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Effect of weed management practices and zinc–iron application on weed dynamics and nutrient uptake by weeds in sweet corn (*Zea mays* L. var. *saccharata*)

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Abstract

A field experiment was conducted during *Kharif* 2024 and 2025 at the Instructional Farm, College of Agriculture, Umedganj-Kota (Rajasthan) to evaluate the effect of six weed management practices and three levels of zinc–iron (Zn–Fe) application on weed dynamics and nutrient removal by weeds in sweet corn (cv. Sugar-75). The experiment was laid out in a factorial randomized block design with 18 treatment combinations replicated thrice. Among weed management practices, sequential application of atrazine 1.0 kg *a.i.*/ha as pre-emergence *fb* tembotrione 120 g *a.i.*/ha as post-emergence (W_6) recorded the lowest total weed density, total weed dry weight, the highest weed control efficiency and lowest weed index and was statistically at par with atrazine *fb* hand weeding (W_3) at later stages. Nutrient removal by weeds followed the same trend as weed biomass: the weedy check recorded highest nutrients removal, whereas W_6 recorded highest reduction in nutrients removal, over the weedy check. Zn–Fe application did not significantly influence weed density or dry weight, but basal application of $ZnSO_4 + FeSO_4$ significantly increased nutrient uptake by weeds compared with control and foliar application, indicating that basally applied micronutrients were also partly accessed by the associated weed flora in the absence of effective weed control. The results establish that integrated pre- and post-emergence herbicide sequences are essential to curtail weed-mediated nutrient loss when micronutrients are applied to sweet corn.

Keywords: Atrazine, nutrient uptake, sweet corn, tembotrione, weed control efficiency, weed index, Zinc–iron application

Introduction

Sweet corn (*Zea mays* L. var. *saccharata*) is a high-value specialty maize valued for its sweet, milky kernels harvested at the immature (milk) stage and its cultivation is expanding rapidly in peri-urban areas of India in response to growing demand from fresh-vegetable and processing markets. Being a widely spaced, slow-establishing *Kharif* crop, sweet corn suffers heavy early-season competition from a mixed flora of grasses, broad-leaved weeds and sedges and yield losses of 30–60% have commonly been reported in maize when weeds are left uncontrolled during the critical period of crop–weed competition.

Weeds are not merely competitors for light, moisture and space; being physiologically more efficient than the crop in the initial growth phase, they also remove disproportionately large quantities of applied nutrients, including the micronutrients that are increasingly being supplemented in cereal systems to correct widespread soil deficiencies and to biofortify grain. When Zn and Fe are broadcast or applied as basal dressings, an uncontrolled weed flora can intercept a part of this applied nutrient before the crop canopy closes, reducing the efficiency of micronutrient fertilization. Sole reliance on a single herbicide molecule such as atrazine or tembotrione is often inadequate for season-long control because of their differing spectra and time of action, and integration of a pre-emergence triazine with a post-emergence HPPD-inhibitor, or with hand weeding, is increasingly recommended to broaden the spectrum and duration of weed suppression in maize-based systems (Roy *et al.*, 2024; Chahal *et al.*, 2022) [13, 2].

Information on how such herbicide sequences, combined with basal or foliar Zn–Fe application, jointly influence weed density, weed dry matter accumulation and, specifically, nutrient removal

by the weed flora in sweet corn is limited under the sub-humid South-Eastern Plain agro-climate of Rajasthan. The present investigation was therefore undertaken to (i) quantify the effect of six weed management practices and three Zn–Fe application methods on weed density, dry weight, weed control efficiency and weed index in sweet corn, and (ii) assess their effect on N, P, K, Zn and Fe content and uptake by the associated weed flora, so as to identify a weed management practice that minimises weed-mediated nutrient loss under micronutrient-fertilized sweet corn.

