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Effect of weed management practices on weed density and yield of wheat (*Triticum aestivum* L.)

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Abstract
A field research was carried out at Agronomy farm, Sai Institute of Paramedical and Allied Science, Dehradun during *rabi* 2021-22. Twelve practices of weed management were used for research with three replications in randomized block design. The wheat variety PBW-154 was used for sowing purpose. The results revealed that post-emergences application of Clodinafop + Metsulfuron (60+4) @ 64 g *a.i.* ha^{-1} was found most effective reduce density of individual as well as other and total weeds, which was statistically at par with over rest of the treatments, except weed free, two hand weeding at 20 and 40 DAS and Sulfosulfuron + Metsulfuron @ 30+2 g ha^{-1} and also increasing grain (51.20 q ha^{-1}), straw (64.10 q ha^{-1}) and biological (115.20 q ha^{-1}) yield of wheat.

Keywords: Wheat, yield, weed density

Introduction
Next to rice, wheat (*Triticum aestivum* L.) is the second-most significant cereal crop, making up 36.2% of the nation's total grain production. It is grown in a variety of agroclimatic environments. There are 215.29 million hectares of wheat in the world, with a yield of 730.84 million tonnes and an annual productivity of 33.90 q ha^{-1}. The European Union is the world's top producer of wheat, followed by China, India, and the United States of America. Although, there are 667 mt of wheat. With the population growing over the last 15 years, consumption has been rising steadily, and in 2020, it's expected to soar even higher to 780 million tonnes. According to estimates, India will require at least 125 million tonnes of wheat by 2023, compared to its current production of 11.5 million tonnes (Anonymous, 2022) [1].
India's food security is built on wheat. It is used to make things like bread, cakes, biscuits, noodles, petri dishes, and chapatti. According to Rathore (2001), wheat grains contain 60–68% starch, 8–15% protein, 1.5–2% fat, 2.5–2% cellulose, and 1.5–2% minerals. By delivering more than 50% of the calories to the population who rely on it the most, the wheat crop significantly contributes to the nation's food security.
Weeds are regarded as one of the obstacles to growing wheat. The advent of high-yielding dwarf types, which, in comparison, need a lot of water and fertiliser has made it easier for weeds to invade new areas and grow lushly. Numerous weeds have invaded the wheat crop, competing with it for resources and reducing grain yield, growth and yield qualities. The continuous and indiscriminate use of a single herbicide can result in a variety of issues, including weed resistance, residue in crops and soil, pollution risks, and health risks to creatures that are not the intended target (Singh *et al*. 2012) [12]. Weeds have been successfully controlled with herbicides. *Phalaris minor* has developed a resistance to isoproturon as a result of ongoing use (Malik and Singh, 1995) [9]. For the control of Isoproturon resistant *Phalaris minor* in rice-wheat growing areas, three alternative herbicides have been suggested: Fenoxaprop-p-ethyl, Clodinafop-propargyl, and Sulfosulfuron (Chhokar and Malik, 2002) [4]. Therefore, it is necessary to assess alternative ready-to-use herbicides with a broad range and a different mechanism of action for the management of wheat's complex weed ecology. The current investigation is being done with the aforementioned facts in consideration.

Materials and Methods
A field research was carried out at Agronomy farm, Sai Institute of Paramedical and Allied Science, Dehradun during *rabi* 2021-22. Twelve practices of weed management were used for research with three replications in randomized block design.

