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Performance of Different *Phalaris minor Retz.* Biotypes Growing with Wheat (*Triticum aestivum* L.) in Relation to Different Herbicides

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ABSTRACT

Background: The major factor responsible for reduction of the wheat production and productivity in India is infestation of wheat with problematic weeds. Introduction of high yielding dwarf wheat varieties changed the spectrum of weed flora from dominance of broadleaf weeds in the 1960s to mixed flora of broadleaf and grassy weeds in early 1970s and then the dominance of grass weeds especially, *Phalaris minor* in late 1970s. The chemical weed control, therefore, became a necessity event in late 1970s. Herbicides were introduced in 1979-80, weed flora changed in favor of complex weeds species in late 1980s and then again in favour of *P. minor* during the early 1990s and thereafter evolution of herbicide resistance was reported in major wheat growing areas.

Methods: The field experiment was conducted at experimental farm of the Department of Agronomy, Lovely Professional University Phagwara, Punjab during *Rabi* season of 2022-2023 and 2023-2024. To check the effectiveness of prominent herbicides *viz*. Axial 5 EC (pinoxaden) 50 g *a.i*/ha, Leader 75 WG (sulfosulfuron) 25 g a.i/ha, Total 75 WG (sulfosulfuron + metsulfuron) 30 g a.i/ha and ACM-9 (clodinafop+metribuzin) 174 g a.i/ha on the resistant population of *Phalaris minor* collected from different districts of Punjab. The experiment was laid out in split plot design having five main plots and four sub plots with four replications. Herbicides were applied at their recommended dose in main plots and four biotypes *viz*. B1-Ferozepur, B2- Ropar, B3- Fazilka, B4- Ludhiana in sub plots. Herbicides were applied as post emergence at 35 days after sowing.

Result: Our investigation reveals that among all the herbicide treatments performance of ready mix (clodinafop+metribuzin) herbicide was satisfactory control the weeds. Whereas other tried herbicides are not able to control the tried biotypes except Fazilka. Fazilka biotype is sensitive to all the tried herbicides whereas other biotypes were sensitive to only clodinafop+metribuzin herbicide and shown their resistance to all other herbicides.

Key words: Biotypes, Resistance, Wheat.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the major staple food crop of the world and a chief source of energy particularly for Indian population. Wheat belongs to Poaceae family and cultivated during *Rabi* season and the edible part of the wheat is called caryopsis. India has achieved remarkable progress in wheat production during the last four decades and is continuing to be second largest wheat producing nation in the world. Wheat has prominent role among food crops because it is rich in protein and carbohydrates. The nutritional value of wheat is quite high than other cereals. Wheat grains contain about 14.7% protein, 2.1% fat, 78.1% carbohydrates and 2.1% mineral matter (Kumar *et al*., 2018). Wheat grains have several industrial uses such as for manufacture of alcohol, starch, gluten and oils *etc*. Wheat straw is used for livestock as fodder and for making straw hats, paper work and art purpose.

After the green revolution or after introducing the dwarf varieties of wheat, a remarkable increase in the production of the wheat has been observed in India but with the passage of time, the production started to decline due to decrease in the cultivated area, continous use of same group of herbicide, cultivation of same varieties which lead to increased incidence of biotic factors like weed infestation, insect pest infestation and also uncertainty of abiotic factors like light, temperature, humidity, wind *etc*. which led to reduction in the production and productivity of wheat in India. Sharma *et al*. (2023).

The seeds of *Phalaris minor* remains viable under both aerobic and anaerobic conditions. It is a serious weed of rice- wheat cropping system. The possible reason might be the result of its seeds entering into secondary dormancy by changing the permeability of their seed membrane and

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producing chemical metabolites that help seeds for non-decomposing under such conditions (Soni *et al*., 2023).

A major factor responsible for less productivity of wheat is the severe weed competition which reduces the yield by 29%. Wheat crop is usually infested with a variety of complex weed flora *i.e.* grasses and broadleaf weeds (BLWs). The composition of these weeds largely depends on soil type, climatic factors such as temperature, humidity, soil moisture availability, fertilizers applied, cultural practices, varieties used, crop rotation *etc*. (Choudhary *et al*., 2016).

