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Empact OR effect of weed management with different herbicide and herbicide combination on yield and economics of maize

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Abstract

The investigation entitled "Studies on weed management with different herbicides and herbicide combinations in *kharif* maize (*Zea mays* L.)" during the year of 2022-23 at the College Farm, College of Agriculture, Badnapur, employed a comprehensive study framework. Employing a randomized block design (RBD) with 12 treatments replicated three times, the research aimed to assess the impact of various herbicides and their combinations on plant growth, weed density, and subsequent crop yield in Maize.

The findings revealed notable variations across treatments in plant growth parameters and weed density. Particularly, Treatment T_{12} (weed free), designated as the weed-free control, consistently showcased superior results across various growth stages of the maize crop. This treatment exhibited optimal initial and final plant populations, highest plant height, maximum leaf area, greatest dry matter accumulation, cob characteristics, grain yield, and straw yield compared to other treatments. These outcomes underscored the pivotal role of effective weed control in maximizing maize growth, cob development, and overall yield.

Treatment T_6 (Topramezone 33.6% (w/v) SC @ 25.2g a.i /ha and Atrazine 50%WP @ 250 g/ha PoE at 15 DAS), comprising a combination of Topramezone and Atrazine, emerged as the second most effective herbicide combination, displaying promising results in enhancing plant growth and yield attributes.

Conversely, the weedy check treatment T_{11} (weedy check) exhibited a stark reduction in maize growth and yield due to heavy weed infestation, underscoring the detrimental impact of uncontrolled weed growth on crop productivity.

The findings emphasized the criticality of judicious herbicide use for effective weed control, ultimately contributing to enhanced maize productivity. Furthermore, the study proposed the need for future research focusing on exploring novel herbicide molecules and diverse application methods, including post+pre and sequential methods, to broaden the spectrum of weed control in maize cropping systems. These initiatives aim to establish sustainable practices that augment crop yields while minimizing adverse impacts on the environment and ecosystem.

Keywords: Weed management, herbicides, herbicide combinations, maize (*Zea mays*)

Introduction

Maize (*Zea mays* L.) occupies an important place in world agriculture Maize crop is the most versatile crop and is grown in more than 166 countries across the globe, including tropical, subtropical and temperate regions, from sea level to 3000 m above mean sea level. It is cultivated in nearly 205 m ha with a production of 1210 m tonnes and productivity of 5878 kg/ha all over the world, having wider diversity of soil, climate, biodiversity and management practices (FAOSTAT 2021) [1]. The total area under Maize is the third most important cereal crop in India after rice and wheat. India produced 33.62 million tonnes in an area of 10.04 million hectares in 2021-22 with average maize productivity in India: 3.24 tons/hectare, 3 whereas in kharif 2022-23, maize production was 23.10 million tonnes (1st advance estimates) in an area of 9.68 million hectares. United States of America (USA) is the largest producer of maize contributing 32 per cent of the global production and is regarded as the driver of the US economy.

The yield losses reported in maize due to uncontrolled weed growth ranged from 30 to 100% (Stanzen, *et al*., 2016) [15]. Idziak *et at*., (2005) [16] reported that weeds reduce crop yield by competing for light and carbon dioxide, interfere with harvesting and increase the cost involved in crop production. Reported that season long weed competition caused considerable yield losses in maize.

Now it is the need of the hour to find effective weed control method. Weed management techniques like manual and herbicidal methods are found to be effective in controlling different groups of weeds in cropped fields. Due to high cost and non-availability of labour at proper time, manual weeding is difficult during the cultural activity of the crop (Singh *et al*., 2012) [14]. Also, some perennial weeds like Cyperus develop underground propagules like rhizome and tuber which makes it difficult to control manually

Control of weeds from the field is therefore very crucial for gaining respectable crop yield. Practices of weed control in corn leads to 77 to 96.7% more yield over weed check. There are several methods available for minimizing weed losses, such as cultural, biological, mechanical and chemical methods. Though hand weeding is having more efficacy in maize in reducing weeds and crop weed rivalry, it takes more time and more labour. Timely non-availability and high costs of human labour have led farmers to use herbicides. Performance in weed control methods depends on many factors but in chemical control the pattern of weed emergence, application timing and crop stage are significant. Similarly, the time of herbicide use is very critical for proper weed control and the herbicide efficacy can be increased by proper application at the right time. Usage of chemical herbicides like atrazine, pendimethalin as a pre-emergence spray was effective in controlling broad leaved weeds and certain annual weeds. Post-emergence application of atrazine, halosulfuron are also operational in regulating the weeds.

