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Integrated weed management in preseasonal sugarcane

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Abstract
A field experiment on "Integrated Weed Management for preseasonal sugarcane" was conducted for three consecutive years at Central Sugarcane Research Station, Padegaon, Tal Phaltan District Satara, Maharashtra, India during 2015-16 to 2017-18 to find out tank mix optimum combination dose of post emergence herbicide for effective control in sugarcane. Dominant weeds observed in sugarcane crop were *Brachiaria eruciformis, Cyperus rotundous, Alternanthera sessils, Parthenium hysterophorus L., Euphorbia geniculata Linn., Cardiosoermum lalicacabum, Ipomoea hederacea* and *Hylandis latiprosa.* The result showed that mean total weed count and weed dry weight reduced with post emergence application of metribuzin @ 0.50 kg a.i.ha^{-1} + 2, 4-D @ 1.00 kg a.i. ha^{-1} at 25 DAP *fb* hoeing at 60 and 90 DAP and found at par with treatment post emergence application of metribuzin @ 1 kg a.i ha^{-1} + 2, 4-D @ 1 kg a.i. ha^{-1} at 25 DAP *fb* hoeing at 60 and 90 DAP. Among the herbicidal treatments, post emergence application of metribuzin @ 0.50 kg a.i ha^{-1} + 2, 4-D @ 1 kg a.i. ha^{-1} at 25 DAP *fb* hoeing at 60 and 90 DAP recorded significantly the highest germination per cent (66.73 %), number of internodes per cane (22) and average cane weight (1.93 kg) over all herbicidal treatments which was at par with pre emergence spray of metribuzin @1 kg a.i. ha^{-1} and post emergence spray of 2,4-D @1kg a.i. ha^{-1} at 60 DAP *fb* hoeing at 90 DAP for number of internodes per cane (21.90) and average cane weight (1.92 kg). Among the herbicidal treatments, maximum weed control efficiency of 60.59 %, 56.38 % and 75.99 % was found in treatment of post emergence application of metribuzin @ 0.50 kg a.i. ha^{-1}+ 2,4-D @ 1.00 kg a.i. ha^{-1} at 25 DAP *fb* hoeing at 60 and 90 DAP to sugarcane crop at 30, 60 and 90 days after application, respectively followed by post emergence application of metribuzin @ 1 kg a.i ha^{-1} + 2, 4-D @ 1 kg a.i. ha^{-1} at 25 DAP with hoeing at 60 and 90 DAP. Similarly, the significantly highest cane yield (155.21 t ha^{-1}) and CCS yield (21.38 t ha^{-1}) was recorded by same treatment over all herbicidal treatments which was at par with treatment metribuzin @1 kg a.i. ha^{-1} as pre emergence, 2,4-D @1 kg a.i. ha^{-1} as post emergence application at 60 DAP *fb* hoeing at 90 DAP for CCS yield. The maximum net return (Rs. 278454) and benefit cost ratio (3.13) was also reported by same treatment followed by post emergence application of metribuzin @1.00 kg a.i. ha^{-1} + 2,4-D @ 0.50 kg a.i. ha^{-1} at 25 DAP *fb* hoeing at 60 and 90 DAP. The cane quality like commercial cane sugar %, sucrose %, brix (0^0) and purity % was not affected by hand weeding, mechanical weed control and application of any herbicide.

Keywords: Cane yield, economics, weed control efficiency, metribuzine, 2, 4-D

Introduction
India is the second largest producer of sugar in the world with over 4 mha of sugarcane growing area. It produces approximately 22 mt of sugar annually. Around 85% sugarcane production of India is from Uttar Pradesh, Maharashtra, Tamil Nadu, Andhra Pradesh, Karnataka and Gujarat (Takalkar and Pawar 2012) [8]. Sugarcane crop faces tough competition with weeds during 60 to 120 days of its planting which causes heavy reduction in cane yield ranging from 40-67% (Shauhan and Srivastava 2002) [5]. Widely spaced crop of sugarcane allows wide range of weed flora to grow profusely in the interspaces between the rows. Frequent irrigations and fertilizer application during early growth stages, increase the weeds menace by many folds in the crop (Singh *et al*. 2008) [6].
Weeds constitute one of the most important problems faced in crop cultivation because of its negative effect on the quality and quantity (Mehra *et al*. 1995) [4]. The competition between crop and weed is one of the important limiting factors in successful raising of plants of commercial value. Use of herbicides is one of the methods currently used to control weeds. The application of these herbicides at early stages of crop growth checks the competition between weeds and the crop during initial stages while weeds emerging later

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cause weak competition and do not cause any damage to crop plants.

