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Influence of weed management by new generation herbicides on yield and economics of maize (*Zea mays* L.)

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Abstract
A field study was conducted during *kharif* 2017 at Main Research Station, University of Agricultural Sciences, Hebbal, Bengaluru to know the effect of different new generation herbicides on the yield and economics of maize. The experiment was carried out by using RCBD design with nine treatments and three replications. The results revealed that spraying of topramezone 33.6% SC + dimethanamid-P 23.4% SC 570 g a.i. ha^{-1} at 20 DAS recorded higher yield attributes and yield of maize like cob length (16.6 cm), cob girth (15.53 cm), number of rows cob^{-1} (14.77), number of kernels per row (29.57), kernel weight cob^{-1} (126.5 g), grain yield (6397 kg ha^{-1}), stover yield (7658 kg ha^{-1}) and lower weed index (2.42%) which was on par with passing cycle weeder followed by hand weeding at 20 and 35 DAS. The same herbicide treatment has recorded higher gross returns (Rs. 97214 ha^{-1}), net returns (Rs. 64634 ha^{-1}) and B:C ratio of 2.98.

Keywords: Atrazine, topramezone, tembotrione, Dimethanamid-P, halosulfuron methyl and 2,4-D

Introduction
Zea mays also known as corn is the third most important cereal crop in India after rice and wheat. It is currently grown in all countries except Antarctica and under a more varied range of climates than any other cereal crops. In addition to staple food for human being and quality feed for birds and animals, maize additionally serves as a basic raw material as an ingredient to thousands of industrial products.

In world maize is grown on an area of 185.9 m ha with a production of 1075.5 mt and an average productivity of 5790 kg ha^{-1}. In India, it occupies an area of 9.89 m ha with a production of 25.9 mt and an average productivity of 2690 kg ha^{-1} (Anon., 2017). In Karnataka, maize occupies an area of 1.3 million ha with an annual production of about 4.4 mt with an average productivity of 2970 kg ha^{-1} (Anon., 2017a).

Heavy fertilization, wider spacing and initial slow growth habit of maize makes them susceptible to weed competition causing a yield loss of 33 to 55 per cent depending upon the type and density of weed flora in the standing crop (Sharma *et al*., 2000) [8]. New generation herbicides used in this study are Topramezone, Tembotrione, Dimethanamid-P and Halosulfuron methyl. Acceptance of any weed control methods in any crop production by the farmers ultimately depends on the economics involved in the weed management. The present study was conducted to analyze the influence of weed management by new generation herbicides on yield and economics of maize.

Material and Methods
A field experiment was carried out during *Kharif* 2017 at the field unit of AICRP on weed management, Main Research Station, University of Agricultural Sciences, Hebbal, Bengaluru. The experiment was laid out in RCBD with 9 treatments replicated thrice. The treatments were Atrazine 50% WP @ 1250 g a.i. ha^{-1} at 3 DAS, Tembotrione 34.4% SC @ 120 g a.i. ha^{-1} + stefes mero adjuvant @ 2 ml lit^{-1} of water at 20 DAS, Topramezone 33.6% SC + dimethanamid-P 23.4% SC @ 570 g a.i. ha^{-1} at 20 DAS, Topramezone 33.6% SC @ 25.2 g a.i. ha^{-1} at 20 DAS, Dimethanamid-P 72% SC @ 600 g a.i. ha^{-1} at 20 DAS, 2,4-D sodium salt 80% WP @ 500 g a.i. ha^{-1} at 20 DAS, Halosulfuron methyl 5% WG + atrazine 48% @ 596 g a.i. ha^{-1} at 20 DAS, Passing cycle weeder followed by hand weeding at 20 and 35 DAS and Unweeded control.

The herbicides were applied using a spray volume of 750 L/ha for pre emergence and 500 L/ha for post emergence with knapsack sprayer having flood jet nozzle.

