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Weed Management Studies in Wheat (*Triticum aestivum* L.) Through New Herbicide Molecule Aclonifen 600 SC under Climate Changing Era

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Changing climate aggregates, the problem of weed management by rapid weed flora shift and resistance development. In these conditions, the best option is to use new herbicide molecules with a diverse mode of action and a wider application time window. Thus, an herbicidal trial was conducted during the *Rabi* 2019-20 at Agricultural Research Farm, BHU, Varanasi. The experiment was laid out in RCBD design with 8 treatments *viz.*, control (W_1), aclonifen 600SC @ 1.05 kg *a.i.*/ha PE (W_2) and early POE (W_5),aclonifen 600SC @ 1.2 kg *a.i.*/ha PE (W_3) and early POE (W_6),

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pendimethalin 30% EC @ 1.25 kg *a.i.*/ha PE (W_4), sulfosulfuron 75% WG @ 0.025 kg *a.i.*/ha POE (W_7), Farmer practice-2 hand weedings at 20 and 40 DAS (W_8) and replicated thrice. Among different treatments aclonifen 600 SC @ 1.25 kg *a.i.*/ha as pre and early post-emergence applied treatments recorded minimum weed density, weed dry matter production, highest weed control efficiency and crop persistence index. The same treatments registered better crop growth performance, and profitable yields.

Keywords: Climate change; weed management; aclonifen 600SC; wheat and profitability.

1. INTRODUCTION

Wheat (*Triticum aestivum L.*) is a Gramineae member cultivated over 216.94 mha (shares 14% of the global arable land area) and serves as a staple food to 2.5 billion people globally [1]. India holds the second position in wheat cultivation after China accounting for 13.5% of the global wheat area with an all-time heights output of 108 mt (13.44% of world production) and average national productivity of 2.98 t/ha [2].This national productivity is far below in comparison to the world's wheat productivity of ~3.40 t/ha [3].

Undoubtedly, weed menace is one of the major reasons behind the lower wheat production and productivity in the country. The *Phalaris minor, Avena ludoviciana, Lolium temulentum* and *Poa annua are the major grassy weeds; while Vicia sativa, Anagallis arvensis, Ranunculus arvensis* and *Coronopus didymus*are the main broad-leaved weeds that grow in association with the wheat crop. Weeds are the most noxious pest of wheat and compete with the crop for water, nutrients, space, and light, thereby reducing crop yields by 10-40 % [4]. It is a cruel fact that the changing global climate aggravates the weed problem through enhanced weed flora shifts and weed resistance. Therefore, the scientific management of weeds is unavoidable to achieve higher wheat yields. Weed researchers are developing and promoting various weed management options such as agronomic/cultural, mechanical and biological. However, these conventional cultural and manual weed management (CCMWM) practices are labour and time-driven technologies [5]. Herbicidal weed management gaining priority over CCMWM practices due to the unavailability of labour during the needy period and higher wage rates.

The advancement in chemistry led to the development of various new herbicide molecules with different modes of action and a wider application window/time. In general, a tank mix of 2,4-D and Isoproturon is recommended in wheat. The complex weed ecology dominated by grassy weeds, such as *Phalaris minor, Avena ludoviciana, Lolium temulentum,* and *Poa annua,* is not efficiently managed by the Isoproturon + 2,4-D combination. Moreover, frequent application of the same herbicide led to the development of resistance by *Phalaris minor*.

All these conditions compel the researchers to develop and adopt suitable herbicidal options, amount, time and appropriate method of application for successful herbicide-based weed management in the climate change era [6] without harming the environment. By keeping these facts and figures in view the present experiment was conducted to identify the optimum dose and application time of a newly developed herbicide molecule i.e.aclonifen 600 SC for effective control of complex weed flora of wheat crop during this climate changing era.

