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Impact of establishment methods and weed control treatments on weed dynamics and yield of wheat

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Abstract
A field experiment was conducted at Jabalpur, Madhya Pradesh, during the *rabi* seasons of 2022-23 and 2023-24 to study the influence of different establishment methods and weed control treatments on weed dynamics and wheat yield. The experiment was laid out in a split-plot design with three replications, comprising four establishment methods in the main plots: zero tillage, zero tillage with chemical stale seedbed, conventional tillage, and conventional tillage with stale seedbed. Four weed control treatments were assigned to the subplots: clodinafop-propargyl + metsulfuron-methyl (60 + 4 g/ha) as post-emergence, mesosulfuron-methyl + iodosulfuron-methyl sodium (12 + 2.4 g/ha) as post-emergence, hand weeding at 20 and 40 days after sowing (DAS), and a weedy check. Among the establishment methods, conventional tillage with stale seedbed significantly reduced the total weed population and weed biomass, whereas zero tillage increased weed density and dry matter. Among the herbicidal treatments, the application of clodinafop-propargyl + metsulfuron-methyl (60 + 4 g/ha) effectively controlled the density and dry weight of both grassy and broadleaf weeds, resulting in 87.63% and 83.93% higher grain yield compared to the other weed control treatments during both years of the study.

Keywords: Establishment methods, weed control treatments, clodinafop+metsulfuron, stale seedbed

Introduction
Wheat (*Triticum aestivum* L.) is a vital cereal crop, serving as a staple food for much of the global population and contributing significantly to food security. Globally, wheat covers 221.94 million hectares, with a production of 780.05 million metric tons and productivity of 3510 kg/ha (USDA, 2021-22). In India, wheat occupies 30.54 million hectares, producing 106.41 million metric tons with a productivity of 3484 kg/ha (ICAR-IIWBR, 2021-22) [9]. Madhya Pradesh accounts for 5.99 million hectares, yielding 17.63 million metric tons at 3298 kg/ha (Department of Agriculture, M.P., 2020) [3]. Despite its adaptability, wheat faces biotic and abiotic stresses, with weed infestations causing 30-80% yield losses (Chauhan *et al*., 2012) [1]. Crop establishment methods; conventional tillage, reduced tillage, and zero tillage affect weed flora, density, and dry matter accumulation. Conventional tillage initially controls weeds but increases the weed seed bank (Hobbs *et al*., 2008) [8]. Reduced tillage preserves soil structure but faces higher weed pressure, while zero tillage minimizes soil disturbance but depends on herbicides (Friedrich *et al*., 2012) [6]. Herbicides are essential for modern weed management, but their overuse has led to herbicide-resistant weeds, threatening agricultural sustainability (Heap, 2014) [7]. This study examines the effects of establishment methods and weed control strategies on weed density, dry matter, and wheat yield, aiming to develop sustainable production practices.

Materials and Methods
The experiment was conducted during the *rabi* seasons of 2022-23 and 2023-24 at the Instructional Research Farm, Krishi Nagar, Adhartal, Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.). A split-plot design with three replications was employed, comprising sixteen treatments derived from four establishment methods and four weed control treatments. The establishment methods included; zero tillage, zero tillage with chemical stale seedbed, conventional tillage and conventional tillage with stale seedbed.

The weed control treatments included four treatments; clodinafop + metsulfuron (60+4 g/ha, as post-emergence), mesosulfuron-methyl + iodosulfuron-methyl sodium (12+2.4 g/ha, as post-emergence), hand weeding at 20 and 40 DAS and weedy check Fertilizers (120 N: 60 P_2O_5: 40 K_2O kg/ha) were applied uniformly, with half of the nitrogen and all phosphorus and potassium as basal, and the remaining nitrogen in two splits after first and second irrigation. Weed data were collected randomly from five locations in each plot, and weeds were identified and counted species-wise. After recording the density, the collected weed samples were sun-dried for two days and then oven-dried at 60 ± 5°C for 48 hours to determine their dry weight. Weed control efficiency (WCE) and weed index (WI) were calculated using the following formulae:

