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Weed dynamics and productivity of wheat as influenced by establishment methods and weed control treatments

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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 assess the impact of establishment methods and weed control treatments on weed dynamics and wheat (*Triticum aestivum*) productivity. The experiment was laid out in a split-plot design with three replications, including four establishment methods in the main plots: zero tillage, zero tillage with chemical stale seedbed, conventional tillage and conventional tillage with stale seedbed and four weed control treatments in the sub plots: 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 weedy check. Among the establishment methods, conventional tillage with stale seedbed resulted in higher dry matter accumulation (1059.78 and 1016.89 g/m² during 2022–23 and 2023–24, respectively), effective tillers (328.95/m² in 2022–23 and 310.72/m² in 2023–24), and grain yield (5328 kg/ha in 2022–23 and 4946 kg/ha in 2023–24) of wheat, while significantly reducing the density and dry weight of total weeds. Among the various weed control treatments, hand weeding twice (at 20 and 40 DAS) was the most effective, as it significantly reduced the density and dry weight of total weeds and achieved the highest grain yield (5413 kg/ha in 2022–23 and 5039 kg/ha in 2023–24). This was followed by the application of clodinafop-propargyl + metsulfuron-methyl at 60 + 4 g/ha, which was superior to other weed control treatments.

Keywords: Weed control treatments, tillage, grain yield, stale seedbed, wheat, weed

Introduction
Wheat (*Triticum aestivum* L.) is one of the most important cereal crops globally, serving as a primary source of calories and nutrition for a large portion of the world's population. Its widespread cultivation across diverse agro-climatic zones underscores its adaptability; however, this adaptability also exposes it to numerous biotic and abiotic stresses. Among these, weed infestation represents one of the most significant challenges, capable of causing severe yield losses ranging from 30% to 80%, depending on the weed species and their density (Chauhan *et al.*, 2012). Weeds not only compete with the crop for essential resources such as nutrients, water, sunlight, and space but also act as alternate hosts for pests and diseases, further threatening crop productivity. To address these challenges, several weed management strategies have been developed, with the stale seedbed technique emerging as a particularly effective approach. This technique involves the elimination of weeds that emerge prior to sowing through pre-sowing irrigation followed by herbicide application or shallow tillage. By removing weeds early in the crop cycle, the stale seedbed method significantly reduces the weed seed bank in the soil, thereby limiting subsequent weed emergence during critical stages of crop growth. This method is especially beneficial in cropping systems where weed pressure is high and poses a persistent threat to productivity. In densely spaced crops like wheat, where manual or mechanical weeding is often impractical due to labor intensity and high costs, herbicides play an indispensable role in controlling weeds. Modern herbicides are designed to selectively target grassy and broadleaf weeds, offering farmers an efficient and cost-effective solution for weed management. However, the indiscriminate and repeated use of herbicides has led to the emergence of herbicide-resistant weed species, posing a significant challenge to sustainable wheat production systems (Yaduraju and Das, 2002) [5].

Considering the importance of integrated weed management strategies in enhancing wheat productivity, the present study focuses on evaluating the effects of different establishment methods and weed control treatments on weed dynamics and productivity of wheat.

Materials and Methods

The field 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 used, involving sixteen treatment combinations based on four establishment methods and four weed control strategies. The establishment methods consisted of zero tillage, zero tillage with chemical stale seedbed, conventional tillage and conventional tillage with stale seedbed. The weed control treatments included; clodinafop + metsulfuron-methyl (60+4 g/ha, as post emergence at 25 DAS), mesosulfuron-methyl + iodosulfuron-methyl sodium (12+2.4 g/ha, as post emergence at 25 DAS), hand weeding at 20 and 40 DAS and weedy check treatment. 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. For field preparation, no tillage was required for zero tillage plots, while conventional tillage plots were subjected to two passes of ploughing, one pass of disc harrowing, and levelling with a planker. In stale seedbed treatments, shallow irrigation was followed by herbicide application (Glufosinate-ammonium for zero tillage with chemical stale seedbed) or shallow harrowing (for conventional tillage with stale seedbed) before sowing. Weed data were collected randomly from five locations in each plot, with weeds identified and counted species-wise. After recording the weed density, the samples were sun-dried for two days, then oven-dried at 60±5 °C for 48 hours to measure their dry weight.

