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Research Paper

Impact of weed management strategies on weeds and nutrient uptake of maize

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ABSTRACT

The research took place during the *kharif* season of 2018 and 2019 at TNAU, Coimbatore to examine the influence of weed control tactics on nutrients absorption and depletion of by maize weeds. The experiment was laid out in a randomized block design consisting often weed management treatments *viz*., eight herbicide treatments along with weed free (hand weeding at 20 and 45 DAS) and weedy check. The findings indicated that the application of atrazine 0.5 kg a.i./ha as pre-emergence (PE) followed by (*fb*) topramezone 25.2 g a.i./ha as early post emergence (EPoE) had significantly lower nutrient removal by weeds (5.1, 2.2 and 3.2 N, P and K kg/ha), higher crop nutrient uptake (191.4, 56.5 and 138.9 N, P and K kg/ha) as well as grain and stover yield of maize i.e., 8.2 t/ha and 14.5 t/ha respectively and it was statistically at par with PE atrazine *fb* EPoE tembotrione 122 g a.i./ha. Therefore, the present study advocated the use of atrazine as PE *fb* topramezone or tembotrione as EPoE for reduced weed density, higher yield and nutrient uptake in maize.

***Keywords**:* Early post emergence herbicides, Nutrients removal, Pre-emergence herbicide, Yield

Maize plays pivotal role in Indian agriculture, serving as a necessary source of food, animal feed, fodder and contributing to various industries. Globally, maize cultivation covers about 203.47 million hectare (Mha), producing 1163.5 million tonnes (mt) with an average yield of 5.73 t/ha. In India, maize is grown on approximately 9.95 mha, yielding 33.7 mt with a productivity of 3.38 t/ha (FAOSTAT, 2022). However, the presence of weed significantly hampers maize yields. Weeds can reduce grain yields to 80–100% by competing with crops for vital resources like water, sunlight, nutrients and space (Malviya and Singh, 2007). This competition is especially harmful during early crop growth, leading to slower development and lower grain production. Weeds that coexist with crops can significantly drain plant nutrients, leading to reduced crop yields. The degree of nutrient loss varies based on soil type and weed types. Maize primarily absorbs a substantial amount of total nitrogen (65–80%) before silking, with fewer nutrients directed to the roots as kernels become the primary nutrient sink. This resulted in a 14% yield drop in weedy conditions in contrast to weed-free ones. Various weed management strategies are employed to control weeds in maize viz. cultural, manual, mechanical and chemical methods. Given the high costs of manual weeding, it's crucial to explore alternative approaches. Atrazine, widely used in maize cultivation, can be applied both pre and post-emergence. Effective weed control can be achieved by applying atrazine 1.0 kg a.i./ha as PE followed by manual weeding 30 DAS (Shukla *et al*., 2024) which is commonly followed. Tembotrione and Topramezone are two novel introduced herbicides aimed to improving weed control specifically in maize. According to Singh *et al*. (2012), these herbicides demonstrate high effectiveness in rapidly reducing both grass and broad-leaf weeds in maize within a short period of 2–5 DAS. To effectively manage weeds, it is essential to utilize either a combination or sequential application of pre or post-emergence herbicides. Effective control of weeds can boost nutrient utilization and minimize unnecessary nutrient loss due to weeds (Samant *et al*., 2015). Hence, our study investigates nutrient removal by weeds and uptake by maize under rainfed conditions.

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MATERIALS AND METHODS

The trial was conducted during *kharif* seasons of 2018 and 2019 at the Eastern Block Farm of Tamil Nadu Agricultural University at Coimbatore, situated at coordinates 11°1' N and 76°58' E, the site has an elevation of 426.7

meters above sea level. The soil in this location had a *p*H level of 8.2. In both 2018 and 2019, during the maize cropping period, the average maximum temperatures were 29.18°C and 31.29°C, while the average minimum temperatures were 21.49°C and 23.21°C with a total rainfall of 327.7 mm and 364.7 mm, respectively. Before sowing, soil analysis revealed available nitrogen (N) content of 216 and 220 kg/ha, available phosphorus (P) content of 11.5 and 11.9 kg/ha, and available potassium (K) content of 310 and 320 kg/ha for the years 2018–2019 and 2019–2020 respectively. The chemical analysis adhered to the guidelines outlined by Subbiah and Asija (1956) (for N), Olsen's method for P (Olsen, 1954) and neutral normal ammonium acetate method for K (Stanford and English, 1949).

