90)	71.98	63.85	98.0	28.05
T_8 - Atrazine at 500 at g a.i./ha	4.77 (20.72)	6.82 (44.54)	76.98	68.82	105.6	21.25	4.22 (15.84)	6.75 (43.50)	80.55	69.11	106.8	21.59
T_9 - Ethoxysulfuron at 60 g a.i./ha	5.92 (33.07)	7.92 (60.66)	63.26	57.53	93.4	30.35	5.39 (27.08)	7.74 (57.86)	66.75	58.91	95.73	29.71
T_{10} - Metribuzin at 1050 g a.i./ha	5.13 (24.32)	7.09 (48.30)	72.98	66.19	104.3	22.22	4.61 (19.28)	6.87 (45.22)	76.33	67.88	106.63	21.71
T_{11} - Hand weeding twice at 30 and 60 DAP	8.40 (68.58)	7.20 (49.86)	23.80	65.09	124.4	7.23	8.34 (67.52)	7.23 (50.22)	0.00	64.33	127.5	6.39
T_{12} - Untreated control	9.59 (90.00)	12.03 (142.84)	0.00	0.00	71.8	46.46	9.13 (81.44)	11.95 (140.8)	0.00	0.00	74.13	45.57
SEd	**0.26**	**0.29**	**-**	**-**	**5.30**	**-**	**0.24**	**0.32**	**-**	**-**	**5.6**	**-**
CD (P=0.05)	**0.52**	**0.60**	**-**	**-**	**10.6**	**-**	**0.48**	**0.64**	**-**	**-**	**11.2**	**-**

Figures in parenthesis are original values; Data subjected to square root transformation; DAA: Days after application; DAP: Days after planting

Table 3. Effect of different weed management treatments of phytotoxicity rating in sugarcane

Treatments	g a.i./ha	1 DAA	3 DAA	5 DAA	7 DAA	10 DAA
T_1 - Tembotrione 420 SC + Surfactant*	241.5 + 2000 ml surfactant	1.00	1.00	0.00	0.00	0.00
T_2 - Tembotrione 420 SC + surfactant + atrazine 50% WP	120.75 + 1000 ml + 500	0.00	0.00	0.00	0.00	0.00
T_3 - Tembotrione 420 SC + surfactant + atrazine 50% WP*	241.5 + 2000 ml surfactant + 1000	3.00	3.00	2.00	0.00	0.00
T_4 - Tembotrione420 SC + surfactant + ethoxysulfuron 15% WG	120.75 + 1000 ml surfactant + 60	0.00	0.00	0.00	0.00	0.00
T_5 - Tembotrione420 SC + surfactant + ethoxysulfuron 15% WG*	241.5 + 2000 ml surfactant + 120	4.00	3.00	2.00	1.00	0.00
T_6 - Tembotrione 420 SC + surfactant + metribuzin 70% WP	120.75 + 1000 ml surfactant + 1050	0.00	0.00	0.00	0.00	0.00
T_7 - Tembotrione 420 SC + surfactant + metribuzin 70% WP*	241.5 + 2000 ml + 2100	2.00	1.00	1.00	0.00	0.00

*** Treatment meant for only phytotoxicity studies; Surfactant (isoxadifen-ethyl) DAA - Days after application**