Hand hoeing in sugarcane has been the most widely practiced method of weed control by farmers. However, in recent years, its practical and economic feasibility has been limited by unfavourable weather conditions, unavailability of laborer during critical period of weeding and also their high wages. Therefore, chemical control of weeds is considered economical in sugarcane (Kumar *et al.* 2014b). Several herbicides have been tried in sugarcane with varying degree of success, but information on combined use of chemical and cultural practices are scarce. Keeping this in view, the present investigation was undertaken to study the integrated weed management in preseasonal sugarcane.

Materials and methods

An experiment was conducted during 2015-16 and 2016-17 and 2017-18 at Central Sugarcane Research Station, Padegaon, Maharashtra, India. The experiment consisted of ten treatments, *viz.* weed control (T_1), weed free check (T_2), two weeding, at 30 and 60 DAP +1 hoeing at 90 DAP (T_3), metribuzin @ 1 kg a.i. ha^{-1} as PE, 2,4-D @ 1kg a.i. ha^{-1} POE at 60 DAP, hoeing at 90 DAP (T_4), metribuzin @ 0.50 kg a.i. ha^{-1} + 2,4-D @ 0.50 kg a.i.ha^{-1} POE at 25 DAP hoeing at 60 and 90 DAP (T_5), metribuzin @0.75 kg a.i.ha^{-1} + 2,4-D @ 0.75 kg a.i.ha^{-1} POE at 25 DAP, hoeing at 60 and 90 DAP (T_6), metribuzin @ 1.00 kg a.i.ha^{-1} + 2,4-D @ 1.00 kg a.i. ha^{-1}POE at 25 DAP, hoeing at 60 and 90 DAP (T_7), metribuzin @1.00 kg a.i. ha^{-1} + 2,4-D @ 0.50 kg a.i. ha^{-1} POE at 25 DAP, hoeing at 60 and 90 DAP (T_8), metribuzin @0.50 kg a.i. ha^{-1}+ 2,4-D @ 1.00 kg a.i. ha^{-1}POE at 25 DAP, hoeing at 60 and 90 DAP (T_9) and atrazine @ 2.00 kg a.i. ha^{-1}+ 2,4-D @ 0.50 kg a.i. ha^{-1}POE at 25 DAP, hoeing at 60 and 90 DAP (T_{10}) were laid out in randomized block design with 3 replications. All herbicides were applied at 25 DAP of sugarcane (3 to 4 active leaf weed stage). Herbicides were applied as per the treatments with spray volume of 500 l ha^{-1}. Two budded setts of sugarcane variety CoM 0265 were planted in first week of November 2015, 2016 and 2017 and harvested in the third week of February 2017, 2018 and 2019. Data pertaining to density and dry matter accumulation by weeds were subjected to square root transformation prior to statistical analysis.

Recommended doses of fertilizers were applied to sugarcane (N: P_2O_5: K_2O 340: 170: 170 kg ha^{-1}). N was applied in four splits (10 % at planting, 40 % at 6-8 weeks after planting, 10 % at 12-16 weeks after planting and 40 % at earthing up) and dose of P and K fertilizers (50 % at the time of planting and 50 % at the time of earthing up).

Results and discussion
Weed Flora
The major weed flora observed in preseasonal sugarcane crop were viz. *Brachiaria eruciformis, Cyperus rotundous, Alternanthera sessils, Parthenium hysterophorus L., Euphorbia geniculata, Linn. Cardiosoermum lalicacabum, Ipomoea hederacea* and *Hylandis latiprosa etc*