This region was comes under subtropical climate and is situated at 30°2 North latitude,77°93 East longitudes with an altitude of 650 meters above mean sea level. This region receives 61.5 mm rainfall during experimental period. The average temperature for the maximum and minimum is 37.8 °C and 3.5 °C, respectively. The experimental site's soil had a silty loam with adequate drainage qualities and a reaction pH of 8.5. The soil had low organic carbon (0.32%) and available nitrogen (180.00 kg ha^{-1}) and medium in available phosphorus (14.70 kg ha^{-1}) as well as potassium (280.5 kg ha^{-1}). The experiment was carried out an twelve treatments i.e. Sulfosulfuron @ 25 g *a.i.* ha^{-1}, Metsulfuron @ 4 g *a.i.* ha^{-1}, Clodinafop @ 60 g *a.i.* ha^{-1}, Metribuzin @ 210 g *a.i.* ha^{-1}, Sulfosulfuron + Metsulfuron (30+2) @ 32 g *a.i.* ha^{-1}, Sulfosulfuron + Metribuzin (25+210) @ 235 g *a.i.* ha^{-1}, Clodinafop + Metsulfuron (60+4) @ 64 g *a.i.* ha^{-1}, Fenoxaprop –p – ethyl @ 120 g *a.i.* ha^{-1}, Fenoxaprop-p-ethyl + Metsulfuron (120+4) @ 124 g *a.i.* ha^{-1}, two hand weeding (20 and 40 DAS), weedy check and weed free. Three replications were used to ensure that the results were consistent. All the treatments were applied as per treatments *i.e*. all the herbicides used as post emergence at 30 DAS with the help of a knap-sack sprayer used flat-fan nozzle with a spray volume of 250 L ha^{-1} water and hand weeding was done 20 and 40 days after sowing.

Field was well pulverized seed bed with the help of harrowed (twice), cultivator and planking. After that the plots were marked according to the layout plan and leveled properly with spade. The experimental crop was evenly fertilised with 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} in the forms of urea, DAP and MOP, respectively. One-third of the nitrogen, full doses of the phosphate and potassium, and the remaining two-thirds of the nitrogen, through urea, were applied as basal dressing. Crop wheat and variety PBW-154 was sown at 20 cm rows distance at the rate of 100 kg ha^{-1} seed rate with the help of seed drill on November 28, 2018. One pre-sown irrigation was applied for good germination and well establishment. After sowing, five irrigations were applied at stress condition (no any water stress). Crop was harvest, when fully matured *i.e*. light brown color occurs at April 18, 2019.

A quadrate measuring 1.0 × 1.0 m was randomly selected from each plot to count weed density (Mahajan and Fatima, 2017) at 30, 60 and 90 DAS and expressed number m^{-2}. *Phalaris minor*, *Chenopodium album*, *Convolvulus arvensis* and *Melilotus indica* individuals were counted individual as the most prevalent weed species in each plot, remaining weeds were included in the other weeds count. The number of weeds data was transformed to a square root using (x+1).

After weighing the entire biomass, the harvest from each net plot was threshed separated, and clean grains were sun dried to retain 12% moisture. Utilising kg $plot^{-1}$, the grain yield was determined and translated to q ha^{-1}. The weight of the net total product $plot^{-1}$ was noted before threshing. The straw yield, expressed in q ha^{-1}, was calculated using the weight of the total produce from the net plot. After the crop was harvested, the product was sun dried for a week before the weight of all the material gathered from the net plot area of each plot was recorded and converted to q ha^{-1}. The harvest index, as determined using the Donald and Hamblin (1976) [5] formula, is the ratio of economic yield to biological yield. It quantifies the % partitioning of photosynthates towards grains and is calculated using the formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield (q ha}^{-1})}{\text{Biological yield (q ha}^{-1})} \times 100$$

The analysis of variance (ANOVA) method, recommended by Gomez and Gomez (1984) [6], was used to statistically analyse the data collected from the various observations. After determining that the F-test was significant, a critical difference at 0.05 probability level was calculated to compare the treatments. The crucial differences (CD) and the standard error of the mean (SEm±) should be computed in each significant case in the manner specified below.

Results and Discussion

Weed flora

During experimentation, major weeds *i.e. Phalaris minor*, *Chenopodium album*, *Convolvulus arvensis* and *Melilotus indica* were observed. A wheat crop with a similar weed flora has also been observed by Bharat *et al*. (2012) [2], Bhullar *et al*. (2012) [3] and Singh *et al*. (2020) [11].

Effect of weed management practices on weed density at 30, 60 and 90 DAS

The species-wise weed density data collected at different stages of crop growth show that both grassy and non-grassy weeds were present in the wheat crop. Weed free plot reduced significantly individual weed species as well as total weed density at various growth stages of wheat crop followed by two hand weeding at 20 and 40 DAS. This might be due to early stage weed free crop growth higher and cover the surface of soil thus reduces weed density at later stages. The findings seem to correspond with Singh *et al*. (2020) [11].

