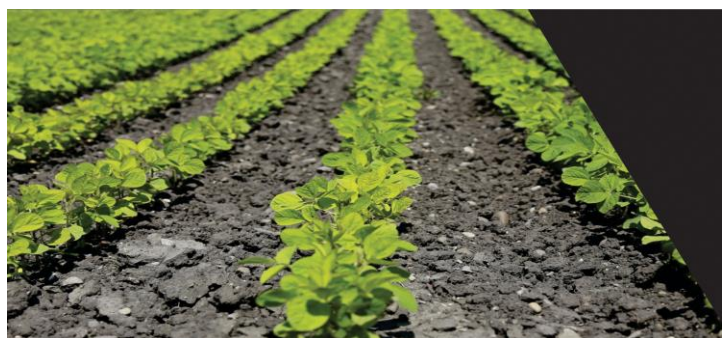




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Lokesh Ojha
M.Sc. Scholar, Department of
Agronomy, Rajasthan College of
Agriculture, MPUAT, Udaipur,
Rajasthan, India

Dr. Hargilas
Professor, Agricultural Research
Station, Banswara, Maharana
Pratap University of Agriculture
and Technology, Udaipur,
Rajasthan, India

Dr. J Choudhary
Professor, Department of
Agronomy, Rajasthan College of
Agriculture, MPUAT, Udaipur,
Rajasthan, India

Dr. RK Sharma
Professor, Department of Soil
Science and Agricultural
Chemistry, RCA, MPUAT,
Udaipur, Rajasthan, India

Dr. Hari Singh
Professor, Department of
Agricultural Economics, RCA,
MPUAT, Udaipur, Rajasthan,
India

Manish Kumar
Ph.D. Scholar, Department of
Agronomy, Rajasthan College of
Agriculture, MPUAT, Udaipur,
Rajasthan, India

Abhijeet Purohit
Ph.D. Scholar, Department of
Agronomy, Rajasthan College of
Agriculture, MPUAT, Udaipur,
Rajasthan, India

Corresponding Author:
Lokesh Ojha
M.Sc. Scholar, Department of
Agronomy, Rajasthan College of
Agriculture, MPUAT, Udaipur,
Rajasthan, India

Effect of pre and post-emergence herbicide combinations on weed dynamics and yield of *rabi* maize (*Zea mays* L.)

Lokesh Ojha, Hargilas, J Choudhary, RK Sharma, Hari Singh, Manish Kumar and Abhijeet Purohit

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Abstract

A field experiment was conducted at the Agricultural Research Station, Banswara, during the *rabi* season of 2025-26 to evaluate the effect of sequential application of different herbicides on weed management and productivity of maize. The experiment was laid out in a randomized block design (RBD) with 12 treatments and three replications. The experimental field was infested with a mixed population of grassy weeds, sedges, and broad-leaved weeds, with grassy weeds being the dominant species. All weed management treatments significantly reduced weed density compared with the weedy check.

Among the treatments, pre-emergence application of pyroxasulfone @ 127 g ha⁻¹ followed by (*fb*) post-emergence application of tembotrione @ 120 g ha⁻¹ at 25 days after sowing (DAS) (T₁₀) recorded the lowest density of grassy weeds (2.51 m⁻²), broad-leaved weeds (4.26 m⁻²), and total weeds (5.89 m⁻²), and was statistically at par with T₁₁. The lowest sedge density (1.95 m⁻²) was recorded under T₉, followed by T₁₂ (2.20 m⁻²) and T₅ (2.24 m⁻²). Treatment T₁₀ reduced total weed density by 65.64% compared with the weedy check (17.14 m⁻²). Grain and stover yields were significantly influenced by the weed management practices. The highest grain yield was obtained under the weed-free treatment (T₂) (6,641 kg ha⁻¹), which was statistically at par with T₁₀ (6,610 kg ha⁻¹) and T₁₁ (6,408 kg ha⁻¹), while the lowest grain yield was recorded under the weedy check (T₁) (3,543 kg ha⁻¹). Similarly, the maximum stover yield was recorded under T₂ (9,569 kg ha⁻¹), followed by T₁₀ (9,338 kg ha⁻¹) and T₁₁ (9,175 kg ha⁻¹). The weed-free treatment increased grain yield by 87.46% over the weedy check. Overall, the sequential application of pyroxasulfone @ 127 g ha⁻¹ as a pre-emergence herbicide followed by tembotrione @ 120 g ha⁻¹ at 25 DAS proved highly effective in suppressing weed populations and enhancing maize productivity. This treatment can be recommended as an efficient weed management strategy for maize cultivation under conditions similar to those of the present study.