1. Effect on total weed count
The weed density observed 30, 60 and 90 days after application of the herbicide spray in sugarcane crop differed significantly during all the three consecutive years of experimentation (2015-16 to 2017-18). The results in (Table 1) revealed that different herbicidal treatments recorded significantly lower total weed count than the weed control. Among the herbicidal treatments, the post-emergence spray of

metribuzin @ 0.50 kg a.i.ha^{-1} + 2,4-D @ 1.00 kg a.i. ha^{-1} at 25 DAP *fb* hoeing at 60 and 90 DAP at 30 DAA recorded lowest weed count (3.18 m^2) than all herbicidal treatment except treatment T_7 were at par. At 60 DAA lowest total weed count (4.43 m^2) was observed in same treatment as compared to treatment T_4, T_8 and T_{10} and rest of the herbicide treatment found at par with each other. At 90 DAA lowest total weed count (4.19 m^2) was observed in same treatment as compared to treatment T_4 and T_{10} which was at par with rest of the herbicide treatment.

2. Effect on dry weight
The significantly lowest weed dry weight (1.86 g m^{-2}) observed at 30 DAA days of observation in treatment of post-emergence spray of metribuzin @ 0.50 kg a.i.ha^{-1} + 2,4-D @ 1.00 kg a.i. ha^{-1} at 25 DAP *fb* hoeing at 60 and 90 DAP than all the herbicidal treatments except treatments T_7 and T_6 were at par. At 60 DAA days of observation, the significantly lowest weed dry weight (2.79 g m^{-2}) observed in same treatment than treatment T_4 and T_{10} which was at par with rest of the herbicidal treatments. At 90 DAA, the significantly lowest weed dry weight (2.40 g m^{-2}) observed in same treatment and found at par with rest of the herbicidal treatments.

3. Weed control efficiency (based on weed dry weight)
The weed control efficiency among the herbicide weed management practices ranged from 27.03 to 60.59 % at 30 DAA, 25.78 to 56.38 % at 60 DAA and 62.10 to 75.99 % at 90 DAA, respectively (Table 1). The highest weed control efficiency of 60.59 %, 56.38 % and 75.99 % was found in treatment of post emergence application of metribuzin @ 0.50 kg a.i ha^{-1} + 2, 4-D @ 1 kg a.i. ha^{-1} at 25 DAP with hoeing at 60 and 90 DAP to sugarcane crop at 30, 60 and 90 DAA, respectively followed by post emergence application of metribuzin @ 1.00 kg a.i. ha^{-1}+ 2,4-D @ 1.00 kg a.i. ha^{-1} at 25 DAP, hoeing at 60 and 90 DAP. Same conformity was reported by Singh *et al.* (2012) [7].

Effect on growth parameters
The data presented in Table 2 revealed that germination per cent (69.04%) was found significantly the highest in weed free check (T_2), Tillering ratio (1.52) was recorded significantly highest in same treatment which was found at par with treatment T_9. The treatment T_2 recorded significantly the highest millable cane height (261.74 cm) and girth (10.94 cm) as compared to other treatments and was found at par with treatment T_5, T_6, T_8, T_9 and T_{10} in respect to girth. Post emergence application of metribuzin @ 0.50 kg a.i.ha^{-1} + 2,4-D @ 1.00 kg a.i.ha^{-1} at 25 DAP, hoeing at 60 and 90 DAP revealed significantly higher number of internodes and average cane weight (22.00 and 1.93 kg) which was found at par with the treatment T_4. The treatment T_2 showed significantly the highest number of millable cane (85976 ha^{-1}) over all treatments and was at par with treatment T_8. These results are consistent with findings of Agrawal *et al.* (1986) [1].

Effect of cane and CCS yield
Sugar yield is a function of per cent CCS and the cane yield. So variation in sugarcane yield levels with the different application rates of herbicides or manual hoeings significantly changed the sugar yield. Data presented in Table 3 revealed that weed free check (T_2) recorded significantly the highest cane yield and CCS yield (158.35 t ha^{-1}and 21.50 t ha^{-1}) which

was found at par with post emergence application of metribuzin @ 0.50 kg a.i.ha^{-1} + 2,4-D @ 1.00 kg a.i.ha^{-1} at 25 DAP, hoeing at 60 and 90 DAP (T$_9$) (155.51 t ha^{-1}) in respect to cane yield and treatment T$_9$ and T$_4$ in respect to CCS yield (21.28 t ha^{-1} and 20.94 t ha^{-1}). Same conformity was reported by Tej *et al.* (2013) [9].

