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Rishita Singh
M.Sc.(Ag.) Agronomy, Department of Agronomy, Tilak Dhari P.G. College, Jaunpur, Uttar Pradesh, India

Dr. Shrish Kumar Singh
Professor and HOD, Department of Agronomy, Tilak Dhari P.G. College, Jaunpur, Uttar Pradesh, India

Dr. Chandra Prakash Singh
Assistant Professor, Department of Agronomy, Tilak Dhari P.G. College, Jaunpur, Uttar Pradesh, India

Dr. Gopal Swaroop Pathak
Assistant Professor, Department of Agronomy, Tilak Dhari P.G. College, Jaunpur, Uttar Pradesh, India

Dr. Harivansh Singh
Assistant Professor, Department of Agronomy, Tilak Dhari P.G. College, Jaunpur, Uttar Pradesh, India

Uddeshya Singh
MBA (Agribusiness management) Veer bahadur Singh Purvanchal University, Jaunpur, Uttar Pradesh, India

Abhiraj Verma
M.Sc.(Ag.) Agronomy, Department of Agronomy Tilak Dhari P.G. College, Jaunpur, Uttar Pradesh, India

Corresponding Author:
Rishita Singh
M.Sc.(Ag.) Agronomy, Department of Agronomy, Tilak Dhari P.G. College, Jaunpur, Uttar Pradesh, India

Performance of herbicides for control of broad-leaved weeds in wheat (*Triticum aestivum* L.)

Rishita Singh, Shrish Kumar Singh, Chandra Prakash Singh, Gopal Swaroop Pathak, Harivansh Singh, Uddeshya Singh and Abhiraj Verma

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Abstract
A field experiment was conducted during the rabi season of 2021-22 on sandy loam soil at the Agricultural Research Farm (Pili Kothi), Department of Agronomy, Tilak Dhari Post Graduate College, Jaunpur (U.P.). The trial was laid out in a randomized block design with three replications and comprised ten treatments: weedy check (T_1), weed-free (T_2), metsulfuron-methyl @ 0.004 kg ha^{-1} (T_3), carfentrazone @ 0.02 kg ha^{-1} (T_4), pendimethalin @ 1.25 kg ha^{-1} (T_5), sulfosulfuron @ 0.025 kg ha^{-1} (T_6), metribuzin @ 0.2 kg ha^{-1} (T_7), 2,4-D @ 0.500 kg ha^{-1} (T_8), sulfosulfuron + metsulfuron @ 32 g ha^{-1} (T_9), and clodinofop + metsulfuron @ 60 + 4 g ha^{-1} (T_{10}). Wheat variety HD-2967 was used as the test crop. Among herbicidal treatments, carfentrazone @ 0.02 kg ha^{-1} recorded maximum plant height and dry matter accumulation across growth stages, which translated into superior yield attributes—effective plant population (307 m^{-2}), grains ear^{-1} (52.0), and 1000-grain weight (39.03 g). Consequently, carfentrazone produced the highest grain yield (4455.33 kg ha^{-1}), straw yield (6214.75 kg ha^{-1}), and biological yield (10,670.80 kg ha^{-1}), significantly outperforming other weed control treatments.

Keywords: Wheat, herbicide, weed, yield

Introduction

Wheat (*Triticum aestivum* L.), emend. Fiori and Paol., is one of the most important staple cereals worldwide. Belonging to the family *Poaceae*, it is the most extensively cultivated cereal crop, ranking first in global cultivation, followed by rice. During 2021-22, wheat was cultivated across nearly 222.62 million hectares, yielding around 779 million metric tons with an average productivity of 3.49 metric tons per hectare (Anonymous, 2021-22) [2]. The European Union is the largest wheat producer globally, followed by China, India, and the United States.

Weed infestation poses a major challenge to wheat cultivation, as it significantly reduces productivity. Effective weed control is therefore vital to harness the full genetic yield potential of the crop. Weeds compete with wheat for essential resources such as nutrients, water, sunlight, and space, thereby lowering yield and complicating harvesting operations. In order to sustain wheat production for an ever-growing population and ensure food security, integrated weed management is crucial.