Keywords: Maize, weed management, sequential herbicide application, pyroxasulfone, tembotrione, grain yield

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops worldwide and is popularly known as the “Queen of Cereals” because of its high yield potential, wide adaptability, and diverse uses as food, feed, fodder, and industrial raw material. It ranks third among cereal crops after rice and wheat in terms of global production and economic importance (Parihar *et al.*, 2011) [10]. As a C4 plant, maize possesses high photosynthetic efficiency and superior water-use efficiency, enabling it to perform well under a wide range of agro-climatic conditions, particularly in tropical and subtropical regions. The crop was domesticated approximately 9,000 years ago in Southern Mexico and Mesoamerica (Awika, 2011) [1] and has since become a staple food and an important source of income for millions of farmers across the world. In India, maize is cultivated over an area of 12.02 million hectares with an annual production of 42.28 million tonnes. Rajasthan is one of the major maize-growing states, accounting for about 1.01 million hectares with a production of 2.67 million tonnes (UPAg, 2024-25). In recent years, *rabi* maize cultivation under irrigated conditions has expanded considerably owing to its higher productivity, better grain quality, and increasing demand from the feed, food processing, and starch industries.

Despite its high genetic yield potential, maize productivity is often limited by severe weed

infestation, particularly during the early stages of crop growth. Weeds are considered one of the most important biotic constraints as they compete aggressively with the crop for nutrients, soil moisture, light, space, and other essential growth resources. The critical period of crop-weed competition in maize generally occurs during the first 30–45 days after sowing, during which uncontrolled weed growth can substantially reduce crop growth and yield. Yield losses due to weed competition have been reported to range from 28 to 100%, depending on weed flora, infestation level, environmental conditions, and management practices (Patel *et al.*, 2006)^[12]. In many situations, losses caused by weeds exceed those resulting from insect pests and diseases combined (Kumar *et al.*, 2019)^[9]. In addition to direct competition, certain weed species release allelopathic compounds that suppress seed germination, retard crop growth, and adversely affect grain yield and quality.

Timely and effective weed management is therefore essential for realizing the full yield potential of maize. Although manual and mechanical weeding are effective, their adoption is often constrained by labour scarcity, increased wages, and the narrow window available for timely operations. Consequently, chemical weed management has emerged as an efficient, economical, and practical alternative for large-scale maize cultivation. The use of pre-emergence (PE) herbicides provides effective control of weeds during the initial stages of crop establishment, whereas post-emergence (PoE) herbicides help manage weeds that emerge later in the growing season. Sequential application of pre- and post-emergence herbicides offers broader-spectrum weed control and improves management of grassy weeds, sedges, and broad-leaved weeds compared with the application of a single herbicide (Triveni *et al.*, 2017)^[19]. Previous studies have demonstrated that effective weed control through appropriate herbicide use can enhance maize grain yield by 77–96.7% over untreated weedy conditions (Khan *et al.*, 1998)^[8]. Therefore, identifying suitable herbicide combinations and their optimum application timing is essential for sustainable weed management, improved crop productivity, and enhanced profitability in maize cultivation.

Materials and Methods

The field experiment was conducted at Field No. 10, Agricultural Research Station, Banswara, Rajasthan, during the *rabi* season of 2025–26 to evaluate the efficacy of sequential herbicide applications for weed management in maize. The experiment was laid out in a Randomized Block Design (RBD) comprising 12 treatments with three replications.