Results and Discussion

Establishment methods

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. Among the treatments, conventional tillage with stale seedbed significantly reduced the density and dry weight of total weeds and achieved the highest weed control efficiency (45.56% in 2022–23 and 39.37% in 2023–24), followed by zero tillage with chemical stale seedbed (44.47% in 2022–23 and 37.10% in 2023–24). These treatments were significantly superior to conventional tillage and zero tillage, likely due to the removal of germinated sprout seeds that were active in the upper soil layer. Conventional tillage with stale seedbed recorded the highest dry matter accumulation in wheat (1059.78 g/ha in 2022–23 and 1016.89 g/ha at harvest in 2023–24) compared to all other treatments during crop growth and at harvest. Yield-attributing traits, such as effective tillers/m², grains/earhead, earhead length, test weight, and grain and straw yield, were also higher under this treatment compared to others. This can be attributed to effective weed control, which reduced the competition from broad-leaved and grassy weeds, leading to significant improvement in dry matter accumulation and a higher number of effective tillers. These results align with the findings of Jain *et al*. (2010) [3] and Kumar *et al.* (2003) [2].

Weed control treatments

During crop growth and at maturity, the lowest density and dry weight of total weeds were observed with hand weeding twice (at 20 and 40 DAS), which achieved the highest weed control efficiency (55.10% in 2022–23 and 40.69% in 2023–24), followed by the application of clodinafop-propargyl + metsulfuron-methyl at 60+4 g/ha (49.27% in 2022–23 and 38.70% in 2023–24) and mesosulfuron + iodosulfuron at 12+2.4 g/ha (49.75% in 2022–23 and 37.37% in 2023–24) compared to the weedy check. The weed control achieved with these herbicides, namely clodinafop-propargyl + metsulfuron-methyl and mesosulfuron + iodosulfuron, can be attributed to their phytotoxic effects on a broad spectrum of weeds. The application of clodinafop-propargyl + metsulfuron-methyl significantly increased the grain and straw yield, followed by mesosulfuron + iodosulfuron. The highest values for yield attributes and yield were recorded under hand weeding twice. These findings are in close agreement with those reported by Das (2008) and Singh *et al.* (2018) [4]. In contrast, the lowest values for yield attributes and yield in the weedy check treatment could be attributed to severe competition from weeds for essential resources such as moisture and nutrients, which rendered the crop plants less competitive. This competition adversely affected crop growth and productivity.

Table 1: Effect of establishment methods and weed control treatments on density of total weeds.

Treatments	20 DAS		40 DAS		60 DAS		Harvest	
Establishment Methods	**2022-23**	**2023-24**	**2022-23**	**2023-24**	**2022-23**	**2023-24**	**2022-23**	**2023-24**
T_1: Zero tillage	13.30 (229.5)	14.95 (290.92)	9.31 (118.25)	11.78 (183.17)	11.76 (143.25)	14.31 (208.17)	9.42 (90.17)	12.16 (148.50)
T_2: Zero tillage with chemical stale seedbed	12.39 (198.67)	13.94 (252.83)	8.41 (98.08)	10.37 (143.92)	10.73 (120.42)	13.23 (179.25)	8.67 (76.67)	11.08 (123.50)
T_3: Conventional tillage	13.06 (221.25)	14.54 (274.67)	8.87 (109.42)	11.14 (165.00)	11.27 (132.25)	13.82 (194.83)	9.11 (84.33)	11.67 (137.00)
T_4: Conventional tillage with stale seedbed	12.11 (189.92)	13.58 (239.46)	8.07 (90.83)	9.94 (131.83)	10.39 (113.25)	12.62 (163.00)	8.38 (71.42)	10.74 (115.92)
SEm±	0.19	0.20	0.14	0.23	0.12	0.09	0.11	0.10
C.D.(P=0.05)	0.64	0.70	0.47	0.78	0.42	0.33	0.37	0.34
Weed Control Treatments								
W1 : Clodinafop – propargyl 15% + Metsulfuron methyl 1% (60+4 g a.i./ha) PoE	16.66 (277.67)	18.71 (350.88)	8.97 (80.58)	12.35 (153.17)	9.95 (99.08)	12.67 (160.75)	7.80 (60.58)	10.48 (109.75)
W2: Mesosulfuron - methyl 3% +	16.92	18.71	9.03	12.49	9.77	12.27	7.92	10.65