Besides competition for growth resources, weeds also release allelopathic chemicals through their roots and other plant parts into the rhizosphere of wheat, further suppressing crop growth. The use of herbicides has proven to be effective in reducing weed density and enhancing grain yield (Akbar *et al*., 2011; Jabran *et al*., 2008; Razzaq *et al*., 2010) [3, 5, 11].

In wheat fields, infestations occur from both grassy weeds (e.g., *Phalaris minor* and *Avena* spp.) and broad-leaved weeds (e.g., *Chenopodium album*, *Convolvulus arvensis*, *Anagallis arvensis*, and *Melilotus alba*). Broad-leaved weeds, in particular, are problematic because they compete aggressively for water, nutrients, light, and space, especially during the early growth stages of wheat. Though manual weeding can help manage these weeds, it requires a large labor force at peak infestation periods. However, due to rising labor costs and limited availability, manual weeding often becomes impractical. Herbicides, on the other hand, provide a more feasible option as they effectively control both inter-row and intra-row weeds.

The intensity and type of weed infestation in wheat depend on factors such as agronomic practices, soil type, irrigation quality, cropping systems, and weed control methods adopted. Yield losses caused by weeds can vary depending on their species, density, and environmental conditions, but these losses can be minimized through appropriate management strategies. Crop rotation, tillage practices, and herbicide application significantly influence the weed flora in wheat fields (Anderson and Beck, 2007) [1].

For controlling broad-leaved weeds in wheat, the most commonly used herbicides in India are Metsulfuron, 2,4-D, and Carfentrazone (Chhokar and Sharma, 2008) [4]. Among the different weed management approaches, chemical herbicides remain the most effective tools for safeguarding wheat yield and quality. Numerous researchers have studied the performance of various herbicides and confirmed their efficacy in controlling weeds in wheat production.

Materials and Methods

A field experiment was conducted during rabi season of 2021-22 on sandy loam soil at Agricultural Research Farm (Pili Kothi), Department of Agronomy, Tilak Dhari Post Graduate College, Jaunpur (U.P.). Which is situated on the right side of river Gomati at latitude of 25^{0}43'58" N along with longitude of 82^{0}41'10" E and altitude of 83 meters above mean sea level. The study area experiences a sub-tropical, sub-humid climate characterized by hot summers and cool winters. The winter season spans from November to February, while the southwest monsoon generally begins in the third week of June and lasts until late September. Occasional rainfall also occurs during winter, and frost is commonly observed towards the end of January.

During the experimental period, the maximum temperature varied between 18.5 °C and 40.5 °C, while the minimum ranged from 6.7 °C to 21.6 °C. Total rainfall received during the crop growth period was 69.2 mm. The soil at the experimental site was sandy loam in texture, slightly alkaline, and non-saline. It was low in available nitrogen (96.75 kg ha^{-1}), medium in organic carbon (0.43%) and phosphorus (23.6 kg ha^{-1}), but rich in available potassium (123.0 kg ha^{-1}).

The experiment was conducted using a randomized block design with three replications. Ten treatments were included: weedy check (T_1), weed-free (T_2), metsulfuron methyl @ 0.004 kg ha^{-1} (T_3), carfentrazone @ 0.02 kg ha^{-1} (T_4), pendimethalin @ 1.25 kg ha^{-1} (T_5), sulfosulfuron @ 0.025 kg ha^{-1} (T_6), metribuzin @ 0.2 kg ha^{-1} (T_7), 2,4-D @ 0.5 kg ha^{-1} (T_8), sulfosulfuron + metsulfuron @ 32 g ha^{-1} (T_9), and clodinafop + metsulfuron @ 60 + 4 g ha^{-1} (T_{10}). Wheat variety HD-2967 served as the test crop. Weed-free plots were maintained manually from germination until harvest.

Sowing was carried out on November 26 during the rabi season with a seed rate of 100 kg ha^{-1}. All recommended agronomic practices were followed. Fertilization included 120 kg ha^{-1} nitrogen (as urea), 60 kg ha^{-1} phosphorus (as single superphosphate), and 40 kg ha^{-1} potassium (as muriate of potash). One-third of nitrogen and the full doses of phosphorus and potassium were applied as basal before sowing, with the remaining nitrogen top-dressed in two equal splits after the first and third irrigations. Herbicides were applied using a hand sprayer with a spray volume of 500 L ha^{-1}.