The treatments consisted of: T₁ - weedy check; T₂ - weed-free; T₃ - atrazine @ 500 g ha⁻¹ + hand weeding at 25 DAS; T₄ - pyroxasulfone @ 127 g ha⁻¹ + hand weeding at 25 DAS; T₅ - atrazine @ 500 g ha⁻¹ followed by (fb) halosulfuron-methyl @ 67 g ha⁻¹ at 25 DAS; T₆ - atrazine @ 500 g ha⁻¹ fb tembotrione @ 120 g ha⁻¹ at 25 DAS; T₇ - atrazine @ 500 g ha⁻¹ fb topramezone @ 25 g ha⁻¹ at 25 DAS; T₈ - atrazine @ 500 g ha⁻¹ fb mesotrione + atrazine @ 300 g ha⁻¹ at 25 DAS; T₉ - pyroxasulfone @ 127 g ha⁻¹ fb halosulfuron-methyl @ 67 g ha⁻¹ at 25 DAS; T₁₀ - pyroxasulfone @ 127 g ha⁻¹ fb tembotrione @ 120 g ha⁻¹ at 25 DAS; T₁₁ - pyroxasulfone @ 127 g ha⁻¹ fb topramezone @ 25 g ha⁻¹ at 25 DAS; and T₁₂ - pyroxasulfone @ 127 g ha⁻¹ fb mesotrione + atrazine @ 300 g ha⁻¹ at 25 DAS.

The maize hybrid Bio-9782 was sown during the second week of November 2025 at a spacing of 60 cm × 20 cm. Recommended agronomic practices were followed uniformly for all treatments throughout the crop growth period. Pre-emergence herbicides (atrazine and pyroxasulfone) were applied two days after sowing, while post-emergence herbicides were sprayed 25 days after

sowing (DAS) using a knapsack sprayer fitted with a flat-fan nozzle.

Weed observations were recorded at 50 DAS using a 0.5 m × 0.5 m quadrat placed randomly at two locations within each plot. Weed density was recorded separately for grassy weeds, sedges, and broad-leaved weeds and expressed as number m⁻². For determination of weed dry matter, weeds within the quadrat were uprooted, washed to remove adhering soil particles, shade-dried for 24 h, and subsequently oven-dried at 65 °C until a constant weight was attained. The dry weight was expressed as g m⁻².

To normalize the distribution of weed count data, observations were subjected to square-root transformation using the formula $\sqrt{(X + 0.5)}$ before statistical analysis. Weed control efficiency (WCE) was calculated based on total weed dry matter using the standard. The crop was harvested manually during the middle of March 2026. Grain and stover yields were recorded on a plot basis and converted to kg ha⁻¹. The experimental data were subjected to analysis of variance (ANOVA) appropriate for the Randomized Block Design, and treatment means were compared using the least significant difference (LSD) test at the 5% probability level.

Results and Discussion

Weed density

The experimental field was infested with mixed population of grassy weeds, sedges and broad-leaved weeds, with dominance of grassy weeds. The total weed density was computed by summing the population of grassy weeds, sedges and broad-leaved weeds. Data presented in Table 1 revealed that different weed management practices significantly reduced the density of grassy weeds as compared to weedy check. The maximum grassy weed density was recorded under weedy check (T₁) with 13.86 m⁻², whereas the minimum was observed under pyroxasulfone @ 127 g ha⁻¹ fb tembotrione @ 120 g ha⁻¹ (T₁₀) with 2.51 m⁻², which was statistically at par with pyroxasulfone @ 127 g ha⁻¹ fb topramezone @ 25 g ha⁻¹ (T₁₁) (2.64 m⁻²) and pyroxasulfone @ 127 g ha⁻¹ fb halosulfuron methyl @ 67 g ha⁻¹ (T₉) (2.67 m⁻²). The reduction in grassy weed density under T₁₀ was about 81.89 per cent over weedy check. This might be due to effective pre and post-emergence herbicidal action which suppressed early as well as later flushes of weeds, as also reported by Sepat and Singh (2024)^[14]. In case of sedges, the highest density was recorded under weedy check (6.52 m⁻²), whereas the lowest density was observed under T₉ (1.95 m⁻²), which was statistically at par with T₁₂ (2.20 m⁻²) and T₅ (2.24 m⁻²). However, treatments involving hand weeding viz., T₃ (6.02 m⁻²) and T₄ (5.47 m⁻²) recorded comparatively higher sedge density. This might be attributed to the regeneration ability of sedges through underground propagules, which proliferate when soil is disturbed, as also reported by Thakur (2022)^[17]. The density of broad-leaved weeds was also significantly influenced by different treatments. The maximum population was recorded under weedy check (7.74 m⁻²), whereas the minimum was observed under T₁₀ (4.26 m⁻²), which was statistically at par with T₆ (4.32 m⁻²) and T₁₁ (4.62 m⁻²). These results are in agreement with the findings of Sundari *et al.* (2019)^[15], who also reported effective control of dicot weeds with sequential herbicide application. Total weed density was significantly reduced under all weed control treatments compared to weedy check (17.14 m⁻²). Among the treatments, pyroxasulfone @ 127 g ha⁻¹ fb tembotrione @ 120 g ha⁻¹ (T₁₀) recorded the lowest total weed density (5.89 m⁻²), which was statistically at par with T₁₁ (6.24 m⁻²) and T₉ (6.18 m⁻²), and proved superior over rest of the treatments. The reduction in total weed density under T₁₀ was about 65.64 per cent over weedy check. This might be due to the fact that pre-emergence