2. MATERIALS AND METHODS

Experimental site and soil analysis: The field experiment was performed at the Agricultural Research Farm of Banaras Hindu University, Varanasi during the *Rabi* 2019-2020. The research farm is geographically located on Northern Gangetic-alluvial plains and it lies at $25^0$18'N latitude and $83^0$31'E longitude with an altitude of about 75.70 m above mean sea level (MSL). Climatologically Varanasi falls under the category of subtropical climate with hot summers and cold winters. As per the Agro-climatic Zones classification of the planning commission of India, the experimental site falls under Middle Gangetic Plain (number IV). The initial soil samples were collected prior to crop sowing from active root zone depth (0-20cm profile) and analyzed in the Agronomy laboratory, Department of Agronomy, IAgS, BHU, Varanasi. The results obtained from the analysis are presented in Table 1.

Table 1. Physio-chemical properties of the experimental field before crop sowing

S. No.	Parameter	Value	Description	Method employed
1	Soil texture	Sand–55.24% Silt–18.69% Clay–26.07%	Sandy clay loam	Hydrometric method [7]
2	Soil pH	7.4	Alkaline	Glass electrode digital ph meter [8]
3	Particle Density (g/cm^3)	2.64	-	Core sample method (Piper, 1966)
4	Bulk Density (g/cm^3)	1.35	-	Core sample method (Piper, 1966)
5	Soil Organic Carbon (%)	0.40	Low	Wet digestion method [9]
6	Available N (kg/ha)	283.85	Medium	Alakaline permanganate method [10]
7	Available P (kg/ha)	27.80	Medium	0.5 N $NaHCO_3$ extractable [11]
8	Available K (kg/ha)	220.32	Medium	Ammonium acetate extractable flame photometer [8]

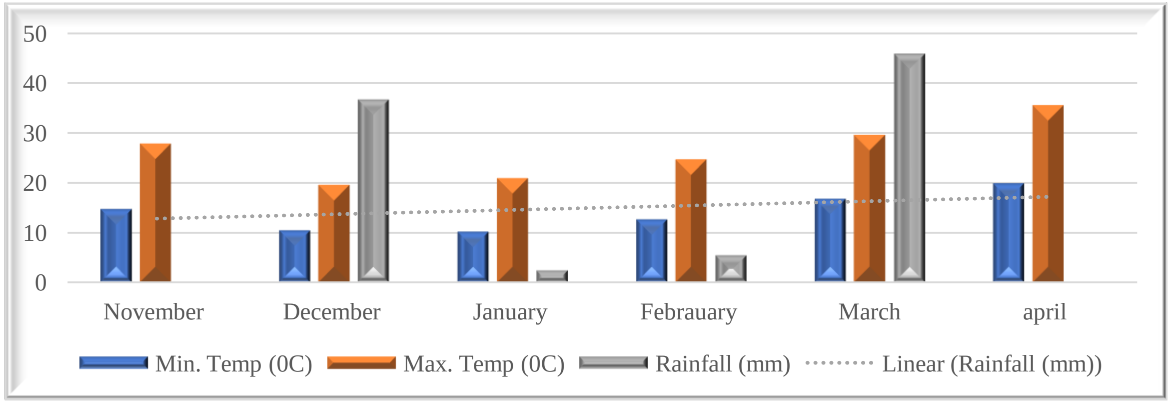

Fig. 1. Mean monthly Maximum, Minimum temperature and rainfall during crop period

Climate during the crop period: Meteorological observations viz., mean monthly minimum, maximum temperature and rainfall prevailed during the course of investigation were collected and recorded from Metrological Observatory, Agro-farm, IAgS, BHU, Varanasi and depicted graphically (Fig. 1).

