

RESEARCH ARTICLE

Estimation of GR₅₀ values of sulfosulfuron + metsulfuron (ready mix) and sulfosulfuron against herbicides resistant *Phalaris minor* Retz. in Punjab

Sangam* and U.S. Walia

Received: 24 January 2025 | Revised: 15 May 2025 | Accepted: 19 May 2025

ABSTRACT

Two separate field experiments were conducted at the experimental farm of the Department of Agronomy, Lovely Professional University Phagwara, Punjab, during 2022-2023 and 2023-2024 to estimate the GR₅₀ values of prominent herbicides, viz. sulfosulfuron + metsulfuron 30 g/ha and sulfosulfuron 25 g/ha against herbicide resistant populations of *Phalaris minor* collected from different districts of Punjab. Split Plot Design (SPD) was used with three replications. The sulfosulfuron + metsulfuron 30 g/ha, at recommended level caused significantly less mortality percentage resulting in significantly greater biomass of *P. minor* during both years as compared to its 2X dose. Among biotypes significantly less mortality was observed with Ropar biotype and significantly less biomass with Fazilka biotype as compared to Ferozepur and Ludhiana biotypes. The biomass of *P. minor* was also significantly higher with sulfosulfuron X level than 2X level of sulfosulfuron. Among all the biotypes significantly higher mortality and significantly less biomass was observed with Fazilka biotype as compared to other biotypes during both the years.

Keywords: Biotypes, GR₅₀, Herbicide resistance, *Phalaris minor*, Sulfosulfuron, Sulfosulfuron + metsulfuron

INTRODUCTION

North western Indo-Gangetic plains (IGPs) of India comprising states of Haryana, Punjab, and western Uttar Pradesh contributes more than 50% of national wheat production (Soni *et al.* 2023). The weeds are the major biotic constraint in wheat production of this region. Wheat is infested by diverse weed flora but among them, *Phalaris minor* Retz. is a major problematic and mimicry weed of wheat (Kadam *et al.* 2021) in rice-wheat cropping system. It germinates in different flushes after wheat sowing and competes with the wheat for different resources.

In wheat herbicide application is recommended 35 days after seeding (DAS) for the control of grassy weeds and many alternative herbicides were used to manage the infestation of *P. minor* like isoproturon, fenoxaprop, clodinafop etc. These herbicides were used prominently and resistance to these herbicides also developed (Das *et al.* 2024). Sulfosulfuron and sulfosulfuron + metsulfuron were the alternatives herbicides, which were used by the farmers of Punjab from last many years (Cessna *et al.* 2015).

These herbicides belong to sulfonylureas group which is very prone to resistance. These herbicides generally inhibit the activity of ALS (acetolactate synthase enzyme) (Adari *et al.* 2024). Now a days farmers are reporting a problem in some areas of Punjab that these herbicide are not giving satisfactory control of *P. minor* where these herbicides are being used (Kaur *et al.* 2023).

Estimation of GR₅₀ (amount of herbicide required for the 50% growth reduction compared to control) of resistant population of *P. minor*, which indicates the level of resistance and time required for the occurrence of resistance in the *P. minor* population (Wei *et al.* 2016). Henceo, these herbicides were used at variable levels to assess their efficacy (Hooda *et al.* 2023). This study was made to estimate the GR₅₀ values of sulfosulfuron and ready-mix formulation of sulfosulfuron + metsulfuron, so that their level of resistance in different biotypes of *P. minor* and also their efficacy can be assessed

MATERIALS AND METHODS

Two separate experiments were conducted during *Rabi seasons* of 2022-23 and 2023-24 at Agronomy Research Farm, School of Agriculture, Lovely Professional University, Phagwara, Punjab.

School of Agriculture, Lovely Professional University
Phagwara, Punjab 144411, India

* Corresponding author email: sangam8100@gmail.com

The experimental site falls under the sub-tropic regions remain cool in winter and hot in summer, maximum rainfall in the month of July, August and September due to the south west monsoon. The temperature never goes below zero degree, however especially in the months of December and January it remains extremely cold. The highest temperature recorded was nearly 46° Celsius during the months of May and June. Different biotypes of *Phalaris minor* were collected in the year 2022 from the different districts of Punjab. i.e. village Mallan wala khas in Ferozepur district, village Mothapur in Ropar district, where sulfosulfuron + metsulfuron was used by the farmers since the last 5-6 years, and from village Islam wala in Fazilka district and from village Barewal in Ludhiana district where the sulfosulfuron was used by the farmers from since last 5-6 years. Both the experiments were laid out in Split Plot Design keeping herbicide dose in 5 main plots and biotypes in 4 sub plots with three replications.

