

HERBICIDAL WEED MANAGEMENT ALTERS WEED DYNAMICS AND ENHANCES WHEAT (*TRITICUM AESTIVUM* L.) PRODUCTIVITY UNDER CONSERVATION AGRICULTURE IN VERTISOLS OF CENTRAL INDIA

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ABSTRACT

Field experiments were conducted to evaluate the effect of different herbicides on weed management and productivity of wheat (*Triticum aestivum* L.) under conservation agriculture (CA). The treatment combinations comprised: absolute control (T1), two hand weedings at 20 and 40 days after sowing (T2), pre-emergence (Pre-E) application of pendimethalin @ 1000 g a.i. ha⁻¹ (T3), Post-emergence (PoE) application of metsulfuron @ 4 g a.i. ha⁻¹ + clodinafop-propargyl @ 60 g a.i. ha⁻¹ at 20 DAS (T4), PoE application of mesosulfuron + idosulfuron @ 400 g a.i. ha⁻¹ at 20 DAS (T5), Pre-E application of pendimethalin @ 750 g a.i. ha⁻¹ followed by (fb) PoE 2,4-D amine salt 1000 g a.i. ha⁻¹ at 30 DAS (T6), and Pre-E pendimethalin @ 750 g a.i. ha⁻¹ fb PoE metsulfuron @ 4 g a.i. ha⁻¹ at 30 DAS (T7). The experiment was laid out in a randomized block design with three replications. Results revealed that weeds can be effectively managed under CA systems through application optimum herbicide rates at the right time. Two hand weeding treatment (T2) proved to be the best among all weed control treatments, recording the highest weed control efficiency (89.40%) and grain yield (37.97 q ha⁻¹). Weed control treatments created a congenial environment for better crop growth by reducing competition for nutrients, water, space and light compared with control, thereby improving plant growth and yield parameters in both hand-weeded and herbicidal treatment plots. Among herbicidal treatments, PoE application of mesosulfuron + idosulfuron @ 400 g a.i. ha⁻¹ at 20 DAS (T5) was the most effective achieving weed control efficiency of 74.90% and grain yield of 36.95 q ha⁻¹. The lowest values for these parameters were recorded under absolute control (21.58 q ha⁻¹). Thus, the weed-free treatment produced an absolute yield advantage of 16.39 q ha⁻¹ over the weedy check, equivalent to 75.94 % higher grain yield than the weedy check.

KEYWORDS: Conservation agriculture, weed management, herbicide, wheat, weed index, weed control efficiency, productivity.

INTRODUCTION

Conservation agriculture (CA) has emerged as one of the most promising technologies for addressing natural resource degradation and environmental pollution while enhancing and sustaining agricultural productivity. The primary objective is to achieve production intensification and high yields while enhancing the natural resource base through resource-conserving sustainable agricultural production system, in accordance with best management practices for plant nutrition and pest management (Abrol and Sangar 2006). CA has been shown to improve crop productivity and water use efficiency (Sawant *et al.*, 2023), as well as the physical, biological and chemical properties of soil compared with conventional tillage systems (Somasundaram *et al.*, 2022; Bharti *et al.*, 2023). Weed management remains a major challenge to the successful adoption of CA by farmers. Weed control under CA systems mainly relies on herbicides (Malgaya *et al.*, 2023). However, over reliance on herbicides can bring substantial changes in weed dynamics, their population, weed shift and resistance development under conservation agriculture (Meena *et al.*, 2016) and may lead to significant reduction in crop yield due to increased densities of weeds due to avoidance of tillage in CA (Vishwakarma *et al.*, 2023). Thus, proper weed management needs special attention for successful adoption of conservation agriculture on large scale. Application of non-selective and selective pre and post emergence herbicides either alone or in combination/ sequential application for weed control under CA will help in crop establishment and consistent yield and creditable performance (Malik *et al.*, 2005; Parmer *et al.*, 2026).