The experiment consists of ten weed control treatments which were application of T_1, PE (pre emergence) atrazine at 0.5 kg a.i./ha *fb* HW (hand weeding) at 20 DAS, T_2, PE atrazine at 0.5 kg a.i./ha *fb* PW (power weeder) at 20 DAS, T_3, PE atrazine at 0.5 kg a.i./ha + pendimethalin at 1 kg a.i./ha (Tank mix), T_4, PE atrazine at 0.5 kg a.i./ha + pendimethalin at 1 kg a.i./ha (Tank mix) *fb* HW at 20 DAS, T_5, EPoE (Early post emergence) topramezone at 25.2 g a.i./ha at 20 DAS, T_6, PE atrazine at 0.5 kg a.i./ha *fb* EPoE topramezone at 25.2 g a.i./ha at 20 DAS,T_7, EPoE tembotrione at 122 g a.i./ha at 20 DAS, T_8, PE atrazine at 0.5 kg a.i./ha *fb* EPoE tembotrione at 122 g a.i./ha at 20 DAS, T_9, hand weeding twice at 20 and 45 DAS (weed free) and T_{10}, weedy check. The herbicides as per the treatment schedule were applied as pre - emergence at 1 DAS and early post emergence at 20 DAS. For mechanically weeded plots, one weeding on 20 DAS was given using power weeder in between rows. Hand operated knapsack sprayer fitted with a flat fan type nozzle (WFN 40) was used for spraying the herbicides adopting a spray volume of 500 litres/ha. The trial was conducted in a randomized block design with three replications. Maize hybrid 'COH (M) 6' seeds were sown at a rate of 20 kg/ha, with a spacing of 60 cm × 25 cm between rows and plants. Fertilizer application consisted of 250:75:75 kg N-P-K/ha with half of the N and the entire P and K were applied at the time of sowing. The other half of the N was divided into two equal doses, specifically at the knee-high and tasseling growth stages. To maintain a healthy crop stand, standard plant protection measures were taken as and when needed.

Samples were gathered from each plot during the harvest period (90 DAS) to assess the absorption and extraction of various nutrients, namely N (nitrogen), P (phosphorus) and K (potassium), by both the maize crop and the weeds. Weeds were removed from each treatment plot using four quadrats measuring 0.25 m² each. The collected samples were dried in ambient air and subsequently oven-dried at a temperature of 65 ± 5°C. After drying, the samples were ground into powder, and their nutrient contents were analyzed using standard methods: N content was determined by micro-kjeldahl method (Humphries, 1956), P content by the triple acid digestion colorimetric method (Jackson, 1973), and K content by the triple acid digestion flame photometer method (Jackson, 1973). The total absorption of N, P and K for both the plant and weed samples were determined using the formula:

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient concentration} \times \text{biomass (kg/ha)}}{100}$$

The weed dry weight data (measured in grams/m²) underwent a square root transformation ("(X+0.5)), as recommended by Gomez and Gomez (1984). Subsequently, the transformed data underwent statistical analysis through Fisher's Analysis of Variance (ANOVA), following the procedure outlined by Panse and Sukhatme (1967). In cases where the F-test yielded a significant result, an appropriate critical difference (CD) value was computed to facilitate the comparison of treatment means. This analysis was conducted with a significance level of 5%, and the results have been presented and discussed accordingly.