The sowing of *P. minor* seeds was done manually on the 18th of November during 2022-23 and 2023-24 in adequate moist soil by maintaining 22.5cm row to row spacing. The gross plot size of 4.5m² (1.5 × 3m) was kept for each treatment. The trial was conducted in *P. minor* seed free land and there was no addition of FYM, poultry or other organic manures because these could be the possible source of *Phalaris* seed contamination.

The herbicide application was done when the *P. minor* plants were in 3-4 leaf stage (which comes nearly 30-35 DAS). The graded levels of each of two herbicides were kept as 1/2X, X, 2X, 4X (X stands for recommended dose). One control treatment where no herbicide application was done was also kept with each herbicide treatment. The recommended dose (X) of Total (sulfosulfuron + metsulfuron) and Leader (sulfosulfuron) used were 30 and 25 g/ha, respectively. Herbicide application was done manually with the help of knap-sack sprayer which was fitted with flat fan nozzle and the herbicide application was done on area basis using 250 l/ha of water. The observations on *Phalaris minor*, like mortality (%), dry matter (biomass) (g/m²) and number of tillers per meter row length, and height (cm) were recorded 75 DAS when experiment was terminated.

RESULTS AND DISCUSSION

A-Mortality percentage

Visual observations were recorded on the mortality % of different treatments at the time of

termination of experiments. The mortality percentage increased with increase in dose of sulfosulfuron + metsulfuron herbicide during both the years (**Table 2**). The mortality % in X dose was found at par with 1/2X dose but it was significantly less than 2X and 4X dose during both the years. Among the biotypes significantly less mortality % was recorded in Ropar biotype as compared to Ferozepur, Fazilka and Ludhiana biotypes with the application of sulfosulfuron + metsulfuron.

Similarly, the mortality percentage increased with increase in dose of sulfosulfuron but its performance was unsatisfactory and less than that of sulfosulfuron + metsulfuron herbicide. The performance of sulfosulfuron was very poor even at 4X level as indicated by *P. minor* biomass. Performance of sulfosulfuron herbicide was very poor among all biotypes except Fazilka biotype. The mortality percentage of Fazilka biotype was significantly more than all other all biotypes. The significantly less mortality percentage was found in Ferozepur, Ropar and Ludhiana biotypes as compared to Fazilka biotype.

Biomass of *Phalaris minor*

Sulfosulfuron+ metsulfuron herbicide reduced the biomass of *Phalaris minor* significantly during both the years and correspondingly with the increase in dose of herbicide from 1/2X to 4X (**Table 2** and **Figure 1**). However significantly higher biomass was found in unweeded (control) than all other level of herbicide during both the years. Among the biotypes

Table 1. Mortality (%) as influenced by *Phalaris minor* biotypes and different doses of sulfosulfuron + metsulfuron and sulfosulfuron

	Mortality %			
	Sulfosulfuron + metsulfuron		Sulfosulfuron	
	2022-23	2023-24	2022-23	2023-24
<i>Main plots- herbicide doses</i>				
Control	0.0	0.0	0.0	0.0
½ X	37.6	31.5	25.3	19.6
X	38.4	29.2	36.4	31.5
2X	52.9	47.4	42.2	39.6
4X	72.7	66.8	43.5	41.5
LSD (p=0.05)	13.9	3.5	9.4	6.5
<i>Subplots- P. minor biotypes</i>				
Ferozepur	49.3	40.4	5.0	0.0
Ropar	13.8	11.6	12.5	8.3
Fazilka	47.7	48.0	64.0	60.6
Ludhiana	50.6	46.6	36.4	30.5
LSD (p=0.05)	7.2	2.5	7.8	5.8

