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Vishal Vikram Singh
Ph.D. Scholar, Department of Agronomy, T.D.P.G. College, Jaunpur, Uttar Pradesh, India

Shrish Kumar Singh
Associate Professor, Department of Agronomy, T.D.P.G. College, Jaunpur, Uttar Pradesh, India

Tej Pratap
Senior Research Officer, Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar U.S. Nagar, Uttarakhand, India

Corresponding Author:
Vishal Vikram Singh
Ph.D. Scholar, Department of Agronomy, T.D.P.G. College, Jaunpur, Uttar Pradesh, India

Tank mix herbicide combination effect on weed and yield of wheat in North-Eastern plain zone

Vishal Vikram Singh, Shrish Kumar Singh and Tej Pratap

Abstract
A field experiment was carried out at main experiment station (Agronomy) of Pili kothi Farm, T.D.P.G. College, Jaunpur. Distt. Jaunpur (Uttar Pradesh) during *Rabi* of 2019-20 and 2020-2021 to assess the efficacy of herbicide combinations in wheat. Treatments comprised of eight different tank mix combinations of post-emergence herbicides with weed free and unweeded control. Total weed density and weed dry weight at 60 days after sowing was recorded minimum with Sulfosulfuron 75% + (Arylex 20.85% + Florasulam 20%) 25 + 12.76 g/ha at 30 DAS followed Sulfosulfuron 75% + (Arylex 6.95% + Pyroxsulam 25%) 25 + 23.96 g/ha at 30 DAS and considerably better than all other control measures except weed free situation and showed parity with the Clodinafop-propargyl 15% WP + Metsulfuron-methyl 20% WP 60 + 4 g/ha and Sulfosulfuron 75% + Metsulfuron-methyl 20% WP 25+4 g/ha and statistically better than all other treatments except weed free situation. Higher grain yield of wheat was observed in weed free (4522 kg/ha) and was at par with Sulfosulfuron 75% + (Arylex 20.85% + Florasulam 20%) 25 + 12.76 g/ha (4443 kg/ha) and significantly better than other treatments. In terms of grain yield Sulfosulfuron 75% + (Arylex 6.95% + Pyroxsulam 25%) 25 + 23.96 g/ha, Clodinafop-propargyl 15% WP + Metsulfuron-methyl 20% WP 60 + 4 g/ha and Sulfosulfuron 75% + Metsulfuron-methyl 20% WP 25+4 g/ha at par with each other. Results revealed that post-emergence application (PoE) of Sulfosulfuron 75% + (Arylex 20.85% + Florasulam 20%) 25 + 12.76 g/ha at 30 DAS and Sulfosulfuron 75% + (Arylex 6.95% + Pyroxsulam 25%) 25 + 23.96 at 30 DAS gave higher weed control efficiency (84.8 and 78.8%) at 60 DAS and lower weed index (1.74 and 3.66%). The weed free treatment recorded significant improvement in yield attributes, *viz*. number of effective tillers, grain weight per spike and 1000 grain weight followed by Sulfosulfuron 75% + (Arylex 20.85% + Florasulam 20%) 25 + 12.76 g/ha at 30 DAS followed by Sulfosulfuron 75% + (Arylex 6.95% + Pyroxsulam 25%) 25 + 23.96. All the weed control treatments significantly influenced the grain and straw yield of wheat excluding unweeded control.

Keywords: herbicides, wheat, yield, weed control efficiency, weed density and dry weight