The soil of the experimental site was sandy loam with a pH of 6.28 and it is low in available N (252.7 kg ha^{-1}), medium in available phosphorus (23.5 kg ha^{-1}) and potassium (268.4 kg ha^{-1}). Maize hybrid '*BRMH-1*' was sown with a spacing of 60 x 30 cm and the recommended dose of fertilizer *i.e.*, 150-75-40 kg of N, P_2O_5 and K_2O was applied with two splits of nitrogen. Observations on yield and yield parameters were recorded at harvest. The experimental data were statistically analyzed using ANOVA technique. The weed index was calculated by using the formula given by Gill and Kumar (1969) [4].

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

Where,
WI = Weed index expressed in percentage
X = Yield of hand weeding plot
Y = Yield from treatment for which weed index is to be worked out

Total cost of cultivation, gross and net returns per hectare for each treatment were worked out based on the cost of inputs, labour charges and prices of outputs during the course of investigation. The Benefit: Cost (B:C) ratio was worked out using the following formula

$$B:C = \frac{\text{Gross return } (ha^{-1})}{\text{Cost of cultivation } (ha^{-1})}$$

Results and Discussion

Effect of New Generation Herbicides on Yield and Yield Attributes of Maize: Among different new generation herbicides, significantly higher cob length, cob girth, no of rows per cob, number of kernels per row, kernel weight per cob, kernel yield and stover yield were observed in topramezone 33.6% SC + dimethanamid-P 23.4% SC 570 g a.i. ha^{-1} at 20 DAS *i.e.*, T_3 (16.6 cm, 15.53 cm, 14.77, 29.57, 126.5 g, 6397 kg ha^{-1} and 7658 kg ha^{-1}, respectively) followed by tembotrione 34.4% SC 120 g a.i. ha^{-1} + stefes mero adjuvant 2 ml lit^{-1} of water at 20 DAS *i.e.*, T_2 (16.37 cm, 15.55 cm, 14.33, 28.70, 117.7 g, 6197 kg ha^{-1} and 7495 kg ha^{-1}, respectively), which was the next best treatment (Table 1 and Fig.1).

The higher kernel and stover yield of maize among herbicide treatments was recorded with topramezone 33.6% SC + dimethanamid-P 23.4% SC 570 g a.i. ha^{-1} at 20 DAS and tembotrione 34.4% SC 120 g a.i. ha^{-1} + stefes mero adjuvant 2 ml lit^{-1} of water at 20 DAS. This is due to control of the broad spectrum of weeds effectively during the critical period of crop weed competition, which otherwise were quite notorious for imposing competition for light, space and nutrients with crop. It has provided congenial environment for better expression of yield attributes like cob length, cob girth, no of rows per cob, number of kernels per row, kernel weight per cob. The cumulative effect of all these yield components resulted in increased grain yield and stover yield. These results corroborate with the findings of Parminder *et al.* (2018) [6] and Ankush Kumar *et al.* (2017) [1].

All the yield attributing characters were adversely affected in unweeded control treatment due to severe weed competition exerted by weeds for space, light, moisture and nutrients throughout the crop growth period which finally resulted in lowest kernel yield of maize. These findings are in accordance with Ankush Kumar *et al.* (2017) [1] and Nadeem *et al*. (2010) [5].

Table 1: Different yield attributes and yield of maize as influenced by weed management practices