Materials and Methods

Experimental site and climate

A two-year field experiment was conducted during *Kharif* 2024 and 2025 at the Instructional Farm, College of Agriculture, Umedganj-Kota, Rajasthan, which falls in Agro-climatic Zone V of Rajasthan. The region receives, 75–85% of annual rainfall from the south-west monsoon between June and September.

Soil characteristics

The experimental soil was clay loam in texture, medium deep, slightly alkaline in, medium in organic carbon and available nitrogen, medium in available phosphorus, high in available potassium and low in DTPA-extractable Zn and Fe.

Treatments and experimental design

The experiment was laid out in a Factorial Randomized Block Design with 18 treatment combinations of six weed management practices (Factor A) and three Zn–Fe application methods (Factor B), replicated thrice (. Sweet corn cv. Sugar-75 was sown at 8 kg seed/ha with 60 cm × 20 cm spacing. The treatment details and symbols used throughout this paper are given in Table 1.

Table 1: Treatment details and symbols

Symbol	Treatment
W ₁	Weed free
W ₂	Weedy check
W ₃	Atrazine @ 1.0 kg a.i./ha PE fb hand weeding at 40 DAS
W ₄	Tembotrione @ 120 g a.i./ha PoE at 15–20 DAS
W ₅	Tembotrione @ 120 g a.i./ha PoE fb hand weeding at 40 DAS
W ₆	Atrazine @ 1.0 kg a.i./ha PE fb tembotrione @ 120 g a.i./ha PoE
B ₁	Control (no Zn–Fe)
B ₂	Basal ZnSO ₄ @ 25 kg/ha + FeSO ₄ @ 25 kg/ha
B ₃	Foliar ZnSO ₄ @ 0.5% + FeSO ₄ @ 0.5% at tasseling stage

Weed observations

Weed density (no./m²) and weed dry weight (g/m²) were recorded

species-wise from two randomly placed 0.5 m × 0.5 m quadrates per plot at 20 and 40 DAS and at harvest; density data were square-root ($\sqrt{x + 0.5}$) transformed before analysis (Gomez and Gomez, 1984) ^[4]. Weed control efficiency was calculated at harvest following Mani *et al.* (1968) ^[9], and weed index was calculated from cob yield following Gill and Kumar (1969) ^[3]. Representative weed samples were oven-dried (65 °C), ground and analysed for N (Kjeldahl method; Piper, 1966) ^[12] and P, K, Zn and Fe (tri-acid digestion followed by vanado-molybdate/flame photometric/AAS estimation; Jackson, 1973) ^[5]; nutrient uptake by weeds was computed by multiplying nutrient content with weed dry matter and expressed as kg/ha (N, P, K) or g/ha (Zn, Fe).

Statistical analysis

Data were analysed by analysis of variance appropriate to the factorial randomized block design as described by Panse and Sukhatme (1985) ^[11], separately for each year and on pooled (two-year) basis. Treatment means were compared using critical difference (CD) at P = 0.05 wherever the F-test was significant.

Results and Discussion

Weed flora and weed density

The experimental field harboured a mixed weed flora comprising four grassy weeds (*Cynodon dactylon*, *Dinebra retroflexa*, *Dactyloctenium aegyptium*, *Echinochloa colona*), six broad-leaved weeds (*Commelina benghalensis*, *Convolvulus arvensis*, *Digera arvensis*, *Eclipta prostrata*, *Euphorbia hirta*, *Phyllanthus niruri*) and one sedge (*Cyperus rotundus*), which is a fairly typical *Kharif* weed spectrum of maize-based cropping systems in semi-arid to sub-humid India (Bhullar *et al.*, 2016) ^[1]. Total weed density was significantly influenced by weed management practices at all three stages of observation, whereas Zn–Fe application had no significant effect on weed density during either year or on pooled basis (Fig. 1). The weedy check recorded the highest pooled weed density (244.3, 327.6 and 403.0 weeds/m² at 20 DAS, 40 DAS and harvest, respectively). Sequential application of atrazine fb tembotrione (W₆) recorded the lowest density (37.5, 69.8 and 82.7 weeds/m², respectively) and was statistically superior to all other treatments at 20 DAS, while remaining at par with atrazine fb hand weeding (W₃) at 40 DAS and harvest. Sole post-emergence tembotrione (W₄) was the least effective herbicidal option, reflecting its narrower spectrum and the flush of late-emerging grasses and sedges that it did not intercept, a limitation also noted for HPPD-inhibitor herbicides used alone in maize (Roy *et al.*, 2024) ^[13].