Introduction
Wheat (*Triticum aestivum*) also known as the "King of Cereals" is the most important staple food of about 36% of the world populations. Wheat is widely grown throughout the temperate zones (in North Europe up to 60^0 N) and in some tropical and subtropical areas at higher elevations. The major wheat producing countries are China, India, USA, France, Russia, Canada, Australia, Pakistan, Turkey, UK, Argentina, Iran Italy etc. In India, it is grown in plains, plateaus as well as hills at altitude ranging from mean to 3000m above sea level. Wheat production in India after independence has taken a quantum jump. In 1956-61, the country produced 11 million tons of wheat while in 2020-21, the national production of wheat was 120.88 million tons. However, the miraculous boost up in production has been attained after 1966-67, the year in which the high yielding variety (HYV) programme was initiated. The spurt in wheat production after this year may be attributed to the introduction of the Mexican dwarf wheat which was very responsive to the high level of inputs such as chemical fertilizer and irrigation. Consequently, the productivity of wheat from 887 kg/ha in 1966-67 reached to 4050kg/ha in 2018-19. In India, the contribution of wheat to total food grains production has been ranging between 34-36% in last five years. India contributes about 13.64% of world wheat production, Directorate of Economics and Statics (DES), Mo A & FW, (2020) India. Weeds are known to be a major biotic constraint in crop production systems. Estimates reveal that more than one-third of the total field losses due to biotic stresses are caused by weeds alone which often go unnoticed due to their multipronged hidden effects on plant growth Sharma *et al*. (2016) [10]. Weeds have better adaptability to the changing environments by virtue of grater genetic diversity in comparison to crops.

Weeds management is likely to increase in their invasiveness, weed shift, herbicides under changing climate Kumar *et al.* (2016) [2]. Weed infestation is one of the major biotic constraints in wheat production and weeds reduce wheat yield up to 60% if not controlled at the critical stages of crop Yadav *et al.* (2019) [11]. Chemical weed control is a preferred practice due to unavailability of labour and high labour costs and also there is lesser feasibility of mechanical or manual weeding in wheat. Hence chemical weed control is a preferred practice due to scarce and costly labour as well as lesser feasibility of mechanical or manual weeding Mukherjee *et al.* (2011) [7]. The effect of herbicide application on soil health (microbial environment) is a great concern as it may affect the microbial growth Kumar *et al.* (2014) [5]. Keeping all these in view, the present investigation was carried out to find out herbicidal effect on yield of wheat under irrigated ecosystem in middle Indo Genetic plains of Eastern India.

Materials and Methods

A field experiment was carried out at main experiment station (Agronomy) of Pili kothi Farm, T.D.P.G. College, Jaunpur. Distt. Jaunpur (Uttar Pradesh) during *Rabi* of 2019-20 and 20-20-2021. The climate of Jaunpur is cold in winters. The experiment was laid out in randomized block design with three replications. Eight different tank mix combinations of post-emergence herbicides with weed free and unweeded control. Herbicides were applied with knapsack sprayer fitted with flat fan nozzle using 500 liter water/ha. A wheat variety "*UP 2565*" was sown manually with 20cm row spacing planting geometry in a plot size of 5.0m x 4.0m with seed rate of 100 kg/ha. Gap filling was done manually to maintain plant population. Irrigation was applied in the field as per requirement. A recommended dose of fertilizer (120:60:40 kg NPK/ha) was applied as per package of practices of crop for the area. The test herbicide *viz*. Sulfosulfuron 75% + Metsulfuron-methyl 20% WP 25+4 g/ha, Sulfosulfuron 75% + Carfentrazone- ethyl 40% DF 25+20 g/ha, Sulfosulfuron 75% + (Arylex 20.85% + Florasulam 20%) 25+12.76 g/ha, Sulfosulfuron 75% + (Arylex 6.95% + Pyroxsulam 25%) 25+23.96 g/ha, Clodinafop-propargyl 15% WP + Metsulfuron-methyl 20% WP 60+4 g/ha, Clodinafop-propargyl 15% WP + Carfentrazone- ethyl 40% DF 60+20 g/ha, Clodinafop-propargyl 15% WP + (Arylex 20.85% + Florasulam 20%) 60+12.76 g/ha and Clodinafop-propargyl 15% WP + (Arylex 6.95% + Pyroxsulam 25%) 60+23.96 g/ha were sprayed (30 days after sowing). The use of new alternate herbicides including (Arylex 20.85% + Florasulam 20%) and (Arylex 6.95% + Pyroxsulam 25%) was recommended, which provides a great relief to wheat crop from resistant population of weed species. Therefore, keeping these facts in mind and importance of problems from the national point, the work was conducted to find out the efficacy of (Arylex 20.85% + Florasulam 20%) and (Arylex 6.95% + Pyroxsulam 25%) under tank mix with Sulfosulfuron 75% and Clodinafop-propargyl 15% WP herbicide against complex weed flora in wheat.