Wheat is a staple cereal crop cultivated in India during *Rabi* season. India is the world's second largest wheat producing country with an production of 117.9 million tonnes accounting for nearly 14% of global production occupying nearly (32.8 m ha) 15% of the global acreage under wheat cultivation and productivity of nearly 3.59 tha⁻¹, respectively (GoI. 2025). Conservation agriculture involves growing crops with minimal disturbance of soil, thereby avoiding frequent tillage traditionally used for seedbed preparation and weed control. CA Weeds being

the major biological constraints for wheat cultivation, they remain the most important aspects in crop production under no till-based conservation agriculture systems (Agrawal *et al.*, 2025), as it does not allow ploughing while preparing the field and intercultural operation which involves soil disturbance (Sawant *et al.*, 2026). Thus, chemical weed management by applying herbicides remains the only viable option for successful adoption of conservation agriculture in Vertisols with low environmental footprints (Bharti *et al.* 2021; Meena *et al.*, 2024). However, no single herbicide can effectively control all weed species present at the time of application as well as those which will emerge later and provide season long control without affecting crop growth and development. In view of these considerations, the present study was undertaken.

MATERIALS AND METHODS

Field experiments were conducted with wheat under CRP on CA (no till) systems to standardize weed management practices for wheat in Vertisols of Central India during Rabi 2015 to 2017 at the Research Farm of ICAR-Indian Institute of Soil Science, Bhopal, Madhya Pradesh. The soil of the experimental site was an Isohyperthermic, Typichaplustert with deep heavy clayey in texture (43.2% clay, 30.5% silt, 26.3% sand), and slightly alkaline in reaction with pH 8.2, bulk density 1.35 Mg m^{-3} , and electrical conductivity (EC) 0.18 dS m^{-1} , soil organic carbon (SOC) was 0.68% with 266 kg ha^{-1} available N, 27.34 kg ha^{-1} P and 524 kg ha^{-1} K, respectively. The mean annual rainfall of 1130 mm (75–80% of which is received during June to September) and potential evapo-transpiration of 1400 mm. The minimum temperature of $9.7\text{--}11.8^\circ\text{C}$ in January, maximum temperature of $41.8\text{--}46.2^\circ\text{C}$ in May and mean monthly maximum.

The experiment was conducted using a randomized block design (RBD) comprising seven treatments and three replications. The treatment combinations comprised: absolute control (T1), two hand weedings at 20 and 40 days after sowing (T2), pre-emergence (Pre-E) application of pendimethalin @ $1000 \text{ g a.i. ha}^{-1}$ (T3), Post-emergence (PoE) application of metsulfuron @ 4 g a.i. ha^{-1} + clodinafop-propargyl @ $60 \text{ g a.i. ha}^{-1}$ at 20 DAS (T4), PoE application of mesosulfuron + idosulfuron @ $400 \text{ g a.i. ha}^{-1}$ at 20 DAS (T5), Pre-E application of pendimethalin @ $750 \text{ g a.i. ha}^{-1}$ followed by (fb) PoE 2,4-D amine salt $1000 \text{ g a.i. ha}^{-1}$ at 30 DAS (T6), and Pre-E pendimethalin @ $750 \text{ g a.i. ha}^{-1}$ fb PoE metsulfuron @ 4 g a.i. ha^{-1} at 30 DAS (T7). Wheat variety C-306 was sown in the experimental field after harvesting of preceding soybean crop in residual moisture at a row spacing of 27.5 cm during the second fortnight of October with the help of happy seeder. Recommended rate of fertilizer ($80 \text{ kg N} + 60 \text{ kg P}_2\text{O}_5 + 40 \text{ kg K}_2\text{O ha}^{-1}$) has been applied uniformly. Whole quantity of P_2O_5 & K_2O was applied as basal application, while half quantity of nitrogen was applied as basal and remaining half in two equal splits at first and second irrigation.

