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Study on the efficacy of weed control in wheat (*Triticum aestivum* L.) with ready-mix and tank-mix herbicides

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Abstract
The impacts of ready-mix and tank-mix herbicides treatment on weed control in wheat were studied in the field during the *Rabi* season of 2022-23 at Dev Bhoomi Uttarakhand University, College of Agriculture, Dehradun, Uttarakhand, India. The agronomic replicated field experiment was carried out in a randomized complete block design, having ten treatments, *viz.* spray of ready-mix herbicide MES + IOD @ 12+2.4 g a.i. ha^{-1} and SUL + MET @ 25 + 4 g a.i. ha^{-1}, and other spray of tank-mix herbicide SUL + CAR @ 25 + 20 g a.i. ha^{-1}, SUL + (HAL+FLO) @ 25+12.76 g a.i. ha^{-1}, SUL + PYR @ 25+18 g a.i. ha^{-1}, CLO + MET @ 60+4 g a.i. ha^{-1}, CLO + (HAL+FLO) 60+12.76 @ g a.i. ha^{-1} and CLO + PYR @ 60 +18 @ g a.i. ha^{-1} and was compared with the weedy check and two-hand weeding (20 and 40 DAS). During the crop growth period, consistently lowest and highest densities of total weed were recorded under 2-HW (20 and 40 DAS) and weed check, respectively. Observation recorded from 30 DAS to 60 DAS showed that the density of total weeds was statistically at par in almost all the herbicidal treatments and was statistically superior in the reduction of total weeds as compared to weed check. Observation recorded at 90 DAS showed that, among the herbicidal treatments, application of SUL+CAR @ 25+20 g a.i. ha^{-1}, CLO+MET @ 60+4 g a.i. $ha^{-1,}$ and CLO+PYR @ 60+18 g a.i. ha^{-1} recorded significantly the lowest density of total weeds and was second best to 2-HW(20 and 40 DAS). Further, at harvest, 2-HW (20 and 40 DAS) and SUL+CAR @ 25+20 g a.i. ha^{-1} recorded at a par density of total weeds. The purpose of the research is to evaluate the response of ready-mix and tank-mix herbicides on weed dynamics in wheat and investigate the effect of ready-mix and tank-mix herbicides on the growth and yield of wheat. then calculate the economics of ready-mix and tank-mix herbicides for weed management in wheat. In Weed control, the experiment shows the result was the treatment of SUL+CAR 25 + 20g a.i. ha^{-1} and CLO+MET 60 + 4 g a.i. ha^{-1} results in increased crop growth, wheat yield, and improved weed suppression, and crop growth was observed with the treatment on sulfosulfuron + Carfentazole (25 + 20 g/ ha). Results indicated that ready-mix and tank-mix herbicide treatment on weed control in wheat resulted in antagonistic effects on wheat profitability as well as productivity.

Keywords: Crop growth, yield percentage, herbicide mixture, post-emergent, tank mix, weed management, wheat.

Introduction
Wheat is the most important component of the Indian diet's staple foods. According to the statistics database maintained by the FAO, wheat production in India occupied around 30 million hectares of land and resulted in a yearly output of 103.5 million tons of grain with an average yield of 3,533 kg ha^{-1} (FAO, 2020). Because of the rise in population, India's wheat production will need to expand by between 110 and 120 million tons by the year 2051 in order to meet the nation's needs. In addition, it is predicted that the area planted for wheat had fallen by approximately 5-6 M hectares by that point because of the growth in population pressure and the urbanization that occurred at that time. Considering the significance of these variables, it is essential to boost wheat production by 5 trillion ha^{-1} in order to completely satisfy the requirements of an ever-increasing population (Sharma *et al.*, 2013, and Singh *et al.*, 2019) [1, 11].

In general, weeds pose a significant threat to the production of wheat and act as a barrier to its growth. In order to increase wheat production, it is essential to select a method of weed management that is effective.

According to Mukherjee *et al*. (2011) [12], one of the most common strategies for managing weeds in wheat nowadays is the use of chemical weed control. This is because labour is in short supply and wages are high. The chemical approach of weed control is more efficient and requires less time and money than other methods, even though it is very successful at managing weeds. Weeds can be controlled without causing any mechanical damage, even within the rows, according to research by Chhokar *et al*. (2012) [13]. This is possible due to the structural similarities that weeds have with crops.

The purpose of the experiment titled "Study on the Efficacy of Weed Control in Wheat (*Triticum Aestivum L.*) with Ready-Mix and Tank-Mix Herbicides" was to determine how ready-mix and tank-mix herbicides respond to the weed dynamics in wheat, examine their impact on the growth and yield of wheat, and then figure out how cost-effective ready-mix and tank-mix herbicides are for controlling weeds in wheat. We talked about the difficulties that wheat farmers have when trying to control weed infestations, which can lead to large losses in crop production. Because hand weeding takes a significant amount of time and is labour-intensive, farmers are required to rely on herbicides in order to achieve easy and efficient weed management. The consistent application of herbicides that have analogous modes of action has led to changes in weed flora, which in turn has contributed to the development of herbicide resistance. On the other hand, the continued use of herbicides that have modes of action that are quite similar has led to changes in the weed flora and the development of herbicide resistance. In order to maintain weed populations at a level below a threshold and avoid or delay the development of weed resistance, the purpose of this study is to investigate how various herbicide mixes influence the growth and production performance of wheat crops.