Half dose of N and full dose of P_2O_5 and K_2O was applied as basal and rest doses of nitrogen were applied in two equal splits at maximum tillering and panicle initiation stages. First irrigation was given at crown root initiation (CRI) stage (21 DAS) and then applied as per crop requirement.

Category-wise weed count and their dry biomass accumulation and total weed density, total weed dry biomass and weed control efficiency were measured at 60 DAS by placing a quadrate of 0.25 m^2 randomly at 2 places in each plot and were subjected to square-root transformation [$\sqrt{(x+0.5)}$] before analysis. Data were analyzed by using standard statistical techniques (STPR package). Treatment means were separated using the least significant difference (LSD) at the 5% level of significance. Differences were considered significant only at P=0.05. Crop was harvested on April 17, 2020 and April 10, 2021 and left in the field for 5-7 days for sun drying. The number of tiller/m^2, grains/spike, spike length, 1000 grain weight, grain yield, straw yield and biological yield were recorded. Phytotoxicity symptoms were recorded at 1, 3, 5, 7 and 10 days after herbicide application by comparing it with weedy check.

Results and Discussion

Effect on weed density and dry weight of weeds

Pooled analysis of data revealed significant reduction in all weed control treatments with respect to weed density and dry weed biomass over unweeded control as indicated in (Table 2). None of weed density and weed dry weight of weeds was recorded under weed free due to complete removal among the herbicides, Sulfosulfuron 75% + (Arylex 20.85% + Florasulam 20%) 25 + 12.76 g/ha was found to be more superior in curtailing the weed population and dry weight of weeds (18.0 no./m2, 10.3 g/m2) followed by Sulfosulfuron 75% + (Arylex 6.95% + Pyroxsulam 25%) 25 + 23.96 (24.0 no./m2, 14.3 g/m2) as compared to unweeded control (Table 2). Application of Clodinafop-propargyl 15% WP + Metsulfuron-methyl 20% WP 60+4 g/ha was less effective in controlling weeds as compared to Sulfosulfuron 75% + (Arylex 20.85% + Florasulam 20%) 25 + 12.76 g/ha. The tank mixtures of broad-leaf and grassy weed killing herbicides provided higher order of performance in terms of weed density and intensity of total weeds as observed by Meena et al. (2017) [9]. Tank-mix application of clodinafop-propargyl + metsulfuron-methyl 60+ 4 g/ha provided better than Sulfosulfuron 75% + Metsulfuron-methyl 20% WP 25+4 g/ha, Sulfosulfuron 75% + Carfentrazone- ethyl 40% DF 25+20 g/ha, Clodinafop-propargyl 15% WP + Carfentrazone-ethyl 40% DF 60+20 g/ha and Clodinafop-propargyl 15% WP + (Arylex 6.95% + Pyroxsulam 25%) 60+23.96 g/ha. Total weed population was reduced significantly due to various weed control treatments. This might be due to the herbicidal application tank-mix which was effective in timely reducing total weed population Lekh Chand and Punia (2017) [6] and Chaudhary *et al.* (2017) [3] also reported similar results.

Effect on weed control efficiency and weed index

Weed control efficiency in wheat was significantly influenced by weed management treatments, where all the treatments resulted in increase of weed control efficiency over the weedy check. Highest value of weed control efficiency (100%) was obtained from weed free treatment. Amongst herbicides, maximum value of WCE was achieved by Sulfosulfuron 75% + (Arylex 20.85% + Florasulam 20%) 25 + 12.76 g/ha (84.8%) and Sulfosulfuron 75% + (Arylex 6.95% + Pyroxsulam 25%) 25 + 23.96 g/ha (78.8%) followed by Clodinafop-propargyl 15% WP + Metsulfuron-methyl 20% WP 60+4 g/ha (73.4%) and Sulfosulfuron 75% + Metsulfuron-methyl 20% WP 25+4 g/ha (72.9%). (Table 2) This indicates that tank-mix application of Sulfosulfuron 75% + (Arylex 20.85% + Florasulam 20%) 25 + 12.76 g/ha