Topramezone and tembotrione are the selective, post-emergence herbicides that have been recently introduced for use in maize. These herbicides inhibit the activity of 4-Hydroxy-phenyl pyruvate dioxygenase (4-HPPD) and the bio-synthesis of plastoquinone, with subsequent carotenoid pigment formation, membrane structure and chlorophyll disruption. HPPD inhibiting herbicides are most effective in newly developing tissues that emerge bleached, as a consequence of failure to properly assemble photosynthetic units and thus they control weeds. (Schonhammer). Tank mix application of these herbicides with lower dose of atrazine was reported to be more effective providing broad spectrum weed control than alone application of individual chemicals. So there is a need to evaluate alternate post-emergence herbicide which can provide broad spectrum weed control in maize in Indian situation. Halosulfuron methyl is a selective post emergence herbicide for control of purple nutsedge and broad-leaved weeds in maize, sugarcane and rice.

Thus, looking into the difficulties of other agronomic practices, suitable on weed control strategies in maize with sequential use of pre-emergence and postemergence herbicides has been a long felt need. Keeping this in view, a field trial was carried out on "Studies on weed management with different herbicides and herbicide combinations in kharif maize (*Zea mays* L.)" was conducted at College Farm, College of Agriculture, Badnapur during kharif 2022-23 with the following.

Materials and Methods

The present field experiment was conducted during Kharif season of 2022-23 at Experimental Farm of Agronomy at College of Agriculture, Badnapur. Geographically Badnapur is situated at 19.86820 North latitude and 75.72560 East longitudes at 523 m altitude above mean sea level. The average annual precipitation is 630 mm. The field experimental site has the clayey soil in texture. The experiment was laid out in Randomized Block Design with 3 replications and 12 treatments 12 treatments were allocated in each replication.

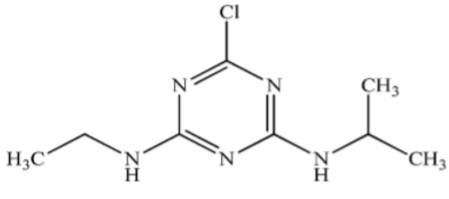
Treatment Details: T_1: Atrazine (50%WP) @1 kg a.i/ha (PE). T_2: 2, 4-D Dimethyl Amine salt 58%SL@ 1kg a.i/ha (PoE) at 20 DAS. T_3: Topramezone 33.6% (w/v) SC @ 67.2g a.i/ha PoE at 15DAS. T_4: Topramezone 33.6% (w/v) SC @ 25.2g a.i /ha PoE at 15DAS. T_5: Tebotrione 42%SC @ 105 g a.i /ha PoE at 15 DAS T_6: Topramezone 33.6% (w/v) SC @ 25.2g a.i /ha and Atrazine 50%WP @ 250 g/ha PoE at 15 DAS T_7: Tebotrione 42%SC @105 g a.i/ha and Atrazine 50%WP @ 250 g a.i/ha PoE a$T_1$5 DAS T_8: Halosulfuron methyl @67.5 g a.i/ha PoE at 20DAS T_9: Atrazine @ 1kg a.i/ha as pre emergence fb Halosufuron methyl @ 67.5 g a.i/ha as PoE T_{10}: One hand weeding @30DAS. T_{11}: weedy check T_{12}: weed free DKC 9133 is high yielding Kharif hybrid use which suitable for both rainfed and irrigated conditions Maize hybrid DKC-9133 was hand dibbled on 3rd July 2022 in ridge and furrow method at a spacing of 60 cm x 30 cm. Basel dose of fertilizer applied at time of sowing 175:50:50 kg of N, P2O5 and K2O ha^{-1} in the form of urea, Di-ammonium phosphate and Muriate of potash respectively. Different weed management practices were done as per the treatments in the experiment. Herbicide *viz*., Atrazine, Tebotrione, Topramezone, Halosulfuron methyl 2, 4-D Dimethyl Amine salt, and was applied as pre-emergence and post emergence was applied as per the treatment.