Experimental details and crop management: The experiment was laid out in RCBD design with 8 treatments *viz.*, control (W_1), aclonifen 600SC @ 1.05 kg *a.i.*/ha PE (W_2) and early POE (W_5),aclonifen 600SC @ 1.2 kg *a.i.*/ha PE (W_3) and early POE (W_6), pendimethalin 30% EC @ 1.25 kg *a.i.*/ha PE (W_4), sulfosulfuron 75% WG @ 0.025 kg *a.i.*/ha POE (W_7), Farmer practice (W_8) and replicated thrice. The study was done by using a wheat variety "HUW 234" sown on 20thDecember with the help of zero till drill at a row spacing of 22.0 cm apart at 4-5 cm depth with a seed rate of 100 kg/ha and the crop was harvested on 20 April. A basal dose of 75 kg N, 60 kg P and 60 kg K/ha was applied at the time of sowing through urea (46%N), single super phosphate (16% P_2O_5) and murate of potash (60% K_2O) respectively. The remaining 60 kg N was top dressed in two equal splits at after first irrigation and at second irrigation. A total of four irrigations were given to the wheat crop during investigation to ensure optimum soil moisture. Crop received first irrigation at the crown root initiation (CRI) stage and next three irrigations were supplied based on the requirement of the crop during the study.

Application of herbicides: The selected pre emergence herbicides were applied at one day after sowing and the early post emergence herbicides were sprayed 15days after crop sowing and the post-emergence herbicide was sprayed at 30 DAS. The herbicides were sprayed with the help of hand operated knapsack sprayer having flat fan nozzle. A spray volume of 600 l/ha for both pre-emergence and early post emergence herbicide application was used. Whereas, the hand weeding treatment was supported by manual hand weeding at 20 and 40 days after sowing (DAS) with the help of *khurpi*.

Data collection and analysis: Data pertaining to the density of weeds and dry matter production were recorded(at 30 DAS) species-wise from 0.25 m^{-2} area by placing 0.5 × 0.5 m quadrate randomly at four spots in each plot and expressed as number per m^2 area and g per m^2, respectively. The weed data was subjected to square root transformation of $\sqrt{x+1}$ in order to normalize the skewed data and finally data was analysed by using standard statistical procedures as suggested by Gomez and Gomez [12] and the level of significant difference judged by using F (variance ratio) test by Fisher [13].

Weed Indices studied: The following weed indices were computed to assess best treatment for effective weed management and profitable wheat yields.

Weed control efficiency (%) was computed by using the following formula given by Choudhary *et al* [5]

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

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

It indicates the extent of control of weeds by the effective action of applied herbicide that shows the highest value is considered as best and based on this parameter the treatment is recommended for field adoption by the farmers.

Weed control index was calculated by adopting the standard procedure as suggested by the Yaduraju *et al.* [14] as follow:

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

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 weedy check plot. It was calculated by using the following formula suggested by Yaduraju *et al.* [14].

$$\text{Weed index (WI)} = \frac{[(\text{Ywf} - \text{Yt})] \times 100}{Ywf}$$

Where Ywf is the wheat grain yield from weed free plot (t/ha) and Yt is the wheat crop yields from treated plots (t/ha).

Weed persistence Index is used to know the extent of weeds that tolerated the applied herbicide and effectively produced dry matter successfully. It was calculated by using standard procedure as suggested by Yaduraju *et al.* [14] as follows:

Weed persistence index (WPI) = $\frac{WPc}{WPt}$ X $\frac{WDMt}{WDMc}$

Where WPc is the weed population in control plot (no. of weeds./m^2); WPt is the weed population in treated plot (no. of weeds/m^2);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).

Crop persistence index was computed by using the standard procedure suggested by Yaduraju *et al.* [14] as follows

Weed persistence index (WPI) = $\frac{CDMt}{CDMc}$ X $\frac{WDMc}{WDMt}$

Where CDMt is the crop dry matter in treated plot (g/m^2); CDMc is the crop dry matter in control plot (g/m^2); WDMc is the weed dry matter obtained from control plot (g/m^2) and WDMt is the weed dry matter in treated plot (g/m^2).

