Environment and Ecology 41 (3D) : 2193—2202, July—September 2023
Article DOI: https://doi.org/10.60151/envec/PPGB3824
ISSN 0970-0420

Evaluation of Aclonifen 600SC a Broad-Spectrum Herbicide Molecule to Control Canary Grass (*Phalaris minor* (*Retz.*) *Pers.*) in Wheat Crop

M. B. Reddy, U. P. Singh, Anurag Upadhyay, Kajal Verma, N. K. Singh, Deeptirekha Mahapatra, Sanjeev Kumar, Avaneesh Kumar

Received 28 April 2023, Accepted 28 June 2023, Published on 20 September 2023

ABSTRACT

A field experiment was undertaken during the *rabi* season of 2019-20 at the agricultural research farm, BHU, Varanasi with an aim to determine the appropriate time and amount of a new broad-spectrum herbicide molecule aclonifen 600SC for effective control of *Phalaris minor* in wheat. The experiment was set up in a Randomized Block Design (RBD) with ten treatments replicated thrice. Among different chemical options tested, aclonifen 600 SC @ 2.4 kg a.i./ha application both as pre and early post-emergence (PE-W_4 and EPOE-W_8) resulted in lower density and dry matter accumulation by *Phalaris minor* and resulted in enhanced control efficiency. Next to it, the application of aclonifen 600 SC as PE (W_3) and EPOE (W_7) at rates of 1.2 kg a.i./ha recorded better results without affecting crop growth and grain yields of wheat, and these treatments were superior to leftover three doses of aclonifen 600 SC applied both as PE and EPOE. From these results, it is clear that aclonifen @ 1.2 a.i./ha applied as pre and early post-emergence (up to 15 DAS-days after sowing) effectively controls *Phalaris minor* (*Retz*.) *Pers*. in wheat, which resulted in enhanced productivity and profitability.

Keywords Aclonifen, Wheat, *Phalaris minor*, Productivity, Profitability.

INTRODUCTION

Wheat (*Triticum aestivum* L.) a grassy foodgrain crop belongs to the family "Graminae". It is India's second significant cereal crop next to rice and provides 50% of the calories and protein requirement of the majority of the Indian population (Choudhary *et al*. 2021). India ranks second in wheat production with a cultivated area of about 30.5 million hectares (12% of the global area), producing an economic output of

M. B. Reddy[1]

Senior Technical Officer, ICAR-Indian Veterinary Research Institute, Izatnagar, Bareilly, UP 243122, India

U. P. Singh[2*], Anurag Upadhyay[3], Kajal Verma[4], N. K. Singh[5], Deeptirekha Mahapatra[6]

[2]Professor, [3,4,6]Asst. Prof, [5]PhD Scholar
[2,3,4,5,6]Dept. of Agronomy, Institute of Agricultural Sciences Banaras Hindu University, Varanasi, UP 221101, India

Sanjeev Kumar[7,] Avaneesh Kumar[8]

[7]Scientist, [8]PhD Scholar Agronomy Section
ICAR-National Dairy Research Institute,Karnal, Haryana 132001, India

Email: udaipratap.singh1@gmail.com
*Corresponding author

106.84 million tonnes (13.44% of global production) with an average productivity of 2.98 tonnes per hectare (Ministry of agriculture and farmers welfare, GoI 2022). Indeed, Uttar Pradesh is the leading producer of wheat in the country where the wheat cultivation is mainly spread in three agro-climatic zones viz., western UP (3.29 m ha), eastern UP (0.68 m ha) and central UP (0.68 m ha). The estimated wheat production from UP is 24.5 mt with an average state productivity of 2.7 t/ha (Directorate of economics and statistics 2022). On the other hands the increasing demographic pressure forces the nation to produce more and more for ensuring food security and safety. By 2050, the demand for wheat had increased by 50%, and to maintain the nation's self-sufficiency in terms of food and nutrition security, wheat output had to be boosted by 2 million tonnes annually (FAO 2018).

Among various biotic stress factors, weeds are considered major ones that limit enhanced wheat production (Swain *et al*. 2022). Surprisingly weeds alone account for one-third of total pest losses (Jeevan *et al*. 2023). Notably, little seed canary grass is now turning into a noxious weed in the rice-wheat system of the IGP belt. Herbicides became popular among Indian wheat farmers due to the morphological imitation of *Phalaris minor* Retz. with wheat crop and labor unavailability and rising labor wage rates (Mishra *et al*. 2021). Yet, long-term dependence on a single herbicide with the e same mode of action and window of application can lead to the development of cross-resistant *P. minor* biotypes and ultimately to a shift in the weed flora (Soni *et al*. 2022). Kaur *et al*. (2022) reported that gehu ka mama (canary grass) developed resistance to isoproturon herbicide in the mid-1990s as a result of its long-term usage. Consequently, for successful herbicide-based weed management in wheat, the development and assessment of new herbicide molecules with diverse mechanisms and modes of action and a wider window of application is a necessity (Duke and Dayan 2022). Given the foregoing explanation, the current study was conducted to determine how well the broad-spectrum herbicide molecule "aclonifen 600SC" worked to control canary grass (*Phalaris minor (Retz.) Pers.*) in wheat.