significant effect on minimizing the weed population, which resulted increased yield over control treatment. Similar results were also reported by Dhiman Mukherjee (2020) [8] with halauxifen-methyl ester + florasulam + carfentrazone in wheat. The lowest weed index (1.74%) was obtained with Sulfosulfuron 75% + (Arylex 20.85% + Florasulam 20%) 25 + 12.76 g/ha followed by Sulfosulfuron 75% + (Arylex 6.95% + Pyroxsulam 25%) 25 + 23.96 g/ha (3.66%). Weed index was lower in all the treatments as compared to unweeded control which provided favorable conditions for crop growth which ultimately increased the grain yield of wheat crop as compared to unweeded control. Similar trends in weed control efficiency and weed index were also recorded.

Effect on growth and yield

Significant reduction in grain per spike was noticed in unweeded control treatment which might be due to competition between crop and weeds for soil moisture, plant nutrients, solar radiation and space during active growth period (Table 1). These results were in accordance with the results reported by Meena *et al.* (2020). Significantly the highest number of effective tillers/m^2 was recorded in weed free treatment (331 no./m^2) but remained at par with those treatment where tank-mix application of post-emergence herbicides were sprayed i.e. Sulfosulfuron 75% + Metsulfuron-methyl 20% WP, Sulfosulfuron 75% + (Arylex 20.85% + Florasulam 20%) and Clodinafop-propargyl 15% WP + Metsulfuron-methyl 20% WP. Data on spike length at harvest showed non significant differences among treatments and showed the similar trends as in case of 1000 grain weight (Table 1). Pooled analysis of different weed control treatments registered significant increase in grain yield of wheat compared to unweeded control during two years of study. Weed free treatment recorded highest grain yield of 4522 kg/ha. Further data explicated that collective application of tank-mix herbicides gave significantly higher yield over unweeded control. Among the herbicides, higher value of grain yield in pooled data was obtained with Sulfosulfuron 75% + (Arylex 20.85% + Florasulam 20%) 25 + 12.76 g/ha at 30 DAS (4443 kg/ha) closely followed by Sulfosulfuron 75% + (Arylex 6.95% + Pyroxsulam 25%) 25 + 23.96 g/ha at 30 DAS (4357 kg/ha), Clodinafop-propargyl 15% WP + Metsulfuron-methyl 20% WP 60+4 g/ha (4320 kg/ha) and Sulfosulfuron 75% + Metsulfuron-methyl 20% WP 25+4 g/ha (4313 kg/ha).This might be due to better weed control efficiency associated, which ultimately caused the higher yield attributes in wheat Amare et *al.* (2014) [1]. Pooled data showed that both these treatments recorded 31.46% increase in grain yield over unweeded control was due to higher growth and yield attributes due to reduced weed infestation by these treatments, which helped the crop plants to accumulate more dry matter through more nutrient uptake that might have provided more quantity of photosynthesis to developing sink in crop plants resulted in more yield. Similar results of improvement grain yield and weed control has been reported by Chaudhary *et al.* (2017) [3] with different herbicides combinations.

Table 1: Effect of weed management practices on yields attributes and yields of wheat (Pooled data of two years)

Treatments	Dose (g/ha)	Spike/ m^2	Grains/ spike (no.)	Spike length (cm)	1000-grain weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)
Sulfosulfuron 75% + Metsulfuron-methyl 20% WP (TM)	25+4	315	40	9.2	42.2	4313	6405	10718
Sulfosulfuron 75% + Carfentrazone- ethyl 40% DF (TM)	25+20	309	39	9.1	41.9	4103	6053	10156
Sulfosulfuron 75% + (Arylex 20.85% + Florasulam 20%) (TM)	25+12.76	324	41	9.7	42.5	4443	6427	10870
Sulfosulfuron 75% + (Arylex 6.95% + Pyroxsulam 25%) (TM)	25+23.96	314	40	9.4	42.2	4357	6230	10587
Clodinafop-propargyl 15% WP + Metsulfuron-methyl 20% WP (TM)	60+4	320	41	9.5	41.7	4320	6448	10768
Clodinafop-propargyl 15% WP + Carfentrazone- ethyl 40% DF (TM)	60+20	298	40	9.4	41.7	4127	6263	10390
Clodinafop-propargyl 15% WP + (Arylex 20.85% + Florasulam) 20%) (TM)	60+12.76	304	40	9.4	42.4	4140	6102	10242
Clodinafop-propargyl 15% WP + (Arylex 6.95% + Pyroxsulam 25%) (TM)	60+23.96	290	40	9.4	42.5	4113	6138	10251
Weed Free	-	331	42	10.1	43.1	4543	6755	11298
Weedy Check	-	250	39	8.9	41.7	3347	5397	8743
SEm±								
LSD (P=0.05)								