Effect on quality parameters
Cane quality parameters worked out in terms of brix (0^0), sucrose %, CCS % and purity % (Table 3) registered non-significant effect between the treatments of weed control and weed free check. The quality parameters were not affected by variable doses of herbicides indicating the quality to be a function of some other factors like enzymes and nutrition and not linked to the effect of weed control. Kumar *et al.* (2014b) also reported non-significant results on quality aspects of sugarcane due to different weed control treatments.

Economics
The pooled data presented in table 4 reported that post emergence application of metribuzin @ 0.50 kg a.i ha^{-1} + 2, 4-D @ 1 kg a.i. ha^{-1} at 25 DAP, hoeing at 60 and 90 DAP (T$_9$) gave significantly the highest net return of Rs. 278454 followed by treatment (T$_2$) and it also recorded highest benefit cost ratio was 3.13 followed by treatment (T$_8$). Same results were reported by Kumar *et al.* (2014a).

Table 1: Effect of different weed control treatments on total weed count, dry weight and WCE in sugarcane. (Pooled data)

Treatment	Total Weed count (No./m^2)			Dry weight (g/m^2)			Weed control efficiency (%) (Dry weight basis)		
	30 DAA	60 DAA	90 DAA	30 DAA	60 DAA	90 DAA	30 DAA	60 DAA	90 DAA
T$_1$	5.31 (27.67)	6.71 (44.56)	7.25 (52.06)	2.83 (7.51)	4.15 (16.76)	4.77 (22.32)	--	--	--
T$_2$	3.17 (9.83)	3.59 (12.72)	3.90 (15.33)	1.62 (2.21)	2.08 (3.93)	2.24 (4.73)	70.57	76.55	78.81
T$_3$	3.00 (8.61)	3.66 (13.00)	4.06 (16.39)	1.67 (2.34)	2.29 (4.74)	2.34 (5.08)	68.84	71.72	77.24
T$_4$	4.19 (17.17)	5.05 (25.22)	4.99 (24.89)	2.24 (4.54)	3.14 (9.43)	2.73 (7.26)	39.55	43.74	67.47
T$_5$	3.96 (15.26)	4.83 (23.11)	4.56 (20.72)	2.15 (4.12)	3.00 (8.58)	2.63 (6.54)	45.14	48.81	70.70
T$_6$	3.74 (13.50)	4.77 (22.33)	4.52 (20.50)	2.00 (3.51)	3.09 (9.16)	2.59 (6.36)	53.26	45.35	71.51
T$_7$	3.56 (12.17)	4.71 (21.94)	4.41 (19.11)	1.95 (3.31)	2.97 (8.38)	2.49 (5.77)	55.93	50.00	74.15
T$_8$	3.85 (14.44)	5.00 (24.72)	4.42 (19.22)	2.11 (3.98)	3.10 (9.14)	2.66 (6.62)	47.00	45.47	70.34
T$_9$	3.18 (9.61)	4.43 (19.17)	4.19 (17.28)	1.86 (2.96)	2.79 (7.31)	2.40 (5.36)	60.59	56.38	75.99
T$_{10}$	4.72 (22.11)	5.75 (32.94)	5.30 (28.06)	2.44 (5.48)	3.50 (12.44)	2.97 (8.46)	27.03	25.78	62.10
SE+	0.14	0.16	0.17	0.08	0.11	0.52			
CD at 5%	0.43	0.49	0.51	0.22	0.33	1.53			

DAA: Days after application, Data were transformed through square-root ($\sqrt{X + 0.5}$) method;   **WCE:**   Weed Control Efficiency
Figures in the parenthesis are original values; NS: Non-significant

Table 2: Biometric observation as affected by different weed control treatments. (Pooled data)