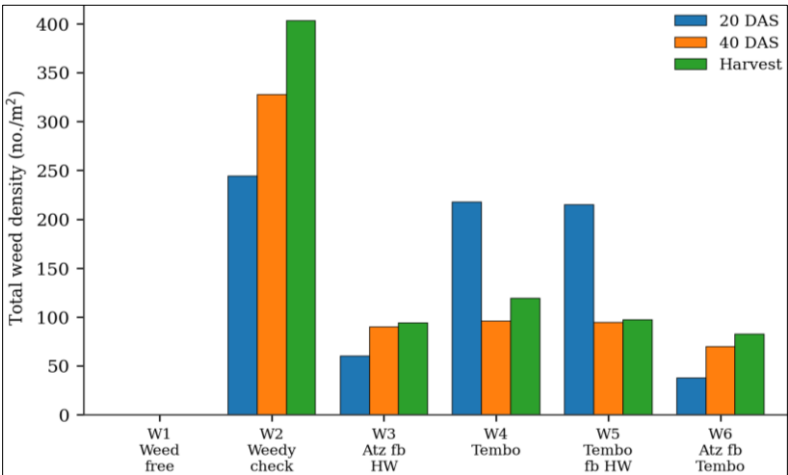


Fig 1: Effect of weed management practices on total weed density (pooled data, 2024 & 2025)

Weed dry weight

Total weed dry weight followed a similar trend, being maximum in the weedy check (103.5, 292.4 and 451.4 g/m² at 20 DAS, 40 DAS and harvest, pooled) and minimum with W₆ (15.9, 38.3 and 59.8 g/m², respectively), representing 84.6, 86.9 and 86.8% reduction over the weedy check at the three stages (Fig. 2). Treatments W₆, W₃ (atrazine fb HW) and W₅ (tembotrione fb HW) remained statistically at par at 40 DAS and harvest, while W₄ (tembotrione alone) was significantly inferior. The consistently lower weed biomass under sequential/integrated treatments over sole post-emergence herbicide use corroborates earlier reports that a pre-emergence triazine effectively

suppresses early-flushing grasses that later-applied HPPD-inhibitors alone cannot control (Bhullar *et al.*, 2016; Chahal *et al.*, 2022) [1, 2]. Zn-Fe application had no significant effect on weed dry weight at 20 DAS, but the basal ZnSO₄ + FeSO₄ treatment recorded significantly higher grass, broad-leaved and sedge weed dry weight than the control and foliar treatments at harvest, suggesting that basally placed micronutrients, applied uniformly across the plot prior to sowing, were also available to the co-emerging weed flora and stimulated a measurable, though comparatively small, increase in weed growth relative to the dominant effect of the herbicide treatments (Kumar, *et al.*, 2025) [7].