MATERIALS AND METHODS

The experiment was performed out during *Rabi* 2022-2023 and 2023-2024 at Agronomy Research Farm, School of Agriculture, Lovely Professional University, Phagwara, Punjab. 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°C during the months of May and June. Different biotypes of *Phalaris minor* were collected from the different districts of Punjab. *i.e.* B1-Ferozepur, B2-Ropar, B3- Fazilka, B4- Ludhiana where these herbicides are used by the farmers from last many years. The experiment was laid out in Split Plot Design having 5 main plots (different herbicides) 4 sub plots (which are different biotypes of *P. minor*) from Ferozepur, Ropar, Fazilka and Ludhiana districts with three replications.

P. minor seeds were sown in row in between the two rows of wheat crop which were sown at 22.5 cm spacings. The gross plot size was 6.75 sq m. The seeds of *Phalaris minor* were mixed with sand for proper seed distribution and were sown in between all the wheat rows. The trial was conducted in *P. minor* seed free land and there is no addition of FYM , Poultry and other organic manures because these are the main path for the seed dispersal. Sowing of *P. minor* seeds was done on the 18th of November during 2022-2023 and 2023-2024 in adequate moist soil. The herbicide application was done when the *P. minor* plants were in 3-4 leaf stage (which comes nearly 30-35 days after sowing).

RESULTS AND DISCUSSION

P. minor dry matter (q/ha)

At 60 DAS, weed dry matter (q/ha) was found to be significantly more in untreated (control) during both the years as compared to all other herbicidal treatments (Table 1). During 2022-23 dry matter accumulation by *P. minor* in pinoxaden and ready mix combination of (clodinafop+ metribuzin) treated crop was at par and both these treatments recorded significantly less dry matter than sulfosulfuron and sulfosulfuron+metsulfuron herbicide treated wheat crop. During 2023-24, the crop treated with pinoxaden, sulfosulfuron and sulfosulfuron+metsulfuron recorded at par dry matter accumulation by *Phalaris minor*.

Table 1: Dry weight of *P. minor* (q/ha) as influenced by different herbicides and biotypes at periodic intervals.

	Dry matter of *P. minor* (q/ha)							
	60 DAS		90 DAS		120 DAS		At harvest	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Main plots (Herbicides)								
Pinoxaden	1.1 (0.2)	1.3 (0.6)	2.0 (3.0)	3.0 (8.2)	2.4 (4.6)	3.1 (8.7)	2.7 (6.3)	3.3 (9.8)
Sulfosulfuron	1.3 (0.9)	1.4 (1.3)	2.3 (5.5)	3.1 (9.1)	2.5 (7.8)	3.1 (10.4)	3.3 (10.1)	3.4 (10.8)
Sulfosulfuron +metsulfuron	1.2(0.5)	1.5 (0.8)	2.5 (4.7)	3.1 (8.8)	2.8 (6.2)	3.2 (9.4)	3.2 (9.3)	3.5 (11.0)
CLODINAFOP +METRIBUZIN	1.1(0.1)	1.2 (0.3)	1.5(1.2)	1.7 (1.9)	1.1 (0.2)	1.0 (0.0)	1.8 (2.1)	1.5(1.2)
Control	1.9 (2.3)	2.3 (4.3)	3.5 (11.2)	4.1 (16.0)	5.2 (25.6)	6.5 (41.2)	9.9 (97.8)	9.5 (89.9)
SE (m)±	0.01	0.03	0.15	0.4	0.4	0.5	0.3	0.6
C.D at 5%	0.02	0.08	0.45	1.25	1.22	1.30	0.84	1.73
Sub plots (Biotypes)								
Ferozepur	1.4 (1.2)	1.6 (1.6)	2.7 (6.8)	3.4 (10.8)	3.1 (10.7)	3.8 (16.1)	5.3 (27.5)	5.0 (24.3)
Ropar	1.3 (0.8)	1.5 (1.4)	2.6 (6.3)	3.3 (10.5)	2.9 (9.5)	3.7 (15.8)	4.9 (22.6)	5.1 (25.0)
Fazilka	1.2 (0.6)	1.4 (1.1)	1.7 (2.6)	2.3 (5.1)	2.1 (5.9)	2.5 (8.5)	4.5 (19.2)	4.7(21.4)
Ludhiana	1.3 (0.9)	1.6 (1.7)	2.3 (4.7)	3.0 (8.8)	3.0 (9.4)	3.7 (15.7)	5.7 (31.3)	5.3 (27.4)
SE (m)±	0.02	0.02	0.10	0.15	0.22	0.21	0.12	0.09
C.D at 5%	0.08	0.09	0.31	0.49	0.71	0.68	0.38	0.27
C.D for interaction	NS	NS	NS	NS	NS	NS	NS	NS