Crop studies: The crop growth parameters like plant height (cm), no. of tillers m^{-2}, and dry matter production per m^2 were recorded at 30 DAS and spike length (cm), no. of grains per spikes were recorded at the harvest stage by adopting the standard procedure suggested by Rana *et al.* [15]. From the net plot area ten wheat plants were selected randomly and tagged from which all the growth and yield attributes were recorded and expressed as mean value. The grain and straw yield was recorded by harvesting wheat crop from the net plot area by using standard procedure. The economics of treatments were calculated based on the prevailing market prices of inputs and output in the market during the crop season.

3. RESULTS AND DISCUSSION

3.1 Effect of Treatments on Weed

Weed flora of wheat crop: In general weed flora vary from field to field depending on prevailing climatic conditions, soil type, cropping system and weed management strategies. The experimental field was nearly infested with ten different species of weeds among which *Cynodon dactylon*, and *Phalaris minor* were the dominant grassy weeds. Among the broad-leaved weeds, *Chenopodium album* and *Anagallis arvensis* were dominant.Whereas in sedges *Cyperus rotundas* was predominant and *Parthenium hysterophorus, Melilotus alba, Rumex denticulate* and *Vicia sativa* were present in fewer numbers were grouped under miscellaneous weeds. Several researchers [16, 17 and 18) have also reported these weeds as predominant weed flora of wheat fields.

Effect of treatments on individual weed density (No. m^{-2}): It is evident from Table 2 that farmer's practice (T_{12}) of two-hand weeding's at 20 and 40 DAS was recorded significantly lower weed population of *Phalaris minor, Cynodon, Anagalis, Chenopodium, cyperus* and miscellaneous 1.75, 1.63, 1.70, 1.68, 1.63 and 1.55 respectively. Choudhary *et al.* [19] and Yadav *et al.* [18] also reported that hand-weeded plots showed the lowest weed density due to the effective removal of entire weed flora. Whereas, among various herbicidal treatments the pre emergence application of aclonifen 600 SC @ 1.2 kg *a.i.*/ha registered lower weed density of *P. minor* (1.84), *Cynodon* (1.65), *Anagalis* (1.78), *Chenopodium* (1.70) *, Cyperus* (1.84) and miscellaneous (1.56) which is at par with early post emergence application of aclonifen 600 SC @ 1.2 kg *a.i.*/ha during 30 DAS. This might be due to the effective action of herbicide to control different categories of weeds and its application at right time. From a study conducted by kilinc [20] revealed that the application of aclonifen @ 1 kg *a.i.*/ha effectively controlled the rye grass and other broad-leaved weeds in winter wheat.

Weed biomass production (g/m^2): The increased atmospheric CO_2 enhanced the rate of biomass production by C_4 weeds rather than the wheat (C_3) plant. However, the adoption of effective weed management method helps us to reduce the dry matter accumulation by weeds. From Table 3 it is clear that application of aclonifen 600 SC @ 1.2 kg *a.i.*/ha one day after sowing as PE registered the minimum weed dry matter production of 18.75% and which is statistically at par with the treatment involved early post emergence application of aclonifen 600SC@1.2 kg a.i./ha. It is due to effective control of all categories of weeds by enhancing the rate of respiration, damaging cell membrane by disrupting photosynthesis and photophosphorylation by inhibiting photoporphyrinogen oxidase/PPO activity in susceptible weed plants. Kilinc [20] and Pala et al. [21] reported that higher efficiency of aclonifen 600 SC as pre and early post-emergence application resulted in greater reduction weed biomass production. Choudhary *et al.* [18] revealed the minimum weed density under weed-free treatment followed by herbicidal weed management treatments.

Weed control Index: Treatment with lower weed dry matter yield eventually reports higher weed control index. It is evident from the data presented in Table 3 that, aclonifen 600 SC @ 1.2 kg *a.i.*/ha as pre and early post-emergence recorded higher weed control index among various herbicidal treatments (60.54) and (57.64) and which were at par with the treatments involved the application of aclonifen 600 SC @ 1.05 kg*a.i.*/ha applied both as pre (52.65) and early post-emergence (51.03). It was mainly due to significant reduction of weed dry matter accumulation with higher efficacy of herbicide. Pala *et al.* [21] have also reported that pre-emergence application of aclonifen 600SC significantly controlled the major broad-leaved weeds viz. *Vicia sativa, Sinapsis arvensis, Rananous arvensis* and *Galium aparine*.