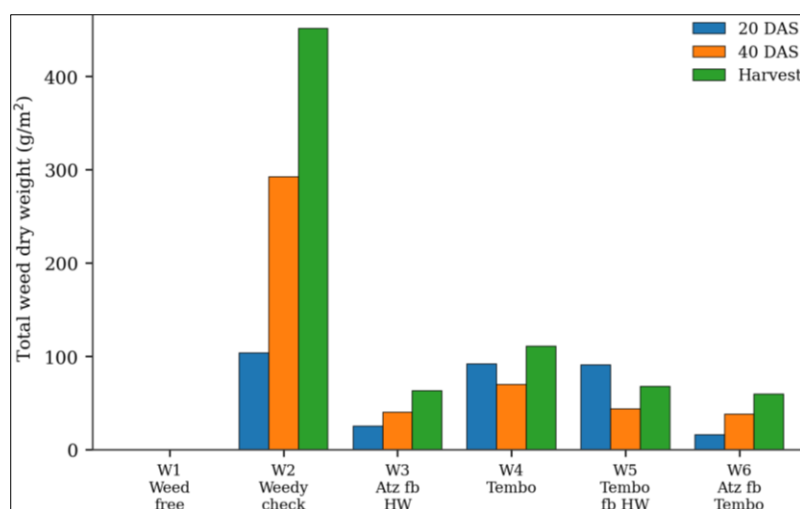


Fig 2: Effect of weed management practices on total weed dry weight (pooled data, 2024 & 2025)

Weed control efficiency and weed index

Weed control efficiency (WCE) at harvest was highest with W₆ (87.0%), statistically at par with W₃ (86.2%) and W₅ (85.2%), and lowest with W₄ (76.1%) (Fig. 3). Correspondingly, weed index — the yield loss attributable to weed competition — was lowest with W₆ (7.7%) and highest with the weedy check (66.2%), confirming that the sequential herbicide programme most effectively protected crop yield potential from weed interference. The close

correspondence between WCE and weed index across treatments is consistent with the general expectation that greater biomass suppression translates directly into reduced yield loss, and mirrors trends reported for tembotrione-based sequential programmes in conservation-agriculture maize (Roy *et al.*, 2024) [13], where the pre + post sequence recorded a weed index of only 7.04% against 88.1% weed control efficiency (Kumar, *et al.*, 2024) [6].

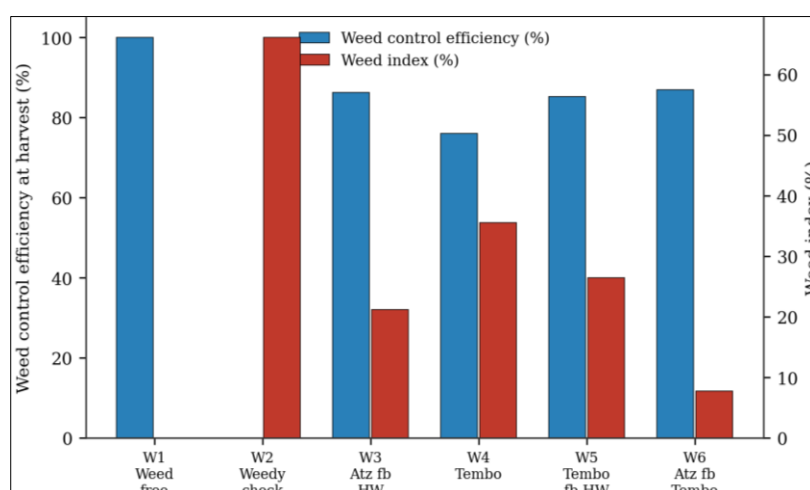


Fig 3: Effect of weed management practices on weed control efficiency (at harvest) and weed index (pooled data, 2024 & 2025)

Nutrient content and uptake by weeds

Nitrogen, phosphorus and potassium content in weed tissue was significantly higher in the weedy check (1.309% N, 0.233% P and 1.685% K, pooled) than under any weed management practice, and was lowest with W₆ (1.259% N, 0.220% P and 1.661% K);