$$\text{WCE}\ (\%) = \frac{\text{DWC-DWT}}{\text{DWC}} \times 100$$

Where,
DWC = Dry weight of weeds in weedy check plot
DWT = Dry weight of weeds in treated plot

$$\text{Weed index}\ (\%) = \frac{\text{X-Y}}{\text{X}} \times 100$$

Where,
X = Yield from weed-free plot
Y = Yield from treated plot for which weed index is to be estimated
Data on weed density and dry weight were transformed through square-root method [(×+0.5)½] before analysis of variance (ANOVA) to reduce the higher coefficient of variation in original/ observed data (Das, 1999) [2].

Results and Discussion

The experimental field was infested with *Phalaris minor* (little canary grass), *Medicago denticulata* (tooth burclover), *Chenopodium album* (lambsquarters), *Solanum nigrum* (black nightshade), and other weed species. During both the years of the experiment, the density of *Phalaris minor* (141.00/m² and 170.33/m²) and *Medicago denticulata* (104.30/m² and 137.33/m²) was higher than that of *Chenopodium album* (35.00/m² and 49.00/m²) and *Solanum nigrum* (13.00/m² and 26.67/m²). Similar findings were reported by Jain *et al*. (2007) [10] in Jabalpur, Madhya Pradesh.

Among the establishment methods, zero tillage resulted in the highest weed population and dry matter accumulation for both grassy and broadleaf weeds, with the lowest Weed Control Efficiency (WCE) at 60 DAS (37.50% in 2022-23 and 25.96% in 2023-24). In contrast, conventional tillage with stale seedbed consistently recorded the lowest weed population and dry matter accumulation, achieving the highest WCE (45.56% in 2022-23 and 39.37% in 2023-24), comparable to zero tillage with chemical stale seedbed (44.47% in 2022-23 and 37.10% in 2023-24).

Among the weed control treatments, the weedy check exhibited the highest weed population and dry matter accumulation for all species, whereas hand weeding twice significantly reduced these parameters and achieved the highest WCE, reaching 55.10% at 60 DAS during 2022-23 and maintaining similarly high levels in 2023-24 (40.69%). Both herbicidal treatments; clodinafop-propargyl + metsulfuron-methyl and mesosulfuron + iodosulfuron-methyl sodium were highly effective in controlling weed populations and dry matter accumulation across all species. Specifically, clodinafop-propargyl + metsulfuron-methyl demonstrated effectiveness comparable to hand weeding for broadleaf weeds, while mesosulfuron + iodosulfuron-methyl sodium was more effective against the grassy weed *(Phalaris minor)*. Similar associations of these weed species with wheat crops were reported by Sharma *et al*. (2020) [15], Raj *et al*. (2024) [14], and Mruthunjaya (2020) [13].

Table 1: Species wise weed density under establishment methods and weed control treatments at 60 DAS in wheat.