Weed control efficiency (%): The effective control of all kinds of weeds in wheat results in higher weed control efficiency. It is evident from the data (Table 3) that among different herbicidal options used for testing, pre emergence application of aclonifen 600 SC @ 1.2 kg *a.i.*/ha recorded maximum weed control efficiency~65.81% which is followed by early post emergence application of aclonifen 600 SC @ 1.2 kg *a.i.*/ha. It is due to effective action of herbicide molecule in reducing weed density through different mode of actions and control mechanisms. This findings are in line with the results of klinic [20].

Weed persistence index: It is revealed from the data that aclonifen 600 SC @ 1.2 g *a.i.*/ha as pre and early post-emergence recorded lower weed persistence index (1.15) and (1.20) respectively and it might be due to better action of new broad spectrum herbicide molecule with low weed resistance and persistence. These treatments are statistically at par with if followed by pre and early post-emergence application of aclonifen 600 SC @ 1.05 kg *a.i.*/ha. These results were in close conformity with Nekhat *et al.* [22].

Crop persistence index: This indice holds greater importance under herbicidal weed management studies because the herbicide with low crop damage will gain popularity for its successful adoption by the farming community. From the study (Table 3) it is revealed that the application of aclonifen 600 SC @ 1.2 g *a.i.*/ha immediately one day after wheat sowing gave greater crop persistence to herbicide i.e., new herbicide molecule is not injurious to wheat crop and this treatment is statistically at par with early post emergence application of aclonifen 600 SC @ 1.2 g *a.i.*/ha~3.14. Klinic [20] disclosed that the application of aclonifen @ 1.5 kg *a.i./*ha gave better weed control without affecting wheat crop. This represents that these dosage levels are most appropriate for effective weed management without causing damage to the crop plants.

3.2 Effect of Treatments on Wheat Crop Growth and Yield Attributes

Initial plant population (no. of plants /m^2): The initial plant population count was taken to assess the effect of pre-emergence applied chemical herbicides on wheat crop germination and its establishment. The results (Table 4) revealed that application of aclonifen affected the initial plant population in a non-significant manner however the application of aclonifen 600SC @ 1.2 kg *a.i*./ha as pre and early post emergence recorded higher plant population 258.12 and 257.46 respectively per unit area which might be due to optimum dose of herbicide. In fact the selective nature of herbicide mainly depends on dosage of the chemical [20].

Plant height (cm) at 30 DAS: Among various weed management practices adopted (table 4) a treatment with two hand weeding's at 20 and 40 DAS registered the highest plant height (24.17). However, among the different herbicidal options (Table 4), the application of aclonifen 600SC @ 1.2 kg *a.i.*/ha both as pre and early post-emergence recorded maximum plant height 23.34 and 23.23 respectively, which is followed by aclonifen 600SC @ 1.05 kg *a.i.*/ha as pre and early post-emergence and they were at par with each other. These experimental findings are in corroborative with the findings of Nekhat *et al.* [22]. Effective control of all categories of weeds without showing any phyto-toxic effect on crop plants leads to the maximum plant height in these treatments [21].

No. of tillers (m^{-2}): Aclonifen 600SC @ 1.2 g *a.i.*/ha applied both as pre and early post-emergence recorded a higher number of tillers~215.78 and 211.94 respectively, and which is statistically at par with the pre and early post-emergence application of aclonifen 600SC @ 1.05 kg *a.i.*/ha. These findings were supported by the reports of Nekhat *et al.* [22]. The major reason behind this is the plenty availability of crop growth factors *viz.,* water, space and nutrients along with less weed competition. Application of herbicides shifted the competitive advantage from weed to crop plants [20].