MATERIALS AND METHODS

The current weed management trial was carried out throughout the winter season of 2019-2020 at the Agro-research farm of BHU Varanasi. Varanasi is situated in the eastern part of Uttar Pradesh and climatologically Varanasi falls under the category of subtropical climate with hot summers and cold winters. The mean monthly minimum and maximum temperatures, and relative humidity and rainfall that prevailed during the investigation period are graphically depicted (Fig. 1). The soil of experimental site is sandy clay loam in texture with a slightly alkaline (pH of 7.4) nature. The soil at the test location is quite fertile, with a low soil organic carbon content (0.40%) and medium levels of accessible nitrogen (283.35 kg/

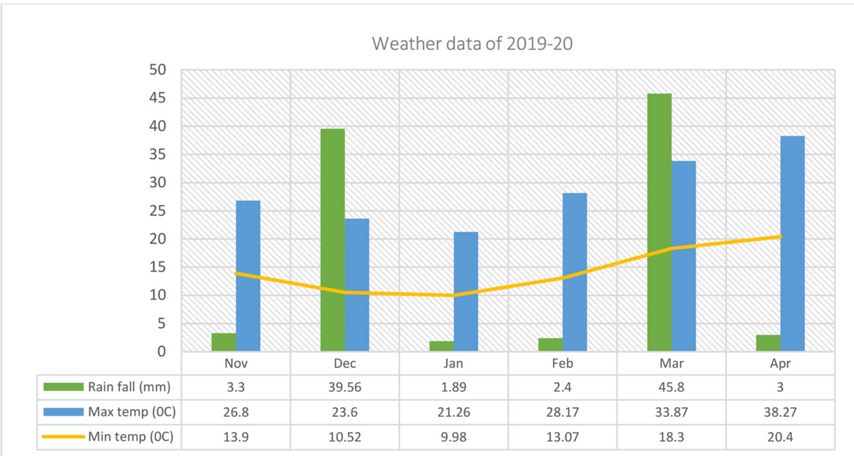

Fig. 1 Monthly mean rainfall(mm), maximum and minimum temperature (^{0}C) during second season of crop (2019-20).

Table 1. Treatment details of the experiment.

Symbol	Treatment	Rate (kg a.i./ha)	Time of application
W1	Untreated control	-	-
W2	Aclonifen 600SC	0.9	PE 1 DAS
W3	Aclonifen 600SC	1.05	PE 1 DAS
W4	Aclonifen 600SC	1.2	PE 1 DAS
W5	Aclonifen 600SC	2.4	PE 1 DAS
W6	Pendimethalin	1.25	PE 1 DAS
W7	Aclonifen 600SC	0.9	PE 1 DAS
W8	Aclonifen 600SC	1.05	Early POE 15 DAS
W9	Aclonifen 600SC	1.2	Early POE 15 DAS
W10	Aclonifen 600SC	2.4	Early POE 15 DAS
W11	Sulfosulfuron	0.025	POE 30 DAS
W12	Farmer's practice	2 hand weeding	20 DAS and 40 DAS

*PE pre-emergence, POE post-emergence and DAS days after sowing.

ha), phosphorus (27.80 kg/ha), and potassium (220.32 kg/ha). The trial was conducted in a Randomized Block Design (RBD) using 13 treatments with three replications (Table 1).

In order to analyze the influence of aclonifen 600SC as a single variable factor, all the best management practices (BMPs) were implemented in all treatments as per recommendations of the Department of Agronomy, I.Ag.Sc. BHU, Varanasi. The study was carried by sowing a wheat cultivar "HUW 234" @ 100kg seed/ha with 22 cm row-to-row spacing on 20 Dec of 2019 by using a ferti cum seed drill machine and the crop was harvested on 20 April. The recommended dose of fertilizers for wheat i.e., 150, 60, 60 kg N, P_2O_5, K_2O / ha was supplied through urea (46 % N), D AP (18%N and 46% P_2O_5) and MOP (60% K_2O) respectively. A total of four irrigations were supplied throughout the crop season as per the crop requirement. All the selected herbicides were applied using a hand-driven knapsack sprayer fitted with a flat fan nozzle with a spray volume of 500 l/ha.