Weed management practices	Cob length (cm)	Cob girth (cm)	No. of rows per cob	No. of kernels per row	Kernel weight per cob (g)	Kernel yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1: Atrazine 50% WP @ 1250 g a.i. ha^{-1} at 3 DAS	15.50	15.10	14.07	28.07	107.6	5775	7030
T_2: Tembotrione 34.4% SC @ 120g a.i. ha^{-1}+ stefes mero adjuvant @ 2 ml lit^{-1} of water at 20 DAS	16.37	15.55	14.33	28.70	117.7	6197	7495
T_3: Topramezone 33.6% SC + dimethanamid-P 23.4% SC @ 570 g a.i. ha^{-1} at 20 DAS	16.60	15.53	14.77	29.57	126.5	6397	7658
T_4: Topramezone 33.6% SC @ 25.2 g a.i. ha^{-1} at 20 DAS	15.17	14.67	13.83	26.40	98.25	5331	6472
T_5: Dimethanamid-P 72% SC @ 600 g a.i. ha^{-1} at 20 DAS	16.07	14.78	13.53	26.43	94.74	5129	6301
T_6: 2,4-D sodium salt 80% WP @ 500 g a.i. ha^{-1} at 20 DAS	15.40	14.84	13.40	25.70	91.09	5035	6257
T_7: Halosulfuron methyl 5% WG+ atrazine 48% @ 596 g a.i. ha^{-1} at 20 DAS	15.63	14.65	13.37	25.93	92.32	5086	6293
T_8: Passing cycle weeded followed by hand weeding at 20 and 35 DAS	16.40	15.41	15.00	29.40	130.8	6556	7742
T_9: Unweeded control	14.07	13.73	11.57	20.67	59.28	2929	3824
S.Em±	0.69	0.50	0.53	0.91	8.07	194	277.35
C. D. at 5%	2.05	1.49	1.59	2.60	24.19	581	831.53
CV (%)	7.56	5.77	6.68	9.91	13.70	6.24	7.32

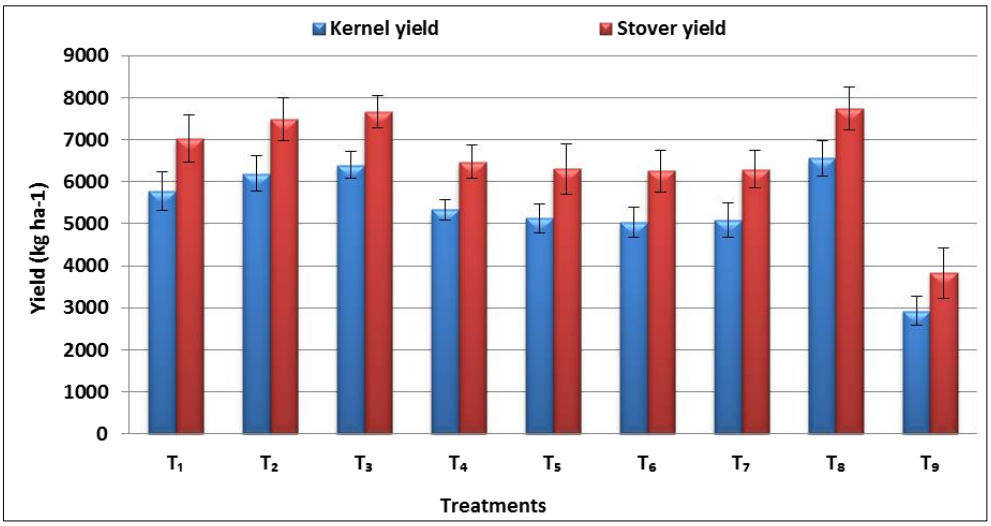

Fig 1: Kernel and stover yield (kg ha^{-1}) of maize as influenced by weed management practices (Vertical bars represent standard errors of the mean values).

Effect of New Generation Herbicides on weed index

Lower the weed index, lower will be the yield losses caused due to weeds. Lowest weed index (Fig.2) was noticed in treatment T_3 *i.e.*, topramezone 33.6% SC + dimethanamid-P 23.4% SC 570 g a.i. ha^{-1} at 20 DAS (2.42%) followed by T_2 (5.48%) and T_1 (11.90%). Highest weed index was noticed in T_9 *i.e.*, unweeded control (55.32%) indicating higher yield losses due to weeds.