RESULTS & DISCUSSION

Effect of weed control treatments on weeds

The major weeds observed in the experimental field included monocotyledonous weeds such as *Dichanthium annulatum* (Forssk.), *Avena fatua*, and *Commelina benghalensis* L. The dicotyledonous weeds included *Anagallis arvensis*, *Convolvulus arvensis*, *Euphorbia geniculata* L., *Alternanthera sessilis* L., *Parthenium hysterophorus* L., *Abutilon indicum*, and *Sonchus asper*. *Cyperus rotundus* was the only sedge species present in the experimental field. The presence of diverse weed species indicates the need for effective and broad-spectrum weed-management strategies under conservation agriculture (Vishwakarma *et al.*, 2023). All the weed control treatments recorded significantly lower weed density than the untreated control T1 (No weeding control) 14.42 m^{-2} at harvest stage (Table 1). Among weed control treatments, treatment T5 recorded lowest weed density (4.98 m^{-2}) which was on par with other weed control treatments except T3 & T4. Among different treatments maximum weed control efficiency in terms of population (88.33%) has been recorded under T5 followed by T6 (87.33%) & T2 (83.53%). Among different treatments lowest weed biomass (3.0 q ha^{-1}) was recorded under T2, i.e., hand weeding which was on par with treatments T5, T6, and T7 and T4 whereas the maximum weed biomass 28.70 q ha^{-1} was recorded under control T1. Maximum weed control efficiency in terms of biomass (89.40%) was recorded under T2 followed by treatment T5 (74.90%) & T6 (73.97%). Manual removal directly eliminates established weeds and can therefore reduce weed biomass more effectively than treatment that allow later emergence weed to survive. Earlier research likewise found that two hand weedings and integrated herbicide-based treatments effectively reduced weed dry matter and increased weed-control efficiency. Higher weed control efficiency of treatment T2 in terms of biomass as compared to weed control efficiency in terms of population is attributed to the fact that higher number of weeds emerged towards maturity phase of the crop (Meena *et al.*, 2016; Agrawal *et al.*, 2025). Although these late-emerging weeds increased the final weed count, they had limited time to accumulate substantial biomass and exert strong competitive pressure on the wheat crop (Malgaya *et al.*, 2023). Among different weed control treatments lowest weed index (2.67%) was recorded under treatment T5 whereas highest weed index (43.16%) was recorded under control T1. This result indicates that T5 provided the most effective season-long weed suppression among the herbicidal treatments and minimized yield losses caused by weed competition.

Table 1. Effect of different weed management treatments on weed density, weed biomass weed control efficiency (WCE) and weed index in wheat

Treatment	Weed density (m ⁻²)	WCE % Population	Weed biomass (q ha ⁻¹)	WCE % Biomass	Weed index %
T ₁	14.42 (208.66)	0	28.7	0.00	43.16
T ₂	5.84 (34.36)	83.53	3.0	89.40	0.00
T ₃	7.00 (50.12)	75.98	14.0	51.22	6.55
T ₄	6.63 (44.04)	78.89	10.4	63.93	10.66
T ₅	4.98 (34.08)	88.33	7.2	74.90	2.67
T ₆	5.19 (24.96)	87.33	7.5	73.97	12.07
T ₇	6.00 (35.76)	82.86	9.6	66.51	9.46
CD P = 0.05	1.05		7.92		

Note: Weed data subject to $\sqrt{X + 0.5}$ transformation. Figures in parenthesis are actual values.

The results showed that hand weeding was most effective in removal of weeds from the field as indicated by the lowest weed biomass and the highest weed-control efficiency based on biomass. Among herbicidal weed control treatments, treatment T5 (PoE application of mesosulfuron+ idosulfuron @ 400 g a.i. ha⁻¹ at 20 DAS (T5) was found to be the best alternative option, because it recorded the lowest weed density, maximum weed-control efficiency based on population, and the lowest weed index. Its effective suppression of the mixed weed flora probably reduced crop-weed competition for nutrients, moisture, light, and space during the critical stages of wheat and maize growth (Singh et al., 2020). Recent studies also show that properly timed post-emergence herbicide mixtures or sequential herbicide applications (Vishwakarma et al., 2023) can reduce weed density and biomass, improve weed-control efficiency, and reduce yield loss under conservation and zero-tillage systems (Somasundaram et al., 2022; Bharti et al., 2023). The present study clearly demonstrated the importance of weed management, as the weedy check recorded significantly higher weed density, weed biomass and higher weed control efficiency of hand weeding and herbicidal weed control treatments in controlling the weeds both in terms of population and biomass (Caon and Vargas 2017, Rathod et al.2021).