Weed studies

To assess the effect of aclonifen 600SC on *P. minor* growth, data with respect to density (no./m^2) were recorded at 45, 60 and 75 DAS from two random locations in a plot using a quadrate of 1 m^2, the observed value was averaged, subjected to square root ($\sqrt{(x+1)}$) transformation, and expressed as number of *P.minor*/m^2. Whereas data pertaining to the dry matter accumulation (g/m^2) and control efficiency (%) of *P. minor* were calculated at 75 DAS by collecting and oven-drying *P. minor* at 72^{0}C for a period of 48 hours. The weed control efficiency (WCE), weed index (WI) and herbicide efficiency index were calculated by adopting standard procedures as mentioned below to find out the best treatment for effective control of *P. minor* in wheat.

Weed control efficiency (%) was computed by using the following formula given by Choudhary *et al*. (2021)

$$\text{Weed control efficiency (WCE)} = \frac{[(\text{WDc - WDt})] \times 100}{\text{WDc}}$$

Where, WDc is the weed density in control plot (no./m^2) and WDt is the weed density in treated plot (no./m^2).

Weed control index was calculated by adopting the standard procedure as suggested by the Das *et al*. (2017) as follows

$$\text{Weed control index (WCI)} = \frac{[(\text{WDMc - WDMt})] \times 100}{\text{WDMc}}$$

Where, WDMc is the weed dry matter in control plot (g/m^2) and WDMt is the weed dry matter in treated plot (g/m^2).

Weed index indicates the extent of economic yield reduction due to weed infestation. In addition to it this is used to know the superiority of treatment over a weedy check plot. It was calculated by using the following formula suggested by Das *et al*. (2017).

$$\text{Weed index (WI)} = \frac{[(Y_{wf} - Y_t)] \times 100}{Y_{wf}}$$

Where Y_{wf} is the wheat grain yield from weed free plot (t/ha) and Y_t is the wheat crop yields from treated plots (t/ha).

Herbicide efficiency index was computed by using the standard procedure suggested by Das *et al*. (2017) as follows

$$\text{Herbicide efficiency index (HEI)} = \frac{[(Y_t - Y_c/Y_t)]\times 100}{[\left(\frac{WDM_t}{WDM_c}\right)\times 100]}$$

Where Y_t is wheat grain yield from treated plot (kg/ha), Y_c is grain yield from untreated control plot (kg/ha); WDM_t is the weed dry matter (kg/ha), WDM_c is the weed dry weight from untreated control plot (kg/ha).

Weed persistence index is used to know the extent of weeds that tolerated the applied herbicide and effectively produced dry matter. It was calculated by using standard procedure as suggested by Das *et al*. (2017) as follows:

Weed persistence index (WP_I) = $WP_c/(WP_t)$ X WDM_t/WDM_c

Where WP_c is the weed population in control plot (no./m^2), WP_t is the weed population in treated plot (no./m^2), WDM_c is the weed dry matter n control plot (g/m^2) and WDM_t is the weed dry matter in treated plot (g/m^2).

Crop studies

To know the effect of adopted chemical weed management practices on crop plants different biometrical observations were recorded. The initial plant population was recorded at 15 DAS and the data pertaining to crop growth attributes viz., plant height (cm), number of tillers (m^2), dry matter accumulation (g/m^2) and yield attributes viz*.,* number of spikes/m^2, number of grains/spikes were recorded at harvest stage by selecting and tagging ten wheat plants randomly from the net plot.

Yield and economics of treatments

The grain individual plots were calculated by harvesting the wheat crop at harvest maturity i.e., around 105 DAS and expressed in terms of t/ha. Whereas the straw yield was recorded after subtracting grain yield from biological yield and finally straw yield was expressed in terms of t/ha. Finally, the economics of treatments were calculated separately by taking into account the existing prices of various inputs and produce (grain and straw) in the market.

Statistical analysis

After collecting the data from on-farm experimentation with 12 treatments and 3 replications with Randomized Block Design was analyzed as per the standard statistical procedures suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect of weather on wheat and weeds

The details concerning the weather parameters viz., temperature and rainfall during the course of field experimentation (2019-20) are presented and depicted (Fig. 1). From the fig. 1, it is clear that the monthly mean maximum temperature of the region was between 9.98^{0}C to 20.40^{0}C, whereas the monthly maximum temperature ranges from 21.60^{0}C to 33.80^{0}C. these sudden increases of temperatures over normal needs at the maturity stage i.e. 25^{0}C in conjunction with poor rainfall resulted in increased demand for water and which in turn led to an increased number of irrigations during the crop growth period in order to combat the adverse effect of terminal heat stress in wheat.