Materials and Methods

A field experiment was conducted during the *Rabi* (winter) season of 2022-23 at Dev Bhoomi Uttarakhand University, Dehradun, and Uttarakhand. The experiment was laid out in a randomized complete block design with three replications on vertosols with pH of 8.4 and EC of 0.23 ds/m. Available major nutrients phosphorus (60 kg P_2O_5 ha^{-1}) potassium (60 kg K_2O ha^{-1}) nitrogen i.e. 60 kg ha^{-1} was applied in the basal application respectively. Tank mix herbicides treatment consisted of MES + IOD @ 12+2.4 g a.i. ha^{-1} and SUL + MET @ 25 + 4 g a.i. ha^{-1}, and application of tank-mix herbicide SUL + CAR @ 25 + 20 g a.i. ha^{-1}, SUL + (HAL+FLO) @ 25+12.76 g a.i. ha^{-1}, SUL + PYR @ 25+18 g a.i. ha^{-1}, CLO + MET @ 60+4 g a.i. ha^{-1}, CLO + (HAL+FLO) 60+12.76 @ g a.i. ha^{-1} and CLO + PYR @ 60 +18 @ g a.i. ha^{-1} and was compared with a weedy check and 2- HW (20 and 40 DAS) and a weedy check. Recommended doses of nitrogen, phosphorus, and potassium were given in the form of urea, diammonium phosphate, and mutate potash. Half of the recommended dose of N (60 kg/ha) and a full dose of P_20_5 (60 kg/ha) and K_20 (60kg/ha) were applied as basal, and the remaining nitrogen was applied after 30 DAS. The variety '*DBW-187,* was sown with a spacing of 20 cm with a seed rate of 150 kg/ha on 24 December 2022 during the year of experimentation. The area received irrigation every two weeks at regular intervals. All of the herbicides were sprayed using a backpack sprayer that was equipped with a flat–fan nozzle and had a spray volume of 500 liters/ha twenty to twenty-five days after the seeds were planted. The weed-free plot was kept that way by performing multiple rounds of manual weeding. At 20–25 DAS, we used a hand–operated wooden hoe to accomplish the in–between cultivation, and at 40-45 DAS, we used the hoe to pull weeds. The crop was picked on April 22 and April 30, 2023, respectively, to complete the harvest. With the assistance of a 1 m2 quadrate, the weed density and weed biomass were measured at 30, 60, and 90 DAS. Prior to conducting the statistical analysis, the data on weed characteristics were transformed using the square root function. The F-test method described in Gomez and Gomez (1984) [2] was utilized to do statistical analysis on each and every one of the collected data sets. To analyze the significance of the difference between the means, the least significant difference (LSD) values at a significance level of 0.05 were utilized.

Results and Discussion

Control of Weed

Weeds of experimental plots were *Chenopodium sp., Anagallis arvensis, Melilotus sp., Phyllanthus niruri, Ageratum conyzoides, Oxalis corniculata, Echinochloa colonum, Convolvulus arvensis, Amaranthus virid is, Portulaca oleraceae, Cynodon dactylon, Sida cordifolia and Digitaria sanguinalis.* All weed control treatments recorded significantly lower weed density than weedy check (Table 1). Among the herbicide treatments, application of tank mix herbicide sulfosulfuron + Canfentazole 25 + 20 g/ha exerted the maximum herbicide effect and caused the highest reduction in total weed density and total biomass which, however, was statistically at par with clodinafop + metsulfuron Hand weeding 2-HW (20 and 40 DAS) improves crop growth and yield while reducing weed infestation. This treatment, however, is not commercially viable for farmers due to the higher cost of manual labour. Thus, considering the economic and crop efficiency, the application of SUL+CAR 25 + 20g a.i. ha^{-1} and CLO+MET 60 + 4 g a.i. ha^{-1} results in increased crop growth, wheat yield, and improved weed suppression. Overall, these treatments had the highest net return and B:C, making them the most cost-effective for producers.

Fig 1: Show hand weeding

Table 1: Wheat plant height and dry matter accumulation are affected by pre-mix and tank-mix herbicides.