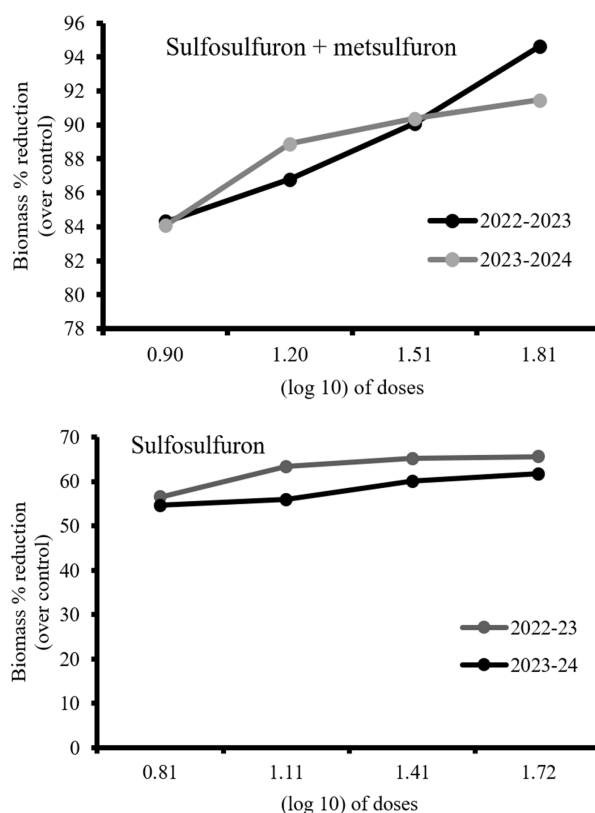
Table 2. Biomass of *Phalaris minor* as influenced by its biotypes and different doses of herbicides

	Biomass (g/m ²)			
	Sulfosulfuron + metsulfuron		Sulfosulfuron	
	2022-23	2023-24	2022-23	2023-24
Main plots- herbicide doses				
Control	128.08	139.8	142.6	135.4
½ X	20.2 (84.3)	22.2 (84.1)	61.9 (56.5)	64.6 (54.6)
X	16.2 (86.8)	15.4 (88.9)	52.1 (63.4)	62.2 (55.9)
2X	12.7 (90.1)	13.3 (90.4)	49.6 (65.2)	56.8 (60.1)
4X	6.9 (94.6)	11.8 (91.5)	49.0 (65.6)	54.5 (61.7)
LSD (p=0.05)	3.1	1.9	2.3	2.5
Sub plots- <i>P. minor</i> biotypes				
Ferozepur	31.3 (75.6)	36.4 (73.9)	125.6 (11.5)	124.0 (13.0)
Ropar	47.8 (62.8)	51.4 (63.2)	73.3 (48.5)	83.5 (41.4)
Fazilka	25.8 (79.9)	26.2 (81.2)	29.6 (79.2)	36.5 (74.4)
Ludhiana	43.0 (66.6)	41.0 (70.6)	55.7 (60.9)	64.5 (54.7)
LSD (p=0.05)	8.0	12.5	6.9	16.8

Data within parentheses represent percent decrease of biomass of *P. minor* over control

significantly less biomass was recorded with Fazilka and Ferozepur biotypes as compared to others during both the years. The percent reduction in biomass of *Phalaris minor* at 1/2X dose was 84.3% and 84.1% less than unweeded (control) in the 1st and 2nd year which indicates that this herbicide is still reasonably effective even at 1/2X dose. Among the biotypes, the percent reduction in biomass of all 4- biotypes was more than 50% as compared to untreated indicating thereby that all biotypes are susceptible to this herbicide. However, Fazilka biotype during both years recorded significantly less biomass than other biotypes.

Sulfosulfuron herbicide reduced the biomass significantly more at X dose than at 1/2 X during 2022-23 but at par during 2023-24, however it was significantly less than control (unsprayed). Biomass of *P. minor* at X dose was significantly more than 2X and 4X during both years (Table 2 and Figure 1). Sulfosulfuron herbicide appeared less effective as compared to sulfosulfuron + metsulfuron because at the X level of herbicide dose it shows 63.4% and 55.9% reduction in growth of *Phalaris minor* during both the years. And the percent reduction in sulfosulfuron at X and 4X level were at par which

**Figure 1. Percent reduction in biomass of *P. minor* with different doses of herbicides**

shows that this herbicide was not capable to provide satisfactory control of *P. minor* populations even at their higher doses. Based on biomass percent reduction, it was observed that Ferozepur and Ropar district population was more resistant to sulfosulfuron than Fazilka district population which showed more susceptibility (79.2% and 74.4% reduction)