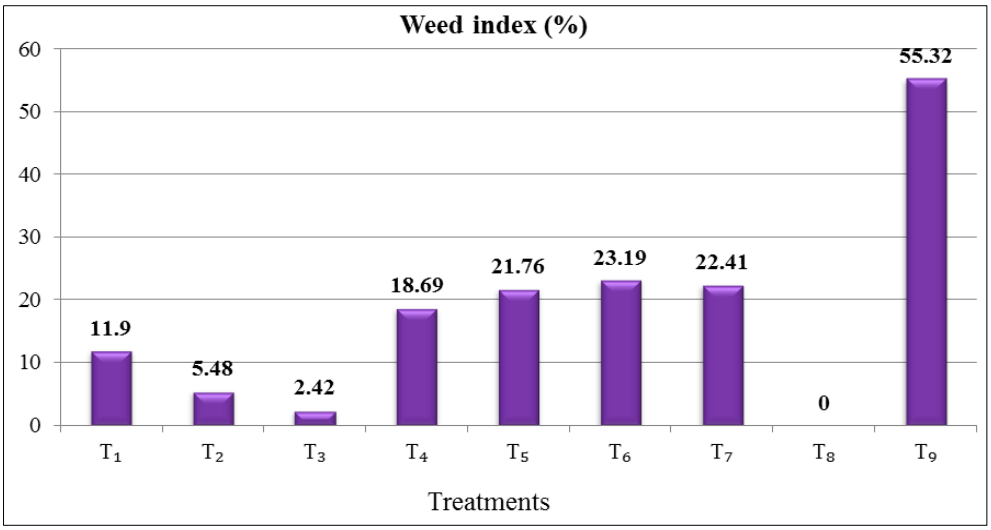

Fig 2: Weed index (WI%) of maize as influenced by weed management practices

Influence of New Generation Herbicides on Economics of Maize Production: Acceptance of any weed control methods in any crop production by the farmers ultimately depends on the economics involved in the weed management. Significantly higher gross returns was realized in treatment passing cycle weeder followed by hand weeding at 20 and 35 DAS (Rs. 99,519 ha^{-1}) as compared to all other treatments except topramezone 33.6% SC + dimethanamid-P 23.4% SC 570 g a.i. ha^{-1} at 20 DAS (Rs. 97,214 ha^{-1}) and tembotrione 34.4% SC 120 g a.i. ha^{-1} + stefes mero adjuvant 2 ml lit^{-1} of water at 20 DAS (Rs. 94,246 ha^{-1}) with which it was on par (Table 2 and Fig.3). Significantly lower gross returns were obtained in unweeded control (Rs. 44,828 ha^{-1}) as compared to all other treatments.

Significantly higher net returns were obtained in T_3 *i.e.*, topramezone 33.6% SC + dimethanamid-P 23.4% SC 570 g a.i. ha^{-1} at 20 DAS (Rs. 64,634 ha^{-1}) compared to other treatments except T_8 *i.e.*, passing cycle weeder followed by hand weeding at 20 and 35 DAS (Rs. 64,489 ha^{-1}), T_2 *i.e.*, tembotrione 34.4% SC 120 g a.i. ha^{-1} + stefes mero adjuvant 2 ml lit^{-1} of water at 20 DAS (Rs. 61,054 ha^{-1}) and T_1 *i.e.*, atrazine 50% WP 1250 g a.i. ha^{-1} at 3 DAS (Rs. 58,101 ha^{-1}) due to higher kernel and stover yields with lesser cost of weeding with herbicide application in these weed management practices The poorest performance of maize under unweeded control (T_9) with the lowest yield level resulted in the lowest net returns (Rs. 16,598 ha^{-1}). The results are in confirmatory with the findings of Rani *et al*., 2011.

Topramezone 33.6% SC + dimethanamid-P 23.4% SC 570 g a.i. ha^{-1} at 20 DAS (T_3) recorded significantly highest B:C ratio of 2.98 followed by T_1 *i.e.*, atrazine 50% WP 1250 g a.i. ha^{-1} at 3 DAS (2.95), T_2 *i.e.*, tembotrione 34.4% SC 120 g a.i. ha^{-1} + stefes mero adjuvant 2 ml lit^{-1} of water at 20 DAS (2.84) and T_8 *i.e.*, passing cycle weeder followed by hand weeding at 20 and 35 DAS (2.84). Significantly lowest B:C ratio was recorded in T_9 *i.e.*, unweeded control (1.59).