Details of herbicides used in the study

Atrazine

Chemical group: Triazines
Trade name: Atrataf
Formulation: Wettable Powder (WP)
Active ingredient: 50%
Chemical name: 2- [2-chloro-4-(methyl sulfonyl)-3- [(2,2,2 trifluoro ethoxy) methyl] benzyl]-1,3 cyclohexanedione
Molecular formula: C17H16ClF3O6S

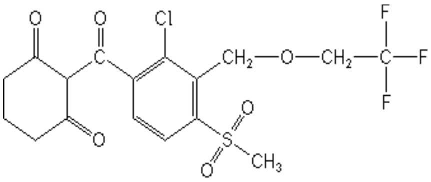
Chemical structure



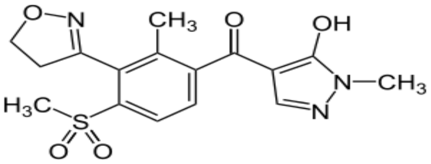
Tembotrione

Chemical group: Triketone
Trade name: Laudis
Formulation: Soluble Concentrate (SC)
Active ingredient: 42%
Chemical name: 2- [2-chloro-4-(methyl sulfonyl)-3- [(2,2,2 trifluoro ethoxy) methyl] benzyl]-1,3 cyclohexanedione
Molecular formula: C17H16ClF3O6S

Chemical structure

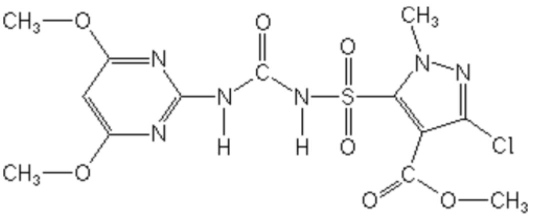


Topramezone
Chemical group: Aromatic ketone
Trade name: Tynzer
Formulation: Soluble Concentrate (SC)
Active ingredient: 33.6%
Chemical name: [3-(4,5-dihydro-isoxazol-3-yl)-4-methylsulfonyl-2-methyl phenyl] (5-hydroxy-1-methyl-1H-pyrazol-4- yl) methanone
Molecular formula: C16H17N3O5S
Chemical structure



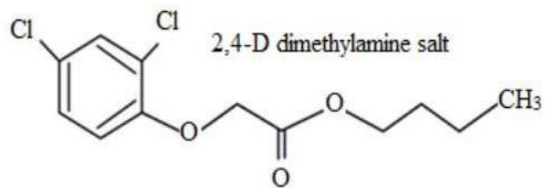
Halosulfuron Methyl
Chemical group: Sulfonyl Ureas Trade name: Sempra
Formulation: Wettable Granule (WG) Active ingredient: 75%
Chemical name: Methyl 3-chloro-5-[(4,6-dimethoxypyrimidin-2-carbamoyl sulfamoyl]-1-methylpyrazole-4- carboxylate Molecular formula: C13H15ClN6O7S

Chemical structure



Dimethyl Amine Salt
Chemical group: Plant growth regulators (PGRs)
Trade name: Weedmar super
Formulation: Soluble Liquid (SL)
Active ingredient: 58%
Chemical name: 3, 6-dichloro-2-methoxybenzoic acid, N-methyl methanamine
Molecular formula: C10H13Cl2NO3