Treatments	*Phalaris minor*		*Medicago denticulata*		*Chenopodium album*		*Solanum nigrum*		Other	
Establishment Methods	**2022-23**	**2023-24**	**2022-23**	**2023-24**	**2022-23**	**2023-24**	**2022-23**	**2023-24**	**2022-23**	**2023-24**
T1: Zero tillage	7.12 (54.33)	8.71 (78.42)	5.73 (33.42)	6.95 (48.75)	4.68 (22.08)	5.57 (31.00)	4.46 (19.92)	5.45 (29.67)	3.73 (13.50)	4.56 (20.33)
T2: Zero tillage with chemical stale seedbed	6.56 (45.92)	8.39 (72.92)	5.27 (28.75)	6.26 (39.75)	4.29 (18.83)	5.20 (27.25)	3.97 (16.58)	4.94 (24.75)	3.27 (10.33)	3.87 (14.58)
T3: Conventional tillage	6.90 (51.17)	8.59 (76.42)	5.55 (31.42)	6.37 (41.08)	4.34 (19.42)	5.47 (30.00)	4.24 (18.08)	5.45 (29.92)	3.55 (12.17)	4.22 (17.42)
T4: Conventional tillage with stale seedbed	6.34 (43.33)	8.32 (71.58)	5.14 (27.58)	5.59 (32.25)	4.08 (17.25)	4.88 (24.08)	3.80 (14.75)	4.66 (21.75)	3.27 (10.33)	3.71 (13.33)
S.Em±	0.13	0.05	0.12	0.17	0.05	0.05	0.13	0.15	0.09	0.11
C.D.(P=0.05)	0.44	0.18	0.41	0.6	0.19	0.16	0.43	0.51	0.33	0.40
Weed Control Treatments										
W1: Clodinafop - propargyl 15% + Metsulfuron methyl 1% (60+4 g a.i./ha) PoE	6.24 (38.75)	8.29 (68.42)	4.72 (22.17)	5.63 (32.08)	3.80 (14.00)	4.85 (23.08)	3.71 (13.50)	4.67 (21.75)	3.32 (10.67)	3.96 (15.42)
W2: Mesosulfuron - methyl 3% + Iodosulfuron - methyl sodium 0.6% (12+2.4 g a.i./ha) PoE	5.49 (29.75)	7.21 (51.50)	4.98 (24.50)	5.88 (34.50)	3.95 (15.17)	4.97 (24.33)	3.79 (14.08)	4.88 (23.58)	3.51 (11.92)	4.12 (16.67)
W3: Hand weeding at 20 and 40 DAS	5.22 (26.83)	7.16 (50.83)	4.73 (22.17)	5.78 (33.25)	3.71 (13.67)	4.74 (22.25)	3.47 (12.00)	4.66 (21.50)	3.66 (13.00)	4.25 (17.75)
W4: Weedy check	9.97 (99.42)	11.35 (128.58)	7.26 (52.33)	7.87 (62.00)	5.93 (34.75)	6.56 (42.67)	5.50 (29.75)	6.29 (39.25)	3.33 (10.75)	4.01 (15.83)
S.Em±	0.14	0.12	0.15	0.19	0.12	0.10	0.15	0.15	0.10	0.09
C.D.(P=0.05)	0.42	0.34	0.44	0.55	0.36	0.30	0.45	0.44	0.30	0.27

Table 2: Species wise weed biomass and weed control efficiency (WCE%) under establishment methods and weed control treatments at 60 DAS in wheat.