Zn and Fe content in weed tissue showed an identical pattern (30.7 and 53.7 ppm in the weedy check versus 24.0 and 11.5 ppm with W₆, respectively). Because uptake integrates content with the much larger biomass differential between treatments, the treatment effect on total nutrient removal was proportionally far

larger than on tissue concentration alone (Fig. 4, Fig. 5). The weedy check removed 59.1 kg N, 10.6 kg P and 76.2 kg K per hectare, together with 138.8 g Zn/ha and 243.5 g Fe/ha — nutrient quantities of the same order of magnitude as a fertilizer dose — whereas W₆ reduced this drain by 87.2, 87.5, 86.9, 89.6 and 97.1%, respectively. This scale of weed-mediated nutrient removal is consistent with earlier findings that an unchecked weed flora can appropriate a substantial share of applied macro- and micronutrients before canopy closure in maize, thereby

depressing crop nutrient-use efficiency (Bhullar *et al.*, 2016) ^[1]; notably, however, the proportion of applied Zn intercepted by weeds relative to the crop itself is typically small once the crop is well established, as also reported for maize agro-ecosystems in which weeds accounted for only about 1–2% of total field Zn uptake once ground cover closed underlining that the practically important window for nutrient interception by weeds in the present study was the early, pre-canopy-closure period captured by the 20 and 40 DAS observations (Kumar, *et al.*, 2024) ^[6].

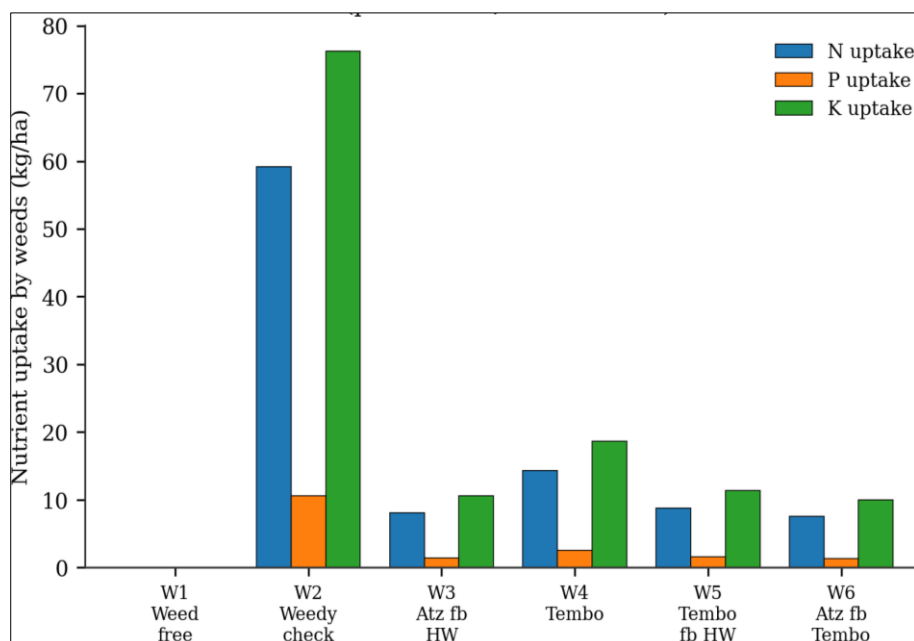


Fig 4: Effect of weed management practices on N, P and K uptake by weeds (pooled data, 2024 & 2025)