Note: Values without paranthesis are square root transformed values ($\sqrt{\chi + 1}$)

Values within paranthesis are original ones.

Among the sub plots, significantly less dry matter accumulation by *P. minor* was found in Fazilka biotype than all other biotypes during both the years respectively. Ferozepur biotype produced significantly more dry matter accumulation than Ropar and Ludhiana biotypes during both the experimental years.

At 90 DAS significantly less dry matter was observed in clodinafop+metribuzin treated crop during both years than all other herbicides *i.e.* pinoxaden, sulfosulfuron and sulfosulfuron+metsulfuron. Significantly more dry matter of *P. minor* was obtained in sulfosulfuron treated crop than all other herbicide treatments. Also pinoxaden recorded significantly less dry matter of *P. minor* than sulfosulfuron and sulfosulfuron+metsulfuron during 2022-23. During 2023-24 the dry matter accumulation was at par in pinoxaden, sulfosulfuron and sulfosulfuron+metsulfuron treated crop. On the other hand significantly more dry matter accumulation was recorded in untreated (control) during both the years (Table 1). Among different biotypes, Fazilka biotype showed significantly less dry matter accumulation as compared to other biotypes during both the years

During both the years at 120 DAS, dry matter accumulation in clodinafop+metribuzin treated plots was significantly less than all other herbicide treatments. The dry matter accumulation in pinoxaden, sulfosulfuron and sulfosulfuron+ metsulfuron treated crop was found at par with each other. Whereas significantly higher dry matter was found in untreated than all other herbicide treatments. The dry matter accumulation in pinoxaden, sulfosulfuron and sulfosulfuron+ metsulfuron herbicides treated crop was found at par during both the years. In sub plot treatments Fazilka biotype associated crop produced significantly less dry matter accumulation than all other biotypes. And significantly more dry matter was found in Ferozepur biotype during both the years as compared to the crop growing in association with Ropar and Ludhiana biotypes.

At the time of harvest, out of all tested herbicides clodinafop+metribuzin treated crop recorded significantly less dry matter accumulation during both the years as compared to other herbicides treated crop. Significantly less dry matter of *P. minor* was recorded in Pinoxaden than sulfosulfuron and sulfosulfuron+metsulfuron herbicide treated crop during first year whereas pinoxaden, sulfosulfuron+metsulfuron and sulfosulfuron treated crop recorded at par dry matter of *P. minor* during second year. The untreated (control) recorded significantly more dry matter than all other treatments during both the years (Table 1). Among biotypes, significantly less dry matter was found in Fazilka district biotype during both the years as compared to other biotype associated crop. Whereas dry matter accumulation by Ludhiana biotypes was significantly more than that of Ferozepur and Ropar biotypes during both years.

Periodic dry matter accumulation by *P. minor* was significantly less in clodinafop+metribuzin herbicide than others which may be due to its better performance on all tested biotypes. In untreated control the growth of *P. minor* was very high as compared to other treatments and this weed dry matter was much more. And among the biotypes Fazilka biotype seems to be more susceptible to nearly all the tested herbicides compared to pinoxaden, sulfosulfuron and sulfosulfuron+metsulfuron (Duary *et al*., 2005).

Table 2: Mortality percentage of *P. minor* as influenced by different herbicides and Biotypes recorded at 60 DAS.