Table 2. Effect of herbicidal weed management treatments on weed density at 30 DAS

Treatment	Weed density species-wise (no./m^2)							
	Dosage (kga.i./ha)	**Application time**	***Phalaris minor***	***Cynodondactylon***	***Anagalis arvensis***	***Chenapodium album***	***Cyprus rotundus***	**Miscellaneous**
W_1-Control	-	-	(6.55) 2.75	(5.35) 2.52	(6.01) 2.65	(5.52) 2.55	(7.62) 2.94	(4.15) 2.27
W_2-Aclonifen 600SC	1.05	PE 1 DAS)	(2.52) 1.88	(1.84) 1.68	(2.31) 1.82	(2.28) 1.81	(3.06) 2.01	(1.62) 1.62
W_3-Aclonifen 600SC	1.2	PE 1 DAS	(2.38) 1.84	(1.72) 1.65	(2.19) 1.78	(1.90) 1.70	(2.41) 1.84	(1.44) 1.56
W_4-Pendimethalin30% EC	1.25	PE 1 DAS	(3.00) 2.00	(2.08) 1.75	(2.58) 1.88	(2.38) 1.82	(2.51) 1.87	(1.97) 1.72
W_5-Aclonifen 600 SC	1.05	EPOE at 15 DAS	(3.06) 2.02	(1.96) 1.72	(2.46) 1.86	(2.19) 1.79	(2.54) 1.88	(1.76) 1.65
W_6-Aclonifen 600SC	1.2	EPOE at 15 DAS	(2.41) 1.85	(1.76) 1.66	(2.20) 1.81	(2.07) 1.75	(2.43) 1.85	(1.58) 1.60
W_7-Sulfosulfuron75% WG	0.025	POE at 30 DAS	(3.15) 2.04	(2.30) 1.82	(2.54) 1.88	(2.28) 1.81	(3.06) 2.01	(1.94) 1.72
W_8-Farmer practice	2 HW	20 & 40 DAS	(2.07) 1.75	(1.67) 1.63	(1.90) 1.70	(1.81) 1.68	(1.65) 1.63	(1.41) 1.55
LSD(P=0.05)			0.03	0.05	0.04-	0.03	0.05	-0.05

Values in paranthesis are original field observed values subjected to $\sqrt{(1+)}$ transformation; PE-pre emergence, EPOE-early post emergence, HW-hand weeding and DAS-days after sowing

Table 3. Effect of herbicidal weed management treatments on weed dynamics

Treatment	**Dosage (kg a.i./ha)**	**Application time**	**Total weed density (no/m^2) at 30 DAS**	**Total weed dry matter (g/m^2)**	**Weed control index**	**Weed control efficiency (%)**	**Weed persistence index**	**Crop persistence index**
W_1-Control	-	-	(35.21) 6.01	47.52	0.00	0.00	1.00	1.00
W_2-Aclonifen 600SC	1.05	PE 1 DAS	(13.63) 3.82	22.50	52.65	61.29	1.22	2.80
W_3-Aclonifen 600SC	1.2	PE 1 DAS	(12.04) 3.61	18.75	60.54	65.81	1.15	3.54
W_4-Pendimethalin30% EC	1.25	PE 1 DAS	(14.52) 3.94	28.55	39.92	58.76	1.46	2.08
W_5-Aclonifen 600 SC	1.05	EPOE at 15DAS	(13.97) 3.87	23.27	51.03	60.32	1.23	2.68
W_6-Aclonifen 600SC	1.2	EPOE at 15DAS	(12.45) 3.66	20.13	57.64	64.64	1.20	3.14
W_7-Sulfosulfuron75% WG	0.025	POE at 30 DAS	(15.27) 4.03	31.25	34.24	56.63	1.52	1.86
W_8-Farmer practice	2 HW	20 & 40 DAS	(10.51) 3.41	16.54	65.19	70.15	1.17	4.03
LSD(P=0.05)			0.19	2.81	4.68	5.78	0.13	0.27