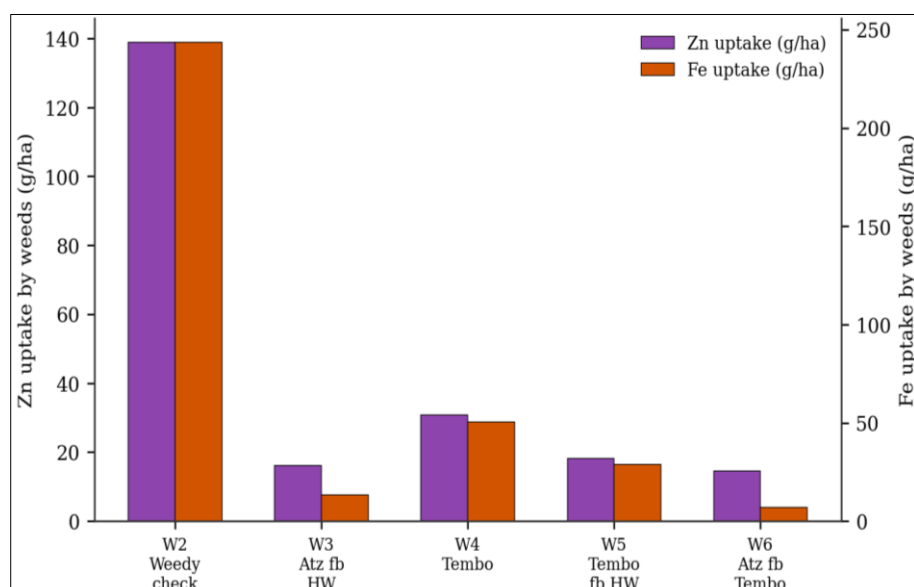


Fig 5: Effect of weed management practices on Zn and Fe uptake by weeds (pooled data, 2024 & 2025)

Among Zn–Fe application methods, basal application of ZnSO₄ + FeSO₄ significantly increased N, P, K, Zn and Fe uptake by weeds (16.78 kg N/ha, 2.99 kg P/ha, 21.62 kg K/ha, 37.55 g Zn/ha and 58.67 g Fe/ha, pooled) compared with the control and foliar application (Fig. 6), even though it did not significantly alter weed density. This indicates that basally placed Zn and Fe, being incorporated into the root zone ahead of sowing, were partly accessed by the co-germinating weed flora before the crop root system could fully exploit the applied dose, whereas foliar Zn–Fe

application — directed at the crop canopy at the tasseling stage, well after early weed emergence — did not measurably enhance weed nutrient uptake. This is an agronomically relevant finding, as it suggests that the efficiency of basal micronutrient fertilization in sweet corn is contingent on effective early-season weed suppression, reinforcing the case for integrating a pre-emergence herbicide component whenever Zn–Fe is applied basally.

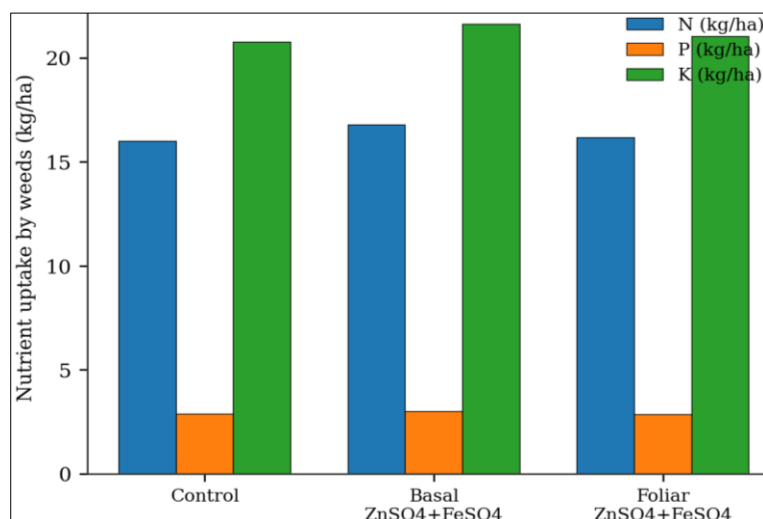


Fig 6: Effect of Zn–Fe application on N, P and K uptake by weeds (pooled data, 2024 & 2025)

Conclusion

Sequential application of atrazine (1.0 kg *a.i.*/ha, pre-emergence) *fb* tembotrione (120 g *a.i.*/ha, post-emergence) most effectively suppressed weed density and dry weight, gave the highest weed control efficiency and lowest weed index and curtailed weed-mediated removal of N, P, K, Zn and Fe most sharply among the tested weed management practices, while remaining statistically comparable with atrazine *fb* hand weeding at later growth stages. Basal application of Zn–Fe, while beneficial to the crop, was also partly captured by an inadequately controlled weed flora; hence, integration of an effective pre- and post-emergence herbicide sequence is recommended as an agronomic prerequisite for realising the full benefit of basal Zn–Fe fertilization in sweet corn.

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