Mortality %		
	60 DAS	
	2022-23	2023-24
Main plots (Herbicides)		
Pinoxaden	49.43	39.91
Sulfosulfuron	31.12	33.33
Sulfosulfuron+metsulfuron	32.37	38.75
Clodinafop+metribuzin	92.62	87.25
untreated	0.00	0.00
SE (m)±	1.03	1.60
C.D at 5%	3.23	5.31
Sub plots (Biotypes)		
Ferozepur	30.00	24.00
Ropar	34.60	35.00
Fazilka	71.95	70.13
Ludhiana	27.90	30.26
SE (m)±	1.05	1.15
C.D at 5%	3.01	3.35
C.D for interaction	NS	NS

Mortality percentage of *P. minor*

Mortality percentage specifies percentage death of *Phalaris minor* plants with herbicide application. Mortality percentage is a reliable parameter in to check the effectiveness of herbicide among the treated weed flora. Visual observations has been taken at 60 DAS because herbicides were applied at 30 to 35 days after sowing and these requires 20-25 days for showing their complete toxic effects on weeds. So, mortality percentage of *P. minor* plants was recorded 60 DAS to get valid information and demonstrated in Table 2.

Among the main plot treatments (clodinafop + metribuzin) ready mix, treated plots showed significantly more mortality percentage of *P. minor i.e.* 92.62 and 87.25% during both the years respectively than all other tried herbicides. Pinoxaden recorded more mortality percentage of *Phalaris minor* than sulfosulfuron+metsulfuron and sulfosulfuron during 2022-23 and 2023-24. Significantly less mortality percentage (0 per cent) was recorded in untreated (control) during both the years than all herbicide treatments. Among the biotypes, Fazilka biotype showed significantly more mortality percentage (71.95 and 70.13%) than all other tested biotypes during both the years respectively. Ferozepur biotype and Ludhiana biotype was statistically at par mortality percentage during 2022-23 but during 2023-24 Ferozepur biotypes was having significantly less mortality percentage than all other biotypes (Table 2).

Different herbicides and biotypes influenced mortality percentage. Data demonstrated in Table 2 clearly indicates

that clodinafop+metribuzin is having more mortality percentage which clearly indicates its effectiveness among all other herbicides. Among sub plot treatments, Fazilka biotype was more susceptible to the applied herbicides among all the tested biotypes showing 71.95 and 70.13% mortality during 2022-23 and 2023-24 respectively. Minimum mortality per cent *i.e.* 24.00% was observed in Ferozepur during 2022-23 and maximum mortality of 71.95% in Fazilka biotype Kamboj *et al.* (2021).

Height of *P. minor* (cm)

Plant height of *P. minor* (cm) is a dependable indicator for growth and indicates the way a plants structure has developed over time. Also the height of *Phalaris minor* indicates its competitive potential with the crop. The data of plant height of *P. minor* was recorded at 60, 90, 120 DAS and at harvest during both years which has been presented in Table 3.

Among the different herbicide treatments, the difference in height (cm) of *P. minor* recorded 60 DAS was found to be significant during 2022-23 (Table 3). Among the different herbicide treatments, significantly less height of *Phalaris minor* was observed in clodinafop+metribuzin treated plots as compared to all other herbicide treated plots. The plant height in Pinoxaden and sulfosulfuron treated plots was statistically at par but significantly more than sulfosulfuron+metsulfuron herbicide treated plot. Significantly more plant height was recorded in untreated (control) as compared to all other herbicide treatments. These findings holds good during 2023-24 also. And in sub plots, significantly less plant height was obtained in Fazilka biotype antly less than Ferozepur biotype. These results holds good for both the years.

Among the different herbicidal treatments the plant height recorded at 90 DAS revealed that clodinafop+metribuzin treated plot treatments recorded significantly less height as compare to other treatments (Table 3). Significantly more plant height was found in untreated (control) during both the years (Table 3) as compared to all other tested herbicide treatments. Among the sub plots, Fazilka biotype recorded significantly less plant height as compared to all other biotypes. Significantly less height of *P. minor* was recorded in Ropar and Ludhiana compared to Ferozepur biotype during first year and in Ferozepur and Ludhiana biotypes as compared to Ropar during second year.