Effect of treatments on *Phalaris minor*

Density (no./m^2)

The observations with respect to the density of *Phalaris minor* as significantly influenced by different weed management practices are presented in Table 2. Apart from the control treatment (W_1), the density of canarygrass was significantly influenced by different chemical weed management options at different crop growth stages. It is clear from the data (Table 2) that the application of aclonifen 600 SC 2.4 kg a.i./ha both as pre (W5) and early post-emergence (W10) resulted in the lower density of *P. minor* ~1.79 and 1.88/m^2 respectively at 30 DAS and this treatment was statistically at par with the pre and early post-emergence applications of aclonifen 600 SC at rates of

Table 2. Effect of herbicidal weed management treatments on density of *Phalaris minor* (No. m^{-2}) in wheat.

Treatment	Dose (kg a.i/ha)	Time of application	*Phalaris minor* (No. m^{-2})				Total biomass production of *P. minor* at 75 DAS (g/m^2)
			30 DAS	45 DAS	60 DAS	75 DAS	
W1-Control	-		(6.55)	(6.91)	(7.31)	(7.85)	(7.46)
			2.75	2.81	2.88	2.98	2.91
W2-Aclonifen 600SC	0.9	PE 1 DAS	(3.51)	(3.57)	(3.87)	(3.94)	(2.08)
			2.12	2.14	2.21	2.22	1.75
W3-Aclonifen 600SC	1.05	PE 1 DAS	(2.52)	(2.59)	(2.65)	(2.70)	(1.63)
			1.88	1.89	1.91	1.92	1.62
W4-Aclonifen 600SC	1.2	PE 1 DAS	(2.38)	(2.46)	(2.51)	(2.54)	(1.49)
			1.84	1.86	1.87	1.88	1.58
W5-Aclonifen 600SC	2.4	PE 1 DAS	(2.17)	(2.21)	(2.18)	(2.20)	(0.84)
			1.78	1.79	1.79	1.79	1.36
W6-Pendimethalin 30% EC	1.25	PE 1 DAS	(3.00)	(3.13)	(3.20)	(3.27)	(3.81)
			2.00	2.03	2.05	2.07	2.19
W7-Aclonifen 600SC	0.9	EPOE (15DAS)	(3.58)	(3.60)	(3.65)	(3.71)	(4.00)
			2.14	2.14	2.16	2.17	2.24
W8-Aclonifen 600SC	1.05	EPOE (15DAS)	(3.06)	(3.17)	(3.21)	(3.31)	(1.39)
			2.02	2.04	2.05	2.08	1.54
W9-Aclonifen 600SC	1.2	EPOE (15DAS)	(2.41)	(2.55)	(2.57)	(2.61)	(1.38)
			1.85	1.88	1.89	1.90	1.54
W10-Aclonifen 600SC	2.4	EPOE (15DAS)	(2.27)	(2.48)	(2.50)	(2.52)	(0.74)
			1.81	1.87	1.87	1.88	1.32
W11-Sulfosulfuron 75%	0.025	POE (35DAS)	(3.15)	(3.23)	(3.34)	(3.42)	(1.51)
			2.04	2.06	2.08	2.10	1.58
W12-Farmer practice	2 Hand weedings	At 29 and 40 DAS	(2.07)	(2.40)	(2.47)	(2.50)	(0.54)
			1.75	1.84	1.86	1.87	1.24
SEm±			0.10	0.11	0.11	0.11	0.02
LSD (p=0.05)			0.03	0.04	0.04	0.04	0.06

Data given in parenthesis are original values. Original data subjected to square root transformation.
HW- Hand weeding, PE – Pre-emergence, EPOE – Early post-emergence, POE – post Emergence.

1.2 kg a.i./ha (W4 and W9) and 1.05 kg a.i./ha (W3 and W8). The same trend was observed at 45, 60 and 75 DAS of wheat. It is due to the effective chemical action aclonifen on *P. minor*. Moreover, aclonifen has a wider window for its usage, this nature made it possible to use aclonifen as both PE and EPOE. These findings are in agreement with the report of Kanatas and Gazoulis (2022). Choudhary *et al.* (2016) and Singh *et al*. (2019) stated that minimum weed density was recorded under hand weeding twice treatment followed by herbicidal treatments. Whereas the highest number of *Phalaris minor* were counted in the un-weeded control plot (W_1) because of its ineffective control.

Biomass production (g/m^2)

Among different herbicidal treatments, treatment with the application of aclonifen 600 SC @ 2.4 kg a.i./ha as PE and EPOE recorded lower biomass production (0.84 and 0.74 g/m^2) at 75 DAS (Table 2) these treatments were at par with pre and early post-emergence application of aclonifen 600 SC @ 1.2 kg a.i./ha (W4 and W9) and 1.05 kg a.i./ha (W3 and W8) in terms of reducing biomass production of canarygrass in comparison to weedy check (W1) plot (Table 2) and it could be due to effective control of gehuka mama through increased rate of respiration, by disrupting photosynthesis, and photophosphorylation by inhibiting photo-porphyrinogen oxidase/PPO activity. Kilinç (2015) and Pannacci and Bartolini (2018) have reported that the application of aclonifen as pre-emergence or as early post-emergence until the plant reach the 1-2 leaf stage resulted in significant control of *P. minor*. None of the treatments, however, were comparable to farmer practice, i.e., manual hand weeding twice at 20 and 40 DAS significantly recorded the lowest biomass accumulation (1.24 g/m) by *P. minor*.