All the herbicidal treatments, application of post-emergences herbicides *i.e*. Clodinafop + Metsulfuron (60+4) @ 64 g *a.i.* ha^{-1} was maximum reduce density of individual as well as other and total weeds, which was statistically at par with Sulfosulfuron + Metsulfuron @ 30+2 g ha^{-1} and both were comparable to two hand weeding and significantly superior to rest of the weed management practices. The broad-spectrum activity of the herbicide, particularly on established plants of both narrow and broad leaf weeds, was the cause of the high weed density in the Clodinafop + Metsulfuron and Sulfosulfuron + Metsulfuron treated plots, almost in agreement with Singh *et al*. (2011) [13] findings.

Effect of weed management practices on yield

The highest grain, straw and biological yield was produced by weed-free plot followed by two hand weeding at 20 and 40 DAS, which were also significantly better than the remaining weed management techniques. This yield was comparable to that produced by post-emergence applications of Clodinafop + Metsulfuron @ 60 +4 g ha^{-1}, Sulfosulfuron + Metsulfuron @ 30 +2 g ha^{-1} and two-hand weeding. It might be because the different weed management techniques have a suffocating effect. Which led to more food being moved ethically from the source to the washbasin, increasing the yield. These findings from Malik *et al*. (2013) [8] and Tomar & Tomar (2014) [14] are almost identical. Harvest index remained unaffected with weed management practices.

Table 1: Effect of weed management practices on weed density in wheat crop

Treatment	Weed density at 30 DAS (Number m^{-2})					
	Phaleris minor	**Chenopodium album**	**Convolvulus arvensis**	**Melilotus alba**	**Other weeds**	**Total weeds**
Sulfosulfuron @ 25 g *a.i.* ha^{-1}	4.66 * (20.75) **	5.11 (25.20)	4.48 (19.10)	2.98 (7.92)	4.34 (17.85)	9.15 (82.80)
Metsulfuron @ 4 g *a.i.* ha^{-1}	4.70 (21.12)	5.07 (24.80)	4.46 (18.95)	3.02 (8.16)	4.38 (18.28)	9.10 (81.92)
Clodinafop @ 60 g *a.i.* ha^{-1}	4.79 (22.00)	5.15 (25.55)	4.50 (19.30)	3.03 (8.25)	4.52 (19.51)	9.19 (83.87)
Metribuzin @ 210 g *a.i.* ha^{-1}	4.77 (21.80)	5.16 (25.70)	4.49 (19.25)	3.03 (8.21)	4.33 (17.10)	9.24 (84.50)
Sulfosulfuron + Metsulfuron (30+2) @ 32 g *a.i.* ha^{-1}	4.76 (21.75)	5.03 (24.40)	4.40 (18.45)	2.84 (7.12)	4.48 (17.80)	9.06 (81.10)
Sulfosulfuron + Metribuzin (25+210) @ 235 g *a.i.* ha^{-1}	4.75 (21.63)	5.05 (24.55)	4.45 (19.05)	2.92 (7.56)	.4.28 (15.75)	9.15 (82.82)
Clodinafop + Metsulfuron (60+4) @ 64 g *a.i.* ha^{-1}	4.59 (20.15)	5.01 (24.21)	4.40 (18.45)	2.85 (7.18)	4.09 (12.75)	8.95 (79.20)
Fenoxaprop –p – ethyl @ 120 g *a.i.* ha^{-1}	4.79 (22.05)	5.22 (26.35)	4.58 (20.05)	3.05 (8.35)	4.96 (20.12)	9.30 (85.56)
Fenoxaprop-p-ethyl + Metsulfuron (120+4) @ 124 g *a.i.* ha^{-1}	4.68 (20.98)	5.04 (24.52)	4.45 (18.90)	2.87 (7.31)	4.59 (11.75)	9.13 (82.53)
Two hand weeding (20 and 40 DAS)	2.65 (6.05)	3.00 (8.15)	2.46 (5.10)	2.28 (4.20)	3.15 (8.95)	5.22 (26.35)
Weedy check	4.69 (21.10)	5.07 (24.82)	5.00 (16.40)	2.89 (7.39)	4.97 (20.25)	9.05 (82.75)
Weed free	2.49 (5.21)	2.66 (6.25)	2.34 (4.55)	2.10 (3.45)	3.02 (8.15)	5.14 (25.85)
S.Em±	0.06	0.11	0.12	0.09	0.07	0.11
CD (P ≥0.05%)	0.19	0.36	0.0.38	0.29	0.25	0.35