At periodic interval of 120 DAS, significantly less height of *P. minor* plants was observed in clodinafop+metribuzin treated plots (53.7 and 52.0 cm) during both the years respectively as compared to other biotypes (Table 3). Significantly more plant height was observed in untreated control *i.e.* 89.3 and 91.7 cm respectively during both the years as compared to all other treatments. On the other hand Fazilka biotype was having 47.7 and 41.0 cm plant height during both the years respectively which was significantly less than all other tested biotypes Ferozepur biotype showed significantly more plant height during 2022-23 than Ropar biotype and during 2023-24 Ropar biotype showed significantly more plant height than Ferozepur biotype. However, plant height of Ludhiana was significantly less than Ropar and Ferozepur biotype during both years (Table 3).

The plant height of *P. minor* treated with clodinafop+ metribuzin was significantly less than all other biotypes. The application of Pinoxaden recorded significantly more height of *P. minor* than sulfosulfuron and sulfosulfuron+ metsulfuron herbicides. In the untreated crop, the height of *P. minor* was significantly more than all herbicide treatments. These findings holds good for both the years. The height of *P. minor* at harvest was significantly less in

Table 3: Height of *Phalaris.minor* (cm) as influenced by different herbicides and biotypes at periodic intervals.

	Height of *P. minor* (cm)							
	60 DAS		90 DAS		120 DAS		At harvest	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Main plots (Herbicides)								
Pinoxaden	16.2	15.6	82.8	81.8	84.3	81.9	84.6	83.5
Sulfosulfuron	16.1	15.5	65.3	64.1	68.9	72.7	68.8	69.6
Sulfosulfuron+metsulfuron	11.9	11.4	72.6	69.9	77.9	72.2	73.0	67.3
clodinafop+metribuzin	2.8	3.3	57.3	47.1	53.7	52.0	53.7	59.7
Untreated	33.5	33.9	89.9	91.3	89.3	91.7	89.3	90.4
SE (m)±	0.80	0.16	0.53	0.40	0.90	0.29	0.91	0.37
C.D at 5%	2.56	0.51	1.64	1.33	2.85	0.95	2.84	1.22
Sub plots (Biotypes)								
Ferozepur	19.5	18.3	85.4	80.7	86.5	86.6	86.7	86.8
Ropar	16.9	17.3	82.3	82.3	84.3	87.7	85.0	84.7
Fazilka	10.9	10.9	43.5	39.9	47.7	41.0	43.7	40.6
Ludhiana	16.9	17.2	83.2	80.4	80.3	81.1	80.3	84.3
SE (m)±	0.78	0.15	0.50	0.27	0.74	0.32	0.74	0.37
C.D at 5%	2.23	0.43	1.44	0.79	2.13	0.93	2.12	1.08
C.D for interaction	NS	NS	NS	NS	NS	NS	NS	NS

Fazilka biotype as compared to biotype of other districts Table (3). Height of *P. minor* of Ferozepur and Ropar was significantly more than Ludhiana during 2022-23 and Ferozepur biotype recorded significantly more plant height than Ropar and Ludhiana biotypes during 2023-24.

Clodinafop+metribuzin treated wheat crop recorded less periodic height of *Phalaris minor* during both years which may be due to effective control of all biotypes with this herbicide as compared to all other herbicides. Also height of *Phalaris minor* of Fazilka biotype was less due to its effective control by nearly all herbicides as compared to biotypes of other districts. Similar results were reported by Hussain *et al*. (2017).

Grain yield of wheat (q/ha)

Grain yield is economic parameter on which economics of farmer depends. The data pertaining to grain yield has been presented in Table 4.

During 2022-23, post emergence application of clodinafop+metribuzin produced significantly higher grain yield (q/ha) as compared to application of all other herbicides (Table 4). Application of Pinoxaden recorded significantly higher wheat grain yield compared to sulfosulfuron and sulfosulfuron+metsulfuron treated crop. Significantly less yield was recorded in sulfosulfuron herbicide treated crop compared to all other herbicides. During 2023-24 grain yield with application of pinoxaden, sulfosulfuron+metsulfuron and sulfosulfuron treated crop was at par but significantly less than clodinafop+metribuzin treated crop. Untreated (control) treatment recorded significantly less grain yield than all herbicide treatments during both years.