Iodosulfuron - methyl sodium 0.6% (12+2.4 g a.i./ha) PoE	(286.25)	(350.58)	(82.00)	(157.00)	(95.42)	(150.58)	(62.58)	(113.42)
W3: Hand weeding at 20 and 40 DAS	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	9.37 (87.67)	12.06 (145.58)	8.96 (80.83)	11.43 (130.67)
W4: Weedy check	16.57 (275.42)	18.88 (356.42)	15.94 (254.00)	17.69 (313.75)	15.07 (227.00)	16.98 (288.33)	10.89 (118.58)	13.08 (171.08)
SEm±	0.19	0.16	0.15	0.18	0.16	0.17	0.21	0.11
C.D.(P=0.05)	0.55	0.47	0.44	0.51	0.47	0.49	0.62	0.33
Interaction T×W : Factor(W) at same level of T	NS	S	NS	S	NS	NS	NS	NS
Interaction W×T: Factor(T) at same level of W	NS	S	NS	S	NS	NS	NS	NS

*Original values are in parentheses. Data subjected to square root transformation.
NS-Not Significant.
S-Significant.

Table 2: Effect of establishment methods and weed control treatments on dry weight of total weeds.

Treatments	**20 DAS**		**40 DAS**		**60 DAS**		**Harvest**	
Establishment Methods	**2022-23**	**2023-24**	**2022-23**	**2023-24**	**2022-23**	**2023-24**	**2022-23**	**2023-24**
T_1: Zero tillage	2.76 (8.51)	3.29 (12.53)	3.92 (19.85)	4.37 (25.06)	7.88 (69.21)	9.38 (91.26)	9.04 (81.52)	9.50 (90.20)
T_2: Zero tillage with chemical stale seedbed	2.49 (6.75)	2.93 (9.77)	3.37 (14.48)	3.84 (18.52)	7.00 (52.44)	7.97 (64.70)	8.27 (68.39)	8.89 (78.97)
T_3: Conventional tillage	2.66 (7.88)	3.13 (11.30)	3.72 (18.03)	4.17 (22.52)	7.59 (63.05)	9.04 (83.06)	8.60 (73.63)	9.22 (85.21)
T_4: Conventional tillage with stale seedbed	2.48 (6.68)	2.81 (8.90)	3.16 (12.34)	3.69 (16.86)	6.86 (48.22)	7.68 (59.45)	8.04 (64.48)	8.58 (73.71)
SEm±	0.04	0.04	0.03	0.05	0.07	0.08	0.05	0.07
C.D.(P=0.05)	0.12	0.13	0.10	0.17	0.25	0.27	0.18	0.23
Weed Control Treatments								
W1: Clodinafop – propargyl 15% + Metsulfuron methyl 1% (60+4 g a.i./ha) PoE	3.21 (9.86)	3.82 (14.10)	3.47 (11.63)	4.13 (16.62)	6.39 (40.51)	7.76 (60.07)	8.17 (66.42)	8.70 (75.38)
W2: Mesosulfuron - methyl 3% + Iodosulfuron - methyl sodium 0.6% (12+2.4 g a.i./ha) PoE	3.21 (9.86)	3.81 (14.10)	3.69 (13.24)	4.30 (18.02)	6.33 (39.71)	7.93 (62.79)	8.29 (68.50)	8.70 (75.48)
W3 : Hand weeding at 20 and 40 DAS	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	5.66 (31.56)	7.51 (56.24)	8.11 (65.54)	8.48 (71.59)
W4 : Weedy check	3.25 (10.10)	3.83 (14.29)	6.31 (39.82)	6.95 (48.32)	10.94 (121.13)	10.86 (119.36)	9.38 (87.55)	10.29 (105.65)
SEm±	0.03	0.03	0.07	0.07	0.10	0.13	0.07	0.08
C.D.(P=0.05)	0.09	0.09	0.20	0.20	0.28	0.37	0.21	0.23
Interaction T×W : Factor(W) at same level of T	NS	S	S	S	S	S	NS	NS
Interaction W×T : Factor(T) at same level of W	NS	S	S	S	S	S	NS	NS

*Original values are in parentheses. Data subjected to square root transformation.
NS-Not Significant.
S-Significant.

Table 3: Effect of establishment methods and weed control treatments on yield attributes of wheat.