Chemical structure



Effect on yield of maize

1. Grain yield (kg ha^{-1})

Grain yield (kg ha^{-1}) was influenced by various all treatment are presented in Table 1 and depicted in Fig 4.13. The data pertaining grain yield was found significantly maximum (5438.42 kg ha^{-1}) in treatment T_{12} (weed free), which was at par with the treatment T_6 (Topramezone 33.6% (w/v) SC @ 25.2 g a.i /ha and Atrazine 50%WP @ 250 g/ha PoE at 15 DAS) of (5346.31 kg ha^{-1}) and T_7 (Tebotrione 42% SC @105 g a.i/ha and Atrazine 50% WP @ 250 g a.i/ha PoE a$T_1$5 DAS) of (5146.31 kg ha^{-1}) and significant minimum grain yield (2530.18 kg ha^{-1}) was observed in treatment T_{11} (weedy check). The higher grain yield observed in T_{12}, T_6, and T_7 treatments can be attributed to the weed-free conditions or the use of herbicides, which effectively controlled weed competition. Weeds compete with crops for resources such as nutrients, water, and sunlight, which can significantly impact crop growth and yield. By eliminating or reducing weed competition, the plants in T_{12}, T_6, and T_7 treatments had fewer constraints on their growth, resulting in higher grain yields. Conversely, the weedy check treatment (T_{11}) had the lowest grain yield, indicating the negative effects of weed competition on crop productivity. Weeds can limit the availability of resources to the crop plants, leading to reduced growth and lower grain yields.
These findings emphasize the importance of effective weed management practices in maximizing grain yield and overall crop productivity. Maintaining a weed-free environment or using herbicides can help optimize crop growth, minimize yield losses, and ultimately contribute to higher grain yields. Similar result was also reported by Duary *et al*., (2015) [2], Patil *et al*., (2016) [4] and Mritunjay (2018) [3].

2. Straw yield (kg ha^{-1})

The data recorded on straw yield (kg ha^{-1}) by various treatments preservatives are shown in table 1 and depicted in Fig 4.14. Significantly maximum (7138.20 kg ha^{-1}) straw yield was found in treatment T_{12} (weed free), which was at par with the treatment T_6 (Topramezone 33.6%(w/v) SC @ 25.2 g a.i /ha and Atrazine 50%WP @ 250 g/ha PoE at 15 DAS) of (7096.60 kg 78 ha^{-1}) and T_7 (Tebotrione 42%SC @105 g a.i/ha and Atrazine 50%WP @ 250 g a.i/ha PoE a$T_1$5 DAS) of (6938.18 kg ha^{-1}) and significant minimum straw yield (5541.13 kg ha^{-1}) was noted in treatment T_{11} (weedy check).
The data shows that treatment T_{12} (weed free) resulted in significantly higher straw yield compared to other treatments. This is likely because the absence of weed competition in T_{12} allowed the crop plants to utilize resources like light, nutrients and water more effectively without sharing these growth factors with weeds. This enabled better vegetative growth and accumulation of higher straw biomass. Treatments T_6 and T_7 involving early post-emergence application of herbicides like Topramezone, Atrazine and Tebotrione also resulted in weed control and straw yields at par with weed-free condition. Timely weed removal in these plots helped reduce crop-weed competition during the critical growth period, allowing better crop establishment and growth. In contrast, the weedy check T_{11} showed the lowest straw yield because of uncontrolled weed growth throughout the crop duration that competed heavily with the crop for resources. This resulted in stunted crop growth and significantly lower straw biomass production in maize. Similar results were also observed by Mali, (2019) [6] and Nazreen *et al*., (2018) [5].

3. Biological yield (kg ha^{-1})

Data pertaining to biological yield (kg ha^{-1}) influenced by various treatments has been presented in Table 1 and depicted in Fig 4.15. Among the significantly maximum biological yield (12576.62 kg ha^{-1}) was observed in treatment T_{12} (weed free), which was at par with the treatment T_6 (Topramezone 33.6%(w/v) SC @ 25.2g a.i /ha and Atrazine 50%WP @ 250 g/ha PoE at 15 DAS) of (12442.91 kg ha^{-1}) and T_7 (Tebotrione 42%SC @105 g a.i/ha and Atrazine 50%WP @ 250 g a.i/ha PoE a$T_1$5 DAS) of (12084.49 kg ha^{-1}) and significant minimum biological yield (8071.31 kg ha^{-1}) was seen in treatment T_{11} (weedy check). The data indicates that weed free treatment T_{12} and herbicide treatments T_6 and T_7 resulted in significantly higher biological yield compared to weedy check T_{11}. Removal of weeds through manual weeding or use of effective herbicides likely reduced crop-weed competition for resources like light, water and nutrients during critical growth stages. This helped the crop to grow better and accumulate higher overall biomass culminating in greater biological yield. In contrast, unchecked weed growth throughout the crop duration in T_{11} created intense competition for resources, suppressing crop growth and biological yield. The finding of present study is in accordance with those of Mali, (2019) [6].