application of pyroxasulfone restricted weed germination by inhibiting very long chain fatty acid synthesis, while post-emergence application of tembotrione inhibited HPPD enzyme, leading to bleaching and death of weeds (Hardwick, 2013)^[7].

Yield

The data presented in Table 2 revealed that grain and stover yield of the crop were significantly influenced by different weed management practices. Among the treatments, the highest grain yield was recorded under T₂ (6641 kg ha⁻¹), which was statistically at par with T₁₀ (6610 kg ha⁻¹) and T₁₁ (6408 kg ha⁻¹). The lowest grain yield was observed under weedy check (T₁) (3543 kg ha⁻¹). The increase in grain yield under T₂ was about 87.46 per cent over weedy check. This increase in yield might be

attributed to effective weed control which reduced crop-weed competition for nutrients, moisture and light, thereby enhancing crop growth and productivity. Similarly, stover yield was also significantly affected by different treatments. The maximum stover yield was recorded under T₂ (9569 kg ha⁻¹), which was closely followed by T₁₀ (9338 kg ha⁻¹) and T₁₁ (9175 kg ha⁻¹), whereas the minimum was recorded under weedy check (T₁) (4543 kg ha⁻¹). The higher stover yield under these treatments might be due to better vegetative growth as a result of reduced weed competition throughout the crop growth period. Overall, treatments involving effective weed management practices resulted in higher grain and stover yield as compared to other treatments. This might be due to season-long weed control which ensured better availability of resources to the crop.

Table 1: Effect of weedicides on weed density at 60 DAS

Treatments	Weed density (m ⁻²)			
	Grasses	Sedges	Broad-leaved	Total weeds
T ₁ : Weedy check	13.86 (91.68)	7.74 (59.45)	6.52 (42.02)	17.14 (293.15)
T ₂ : Weed free	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T ₃ : Atrazine 500 g ha ⁻¹ fb hand weeding at 25 DAS	3.69 (13.15)	6.43 (40.88)	6.02 (35.70)	9.50 (89.72)
T ₄ : Pyroxasulfone @ 127 g ha ⁻¹ fb hand weeding at 25 DAS	3.46 (11.50)	6.74 (44.96)	5.47 (29.45)	9.30 (85.91)
T ₅ : Atrazine 500 g ha ⁻¹ fb halosulfuron methyl @ 67 g ha ⁻¹ at 25 DAS	3.99 (15.42)	4.77 (22.27)	3.29 (10.36)	6.97 (48.05)
T ₆ : Atrazine 500 g ha ⁻¹ fb tembotrione @ 120 g ha ⁻¹ at 25 DAS	3.75 (13.56)	4.32 (18.13)	3.32 (10.54)	6.54 (42.23)
T ₇ : Atrazine 500 g ha ⁻¹ fb topamezone @ 25 g ha ⁻¹ at 25 DAS	3.13 (9.31)	4.60 (20.68)	3.56 (12.21)	6.53 (42.20)
T ₈ : Atrazine 500 g ha ⁻¹ fb mesotrione + atrazine @ 300 g ha ⁻¹ at 25 DAS	4.10 (16.28)	5.37 (28.31)	4.14 (16.65)	7.86 (61.24)
T ₉ : Pyroxasulfone @ 127 g ha ⁻¹ fb halosulfuron methyl @ 67 g ha ⁻¹ at 25 DAS	2.67 (6.65)	4.79 (22.45)	3.00 (8.53)	6.18 (37.63)
T ₁₀ : Pyroxasulfone @ 127 g ha ⁻¹ fb tembotrione @ 120 g ha ⁻¹ at 25 DAS	2.51 (5.82)	4.26 (17.68)	3.34 (10.64)	5.89 (34.14)
T ₁₁ : Pyroxasulfone @ 127 g ha ⁻¹ fb topamezone @ 25 g ha ⁻¹ at 25 DAS	2.64 (6.45)	4.62 (20.85)	3.42 (11.19)	6.24 (38.49)
T ₁₂ : Pyroxasulfone @ 127 g ha ⁻¹ fb mesotrione + atrazine @ 300 g ha ⁻¹ at 25 DAS	3.05 (8.80)	5.34 (27.99)	3.86 (14.39)	7.19 (51.18)
S.E.m.±	0.04	0.05	0.05	0.05
C.D. (P=0.05)	0.12	0.15	0.14	0.15