P. minor control efficiency (%)

The study found that the hand weeding twice (20 and 40 DAS) treatment (W12) had the highest weed control efficiency compared to the untreated control plot (W1), which had the lowest weed control efficiency (Table 3). Among different herbicidal treatment options, aclonifen 600 SC @ 2.4 kg a.i./ha applied both pre (W5) and early post-emergence (W10) recorded the highest weed control efficiency 88.74 and 90.08 % respectively, followed by PE and EPOE application of aclonifen 600SC at rates of 1.2 kg a.i./ha (W4 and W9) and 1.05 kg a.i./ha (W3 and W8) (Table 3), which were statistically at par with each other. Of course, all chemical management options were superior over the control plot (W1) with respect to *P. minor* control efficiency and this was mainly attributable due to a significant reduction in dry matter accumulation of *P. minor* with increased herbicide activity with diverse mechanisms of action. These findings agree with those of Kilinç (2015) and Pala *et al*. (2018).

Weed index (%)

Among four different doses of aclonifen 600SC, treatment with a dose of 1.2 kg a.i./ha as pre (W4)

Table 3. Effect of herbicidal weed management treatments on *P. minor*.

Treatment	Dose (kg a.i/ha)	Time of application	*P. minor* control index	*P. minor* control efficiency	Weed index	Herbicide efficiency index	*P. minor* persistence index
W1-Control	-		0.0	0.00	35.12	0.00	1.00
W2-Aclonifen 600SC	0.9	PE 1 DAS	49.8	72.12	23.95	0.53	0.64
W3-Aclonifen 600SC	1.05	PE 1 DAS	65.6	78.15	6.05	1.42	0.56
W4-Aclonifen 600SC	1.2	PE 1 DAS	67.6	80.03	0.7	1.74	0.56
W5-Aclonifen 600SC	2.4	PE 1 DAS	72.0	88.74	14.65	2.13	0.40
W6-Pendimethalin 30% EC	1.25	PE 1 DAS	58.3	48.93	32.79	0.07	1.23
W7-Aclonifen 600SC	0.9	EPOE (15DAS)	52.7	46.38	32.09	0.08	1.13
W8-Aclonifen 600SC	1.05	EPOE (15DAS)	57.8	81.37	11.86	1.42	0.62
W9-Aclonifen 600SC	1.2	EPOE (15DAS)	66.8	81.50	5.12	1.71	0.44
W10-Aclonifen 600SC	2.4	EPOE (15DAS)	67.9	90.08	21.63	1.74	0.31
W11-Sulfosulfuron 75%	0.025	POE (35DAS)	56.4	79.76	22.79	0.82	0.46
W12-Farmer practice	2 HW	At 29 and 40 DAS	68.2	92.76	0.00	4.85	0.23
SEm±			3.10	3.96	0.88	0.11	0.03
LSD (p=0.05)			6.55	8.26	1.84	0.23	0.06

HW- Hand weeding, PE – Pre-emergence, EPOE – Early post-emergence, POE – Post emergence.

and early post-emergence (W9) was recorded a minimum weed index value of 0.70 and 5.12 respectively (Table 3). This proves that the weeds were effectively controlled with aclonifen application at 1.2 kg a.i./ha without harming the crop, leading to higher crop yields in this plot. Whereas the maximum weed index of ~ 35.12 was recorded in the control plot (W1) and it is mainly due to unchecked growth of *P. minor*. These findings agreed with those of Nekhat *et al.* (2020) findings.

Herbicide efficacy index (HBI)

The data (Table 3) revealed that among different herbicides with different times and doses, the application of aclonifen 600SC @ 1.2 kg a.i./ha as pre-emergence (W4) and early post emergence (W9) showed maximum HEI values of 2.13 and 1.74 respectively (Table 3). Next to these treatments aclonifen 600SC @ 1.05 kg a.i./ha both as PE and EPOE were recorded higher HEI in terms of selectivity to the wheat crop (Table 3). Due to higher HEI weeds were effectively controlled in these treatments without reducing crop yields. Klinic (2015) from his study concluded that the application of aclonifen @ 1.2 kg a.i./ha showed better selectively to crop without causing any injury.