Treatments	*Phalaris minor*		*Medicago denticulata*		*Chenopodium album*		*Solanum nigrum*		Other		WCE (%)	
Establishment Methods	**2022-23**	**2023-24**	**2022-23**	**2023-24**	**2022-23**	**2022-23**	**2022-23**	**2023-24**	**2022-23**	**2023-24**	**2022-23**	**2023-24**
T1: Zero tillage	4.31 (25.22)	5.61 (35.10)	3.54 (12.82)	4.07 (16.63)	3.34 (11.04)	3.73 (13.52)	3.09 (9.38)	3.62 (12.84)	2.93 (8.32)	3.66 (13.17)	37.50	25.96
T2: Zero tillage with chemical stale seedbed	3.86 (19.62)	4.27 (19.71)	3.20 (10.10)	3.69 (13.45)	3.03 (8.91)	3.36 (10.81)	2.78 (7.42)	3.18 (9.77)	2.74 (7.13)	3.36 (10.96)	44.47	37.10
T3: Conventional tillage	4.25 (24.63)	5.51 (31.75)	3.50 (12.45)	3.87 (14.95)	3.23 (10.15)	3.59 (12.44)	2.99 (8.73)	3.48 (11.75)	2.89 (7.95)	3.54 (12.18)	39.79	28.66
T4: Conventional tillage with stale seedbed	3.70 (17.94)	4.16 (17.93)	3.02 (8.82)	3.55 (12.34)	2.92 (8.14)	3.27 (10.22)	2.69 (6.85)	3.04 (8.84)	2.55 (6.19)	3.23 (10.12)	45.56	39.37
S.Em±	0.09	0.10	0.09	0.06	0.06	0.04	0.04	0.07	0.05	0.09	0.57	0.56
C.D.(P=0.05)	0.33	0.36	0.31	0.22	0.19	0.15	0.14	0.23	0.18	0.29	1.96	1.95
Weed Control Treatments												
W1: Clodinafop - propargyl 15% + Metsulfuron methyl 1% (60+4 g a.i./ha) PoE	3.63 (12.70)	4.34 (18.62)	3.12 (9.29)	3.47 (11.64)	2.92 (8.09)	3.38 (10.95)	2.56 (6.10)	3.30 (10.50)	2.33 (5.03)	2.97 (8.37)	49.27	38.70
W2: Mesosulfuron - methyl 3% + Iodosulfuron - methyl sodium 0.6% (12+2.4 g a.i./ha) PoE	2.21 (4.44)	3.98 (15.82)	3.29 (10.39)	3.77 (13.79)	2.96 (8.38)	3.53 (12.03)	2.85 (7.68)	3.42 (11.28)	2.60 (6.33)	3.21 (9.87)	49.75	37.37
W3: Hand weeding at 20 and 40 DAS	2.17 (4.25)	3.95 (15.51)	2.56 (6.07)	3.17 (9.61)	2.86 (7.69)	3.31 (10.49)	2.50 (5.79)	2.81 (7.44)	3.00 (8.55)	3.69 (13.20)	55.10	40.69
W4: Weedy check	8.11 (66.02)	7.29 (54.56)	4.30 (18.44)	4.76 (22.33)	3.79 (14.07)	3.73 (13.52)	3.64 (12.8)	3.79 (13.98)	3.18 (9.66)	3.92 (14.98)	13.21	14.34
S.Em±	0.11	0.16	0.1	0.08	0.09	0.05	0.06	0.06	0.09	0.07	0.75	0.90
C.D.(P=0.05)	0.31	0.47	0.28	0.24	0.27	0.14	0.18	0.17	0.25	0.20	2.19	2.63