*The value in parenthesis are original value
**Value transformed by $\sqrt{X} + 1$

Table 2: Effect of weed management practices on weed density in wheat crop

Treatment	Weed density at 60 DAS (Number m^{-2})					
	Phaleris minor	**Chenopodium album**	**Convolvulus arvensis**	**Melilotus alba**	**Other weeds**	**Total weeds**
Sulfosulfuron @ 25 g *a.i.* ha^{-1}	2.40 (4.85)	3.50 (9.20)	2.28 (4.18)	1.65 (1.82)	2.81 (6.95)	4.97 (23.75)
Metsulfuron @ 4 g *a.i.* ha^{-1}	2.43 (4.95)	3.24 (9.50)	2.29 (4.25)	1.72 (1.98)	2.81 (6.98)	5.01 (24.15)
Clodinafop @ 60 g *a.i.* ha^{-1}	2.46 (5.10)	3.42 (10.78)	2.42 (4.95)	1.79 (2.24)	2.84 (7.15)	5.24 (26.55)
Metribuzin @ 210 g *a.i.* ha^{-1}	2.44 (4.98)	3.33 (10.25)	2.35 (4.60)	1.74 (2.09)	2.83 (7.11)	5.12 (25.30)
Sulfosulfuron + Metsulfuron (30+2) @ 32 g *a.i.* ha^{-1}	2.35 (4.57)	2.23 (4.10)	2.11 (3.60)	1.58 (1.52)	2.46 (5.15)	4.38 (18.25)
Sulfosulfuron + Metribuzin (25+210) @ 235 g *a.i.* ha^{-1}	2.39 (4.75)	2.53 (5.50)	2.26 (4.15)	1.64 (1.72)	2.79 (6.85)	4.90 (23.08)
Clodinafop + Metsulfuron (60+4) @ 64 g *a.i.* ha^{-1}	2.21 (3.90)	2.03 (4.05)	1.94 (2.78)	1.45 (1.11)	2.45 (5.08)	4.21 (16.70)
Fenoxaprop –p – ethyl @ 120 g *a.i.* ha^{-1}	2.49 (5.25)	3.13 (9.02)	2.45 (5.10)	1.84 (2.45)	2.86 (7.25)	5.45 (28.70)
Fenoxaprop-p-ethyl + Metsulfuron (120+4) @ 124 g *a.i.* ha^{-1}	2.37 (4.65)	3.08 (8.75)	2.21 (4.05)	1.59 (1.60)	2.77 (6.71)	4.74 (21.50)
Two hand weeding (20 and 40 DAS)	1.51 (1.30)	2.31 (4.35)	2.19 (3.94)	1.58 (1.54)	2.65 (6.10)	3.36 (10.35)
Weedy check	5.38 (28.10)	5.29 (27.10)	4.20 (17.45)	2.85 (7.15)	5.22 (26.35)	9.58 (90.80)
Weed free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
S.Em±	0.05	0.11	0.10	0.08	0.11	0.08
CD (P ≥0.05%)	0.16	0.37	0.31	0.35	0.35	0.25