Number of *P. minor* tillers per meter row length

Number of tillers of *P. minor* were significantly more in unsprayed (control) during both the years when treated with sulfosulfuron + metsulfuron. During 2022-23 total tillers were at par among all herbicide levels except 1/2X and during 2023-24, the recommended dose produced significantly more total tillers than its 2X and 4X levels. Fazilka biotype produced significantly greater number of tillers than all other biotypes during both the years. Significantly higher numbers of tillers were observed in Ludhiana biotype as compared to other during 2022-23 and these were at par in Ferozepur, Ropar and Ludhiana biotypes. At the recommended dose of sulfosulfuron + metsulfuron, the percent decrease in number of tillers of *Phalaris minor* was less than 50% during both the years and complete mortality was not

Table 3. Number of *P. minor* tillers as influenced by different doses and biotypes

	No. of tillers of <i>P. minor</i> per meter row length			
	Sulfosulfuron + metsulfuron		Sulfosulfuron	
	2022-23	2023-24	2022-23	2023-24
Main plot- herbicide doses				
Control	26.2	26.9	50.3	61.0
½ X	15.1 (42.3)	24.3 (9.6)	46.8 (6.9)	58.8 (3.6)
X	13.2 (49.6)	16.5 (38.6)	33.5 (33.4)	46.6 (23.6)
2X	11.3 (56.8)	10.7 (60.2)	32.5 (35.3)	37.2 (39.0)
4X	8.8 (66.4)	8.2 (69.5)	30.5 (39.3)	36.8 (39.6)
LSD (p=0.05)	7.4	4.6	6.1	3.1
Sub plots- <i>P. minor</i> biotypes				
Ferozepur	15.8 (58.0)	17.1 (36.4)	55.0 (-9.3)	58.3 (4.4)
Ropar	15.1 (42.3)	20.2 (24.9)	40.0 (20.4)	57.6 (5.5)
Fazilka	11.0 (39.6)	9.9 (63.1)	16.3 (67.5)	23.2 (61.9)
Ludhiana	17.9 (31.6)	19.3 (28.2)	43.6 (13.3)	53.1 (12.9)
LSD (p=0.05)	2.3	3.4	3.9	3.5

Data in parentheses represents percent decrease of number of tillers over control

obtained even at 4X reflecting probably the beginning of resistance development. Among the biotypes, the highest percent reduction was recorded in Ferozepur biotype (58.0%) during 2022-23 and Fazilka biotype (63.1%) during the 2023-24.

Number of tillers at X dose were significantly less than 1/2Xdose and were at par at 2Xand 4Xduring both the years. However, significantly higher number of tillers were recorded in unsprayed (control) than all other treatments. Among the biotypes, Fazilka biotype showed susceptibility to the sulfosulfuron herbicide. This biotype showed significantly a smaller number of tillers than all other biotypes during both years. Significantly higher numbers of tillers during both the years were recorded in Ferozepur biotype as compared to other biotypes. Whereas percent reduction in total tillers was not more than 50% even at its higher doses. At the 4X, the percent reduction was 39.3% and 39.6% during 2022-23 and 2023-24 indicating that *Phalaris minor* has developed resistance to this herbicide. Among the biotypes, Fazilka biotype recorded 67.5 and 61.9 % reduction during both the years. Whereas

Table 4. Height of *Phalaris minor* plants as affected by its biotypes and different dose of herbicides

	<i>Phalaris minor</i> plant height (cm)			
	Sulfosulfuron + metsulfuron		Sulfosulfuron	
	2022-23	2023-24	2022-23	2023-24
Main plots - herbicide doses				
Control	38.8	39.2	46.5	44.2
½ X	29.8 (23.1)	30.2 (22.9)	36.9 (20.6)	38.9 (11.9)
X	27.6 (28.8)	26.4 (32.6)	33.2 (28.6)	30.2 (31.6)
2X	25.7 (33.7)	21.0 (46.4)	32.0 (31.1)	23.5 (46.8)
4X	21.5 (44.5)	19.4 (50.5)	29.5 (36.5)	26.3 (40.4)
LSD (p=0.05)	2.2	2.0	5.6	2.5
Sub plots - <i>P. minor</i> biotypes				
Ferozepur	26.9 (30.6)	32.8 (16.0)	42.5 (8.6)	46.4 (4.9)
Ropar	33.6 (13.4)	32.5 (17.0)	38.4 (17.4)	39.0 (11.7)
Fazilka	24.2 (37.6)	20.6 (47.4)	28.7 (38.2)	25.6 (42.0)
Ludhiana	29.9 (22.9)	28.5 (27.2)	33.0 (29.0)	35.2 (20.3)
LSD (p=0.05)	3.9	1.6	7.0	1.6