*TM- Tank mix

Table 2: Effect of weed management practices on weed density, weed dry weight, WCE %, harvest index % and Percent increase in yield over weedy check (%) (Pooled data of two years)

Treatments	Crop phytotoxicity visual rating score		Total weed density (no./m^2) at 60 DAS	Total weed dry weight (g/m^2) at 60 DAS	WEC (%) at 60 DAS	Weed index (%)	Percent increase in yield over Weedy check (%)
Sulfosulfuron 75% + Metsulfuron-methyl 20% WP (TM)	Score	Effect on crop	5.7 (32.3)	4.4 (18.4)	72.9	4.61	20.6
Sulfosulfuron 75% + Carfentrazone- ethyl 40% DF (TM)	0	No injury	7.2 (51.7)	5.3 (27.3)	59.8	9.27	14.7
Sulfosulfuron 75% + (Arylex 20.85% + Florasulam 20%) (TM)	0	No injury	4.3 (18.0)	3.3 (10.3)	84.8	1.74	24.2
Sulfosulfuron 75% + (Arylex 6.95% + Pyroxsulam 25%) (TM)	0	No injury	5.0 (24.0)	3.9 (14.3)	78.8	3.66	21.8

Clodinafop-propargyl 15% WP + Metsulfuron-methyl 20% WP (TM)	0	No injury	5.3 (27.7)	4.3 (18.1)	73.4	4.47	20.7
Clodinafop-propargyl 15% WP + Carfentrazone-ethyl 40% DF (TM)	0	No injury	8.0 (62.3)	5.7 (31.6)	53.5	8.74	15.3
Clodinafop-propargyl 15% WP + (Arylex 20.85% + Florasulam) 20%) (TM)	0	No injury	5.6 (32.0)	4.4 (19.1)	71.9	8.45	15.7
Clodinafop-propargyl 15% WP + (Arylex 6.95% + Pyroxsulam 25%) (TM)	0	No injury	6.8 (45.3)	4.9 (23.3)	65.6	9.04	15.0
Weed Free	-	-	1.0 (0.0)	1.0 (0.0)	100.0	-	27.0
Weedy Check	-	-	11.7 (137.3)	8.3 (67.8)	-	25.99	-
SEm±	-	-	0.20	0.16	-	-	-
LSD (P=0.05)	-	-	0.58	0.46	-	-	-

Conclusion

Hence, in this trial best efficacy of total weed biomass and maximize the yield potential with the application of Sulfosulfuron 75% + (Arylex 20.85% + Florasulam 20%) 25+12.76 g/ha and Sulfosulfuron 75% + (Arylex 6.95% + Pyroxsulam 25%) 25 + 23.96 g/ha followed by Clodinafop-propargyl 15% WP + Metsulfuron-methyl 20% WP 60+4 g/ha and Sulfosulfuron 75% + Metsulfuron-methyl 20% WP 25+4 g/ha were achieved highest as compared to another application of Sulfosulfuron 75% + Carfentrazone- ethyl 40% DF 25+20 g/ha, Clodinafop-propargyl 15% WP + Carfentrazone- ethyl 40% DF 60+20 g/ha, Clodinafop-propargyl 15% WP + (Arylex 6.95% + Pyroxsulam 25%) 60+23.96 g/ha and Clodinafop-propargyl 15% WP + (Arylex 20.85% + Florasulam 20%) 60+12.76 g/ha. Therefore, it may be a valid approach to improve the productivity and profitability of wheat in irrigated ecosystem in middle Indo Genetic plains of Eastern India.

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