RESULTS AND DISCUSSION

Weed flora

During a two-year field trial, the maize crop faced infestation from a diverse mixture of broad-leaved and narrow-leaved weeds. Total 14 species of weeds were observed out of which four were grasses (*Cynodon dactylon*, *Dinebra retroflexa, Dactyloctenium aegyptium* and *Echinochloa colona*). Nine species were broadleaved weeds (BLW) (*Amaranthus viridis*, *Corchorus olitorius*, *Boerhavia diffusa*, *Digera arvensis*, *Parthenium hysterophorus*, *Euphorbia hirta*, *Phyllanthus nirurui*, *Sida acuta* and *Trianthema portulacastrum*) and only one species was sedge (*Cyperus rotundus*). Among the narrow-leaved weed species, *Dactyloctenium aegyptium* stood out as particularly significant. *Trianthema portulacastrum* emerged as the most prevalent BLW'S species at the experimental location over the course of both trial years.

Weed biomass

The combined analysis of data at 90 DAS (at harvest data) (Table 1) depicted that all weed control treatments demonstrated that significant reduction in weed biomass when compared to atrazine as PE *fb* HW at 20 DAS. Application of atrazine as PE *fb* either topramezone as EPOE or tembotrione as EPoE at 20 DAS resulted in increased

Table 1. Pooled data on weed management strategies on weed biomass in maize at 90 DAS during *kharif* 2018 and 2019

Treatment	Weed biomass 2018 (g/m^2)			Weed biomass 2019 (g/m^2)				Total Pooled data (g/m^2)
	BLW	Grasses	Total	BLW	Grasses	Sedge	Total	
PE atrazine *fb* HW at 20 DAS	5.01 (24.65)	4.35 (18.46)	6.6 (43.11)	5.38 (28.47)	4.42 (19.01)	1.57 (1.95)	7.07 (49.43)	6.83 (46.27)
PE atrazine at *fb* PW at 20 DAS	6.13 (37.06)	5.5 (29.74)	8.2 (66.8)	6.34 (39.67)	6.29 (39.04)	1.84 (2.87)	9.06 (81.58)	8.64 (74.19)
PE atrazine + pendimethalin (Tank mix)	7.25 (52.12)	5.52 (30.01)	9.09 (82.13)	6.56 (42.5)	6.85 (46.47)	1.91 (3.16)	9.62 (92.13)	9.36 (87.13)
PE atrazine + pendimethalin (Tank mix) *fb* HW a 20 DAS	5.03 (24.79)	4.22 (17.32)	6.53 (42.11)	5.34 (28.01)	4.25 (17.56)	1.62 (2.13)	6.94 (47.7)	6.73 (44.9)
EPOE topramezone at 20 DAS	5.17 (26.18)	4.4 (18.85)	6.75 (45.03)	5.45 (29.25)	4.59 (20.54)	1.72 (2.45)	7.26 (52.24)	7.01 (48.63)
PE atrazine *fb* EPoE Topramezone at 20 DAS	4.46 (19.43)	3.45 (11.38)	5.6 (30.81)	4.42 (19.02)	3.64 (12.75)	1.23 (1.01)	5.77 (32.78)	5.68 (31.79)
EPOE tembotrione at 20DAS	5.24 (27)	4.41 (18.91)	6.81 (45.91)	5.51 (29.91)	4.64 (21.06)	1.73 (2.5)	7.35 (53.47)	7.08 (49.69)
PE atrazine *fb* EPoE Tembotrione at 20 DAS	4.53 (20)	3.56 (12.17)	5.72 (32.17)	4.52 (19.95)	3.68 (13.01)	1.33 (1.26)	5.89 (34.22)	5.80 (33.19)
Hand weeding twice at 20 and 45 DAS	4.3 (18.02)	3.32 (10.51)	5.39 (28.53)	4.33 (18.26)	3.39 (10.98)	0.96 (0.42)	5.49 (29.66)	5.44 (29.09)
Weedy check	10.15 (102.54)	6.48 (41.54)	12.02 (144.1)	9.48 (89.34)	6.93 (47.53)	2.00 (3.52)	11.87 (140.4)	11.95 (142.23)
SEm±	0.11	0.09	0.12	0.08	0.13	0.07	0.13	0.13
CD (P=0.05)	0.32	0.28	0.37	0.25	0.39	0.21	0.42	0.40