From each sampling area, five plants were randomly selected, and their height was measured using a meter scale—from the plant base to the tip of the tallest leaf before spike emergence, and later up to the spike tip. The mean shoot height was calculated and expressed in centimetres. Dry matter accumulation was recorded at 30, 60, 90, and 120 days after sowing (DAS).

For dry matter estimation, plants from a 25 cm row length in the second row of each plot were harvested close to the ground at the same intervals (30, 60, 90, and 120 DAS). The samples were oven-dried at 85 °C and the dry matter was expressed as g/m².

Experimental Findings

Table 1: Number of shoots, plant height and crop dry matter accumulation of wheat as affected by different weed management practices at 60 DAS

	Treatment	No. of shoots/m^2	Plant height (cm)	Dry matter accumulation (g/m^2)
T_1	Weedy check	273.00	73.23	241.10
T_2	Weed free	350.00	79.70	283.50
T_3	Metsulfuron-methyl @ 0.004 kg ha^{-1}	278.67	76.34	261.50
T_4	Carfentrazone @ 0.02 kg ha^{-1}	346.00	78.60	280.25
T_5	Pendimethalin @ 1.25 kg ha^{-1}	292.00	76.40	271.40
T_6	Sulfosulfuron @ 0.025 kg ha^{-1}	276.00	75.67	269.50
T_7	Metribuzin @ 0.2 kg ha^{-1}	275.33	76.03	264.25
T_8	2,4-D @ 0.500 kg ha^{-1}	341.00	77.26	278.08
T_9	Sulfosulfuron + metsulfuron @ 32 g ha^{-1}	277.33	76.10	269.75
T_{10}	Clodinofop + metsulfuron @ 60 + 4g ha^{-1}	274.33	74.67	252.25
	SEm±	0.98	0.26	0.29
	CD at 5%	2.92	0.78	0.87

Table 2: Yield attributes of wheat of as affected by different weed management practices at 120 days

	Treatment	No. of spikes m^{-2}	No. of grain $spike^{-1}$	Test weight (g)	Length of spike (cm)
T_1	Weedy check	212.00	42.00	33.97	9.35
T_2	Weed free	289.00	54.00	40.74	12.31
T_3	Metsulfuron-methyl @ 0.004 kg ha^{-1}	245.33	49.67	36.49	10.38
T_4	Carfentrazone @ 0.02 kg ha^{-1}	285.00	52.00	39.03	10.82
T_5	Pendimethalin @ 1.25 kg ha^{-1}	226.33	46.67	36.27	10.30
T_6	Sulfosulfuron @ 0.025 kg ha^{-1}	215.00	44.00	36.68	10.18
T_7	Metribuzin @ 0.2 kg ha^{-1}	217.67	47.67	35.88	10.22
T_8	2,4-D @ 0.500 kg ha^{-1}	270.00	51.00	38.81	10.65
T_9	Sulfosulfuron + metsulfuron @ 32 g ha^{-1}	268.00	50.00	37.81	10.46
T_{10}	Clodinofop + metsulfuron @ 60 + 4g ha^{-1}	251.00	43.00	34.63	9.92
	SEm±	2.07	1.47	1.27	0.46
	CD at 5%	6.20	4.41	3.79	1.38

Table 3: Grain, straw, biological yield and harvest index of wheat as affected by different weed management practices.

	Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
T_1	Weedy check	3560.50	6163.33	9723.83	36.61
T_2	Weed free	4560.75	6216.50	10777.25	42.31
T_3	Metsulfuron-methyl @ 0.004 kg ha^{-1}	3870.25	6163.50	10033.75	38.58
T_4	Carfentrazone @ 0.02 kg ha^{-1}	4455.33	6214.75	10670.80	41.75
T_5	Pendimethalin @ 1.25 kg ha^{-1}	4170.15	6203.00	10373.15	40.20
T_6	Sulfosulfuron @ 0.025 kg ha^{-1}	3965.58	6176.25	10141.83	39.10
T_7	Metribuzin @ 0.2 kg ha^{-1}	3970.75	6185.00	10155.75	39.10
T_8	2,4-D @ 0.500 kg ha^{-1}	4255.30	6211.50	10466.80	40.65
T_9	Sulfosulfuron + metsulfuron @ 32 g ha^{-1}	4076.75	6179.25	10256.00	39.74
T_{10}	Clodinofop + metsulfuron @ 60 + 4 g ha^{-1}	3605.50	6061.67	9667.17	37.30
	SEm±	0.91	1.29	11.24	0.37
	CD at 5%	2.73	3.89	33.65	1.09