Treatment	Germ. (%)	Tillering Ratio	Millable height (cm)	Girth (cm)	No of Internodes/cane	Number of Millable Cane (ha)	Average cane weight (kg)
T$_1$: Weed Control.	50.68	0.92	176.14	10.30	17.82	70526	1.05
T$_2$: Weed free check	69.04	1.52	261.74	10.94	21.32	85976	1.83
T$_3$: Two weeding, at 30 and 60 DAP + 1 hoeing at 90 DAP	64.51	1.48	230.64	10.13	21.01	82477	1.82
T$_4$: Metribuzin @ 1 kg a.i. ha^{-1} as PE, 2,4-D @1kg a.i.ha^{-1} POE at 60 DAP, hoeing at 90 DAP	62.25	1.41	246.93	10.18	21.90	78638	1.92
T$_5$: Metribuzin @ 0.50 kg a.i. ha^{-1} + 2,4-D @ 0.50 kg a.i.ha^{-1} POE at 25 DAP, hoeing at 60 and 90 DAP	64.79	1.31	231.83	10.91	20.00	77166	1..77
T$_6$: Metribuzin @ 0.75 kg a.i./ha + 2,4-D @ 0.75 kg a.i.ha^{-1} POE at 25 DAP, hoeing at 60 and 90 DAP	63.67	1.46	234.38	10.81	20.12	80722	1.81
T$_7$: Metribuzin @ 1.00 kg a.i.ha^{-1} + 2,4-D @ 1.00 kg a.i.ha^{-1} POE at 25 DAP, hoeing at 60 and 90 DAP	65.15	1.45	234.59	10.45	19.99	83340	1.76
T$_8$: Metribuzin @ 1.00 kg a.i. ha^{-1} + 2,4-D @ 0.50 kg a.i.ha^{-1} POE at 25 DAP, hoeing at 60and 90DAP	64.61	1.48	237.88	10.65	20.11	85913	1.74
T$_9$: Metribuzin @ 0.50 kg a.i. ha^{-1}+ 2,4-D @ 1.00 kg a.i.ha^{-1} POE at 25 DAP, hoeing at 60 and 90 DAP	66.73	1.50	240.38	10.71	22.00	80796	1.93
T$_{10}$: Atrazine @ 2.00 kg a.i. ha^{-1}+ 2,4-D @ 0.50 kg a.i.ha^{-1} POE at 25 DAP, hoeing at 60 and 90 DAP	60.69	1.39	230.97	10.72	19.10	76728	1.73

SE+	0.27	0.01	2.39	0.11	0.20	565	0.01
CD at 5%	0.79	0.03	7.09	0.32	0.60	1681	0.04

PE: Pre emergence, **POE:** Post emergence

Table 3: Cane yield, sugar yield (t/ha) and quality parameters as affected by different weed control treatments. (Pooled data)

Treatment	Cane yield (t ha⁻¹)	CCS yield (t ha⁻¹)	Brix (0^0)	Sucrose (%)	Purity (%)	CCS (%)
T_1 : Weed Control.	73.22	9.80	21.04	19.11	90.90	13.39
T_2 : Weed free check	158.35	21.50	21.15	19.35	91.41	13.58
T_3 : Two weeding, at 30and 60 DAP +1 hoeing at 90 DAP	149.89	20.69	21.48	19.61	91.84	13.80
T_4 : Metribuzin @ 1 kg a.i. ha⁻¹ as PE, 2,4-D @1kg a.i. ha⁻¹ POE at 60 DAP, hoeing at 90 DAP	151.29	20.94	21.44	19.60	91.87	13.84
T_5 : Metribuzin @ 0.50 kg a.i. ha⁻¹ + 2,4-D @ 0.50 kg a.i.ha⁻¹ POE at 25 DAP, hoeing at 60 and 90 DAP	136.37	18.90	21.19	19.30	91.51	13.61
T_6 : Metribuzin @ 0.75 kg a.i./ha + 2,4-D @ 0.75 kg a.i. ha⁻¹ POE at 25 DAP, hoeing at 60 and 90 DAP	145.92	20.28	21.42	19.64	92.09	13.90
T_7 : Metribuzin @ 1.00 kg a.i.ha⁻¹ + 2,4-D @ 1.00 kg a.i. ha⁻¹ POE at 25 DAP, hoeing at 60 and 90 DAP	146.57	20.16	21.38	19.63	91.55	13.76
T_8 : Metribuzin @ 1.00 kg a.i. ha⁻¹ + 2,4-D @ 0.50 kg a.i. ha⁻¹ POE at 25 DAP, hoeing at 60and 90DAP	150.63	20.50	21.28	19.30	90.98	13.60
T_9 : Metribuzin @ 0.50 kg a.i. ha⁻¹+ 2,4-D @ 1.00 kg a.i. ha⁻¹ POE at 25 DAP, hoeing at 60 and 90 DAP	155.51	21.38	21.47	19.55	90.01	13.75
T_{10} : Atrazine @ 2.00 kg a.i. ha⁻¹+ 2,4-D @ 0.50 kg a.i. ha⁻¹ POE at 25 DAP, hoeing at 60 and 90 DAP	132.22	17.76	21.03	19.11	90.92	13.37
SE+	1.30	0.22	0.11	0.18	0.40	0.12
CD at 5%	3.37	0.67	NS	NS	NS	NS