Note: The data underwent a square root transformation, and the values enclosed in parentheses represent the actual mean values.

efficiency of weed biomass reduction to the tune of 31.29% and 28.26% respectively and it was on par with PE atrazine + pendimethalin (Tank mix) *fb* HW at 20DAS (2.96 %) reduction of weed biomass over atrazine as PE *fb* HW at 20 DAS. Both PE and EPoE herbicidal treatments proved significantly more effective than other methods such as application of either PE herbicide or EPoE herbicides alone. This enhanced weed control can be attributed to the PE application of herbicides, which effectively suppressed the germination and growth of the most of weeds persisted over an extended period. This prolonged impact is likely a result of the herbicides persisting in the soil. Additionally, any weeds that managed to evade the pre-emergence treatment were efficiently controlled by the EPoE herbicide application carried out 20 DAS. These findings align with earlier research reported by Nadiger *et al*. (2013). The sedge group was not found throughout the cropping period of 2018; they were recorded only in the second year, 2019. The research was conducted at the same area (Eastern block farm) with same texture of soil (sandy clay loam) in both years but in different location.

Nutrient removal by weeds

Each of the weed management treatments arose in a significant decrease in removal of nutrient by the weeds owing to various herbicides were significant (Table 2). Among the herbicidal treatment, application of PE atrazine *fb* EPoE topramezone ranked first in the least drain of total N (36.04%), P (18.14%) and K (16.75%) due to weeds which was closely followed by PE atrazine *fb* EPoE tembotrione (31.16% N, 12.59% P and 13.40% K), ranked second. The N, P and K uptake by weeds accounted for 5.23%, 5.59%, and 3.33% respectively, of the total removal (weed + crop) in PE atrazine *fb* HW at 20 DAS and only 2.59%, 3.76% and 2.27% in PE atrazine *fb* EPoE topramezone at 20 DAS and 2.85%, 4.01% and 2.44% in PE atrazine at *fb* EPoE tembotrione at 20 DAS. Thus, saving of 2.64% N and 1.83% P and 1.06% K could be obtained by the adoption of treatment PE atrazine *fb* EPoE topramezone while the respective saving of these nutrients under PE atrazine at *fb* EPoE tembotrione was 2.38% N, 1.58% P and 0.89% K. The absorption of N, P and K by both the crop and weeds are primarily influenced by their respective dry matter production.

Table 2. Pooled data on weed management strategies nutrient removal by weeds in maize at 90 DAS during *kharif* 2018 and 2019

Treatments	N (kg/ha)			P (kg/ha)			K (kg/ha)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
PE atrazine *fb* HW at 20DAS	8.02	7.95	7.99	2.5	2.89	2.70	3.64	4.12	3.88
PE atrazine at *fb* PW at 20DAS	11.89	12.01	11.95	3.34	3.68	3.51	5.23	5.84	5.54
PE atrazine + pendimethalin (Tank mix)	13.74	16.24	14.99	4.78	6.57	5.68	8.6	10.26	9.43
PE atrazine + pendimethalin (Tank mix) *fb* HW at 20 DAS	7.96	7.04	7.50	2.46	2.83	2.65	3.35	3.96	3.66
EPOE topramezone at 20DAS	9.52	8.32	8.92	2.63	3.05	2.84	3.78	4.35	4.07
PE atrazine *fb* EPOE	5.01	5.21	5.11	2.14	2.27	2.21	3.09	3.36	3.23
Topramezone at 20 DAS									
EPoE tembotrione at20 DAS	9.86	8.44	9.15	2.71	3.12	2.92	3.89	4.56	4.23
PE atrazine *fb* EPoE Tembotrione at 20 DAS	5.45	5.54	5.50	2.25	2.46	2.36	3.17	3.54	3.36
Hand weeding twice at 20and 45 DAS	3.55	4.18	3.87	1.94	2.01	1.98	2.58	2.97	2.78
Weedy check	25.08	29.56	27.32	8.14	11.72	9.93	14.6	23.45	19.05
SEm±	0.65	0.46	0.56	0.14	0.20	0.17	0.23	0.31	0.27
CD (P=0.05)	2.01	1.41	1.71	0.42	0.61	0.52	0.71	0.94	0.83