Results and Discussion

Effect of weed control measures on Number of shoots, plant height and crop dry matter accumulation of wheat

From Table 1, it was observed that the growth parameters of wheat were greatly affected by different weed management practices. The maximum number of shoots, plant height, and dry matter production were recorded under the weed-free condition. These findings are in close agreement with the results reported by Meena and Singh (2011) [8]. Among the herbicidal treatments, the application of Carfentrazone at 0.02 kg ha^{-1} produced the highest values for shoots per square metre (346.00), plant height (78.60 cm), and dry matter accumulation (280.25 g m^{-2}). In contrast, the weedy check resulted in the lowest values for shoots per square metre (273.00), plant height (73.23 cm), and dry matter accumulation (241.10 g m^{-2}). The effectiveness of herbicides in weed management not only reduces competition for essential growth resources but also promotes better crop growth and development due to reduced nutrient depletion by weeds. These observations are in agreement with the findings of Pala *et al*., (2018) [9].

Effect of weed control measures on yield attributes of wheat

The yield attributing characters such as number of spikes m^{-2}, spike length, grains $spike^{-1}$, test weight was greatly influenced by different weed management practices and out of different treatments weed free treatments recorded maximum number of spikes m^{-2}, spike length, grains $spike^{-1}$, test weight over untreated weedy check. These results are corroborated with research findings of Kironmay *et al*., (2006) [14].

From the table-2. Among the herbicidal treatments Carfentrazone @ 0.02 kg ha^{-1} recorded maximum number of spikes m^{-2} (285.00), spike length (10.82 cm), grains $spike^{-1}$ (52.00), test weight (39.03) followed 2,4-D @ 0.500kg ha^{-1} Maximum number of spikes m^{-2}, spike length, grains $spike^{-1}$, test weight under these treatments is due to lesser crop weed competition, which in turn gave better environment for crop growth and development. Moreover, in these treatments weed population, and their dry matter accumulation was significantly reduced due to the broad-spectrum control herbicide. These results are in line with Pala *et al*., (2018) [9]. Singh *et al*., (2015) [12] has also reported lowest number of spike m^{-2}, grains $spike^{-1}$ and 1000 grain weight (g) under weedy check plot of wheat crop.

Wheat yield and harvest index

Crop yield is an ultimate result of successful crop growth as well as yield components. The various weed management practices had shown significant influence on grain and straw yield of wheat crop.

From the Table-3. The weed free condition produced highest grain yield (4560.75 kg ha^{-1}), straw yield (6216.50 kg ha^{-1}), biological yield (10777.25 kg ha^{-1}) and harvest index (42.32%) which was at par with Carfentrazone @ 0.02 kg ha^{-1} @ and on par with rest applied herbicide. The higher grain yield ha^{-1} in weed free and Carfentrazone @ 0.02 kg ha^{-1} treated plot. The higher grain yield, straw yield, biological yield and harvest index in weed free and herbicidal treated plot as compare to weedy plot may be because of poor crop weed competition and better growth of plants as evident from higher crop dry matter accumulation at different stages of crop growth. Whereas, lowest grain yield (3560.50 kg ha^{-1}), straw yield (6161.33 kg ha^{-1}), biological yield (9721.83 kg ha^{-1}) and harvest index (36.62%) were observed in untreated control treatment,which is mainly due to uncontrolled weed growth and poor performance of crop yield attributing characters Tomar and Tomar (2004) [13], Pal *et al*., (2016) [9] have also reported that herbicidal treated plots significantly reduced the crop weed competition and resulted in increased vegetative growth and yield attributing characters of wheat which ultimately lead to highest grain yield and harvest index.

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