CCS: Commercial Cane Sugar

Table 4: Economics of different weed control treatments (Pooled data)

| Treatment	Gross Return (Rs. ha⁻¹)	Cost of Cultivation (Rs. ha⁻¹)	Net Return (Rs. ha⁻¹)	B:C Ratio
T_1 : Weed Control.	192788	121900	70888	1.58
T_2 : Weed free check	416935	145900	271036	2.86
T_3 : Two weeding, at 30and 60 DAP +1 hoeing at 90 DAP	394660	135430	259230	2.91
T_4 : Metribuzin @ 1 kg a.i. ha⁻¹ as PE, 2,4-D @1kg a.i. ha⁻¹ POE at 60 DAP, hoeing at 90 DAP	398346	132743	265604	3.00
T_5 : Metribuzin @ 0.50 kg a.i. ha⁻¹ + 2,4-D @ 0.50 kg a.i.ha⁻¹ POE at 25 DAP, hoeing at 60 and 90 DAP	359062	130683	228379	2.75
T_6 : Metribuzin @ 0.75 kg a.i./ha + 2,4-D @ 0.75 kg a.i. ha⁻¹ POE at 25 DAP, hoeing at 60 and 90 DAP	384207	131637	252570	2.92
T_7 : Metribuzin @ 1.00 kg a.i.ha⁻¹ + 2,4-D @ 1.00 kg a.i. ha⁻¹ POE at 25 DAP, hoeing at 60 and 90 DAP	385918	132743	253176	2.91
T_8 : Metribuzin @ 1.00 kg a.i. ha⁻¹ + 2,4-D @ 0.50 kg a.i. ha⁻¹ POE at 25 DAP, hoeing at 60and 90DAP	396608	131004	265605	3.03