Data within parentheses represent percent decrease in plant height over control

all other biotypes are having less than 50 % reduction. In general, the efficiency of sulfosulfuron + metsulfuron was more than sulfosulfuron.

Height of *Phalaris minor* plants (cm)

The plant height during both the years was significantly more in untreated (control) as compared to all other herbicidal treatments. Plant height during both the years at X dose was significantly more than 2Xand 4Xlevels. Among the biotypes, significantly less plant height was found in Fazilka biotype during both the years as compared to Ferozepur, Ropar and Ludhiana biotypes. During 2022-23 significantly less plant height was attained in Fazilka and Ferozepur biotypes, and in Fazilka biotype during 2023-24 as compared to other tested biotypes.

Sulfosulfuron herbicide at X level showed significantly less plant height than untreated (control) however it was at par at X, 2Xand 4X levels of sulfosulfuron during 2022-23. Among the biotypes, significantly higher plant height was found in Ferozepur biotype during both the years as compared to all other biotypes.

Conclusion

It may be concluded that with the recommended dose of sulfosulfuron + metsulfuron and sulfosulfuron, *P. minor* biotypes were not controlled satisfactorily. The performance of sulfosulfuron + metsulfuron was superior than that of sulfosulfuron. Only Fazilka biotype of *P. minor* was found susceptible to the sulfosulfuron and sulfosulfuron + metsulfuron while all other biotypes showed resistance to both tested herbicides.

REFERENCES

- Adari MD, Pandian BA, Gaines TA, Prasad PV, Jugulam M. 2024. Confirmation and characterization of the first case of acetolactate synthase (ALS)-inhibitor resistance in Japanese brome (*Bromus japonicus*) in the US. *Pest Management Science*. **80**(8): 3717–3725.
- Cessna AJ, Donald DB, Bailey J, Waiser M. 2015. Persistence of the Sulfonylurea Herbicides Sulfosulfuron, Rimsulfuron, and Nicosulfuron in Farm Dugouts (Ponds). *Journal of Environmental Quality*. **44**(6): 1948–1955.
- Das TK, Behera B, Nath CP, Ghosh S, Sen S, Raj R, Ghosh S, et al. 2024. Herbicides Use in Crop Production: An Analysis of Cost-Benefit, Non-Target Toxicities and Environmental Risks. *Crop Protection (Guildford, Surrey)* **181**(106691): 106691.
- Hooda VS, Sangwan M, Karwasra A and Gupta G. 2023. “Management of Herbicide-Resistant Little Seed Canary Grass (*Phalaris Minor*) by Integrating Malathion with Post-Emergence Herbicides in Wheat Crop *Annals of Agricultural Research* **43**(4): 382–390.
- Kadam AD, Thalkar MG, Somanath L, Vyvhare P JK and Joshi GH. 2021. Integrated Weed Management in Wheat (*Triticum Aestivum* L). *The Pharma Innovation Journal* **10**(4): 737–741.
- Kaur G, Kaur T and Bhullar M. S. 2023. *Susceptibility of Long-Term Unexposed Population of Phalaris Minor to Isoproturon*. *Indian Journal of Weed Science*. **55**(3): 311–314.
- Soni JK, Nibhoria A, Punia S.S. et al. 2023. Herbicide resistant *Phalaris minor* in India—history of evolution, present status and its management. *Phytoparasitica*. **51**: 353–378.
- Wei D E N G, Qian Y A N G, Jiao H T, Zhang Y ., Li X F and Zheng M Q. 2016. Cross-Resistance Pattern to Four AHAS-Inhibiting Herbicides of Tribenuron-Methyl-Resistant Flixweed (*Descurainia Sophia*) Conferred by Asp-376-Glu Mutation in AHAS. *Journal of Integrative Agriculture* **15**(11): 2563–2570.