Persistence index (PI)

It is evident from Table 3 that the pre and early postemergence applications of aclonifen 600SC at 2.4 kg a.i./ha (W5 and W10) showed lower PI values of 0.40 and 0.31 respectively and next to these treatment's PE and EPOE application of aclonifen 600 SC@ 1.2 kg a.i./ha (W4 &W9) recorded lower PI values (W4-0.56 & W9-0.44) in comparison with un-weeded control plot (W1-1.00). It might be due to the effective action of aclonifen at these dosages and application time. Moreover, aclonifen a diphenyl-ether group herbicide with a different mechanism of action (inhibition of photosynthesis, respiration and carotene) made it complex to develop persistence by weeds. These results are close confirmative with the findings of Nekhat *et al*. (2020).

Effect of treatments on wheat

Table 4. Effect of herbicidal weed management treatments on crop growth parameters and yield attributes of wheat.

Treatment	Dose (kg a.i/ha)	Time of application	Initial plant population (no/m^2)	Plant height (cm)	No. of tillers/m^2	Biomass production (g/m^2)	No. of spikes/m^2	Spike length (cm)
W1-Control	-	-	257.00	22.91	173.53	120.21	235.00	7.12
W2-Aclonifen 600SC	0.9	PE 1 DAS	254.54	22.93	182.45	152.16	249.00	7.56
W3-Aclonifen 600SC	1.05	PE 1 DAS	255.62	23.01	197.56	157.56	287.04	8.74
W4-Aclonifen 600SC	1.2	PE 1 DAS	256.03	23.34	215.78	167.89	288.00	9.21
W5-Aclonifen 600SC	2.4	PE 1 DAS	257.46	22.82	191.25	155.80	281.00	7.86
W6-Pendimethalin 30% EC	1.25	PE 1 DAS	253.76	21.67	191.44	150.57	245.00	7.74
W7-Aclonifen 600SC	0.9	EPOE (15DAS)	255.03	22.99	185.22	151.63	242.04	7.32
W8-Aclonifen 600SC	1.05	EPOE (15DAS)	256.42	23.15	208.09	159.24	285.00	8.23
W9-Aclonifen 600SC	1.2	EPOE (15DAS)	257.10	23.23	211.94	160.11	291.00	8.56
W10-Aclonifen 600SC	2.4	EPOE (15DAS)	258.12	22.93	194.34	152.16	279.34	7.56
W11-Sulfosulfuron 75%	0.025	POE (35DAS)	253.05	21.70	181.77	147.15	257.00	7.96
W12-Farmer practice	2 HW	At 29 and 40 DAS	256.03	24.70	221.94	168.51	294.00	8.89
SEm±	-	-	9.36	1.16	6.76	5.30	10.28	0.31
LSD(p=0.05)	-	-	NS	NS	19.72	15.46	29.91	0.90

HW- Hand weeding, PE – Pre-emergence, EPOE – Early post-emergence, POE – Post emergence.

Initial plant population (No./m^2) at 20 days of crop stage

It is apparent from the data (Table 4) that the different weed management practices had a non-significant influence on initial plant stand. It has also been proven that aclonifen application as PE or EPOE also does not affect the initial crop stand in the field.

Plant height (cm) at 30 DAS of wheat

The plant height at 30 DAS had not-significantly influenced by various weed management practices (Table 4). However, maximum plant height was recorded with pre and early post emergence application of aclonifen 600SC @ 1200 g a.i/ha (W4-23.34 and W9-23.23) followed by aclonifen 600SC @ 1050 g a.i./ha over weedy check (W1-22.91 cm). These results are in line with Pala *et al*. (2018).

No. of tillers/m^2

The data recorded (Table 4) with respect to the number of tillers per m^2 indicated that the maximum number of tillers/m^2 was recorded in farmers' practice (two hand weeding at 20 and 40 DAS) treatment (W12-221.94). Amongst the different herbicidal treatments, treatment with application of aclonifen 600SC @1.2 kg a.i./ha both as pre and early post emergence recorded highest number of tillers/m^2 i.e., W4-215 and W9-211.94 (Table 4) followed by pre and early post emergence application of aclonifen 600 SC @ 1050 g a.i./ha and which were statistically at par with each other. These findings are in agreement with the results of Pala *et al*. (2018). It is also clear from the data that the minimum number of tillers/m^2 was recorded in untreated control plot throughout the crop growth stages. Choudhary *et al*. (2021) reported that unchecked weed growth in control treatment resulted in poor plant performance and affected tiller production which led to reduced tiller number per hill.

Dry matter production (g/m^2)

The data (Table 4) clearly indicate that various weed management options have shown a significant effect of dry matter accumulation by wheat crop and among various treatments, pre and early post emergence application of aclonifen 600SC @ 1.2 kg a.i./ha recorded maximum biomass accumulation of about 167.89 and 160.11 g/m^2 respectively and which is standing at par with farmers practice (W12-168.51) and pre and early post emergence application of aclonifen 600SC @ 1.05 kg a.i./ha. In fact, herbicide usage not only reduced the weed competition for various crop growth factors viz., nutrients, moisture, sunlight and space but also facilitates vigorus growth and development of wheat crops due to lower nutrient removal by weeds Pala *et al*. (2018).