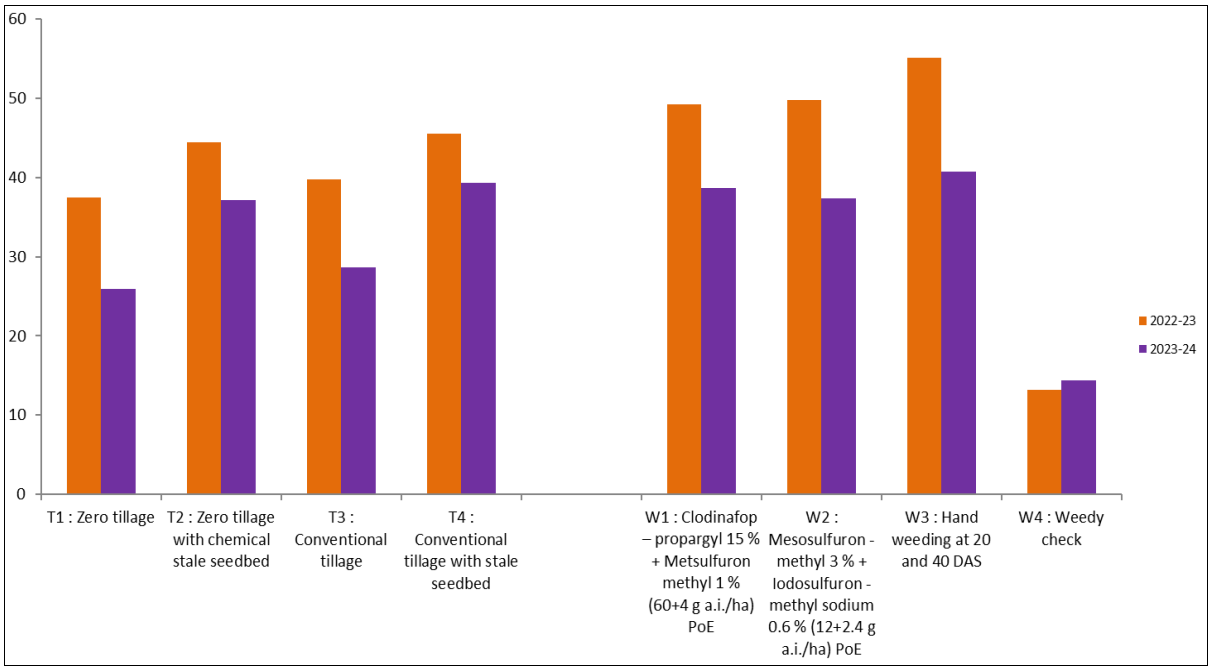

Fig 1: Weed control efficiency of different treatments during 2022-23 and 2023-24

Table 3: Effect of establishment methods and weed control treatments on grain yield, straw yield, harvest index and weed index of wheat.

Ttreatments	Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})		Harvest Index (%)		Weed Index (%)	
Establishment Methods	**2022-23**	**2023-24**	**2022-23**	**2023-24**	**2022-23**	**2023-24**	**2022-23**	**2023-24**
T1: Zero tillage	4441	4108	5268	4877	45.70	45.63	23.75	26.79
T2: Zero tillage with chemical stale seedbed	5018	4680	5782	5338	46.34	46.54	13.86	16.62
T3: Conventional tillage	4663	4208	5441	5172	46.10	44.78	19.95	24.97
T4: Conventional tillage with stale seedbed	5328	4946	5860	5731	47.53	46.26	8.55	11.86
S.Em±	105.0	117.3	113.2	138.4	0.64	1.04	1.77	2.07
C.D.(P=0.05)	363.4	406.0	391.7	478.8	NS	NS	6.14	7.15
Weed Control Treatments								
W1: Clodinafop - propargyl 15% + Metsulfuron methyl 1% (60+4 g a.i./ha) PoE	5104	4710	5720	5432	47.08	46.43	12.37	16.07
W2: Mesosulfuron - methyl 3% + Iodosulfuron - methyl sodium 0.6% (12+2.4 g a.i./ha) PoE	4947	4563	5604	5348	46.85	45.94	15.07	18.68
W3: Hand weeding at 20 and 40 DAS	5413	5039	6048	5675	47.22	47.07	7.10	10.21
W4: Weedy check	3986	3631	4979	4662	44.52	43.77	31.56	35.28
S.Em±	78.4	81.4	116.5	113.6	0.69	0.69	1.33	1.45
C.D.(P=0.05)	228.8	237.5	340.1	331.7	2.01	2.02	3.90	4.23

Harvest index (%) & Weed index (%)

The highest harvest index and lowest weed index were observed under conventional tillage with a stale seedbed, achieving 47.53% and 46.26% for the harvest index and 8.55% and 11.86% for the weed index during 2022-23 and 2023-24, respectively, which were comparable to zero tillage with a chemical stale seedbed. In contrast, the lowest harvest index and highest weed index were recorded under zero tillage, with values of 45.70% and 45.63% for the harvest index and 23.75% and 26.79% for the weed index during the respective years.

Among the weed control treatments, hand weeding twice recorded the highest harvest index (47.22% and 47.07%) and the lowest weed index (7.10% and 10.21%) during 2022-23 and 2023-24, respectively. These results were comparable to the application of clodinafop-propargyl + metsulfuron-methyl at 60+4 g/ha, which achieved harvest index values of 47.08% and 46.43% and weed index values of 12.37% and 16.07% during the respective years. The lowest harvest index and highest weed index were recorded under the weedy check treatment.

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