4. Harvest index (%)

Data pertaining to harvest index (%) influenced by various treatments has been presented in Table 1 and depicted in Fig 4.16. Among the significantly maximum harvest index (43.22%) was observed in treatment T_{12} (weed free), which was at par with the treatment T_6 (Topramezone 33.6%(w/v) SC @ 25.2g a.i /ha and Atrazine 50%WP @ 250 g/ha PoE at 15 DAS) of (43.03%) and T_7 (Tebotrione 42%SC @105 g a.i/ha and Atrazine 50%WP @ 250 g a.i/ha PoE a$T_1$5 DAS) of (42.66%) and significant minimum harvest index (31.29%) was seen in treatment T_{11} (weedy check). The data shows that weed free treatment T_{12} and herbicide treatments T_6 & T_7 had significantly higher harvest index compared to weedy check T_{11}. Removing weeds through manual weeding or herbicides likely optimized partitioning of photosynthates towards grain formation over vegetative parts, increasing harvest index. In contrast, weed competition probably encouraged more carbon allocation towards stems rather than grains, reducing harvest index in T_{11}. The results obtained in the present study is in accordance with the results of Swetha *et al*., (2015) [7] and Kumar and Chawla (2019) [8].

Table 1: Weed management with different herbicides and herbicides combinations on grain yield (kg ha^{-1}), straw yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index (%)

Tr. No.	Treatment Details	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
T_1	Atrazine (50%WP) @1kg a.i/ha (PE).	3155.20	6066.82	9222.02	34.21
T_2	2, 4-D Dimethyl Amine salt 58%SL@ 1kg a.i/ha (PoE) at 20 DAS.	3463.89	6243.33	9707.22	35.68
T_3	Topramezone 33.6%(w/v) SC @ 67.2g a.i/ha PoE at 15DAS.	3672.11	6358.72	10030.83	36.60
T_4	Topramezone 33.6%(w/v) SC @ 25.2g a.i /ha PoE at 15DAS.	3272.31	6173.30	9445.61	34.64
T_5	Tebotrione 42%SC @ 105 g a.i /ha PoE at 15 DAS	4311.10	6650.36	10961.46	39.33
T_6	Topramezone 33.6%(w/v) SC @ 25.2g a.i /ha and Atrazine 50%WP @ 250 g/ha PoE at 15 DAS	5346.31	7096.60	12442.91	43.03
T_7	Tebotrione 42%SC @105 g a.i/ha and Atrazine 50%WP @ 250 g a.i/ha PoE a$T_1$5 DAS	5146.31	6938.18	12084.49	42.66
T_8	Halosulfuron methyl @67.5 g a.i/ha PoE at 20 DAS	4255.18	6520.63	10775.81	39.51
T_9	Atrazine @ 1kg a.i/ha as pre emergence fb Halosufuron methyl @ 67.5 g a.i/ha as PoE	4733.40	6853.42	11586.82	40.85
T_{10}	One hand weeding @30DAS.	2956.63	5956.31	8912.94	32.97
T_{11}	Weedy check	2530.18	5541.13	8071.31	31.29
T_{12}	Weed free	5438.42	7138.20	12576.62	43.22
	S.Em±	124.07	204.37	300.61	0.64
	CD (0.05)	363.88	599.40	881.67	1.88
	CV (%)	5.34	5.48	4.97	2.94
	General mean	4023.42	6461.42	10484.84	37.83