Table 3. Pooled data on weed management strategies on nutrient uptake by maize at 90 DAS during *kharif* 2018 and 2019

Treatment	N (kg/ha)			P (kg/ha)			K (kg/ha)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
PE atrazine *fb* HW at 20 DAS	137.0	152.3	144.6	44.1	47.1	45.6	106.6	118.5	112.5
PE atrazine at *fb* PW at 20 DAS	99.8	103.3	101.5	24.3	26.1	25.2	58.7	60.5	59.6
PE atrazine + pendimethalin (Tank mix)	90.3	94.2	92.25	21.9	23.7	22.8	56.1	58.3	57.2
PE atrazine + pendimethalin (Tank mix) *fb* HW at 20DAS	140.7	156.0	148.3	46.2	49.3	47.7	110.7	122.8	116.7
EPoE topramezone at 20DAS	120.3	135.3	127.8	33.6	36.2	34.9	79.3	99.3	89.3
PE atrazine *fb* EPoE Topramezone at 20 DAS	188.6	194.3	191.4	54.7	58.3	56.5	137.8	140.1	138.9
EPoE tembotrione at20DAS	117.5	132.7	125.1	31.5	33.8	32.6	74.7	89.6	82.1
PE atrazine *fb* EPoETembotrione at 20 DAS	186.0	188.2	187.1	55.3	57.6	56.4	132.4	136.2	134.3
Hand weeding twice at 20and 45 DAS	191.9	200.3	196.1	56.2	61.3	58.7	143.3	146.7	145
Weedy check	64.3	66.3	65.3	9.5	11.2	10.3	43.5	44.8	44.1
SEm±	3.29	4.10	3.70	1.90	1.83	1.87	3.89	3.96	3.93
CD (P=0.05)	10.3	12.5	11.40	5.9	5.8	5.85	12	11.8	11.90

As indicated in Table 2, when weeds removed a greater quantity of nutrients, the corresponding uptake by the crop decreased, and vice versa. Therefore, to effectively utilize the applied nutrients, it is crucial to manage weed growth. Among the weed-control treatments, the combination of PE application of atrazine *fb* EPoE application of either topramezone or tembotrione resulted in the lowest removal of N, P and K by weeds. This could be attributed to the reduced weed density and dry matter accumulation, which in turn leads to a decreased removal of nutrients (N, P and K) by weeds due to the sequential application of pre-emergence followed by early post-emergence herbicide. These results are in the line of work reported by Yadav *et al*. (2017).

Table 4. Pooled data on weed management strategies on maize crop yield during *kharif* 2018 and 2019

Treatment	Grain yield (t/ha)			Stover yield (t/ha)			Biological yield (t/ha)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
PE atrazine *fb* HW at 20 DAS	7.6	7.8	7.7	12.6	13.0	12.8	20.2	20.8	20.5
PE atrazine at *fb* PW at 20DAS	6.7	6.6	6.6	9.9	10.0	10.0	16.6	16.6	16.6
PE atrazine + pendimethalin(Tank mix)	6.4	6.3	6.4	9.6	9.8	9.8	16.1	16.2	16.1
PE atrazine + pendimethalin(Tank mix) *fb* HW at 20 DAS	7.7	7.8	7.8	12.9	13.1	13.0	20.6	21.0	20.8
EPOE topramezone at 20 DAS	7.2	7.5	7.4	12.0	12.4	12.2	19.3	19.9	19.6
PE atrazine *fb* EPOETopramezone at 20 DAS	8.2	8.3	8.2	14.4	14.5	14.5	22.6	22.8	22.7
EPOE tembotrione at 20DAS	7.2	7.5	7.3	11.9	12.1	12.0	19.0	19.6	19.3
PE atrazine *fb* EPOETembotrione at 20 DAS	8.1	8.2	8.1	14.2	14.4	14.3	22.3	22.6	22.4
Hand weeding twice at 20and 45DAS	8.4	8.4	8.4	14.5	14.7	14.6	22.9	23.1	23.0
Weedy check	4.4	4.2	4.3	6.9	6.9	7.0	11.4	11.2	11.3
SEm±	0.11	0.09	0.10	0.13	0.14	0.14	0.27	0.23	0.25
CD (P=0.05)	0.32	0.28	0.30	0.43	0.41	0.42	0.74	0.69	0.72