Table 2: Effect of weedicides on grain and stover yield of maize

Treatments	Yield (kg ha ⁻¹)	
	Grain	Stover
T ₁ : Weedy check	3543	4543
T ₂ : Weed free	6641	9569
T ₃ : Atrazine 500 g ha ⁻¹ fb hand weeding at 25 DAS	5264	8298
T ₄ : Pyroxasulfone @ 127 g ha ⁻¹ fb hand weeding at 25 DAS	5343	8009
T ₅ : Atrazine 500 g ha ⁻¹ fb halosulfuron methyl @ 67 g ha ⁻¹ at 25 DAS	5240	8207
T ₆ : Atrazine 500 g ha ⁻¹ fb tembotrione @ 120 g ha ⁻¹ at 25 DAS	5432	8632
T ₇ : Atrazine 500 g ha ⁻¹ fb topamezone @ 25 g ha ⁻¹ at 25 DAS	5230	8130
T ₈ : Atrazine 500 g ha ⁻¹ fb mesotrione + atrazine @ 300 g ha ⁻¹ at 25 DAS	6005	8125
T ₉ : Pyroxasulfone @ 127 g ha ⁻¹ fb halosulfuron methyl @ 67 g ha ⁻¹ at 25 DAS	5843	7993
T ₁₀ : Pyroxasulfone @ 127 g ha ⁻¹ fb tembotrione @ 120 g ha ⁻¹ at 25 DAS	6610	9338
T ₁₁ : Pyroxasulfone @ 127 g ha ⁻¹ fb topamezone @ 25 g ha ⁻¹ at 25 DAS	6408	9175
T ₁₂ : Pyroxasulfone @ 127 g ha ⁻¹ fb mesotrione + atrazine @ 300 g ha ⁻¹ at 25 DAS	6205	8795
S.E.m.±	115	323
C.D. (P=0.05)	336	949

Conclusion

The findings of the present study demonstrated that sequential herbicide application was more effective than single herbicide application in managing the diverse weed flora of maize. Among the treatments evaluated, the application of pyroxasulfone @ 127 g ha⁻¹ as a pre-emergence herbicide followed by (fb) tembotrione @ 120 g ha⁻¹ at 25 DAS as a post-emergence herbicide proved to be the most effective, resulting in superior weed control efficiency and significantly higher grain and stover yields. The performance of this treatment was comparable to the weed-free treatment, indicating its effectiveness in suppressing grassy, broad-leaved, and sedge weeds throughout the critical crop growth period. Therefore, this sequential herbicide application can be recommended as an efficient and economical weed management

strategy for *rabi* maize cultivation, particularly under conditions of labour scarcity and rising labour costs. Its adoption has the potential to improve maize productivity while ensuring timely and effective weed control.

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