Effect on crop growth and yield parameters

A significant response of various herbicidal treatments was observed in plant-growth and yield parameters compared with the untreated control. The maximum plant height (89.33 cm) was recorded under T2, which was statistically at par with all other herbicidal weed control treatments except the untreated control T1 (Table 2). The maximum number of tillers 298.47 m⁻² was recorded under T2 which was on par with treatment T5 (290.49 m⁻²). Lowest number of tillers 201.13 m⁻² was recorded under control T1. All the weed control treatments recorded significantly higher ear length (9.93 to 11.02 cm) as compared to control (8.69 cm). Maximum number of grains per ear head (43.37 to 48.22) was recorded in herbicide treated plots and weed free treatment which were on par with each other and significantly superior over weedy check with 34.96 seeds per ear head. The test weight varied from 40.93 to 42.75 g, however the differences in test weight could not attain the level of significance. Maximum crop biomass and straw yield (98.28 qha⁻¹ and 61.32 q ha⁻¹) was recorded under treatment T5 followed by treatment T2 (95.40 qha⁻¹ and 57.44 qha⁻¹) which were on par with each other along with treatments T3 and T7. Maximum grain yield (37.97 q ha⁻¹) and harvest index (39.80%) was recorded under treatment T2 which was on par with treatment T5 (PoE application of mesosulfuron+ idosulfuron @ 400 g a.i. ha⁻¹ at 20 DAS (T5) and significantly higher as compared to rest of the treatments. The lowest crop biomass, grain yield straw yield and harvest index 64.02 qha⁻¹, 21.58 qha⁻¹, 42.44 qha⁻¹ & 33.71% respectively were recorded under no weeding control treatment T1. Similar results were also observed by the Meena et al. (2019), Tuli et al. (2022) and Muralidhara et al. (2020) in late sown wheat crop.

Table 2 Effect of different weed management practices on crop growth and yield parameters									
Treatment	Plant height (cm)	No. of tillers (m ⁻²)	Ear length (cm)	Grains/ear	Test weight (g)	Biological yield (qha ⁻¹)	Grain yield (qha ⁻¹)	Straw yield (qha ⁻¹)	Harvest index (%)
T ₁	69.88	201.13	8.69	34.96	40.93	64.02	21.58	42.44	33.71
T ₂	89.33	298.47	11.02	46.77	42.75	95.40	37.97	57.44	39.80
T ₃	88.70	282.48	10.34	44.07	42.83	90.50	35.48	55.02	39.20
T ₄	87.04	260.71	10.17	44.63	41.30	88.12	33.92	54.20	38.49
T ₅	88.55	290.49	10.57	48.22	42.69	98.28	36.95	61.32	37.60
T ₆	86.29	274.60	10.24	44.41	42.59	88.60	33.38	55.22	37.68
T ₇	86.62	257.46	9.93	43.37	42.46	91.67	34.38	57.30	37.50

CD P = 0.05	5.31	15.66	0.85	4.61	NS	8.23	2.32	7.56	
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The weed control treatments provided congenial environment for better crop growth due to reduced competition for nutrients, water, space and light in the treated plots as compared to the control treatment which resulted in improved plant growth and yield parameters in the hand weeded and herbicidal treatment plots (Singh et al., 2020; Parmar et al., 2026). As a result of weed control there is substantial difference between the weed-free treatment and weedy check clearly demonstrated the adverse effect of weed competition on growth and yield attributes of wheat, which ultimately resulted in improved crop productivity as compared to weedy check (Meena et al., 2019) Parmar et al.(2022), Gopal et al.(2014) and Brajendra et al. (2012). The grain yield increased from 21.58 q ha⁻¹ under the weedy check to 37.97 qha⁻¹ under the weed-free treatment. Thus, the weed-free treatment produced an absolute yield advantage of 16.39 qha⁻¹ over the weedy check, equivalent to 75.94 % higher grain yield than the weedy check.

The result indicates that wheat is highly sensitive to weed competition under CA particularly during the crop establishment and early growth. Although, hand weeding is an effective weed-control practice in wheat under CA, it is labour-intensive and costly. The present study concluded that in a wheat based CA system on Vertisols, weeds can be managed effectively either by hand weeding twice at 20 and 40 days after sowing or through PoE application of mesosulfuron+ idosulfuron at 400 g a.i. ha⁻¹ at 20 DAS (T5) which was comparable to hand weeding and will be economically beneficial due to lower cost of herbicide under the CA system in Vertisol.

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