Effect of treatments on yield attributes

The yield attributing characters such as no. of spikes/plant and spike length was greatly influenced by the adopted weed management strategies. Data (Table 4) revealed that out of various treatments application of aclonifen 600SC@ 1.2 kg a.i./ha both as PE and EPOE showed higher spike numbers per plant (W4-288 and W9-291) and spike length (W4-9.21 and 8.56) at harvest stage it might be due to availability of congenial environment for grain formation with less weed competition in these treatments. These findings are in line with Klinic (2015).

Effect of treatments on yields and economics of wheat

Effect of treatments on wheat yields

The various weed control treatments had shown significant effects on wheat crop yields. The application of aclonifen 600 SC @ 1.2 kg a.i./ha both pre and early post emergence registered the maximum wheat crop yields of 42.70 and 40.80 q/ha respectively (Table 5), which is at par with the pre and early post-emergence application of aclonifen 600 SC @ 1.05 kg a.i./ha. The same trend was observed with respect to straw yield and harvest index (Table 5) and was attributed due to he no damage of crop plants at these dosage levels and application time along with higher selectivity of aclonifen. Nekhat *et al.* (2020) reported that the application of aclonifen @ 1-1.5 kg a.i./ha resulted in higher wheat yields due to effective control of *P. minor*.

Economics of treatments

The results (Table 5) indicate that the lower net returns

Table 5. Effect of herbicidal weed management treatments on crop yields and economics in wheat.

Treatment	Dose (kg a.i/ ha)	Time of application	Grain yield (q/ha)	Straw yield (q/ha)	Harvest index	Net returns (Rs/ha)	B:C ratio
W1-Control	-	-	27.9	47.9	36.81	40754.34	1.07
W2-Aclonifen 600SC	0.9	PE 1 DAS	32.7	53.1	38.11	50495.30	1.26
W3-Aclonifen 600SC	1.05	PE 1 DAS	40.4	63	39.07	70183.30	1.74
W4-Aclonifen 600SC	1.2	PE 1 DAS	42.7	63.5	40.21	74510.30	1.84
W5-Aclonifen 600SC	2.4	PE 1 DAS	36.7	61.3	37.45	61490.30	1.49
W6-Pendimethalin 30% EC	1.25	PE 1 DAS	28.9	48.7	36.92	45488.30	1.09
W7-Aclonifen 600SC	0.9	EPOE (15DAS)	29.2	47.6	38.02	43475.30	1.08
W8-Aclonifen 600SC	1.05	EPOE (15DAS)	37.9	60.6	38.48	64243.30	1.59
W9-Aclonifen 600SC	1.2	EPOE (15DAS)	40.8	62.3	39.57	70370.30	1.74
W10-Aclonifen 600SC	2.4	EPOE (15DAS)	33.7	57	37.15	55130.30	1.33
W11-Sulfosulfuron 75%	0.025	POE (35DAS)	33.2	56	37.22	53130.30	1.32
W12-Farmer practice	2 HW	At 29 and 40 DAS	43	65	39.81	62066.30	1.14
SEm±	-	-	1.88	2.96	1.93	-	-
LSD (p=0.05)	-	-	3.93	1.69	(NS)	-	-

HW- Hand weeding, PE – Pre-emergence, EPOE – Early post-emergence, POE – Post emergence.

(Rs 53130.30/-) and the benefit-to-cost ratio (1.32) were found with local farmers' practice (W12) in comparison to the rest of the chemical treatments. This might be due to higher cost incurrence on hand weeding. Nevertheless, all chemical management options resulted profitability over the control plot (W1). However, among various herbicidal treatments, pre and early post-emergence application of aclonifen 600 SC @ 1.2 kg a.i./ha recorded the maximum net returns (W4-Rs 74510.30/- and W9-Rs 70370.30/-) and B: C ratio (W4-1.84 and W9-1.74) and which is at par with PE and EPOE application of aclonifen 600 SC @ 1.05 kg a.i./ha (Table 5). These results are in line with the findings of Nekhat *et al*. (2020) and Narayan *et al.* (2020).

Based on the research findings, it is recommended that a new broad-spectrum herbicide molecule aclonifen 600 SC with a dosage of 1.2 kg a.i./ha or 1.05 kg a.i./ha either as pre or early post-emergence (up to 15DAS) could be used for effective control of multiple herbicide-resistant *Phalaris minor* populations in wheat and wheat-based cropping systems without incurring much cost for achieving higher grain yields and profitability.