Among sub plot treatments, grain yield was significantly higher in the crop infested with Fazilka biotype of *Phalaris minor* as compared to other biotypes (Table 4). Significantly higher wheat grain yield was obtained in wheat infested with Ludhiana district biotype than Ferozepur and Ropar biotype. These findings holds good for both years. During 2023-24 seed yield of crop growing with Ferozepur biotype was significantly less than all other biotypes.

On the basis of pooled analysis, it can be concluded that application of clodinafop+metribuzin produced significantly higher wheat grain yield (q/ha) than all other herbicides. Pinoxaden application increased wheat grain yield significantly than sulfosulfuron and sulfosulfuron+ metsulfuron treated crop and the latter treatments being at par among each other. Grain yield of wheat was significantly less in untreated (control) as compared to all other herbicide treatments on the basis of pooled data. Application of clodinafop+metribuzin, pinoxaden, sulfosulfuron + metsulfuron and sulfosulfuron increased grain yield by 12.3, 5.9, 4.2 and 1.5 per cent than untreated (control) crop respectively. Among sub plot treatments, crop growing in association of Fazilka biotype produced significantly more grain yield as compared to all other biotypes. The crop growing in association of Ludhiana biotype significantly increased grain yield than that of Ferozepur and Ropar districts biotypes. Also grain yield of wheat growing in association with Ferozepur biotype was found to produce significantly less yield than Ropar, Ludhiana and Fazilka biotypes. High yield of crop growing in association of Fazilka biotype may be due to its more sensitivity to herbicides. On the basis of pooled data, grain yield of crop growing in association of Fazilka, Ludhiana and Ropar districts increased grain yield by 33.8, 26.5 and 22.1 per cent than Ferozepur biotype (Gopal *et al*., 2017).

Higher grain yield in clodinafop+metribuzin treated wheat crop may be due to its more effectiveness on different biotypes of *Phalaris minor* as compared to all other herbicides. Grain yield of wheat was much higher in Fazilka infesting crop compared to all other biotypes which may be

Table 4: Grain yield of wheat (q/ha) as influenced by different herbicides and biotypes.

	Grain yield (q/ha)		Pooled
	2022-23	2023-24	
Main plots (Herbicides)			
Pinoxaden	62.0	53.0	57.5
Sulfosulfuron	54.5	53.0	53.7
Sulfosulfuron+metsulfuron	56.9	53.8	55.4
clodinafop+metribuzin	67.0	59.5	63.3
Untreated	46.7	41.8	44.2
SE (m)±	0.51	0.60	0.54
C.D at 5%	1.46	1.71	1.74
Sub plots (Biotypes)			
Ferozepur	53.7	35.6	44.0
Ropar	54.6	53.5	54.0
Fazilka	63.4	64.3	63.8
Ludhiana	58.0	55.5	56.7
SE (m)±	0.47	0.31	0.42
C.D at 5%	1.46	1.08	1.26
C.D for interaction	NS	NS	

due to the reason that Fazilka biotype was more sensitive to nearly all tried herbicides. Moreover plants of Fazilka biotype were less vigorous during initial stages compared to other biotypes and hence they were killed more effectively with applied herbicides. Among all tested biotypes, Ferozepur biotype reduced more wheat grain yield indicating that it is very hardy biotype compared to others. The results are similar with the findings of Dangwal *et al*. (2010).

CONCLUSION

Our investigation reveals that among all the herbicide treatments performance of clodinafop+metribuzin herbicide was satisfactory. Whereas other tried herbicides are not able to control the tried biotypes except Fazilka. Fazilka biotype is sensitive to all the tried herbicides whereas other biotypes were sensitive to only clodinafop+metribuzin herbicide and shown their resistance to all other herbicides. Higher grain yield of wheat was found in clodinafop+ metribuzin treated plots due to its more effectiveness among all the biotypes of *P. minor* among the sub plots Fazilka biotype associated crop produce more grain yield as compared to associated with all other biotypes.

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Disclaimers

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Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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