Table 3: Effect of weed management practices on weed density in wheat crop

Treatment	Weed density at 90 DAS (Number m^{-2})					
	Phaleris minor	Chenopodium album	Convolvulus arvensis	Melilotus alba	Other weeds	Total weeds
Sulfosulfuron @ 25 g *a.i.* ha^{-1}	2.34 (4.50)	3.00 (8.15)	2.45 (5.12)	1.99 (2.99)	2.72 (6.45)	5.19 (26.30)
Metsulfuron @ 4 g *a.i.* ha^{-1}	2.39 (4.75)	3.17 (9.20)	2.49 (5.35)	2.02 (3.05)	2.75 (6.59)	5.27 (27.50)
Clodinafop @ 60 g *a.i.* ha^{-1}	2.46 (5.10)	3.49 (11.25)	2.62 (6.00)	2.03 (3.40)	2.80 (6.91)	5.63 (30.75)
Metribuzin @ 210 g *a.i.* ha^{-1}	2.46 (4.85)	3.47 (10.12)	2.60 (5.85)	2.01 (3.25)	2.80 (6.85)	5.40 (28.22)
Sulfosulfuron + Metsulfuron (30+2) @ 32 g *a.i.* ha^{-1}	1.84 (2.45)	2.76 (6.70)	2.29 (4.31)	1.82 (2.51)	2.62 (5.91)	4.97 (23.75)
Sulfosulfuron + Metribuzin (25+210) @ 235 g *a.i.* ha^{-1}	2.35 (4.18)	2.88 (7.35)	2.34 (4.61)	1.97 (2.96)	2.66 (6.13)	5.05 (24.55)
Clodinafop + Metsulfuron (60+4) @ 64 g *a.i.* ha^{-1}	1.81 (2.30)	2.50 (5.25)	2.00 (3.10)	1.66 (1.75)	2.33 (4.45)	4.69 (21.8)
Fenoxaprop –p – ethyl @ 120 g *a.i.* ha^{-1}	2.73 (6.50)	3.65 (12.55)	2.69 (6.35)	2.03 (5.15)	2.86 (7.21)	5.89 (33.85)
Fenoxaprop-p-ethyl + Metsulfuron (120+4) @ 124 g *a.i.* ha^{-1}	2.01 (3.00)	2.87 (7.02)	2.40 (4.99)	1.95 (2.85)	2.65 (6.05)	5.13 (25.35)
Two hand weeding (20 and 40 DAS)	1.87 (2.55)	2.78 (6.91)	2.31 (4.40)	1.88 (2.60)	2.62 (5.96)	3.96 (14.70)
Weedy check	6.25 (38.50)	5.69 (31.33)	4.30 (17.91)	2.94 (7.65)	5.94 (34.3)	10.14 (101.85)
Weed free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
S.Em±	0.06	0.16	0.13	0.10	0.12	0.09
CD (P ≥0.05%)	0.19	0.51	0.41	0.38	0.38	0.28

Table 4: Effect of weed management practices on weed density in wheat crop

Treatment	Yield (q ha^{-1})			Harvest index (%)
	Grain	Straw	Biological	
Sulfosulfuron @ 25 g *a.i.* ha^{-1}	46.20	60.45	106.65	39.96
Metsulfuron @ 4 g *a.i.* ha^{-1}	45.80	59.10	104.90	43.66
Clodinafop @ 60 g *a.i.* ha^{-1}	44.50	58.20	102.70	43.33
Metribuzin @ 210 g *a.i.* ha^{-1}	45.00	58.75	103.75	43.37
Sulfosulfuron + Metsulfuron (30+2) @ 32 g *a.i.* ha^{-1}	50.20	64.50	114.70	43.76
Sulfosulfuron + Metribuzin (25+210) @ 235 g *a.i.* ha^{-1}	47.10	61.15	108.25	43.51
Clodinafop + Metsulfuron (60+4) @ 64 g *a.i.* ha^{-1}	51.10	64.10	115.20	44.35
Fenoxaprop –p – ethyl @ 120 g *a.i.* ha^{-1}	43.18	58.65	101.83	42.40
Fenoxaprop-p-ethyl + Metsulfuron (120+4) @ 124 g *a.i.* ha^{-1}	47.50	61.50	108.65	43.71
Two hand weeding (20 and 40 DAS)	49.80	64.95	114.75	43.39
Weedy check	32.50	47.90	80.40	40.42
Weed free	52.50	66.45	118.95	44.13
S.Em±	1.33	1.03	1.48	1.19
CD (P ≥0.05%)	3.98	2.98	4.33	NS

Conclusion

Weed free plots and hand weeding at 20 and 40 DAS were found to minimise weed density at all development stages, followed by Clodinafop + Metsulfuron @ 60 +4 g ha^{-1}, according to the results of our one-year research. These methods improved the wheat crop's grain, straw and biological yield as well.

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