Treatment (Application Rate g a.i/ha)	Pre-mix herbicides				Tank mix herbicides		
	30 DAA	60 DAA	90 DAA	At harvest	30 DAA	60 DAA	90 DAA
MES+IOD [12+2.4] *	16.58	56.23	91.40	89.82	25.20	337.68b	937.07b
SUL+MET [25+4]	16.61	56.70	91.62	90.58	21.92	298.59b	867.25b
SUL+CAR [25+20]	17.19	57.50	90.63	89.30	27.89	335.60b	1230.61a
SUL+ (HAL+FLO) * [25+12.76]	16.50	55.80	88.40	87.41	22.88	307.25b	884.37b
SUL+PYR [25+18]	16.63	57.20	89.43	89.00	37.28	312.03b	996.32b
CLO+MET [60+4]	16.19	56.30	88.47	88.07	29.41	345.41ab	1219.68a
CLO+(HAL+FLO) * [60+12.76]	16.75	57.23	89.07	88.10	33.52	300.19b	884.75b
CLO+PYR [60+18]	16.68	54.53	89.97	89.13	35.28	332.93b	851.15b
HW (20&40DAS)	16.80	58.80	90.40	88.71	24.93	418.99a	1258.67a
Weedy check	15.96	52.15	91.93	90.43	21.28	252.99b	851.20b
SEm±	0.76	1.77	0.97	1.02	4.88	25.45	63.50
CD(P=0.05)	NS	NS	NS	NS	NS	74.28	185.36

Table 2: Tiller count and leaf area index of wheat as influenced by pre-mix and tank-mix herbicides.

Treatment (Application Rate g a.i/ha)	Pre-mix herbicides				Tank mix herbicides		
	30 DAA	60 DAA	90 DAA	At harvest	30 DAA	60 DAA	90 DAA
MES+IOD [12+2.4] *	250.67	408.00	436.00	434.67	0.16	2.25b	4.37b
SUL+MET [25+4]	230.67	406.67	453.33	453.33	0.14	1.99b	4.04b
SUL+CAR [25+20]	258.67	428.00	464.00	461.33	0.18	2.23b	5.74a
SUL+ (HAL+FLO) * [25+12.76]	236.00	373.33	416.00	436.00	0.15	2.04b	4.12b
SUL+PYR [25+18]	286.67	402.67	428.00	429.33	0.24	2.07b	4.65b
CLO+MET [60+4]	227.33	429.33	452.00	450.67	0.19	2.30ab	5.69a
CLO+(HAL+FLO) * [60+12.76]	278.67	428.00	402.67	442.67	0.21	2.00b	4.13b
CLO+PYR [60+18]	229.33	393.33	442.67	442.67	0.23	2.21b	3.97b
HW (20&40DAS)	278.67	417.33	436.00	480.00	0.16	2.79a	5.87a
Weedy check	229.33	402.67	425.33	425.33	0.14	1.68c	3.97b
S.Em±	29.41	11.64	13.05	12.49	0.03	0.17	0.30
CD(P=0.05)	NS	NS	NS	NS	NS	0.49	0.86

However, it can further be tested for varied locations over the season for its recommendation and adoption by the farmers of Uttarakhand.

Crop growth

The larger plant height, a greater number of tillers, and dry matter accumulation were observed with the treatment of sulfosulfuron + Carfentazole (25 + 20 g/ ha) and recorded substantially higher with Clodinafope + Metsulfuron methyle alone (Table 1). All these observations were made with the treatment on sulfosulfuron + Carfentazole (25 + 20 g/ ha). This agreed with what Singh *et al*. (1997) [6] discovered in their research.

Yield and yield parameters and economics

Application of tank mix herbicide Application of Chlodinofop + metsulfuron 60+4 g a.i. ha^{-1} and sulfosulfuron+ carfentrazone 25+20 g a.i. ha^{-1} was the most economically viable treatment because these treatments efficiently manage weeds and positively influence crop yield. It is important to mention that sulfosulfuron+ carfentrazone 25+20 g a.i. ha^{-1} although found to be the one of best treatments, but due to the higher cost of herbicide along with a little bit lower yield make this herbicide is economically less remunerative as compared to clodinafop + metsulfuron 60+4 g a.i. ha^{-1}.

Twice-hand weeding maintains higher CGR at the duration of 30-60 DAS and 90 DAS at harvest and was statistically at par to CLO+MET @ 60+4 g a.i. ha^{-1} at the duration 30 to 60 DAS and 60 to 90 DAS and SUL + CAR @ 25+20 g a.i. ha^{-1} at 60 to 90 DAS. In fact, 90 DAS to at harvest duration all the treatments showed at par crop growth rate, except CLO+MET @ 60+4 g a.i. ha^{-1} which showed significantly lowest CGR.

Application of herbicidal treatment did not bring significant change in RGR from 0-30 day's duration. From 30 days onward, weedy check, 2-HW (20 and 40DAS) and SUL+MET @ 25+4 g a.i. ha^{-1} recorded at par consistently higher RGR, though application of SUL+CAR @ 25+20 a g a.i. ha^{-1} and CLO+MET @ 60+4 g a.i. ha^{-1} produced at par RGR from 30-60 days and 60-90 days duration, and SUL+PYR and CLO + (HAL+FLO) produced at par RGR from 60-90 days and 90 days to at harvest.

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