T_9 : Metribuzin @ 0.50 kg a.i. ha⁻¹+ 2,4-D @ 1.00 kg a.i. ha⁻¹ POE at 25 DAP, hoeing at 60 and 90 DAP	409457	131004	278454	3.13
T_{10} : Atrazine @ 2.00 kg a.i. ha⁻¹+ 2,4-D @ 0.50 kg a.i. ha⁻¹ POE at 25 DAP, hoeing at 60 and 90 DAP	348135	130094	218041	2.68
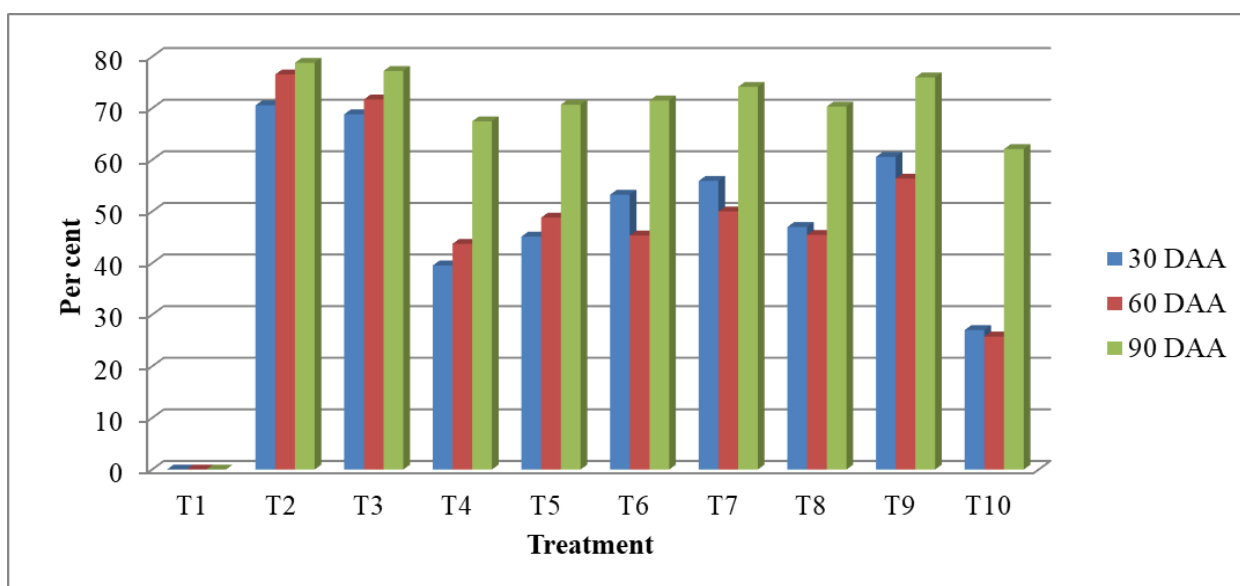
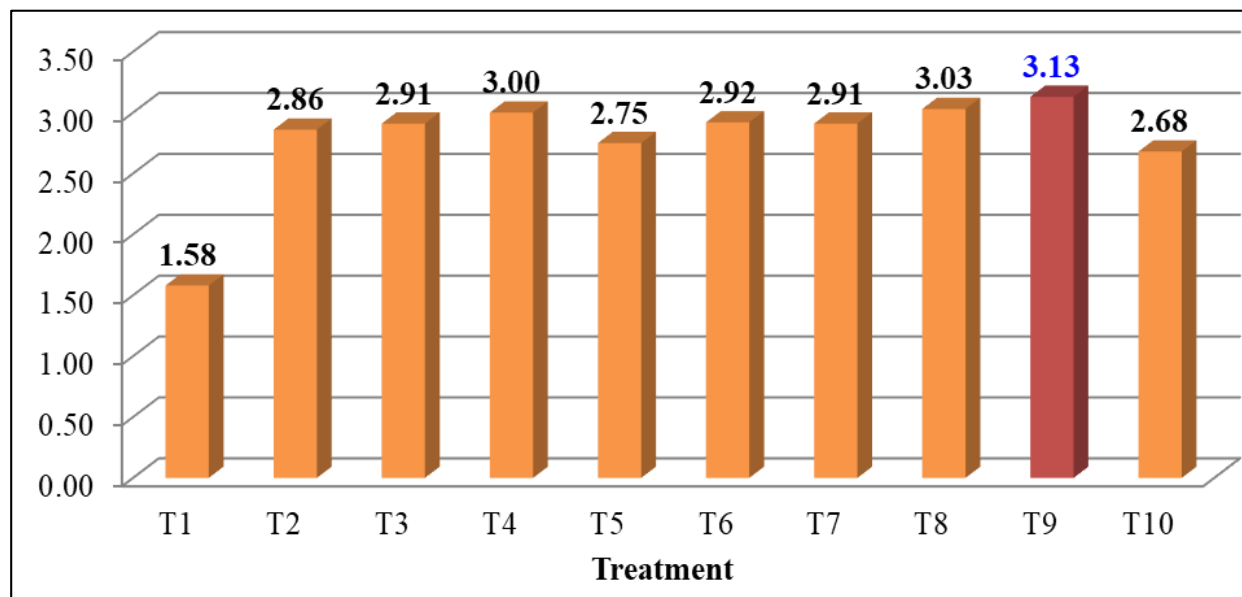**Fig 1:** Weed Control Efficiency (%) at 30, 60 and 90 days after application

Fig 2: Benefit Cost ratio

Conclusion
Thus, post emergence application of metribuzin @ 0.50 kg a.i ha^{-1} + 2, 4-D @ 1 kg a.i. ha^{-1} at 25 DAP, hoeing at 60 and 90 days after application was found to be effective for weed control and it produced higher yield attributes and cane yield with higher returns. This integrated weed management practice effectively reduced the weed menace during early slow growth period of sugarcane while the hoeing done at 60 and 90 DAP eradicated residual weed flora from the field. In this way, this approach of chemical weed control followed by mechanical weed control proved effectively.

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