Even though highest gross returns was recorded in passing cycle weeder followed by hand weeding at 20 and 35 DAS, higher labour wages increased the cost of cultivation and lowered the B:C ratio. Whereas in herbicide treatments, T_3 and T_1 lower cost of cultivation due to lower labour requirement for herbicide application decreased the cost of cultivation which further increased the B:C ratio. Similar results were reported by Swetha *et al*. (2015) [9].

Table 2: Economics of weed management practices in maize

Weed management practices	Gross returns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
T_1: Atrazine 50% WP @ 1250 g a.i. ha^{-1} at 3 DAS	87882	29780	58101	2.95
T_2: Tembotrione 34.4% SC @ 120g a.i. ha^{-1}+ stefes mero adjuvant @ 2 ml lit^{-1} of water at 20 DAS	94246	33193	61054	2.84
T_3: Topramezone 33.6% SC + dimethanamid-P 23.4% SC @ 570 g a.i. ha^{-1} at 20 DAS	97214	32580	64634	2.98
T_4: Topramezone 33.6% SC @ 25.2 g a.i. ha^{-1} at 20 DAS	81100	31305	49795	2.59
T_5: Dimethanamid-P 72% SC @ 600 g a.i. ha^{-1} at 20 DAS	78108	29497	48611	2.65
T_6: 2,4-D sodium salt 80% WP @ 500 g a.i. ha^{-1} at 20 DAS	76746	29011	47735	2.65
T_7: Halosulfuron methyl 5% WG+ atrazine 48% @ 596 g a.i. ha^{-1} at 20 DAS	77504	30855	46649	2.51
T_8: Passing cycle weeder followed by hand weeding at 20 and 35 DAS	99519	35030	64489	2.84
T_9: Unweeded control	44828	28230	16598	1.59
S.Em±	2928	NA	2928	0.10
C. D. at 5%	8778		8778	0.29

DAS: days after sowing; NA: not analyzed

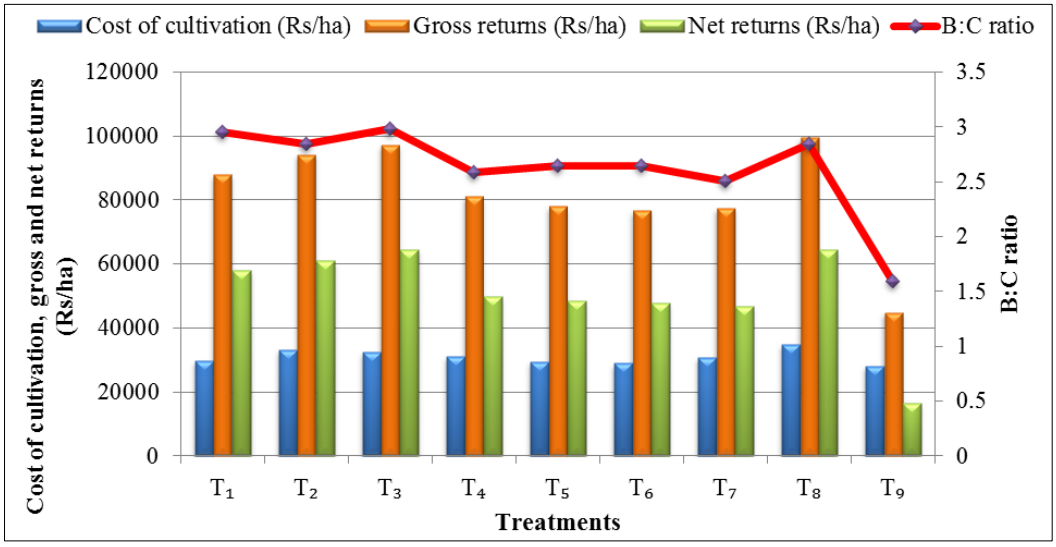

Fig 3: Economics of weed management practices in maize

Conclusion

In the current scenario of labour scarcity, application of new generation herbicides like topramezone 33.6% SC + dimethanamid-P 23.4% SC 570 g a.i. ha^{-1} as early post emergence offers better weed management with higher yield parameters, net returns and B:C ratio of maize.

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