Nutrient uptake by crop

The application of various weed management treatments resulted in a significant enhanced N, P and K uptake by maize over weedy check (Table 3).

The highest N, P and K uptake (32.36%, 23.90%, 23.46%) by the crop was recorded with PE atrazine *fb* EPoE topramezone after weed free treatment (35.61%, 28.72%, 28.88%) which was closely followed by PE atrazine *fb* EPoE tembotrione (29.39%, 23.68%, 19.37%). The enhanced absorption of N, P and K by the maize crop in response to the weed management treatments can be credited to the successful regulation of weed growth, resulting in decreased weed biomass. This could be attributed to the reduced weed population and dry weight, facilitating a weed-free environment that allowed the crops to absorb more nutrients from the soil. Additionally, the active and extensive root system of the crops might have contributed to increased nutrient uptake. This observation aligns with the results of Meyyappan *et al*. (2018) and Kien *et al*. (2016).

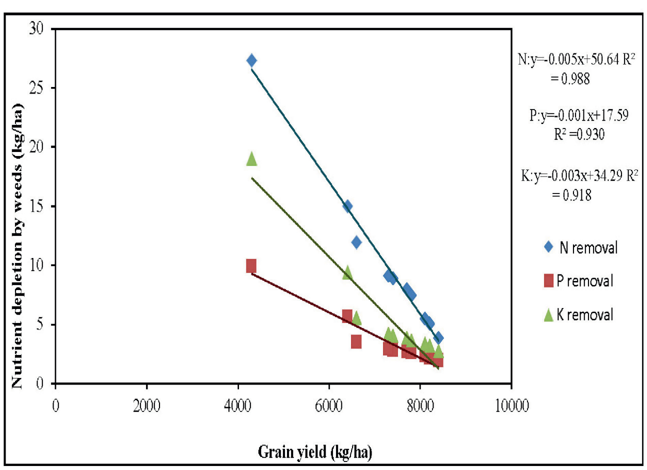

Fig. 1. The relationship between grain yield of maize and the nutrient removal (N, P and K) by total weeds at 90 DAS in maize crop

Crop yield

Over the course experimentation, grain and stover yields of maize varied significantly among the treatments (Table 4). Notably, the most substantial increases in grain and stover yields were observed with the PE atrazine *fb* EPOE topramezone treatment (6.49% and 13.28%) and the PE atrazine *fb* EPoE tembotrione treatment (5.19% and 11.71%) in comparison to the PE atrazine *fb* HW at 20 DAS.

The notable reduction in weed biomass, as evidenced in Table 1, likely played a pivotal role in the yield enhancement observed across various weed management treatments. In this trial, a direct negative linear correlation between the nutrient removal (N, P, and K) by weeds and the grain yield of the maize crop was observed (Fig. 1). This decrease in weed biomass may have mitigated competition between the crop and weeds, creating a more favorable environment for the crop to fully express its vegetative and reproductive potential. Consequently, this contributed to the overall increase in yield, as elucidated in the study by Gosh *et al*. 2020.

Thus, the application of atrazine 0.5 kg a.i./ha in combination with an EPoE application of topramezone 25.2 g a.i./ha or tembotrione 122 g a.i./ha at 20 DAS significantly increased yield by improving resource use, enhancing nutrient uptake by crops and reducing nutrient depletion by weeds.

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