Treatments	**Effective tillers (m^{-2})**		**No. of grains earhead^{-1}**		**Length of ear head (cm)**		**Test weight**		**Dry matter accumulation (g m^{-2}) at harvest**	
Establishment Methods	**2022-23**	**2023-24**	**2022-23**	**2023-24**	**2022-23**	**2023-24**	**2022-23**	**2023-24**	**2022-23**	**2023-24**
T_1: Zero tillage	288.92	261.70	38.45	36.56	8.32	7.94	43.17	42.49	917.51	850.97
T_2: Zero tillage with chemical stale seedbed	313.36	295.75	43.19	40.77	8.45	8.17	43.83	42.98	1023.31	956.44
T_3: Conventional tillage	294.92	275.00	40.90	36.97	8.36	7.98	43.81	42.79	950.85	891.34
T_4: Conventional tillage with stale seedbed	328.95	310.72	44.09	42.36	8.51	8.29	44.85	43.16	1059.78	1016.89
SEm±	7.43	7.86	0.89	0.90	0.10	0.16	0.68	0.42	17.28	14.87
C.D.(P=0.05)	25.70	27.19	3.09	3.11	NS	NS	NS	NS	59.81	51.44
Weed Control Treatment										
W1 : Clodinafop – propargyl 15% + Metsulfuron methyl 1% (60+4 g a.i./ha) PoE	317.56	298.75	42.68	40.42	8.64	8.20	43.77	42.66	1032.44	970.87
W2 : Mesosulfuron - methyl 3% + Iodosulfuron - methyl sodium 0.6% (12+2.4 g	306.36	280.08	40.98	38.66	8.04	7.61	43.61	42.59	1005.09	947.78

a.i./ha) PoE										
W3 : Hand weeding at 20 and 40 DAS	335.53	320.41	45.93	43.07	8.66	8.61	44.96	43.79	1096.02	1028.04
W4 : Weedy check	266.70	243.92	37.04	34.51	8.29	7.96	43.31	42.39	817.91	768.94
SEm±	5.17	5.66	1.20	1.54	0.11	0.13	0.60	0.54	11.42	12.90
C.D.(P=0.05)	15.10	16.52	3.51	4.49	0.31	0.36	NS	NS	33.32	37.64
Interaction T×W : Factor(W) at same level of T	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction W×T : Factor(T) at same level of W	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*NS-Not Significant.
S-Significant.

Table 4: Effect of establishment methods and weed control treatments on yield of wheat.

Treatments	**Grain yield (kg ha^{-1})**		**Straw yield (kg ha^{-1})**	
Establishment Methods	**2022-23**	**2023-24**	**2022-23**	**2023-24**
T_1: Zero tillage	4441	4108	5268	4877
T_2: Zero tillage with chemical stale seedbed	5018	4680	5782	5338
T3: Conventional tillage	4663	4208	5441	5172
T_4: Conventional tillage with stale seedbed	5328	4946	5860	5731
SEm±	105.0	117.3	113.2	138.4
C.D.(P=0.05)	363.4	406.0	391.7	478.8
Weed Control Treatments				
W1 : Clodinafop – propargyl 15% + Metsulfuron methyl 1% (60+4 g a.i./ha) PoE	5104	4710	5720	5432
W2 : Mesosulfuron - methyl 3% + Iodosulfuron - methyl sodium 0.6% (12+2.4 g a.i./ha) PoE	4947	4563	5604	5348
W3 : Hand weeding at 20 and 40 DAS	5413	5039	6048	5675
W4 : Weedy check	3986	3631	4979	4662
SEm±	78.4	81.4	116.5	113.6
C.D.(P=0.05)	228.8	237.5	340.1	331.7
Interaction T×W : Factor(W) at same level of T	NS	NS	NS	NS
Interaction W×T : Factor(T) at same level of W	NS	NS	NS	NS

*NS-Not Significant.
S-Significant.

Conclusion

This study highlights the differential impacts of establishment methods and weed control strategies on weed dynamics and wheat productivity. Zero tillage was associated with higher weed density and biomass, while conventional tillage with stale seedbed demonstrated the most effective weed suppression and yield enhancement, closely followed by zero tillage with chemical stale seedbed. Among weed control strategies, hand weeding twice (at 20 and 40 DAS) achieved the highest values for yield attributes, grain yield, and straw yield, followed by clodinafop + metsulfuron-methyl (60+4 g/ha) and mesosulfuron-methyl + iodosulfuron-methyl sodium (12+2.4 g/ha). The integration of conventional tillage with a stale seedbed and herbicide application emerged as the most effective and sustainable approach for optimizing wheat productivity and managing weed populations.

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