Empact on Economics of maize

Table 2: Economics of Maize

Tr. No.	Treatment Details	Economics of Maize			
		Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	Benefit: cost ratio
T_1	Atrazine (50%WP) @1kg a.i/ha (PE).	32638.00	65943.68	33305.68	1.02
T_2	2, 4-D Dimethyl Amine salt 58%SL@ 1kg a.i/ha (PoE) at 20 DAS.	32884.00	72395.30	39511.30	1.20
T_3	Topramezone 33.6%(w/v) SC @ 67.2g a.i/ha PoE at 15 DAS.	33108.00	76747.10	43639.10	1.32
T_4	Topramezone 33.6%(w/v) SC @ 25.2g a.i /ha PoE at 15 DAS.	32975.00	68391.28	35416.28	1.07
T_5	Tebotrione 42%SC @ 105 g a.i /ha PoE at 15 DAS	32808.00	90101.99	57293.99	1.75
T_6	Topramezone 33.6%(w/v) SC @ 25.2g a.i /ha and Atrazine 50%WP @ 250 g/ha PoE at 15 DAS	34150.00	111737.88	77587.88	**2.27**
T_7	Tebotrione 42%SC @105 g a.i/ha and Atrazine 50%WP @ 250 g a.i/ha PoE a$T_1$5 DAS	33983.00	107557.88	73574.88	**2.17**
T_8	Halosulfuron methyl @67.5 g a.i/ha PoE at 20 DAS	33138.00	88933.26	55795.26	1.68
T_9	Atrazine @ 1kg a.i/ha as pre emergence fb Halosufuron methyl @ 67.5 g a.i/ha as PoE	34313.00	98928.06	64615.06	1.88
T_{10}	One hand weeding @ 30 DAS.	38183.00	61793.57	23610.57	0.62
T_{11}	Weedy check	31463.00	52880.76	21417.76	0.68
T_{12}	Weed free	44903.00	113662.98	68759.98	1.53

The data recorded on cost of cultivation (₹ ha^{-1}), gross returns (₹ ha^{-1}), net returns (₹ ha^{-1}) and benefit cost ratio (B:C ratio) by various all treatment is shown in table 2. Cost of cultivation was noted maximum (44903.00 ₹ ha^{-1}) in the treatment T_{12} (Weed free), which was followed by the treatment T_{10} (One hand weeding @ 30 DAS) (38183.00 ₹ ha^{-1}). while minimum cost of cultivation (31463 ₹ ha^{-1}) was noted in the treatment T_1 (Weedy check). Gross returns (₹ ha^{-1}) was noted maximum (113662.98 ₹ ha^{-1}) in the treatment T_{12} (Weed free), which was followed by the treatment T_6 (Topramezone 33.6%(w/v) SC @ 25.2g a.i /ha and Atrazine 50%WP @ 250 g/ha PoE at 15 DAS) (111737.88 ₹ ha^{-1}). while minimum gross returns (52880.76 ₹ ha^{-1}) was noted in the treatment T_{11} (Weedy check). Net returns (₹ ha^{-1}) was noted maximum (77587.88 ₹ ha^{-1}) in the treatment T_6 (Topramezone 33.6%(w/v) SC @ 25.2g a.i /ha and Atrazine 50%WP @ 250 g/ha PoE at 15 DAS), which was followed by the treatment T_7 (Tebotrione 42%SC @105 g a.i/ha and Atrazine 50%WP @ 250 g a.i/ha PoE a$T_1$5 DAS) (73574.88 ₹ ha^{-1}). while minimum net returns (21417.76 ₹ ha^{-1}) was noted in the treatment T_{11} (Weedy check). Benefit: cost ratio was noted maximum (2.27) in the treatment T_6 (Topramezone 33.6% (w/v) SC @ 25.2g a.i /ha and Atrazine 50%WP @ 250 g/ha PoE at 15 DAS), which was followed by the treatment T_7 (Tebotrione 42%SC @105 g a.i/ha and Atrazine 50%WP @ 250 g a.i/ha PoE a$T_1$5 DAS) (2.17). while minimum Benefit: cost ratio (0.62) was noted in the treatment T_{10} (One hand weeding @ 30 DAS). The result obtained in the present study is in accordance with the results of Prithviraj *et al* (2018) [12], Kumar *et al*., (2019) [8] and Radheshyam *et al*., (2019) [10].

Conclusion

In conclusion the research underscores the significance of weed management strategies in *Kharif* Maize cultivation, emphasizing Treatment T_{12} (weed free) as the most effective in optimizing growth parameters and yield. This study contributes valuable insights that can aid in the formulation of efficient weed control measures, subsequently enhancing agricultural productivity and ensuring sustainable crop production in maize cultivation systems.

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