ACKNOWLEDGEMENT

I am thankful to my advisor for supervising the research trial during the study. Also thankful to the Department of Agronomy, I.Ag.Sc. BHU for providing farm area, labor and lab facilities for carrying the research. I am greatly thankful to the co-authors of the article who contributed equally to bringing out this article. Last but not least I am thankful to the Indian Council Of Agricultural Reseach, New Delhi for providing financial support through JRF.

REFERENCES

Choudhary AK, Yadav DS, Sood P, Rahi S, Arya K, Thakur SK, Singh R (2021) Post-emergence herbicides for effective weed management, enhanced wheat productivity, profitability and quality in North-Western Himalayas: A 'Participatory-Mode'Technology Development and Dissemination. *Sustainability* 13 (10): 5425.

Choudhary D, Singh PK, Chopra NK, Rana SC (2016) Effect of herbicides and herbicide mixtures on weeds in wheat. *Ind J of Agric Res* 50 (2):29-33.

Das TK, Kaur R; Singh R, Shekhawat K, Choudhary AK (2017) Weed Management; Division of Agronomy, ICAR-Indian Agricultural Research Institute: New Delhi, India, p 44.

Directorate of economics and statistics (2022) GoI: https://eands.dacnet.nic.in/

Duke SO, Dayan FE (2022) The search for new herbicide mechanisms of action: Is there a 'holy grail'?. *Pest Management Science* 78(4):1303-1313.

FAO (2018) The future of food and agriculture – Alternative path ways to 2050. https://www.fao.org/global-perspectives-studies/food-agriculture-projections-to-2050/en/

Gomez KA, Gomez AA (1984) Statistical Procedures for Agricultural Research. 2nd edn. Wiley-Inter-Science Publication; John Wiley & Sons: New York, NY, USA.

Jeevan N, Singh JK, Singh MK, Sharma PK (2023) Effect of herbicides and nitrogen levels on *Phalaris minor* and 1ts Impact on Nutrient Uptake in Wheat (*Triticum aestivum* L.). *Int J Environ Climate Change* 13 (4):48-55.

Kanatas PJ, Gazoulis I (2022) The integration of increased seeding rates, mechanical weed control and herbicide application for weed management in chickpea (*Cicer arietinum* L.). *Phytoparasitica* 50(1): 255-267.

Kaur S, Kaur N, Bhullar MS (2022) Quantification of multiple herbicide resistance in *Phalaris minor* populations of the North-Western Indo-Gangetic Plains of India. *Agric Res* 11(1): 104-111.

Kilinç OK (2015) The effects of aclonifen treatment times on the critical concentration values in the leaves of blackgrass [*Alopecurus myosuroides* huds. (Poaceae)]. *Tiirk Tarım – Gıda Bilim ve Teknoloji Dergisi* 3(6):491- 497.

Mishra JS, Choudhary VK, Dubey RP, Chethan CR, Sondhia S, Kumar S (2021) Advances in weed management–An Indian perspective. *Ind J Agron* 66 (3): 251-263.

Narayan K, Dayanidhi P, Bisheshwor PP, Mamata B, Mahendra M, Govinda PP, Bishnu PC (2020) Economics and yield of wheat as affected by pre and post-emergence herbicides in western Terai Region of Nepal. *J Res Weed Sci* 3 (2):181-187.

Nekhat AF, Dhaka AK, Singh B, Amit Kumar, Ram Prakash (2020) Evaluation of herbicides and their mixtures for control of broad leaf weeds in wheat and their economics. *Ind J Pure Application Biosci* 8 (5):83-89.

Pala F, Mennan H, Demir A (2018) Optimum application time of aclonifen active ingredient to weed management in lentils. *Türkiye Herboloji Dergisi* 21(1):33-42.

Pannacci E, Bartolini S (2018) Evaluation of chemical weed control strategies in biomass sorghum. *J Pl Protection Res* 58 (4):404 – 412.

Singh UP, Singh MK, Upadhyay Anurag, Kashyap Sanjeev Kumar, Verma Kajal, Tiwari Naveen (2019) Weed Management in Rice-Wheat System in Indo- Gangetic Plains of India. In: 27th Asian-Pacific Weed Science Society Conference on ― Weed Science for Sustainable Agriculture and Environment‖, 3-6 September, 2019, Kuching, Sarawak, Malaysia, pp 143.

Soni JK, Nibhoria A, Punia SS, Kamboj P, Choudhary VK (2022) Wheat growth and physiological response and management of herbicide resistant *Phalaris minor* Retz. as affected by selective herbicides. *Ind J Weed Sci* 54 (2): 151–156.

Swain A, Shekhawat K, Rathore SS, Upadhyay PK, Muduli S (2022) Integrated weed management in wheat under conservation agriculture-based maize-wheat-mungbean system. *Ind J Agron* 67 (4): 442-446.

Year-End Review (2022): Ministry of Agriculture & Farmers Welfare: https://pib.gov.in/PressReleasePage.aspx-?PRID=1886630