Values in paranthesis are original field observed values subjected to $\sqrt{(1+)}$ transformation; PE-pre emergence, EPOE-early post emergence, HW-hand weeding and DAS-days after sowing

Table 4. Effect of herbicidal weed management treatments on crop growth (30 DAS) and yield attributes in wheat

Treatment	Dosage (kga.i./ha)	Time of application (DAS)	Initial plant population/m^2	Plant height (cm)	No. of tillers (m-2)	Dry matter accumulation(g/m2)	Spike length (cm)	No. of grains/spike
W_1-Control	-	-	257.00	22.91	173.53	120.21	7.12	32.50
W_2-Aclonifen 600SC	1.05	PE 1 DAS)	255.62	23.15	208.09	159.24	8.74	35.09
W_3-Aclonifen 600SC	1.2	PE 1 DAS	258.12	23.34	215.78	167.89	8.89	37.00
W_4-Pendimethalin30% EC	1.25	PE 1 DAS	253.76	21.67	191.44	150.57	7.74	33.43
W_5-Aclonifen 600 SC	1.05	EPOE at 15 DAS	256.42	23.01	197.56	157.56	8.23	35.07
W_6-Aclonifen 600SC	1.2	EPOE at 15 DAS	257.46	23.23	211.94	160.11	8.56	36.00
W_7-Sulfosulfuron75% WG	0.025	POE at 30 DAS	253.05	21.70	181.77	147.15	7.96	35.20
W_8-Farmer practice	2 HW	20 & 40 DAS	258.23	24.17	201.94	168.51	9.21	38.00
LSD(P=0.05)			NS	0.03	0.05	0.62	6.76	5.30

PE-pre emergence, EPOE-early post emergence, HW-hand weeding and DAS-days after sowing

Table 5. Effect of herbicidal weed management treatments on crop yield and economics

Treatment	Dosage (kga.i. ha-1)	Time of application (DAS)	Grain yield (t /ha)	Straw yield (t /ha)	Biological yield (t /ha)	Net returns (Rs/ha)	Per day returns
W_1-Control	-	-	2.79	4.79	7.58	42728.34	284.86
W_2-Aclonifen 600SC	1.05	PE 1 DAS)	4.04	6.30	10.34	74155.54	494.37
W_3-Aclonifen 600SC	1.2	PE 1 DAS	4.27	6.35	10.62	79108.70	527.39
W_4-Pendimethalin30% EC	1.25	PE 1 DAS	2.89	4.87	7.72	46744.70	311.63
W_5-Aclonifen 600 SC	1.05	EPOE at 15 DAS	3.79	6.06	9.85	61105.90	407.37
W_6-Aclonifen 600SC	1.2	EPOE at 15 DAS	4.08	6.23	10.36	70370.30	500.91
W_7-Sulfosulfuron75% WG	0.025	POE at 30 DAS	3.32	5.60	8.92	53497.50	356.65
W_8-Farmer practice	2 HW	20 & 40 DAS	4.30	6.50	10.80	67066.30	447.11
LSD(P=0.05)			0.35	0.56	0.92	-	-

PE-pre emergence, EPOE-early post emergence, HW-hand weeding and DAS-days after sowing

Dry matter accumulation (g m^{-2}): It is clear from the data (Table 4) with respect to dry matter production by wheat plants at 30 DAS that, application of aclonifen 600SC @ 1.2 kg *a.i.*/ha as pre and early post-emergence recorded maximum dry matter production of 167.89 and 160.11 respectively. and which is at par with the application of aclonifen 600SC @ 1.05 kg *a.i.*/ha both as pre and early post-emergence. These results are in line with Pala *et al.* [21] and Kilinc [20]. As we know reduced weed competition and full fledge availability of crop growth factors facilitate the vigorous growth and development of wheat crop and which eventually results in enhanced biomass production.

Yield attributes: Out of different options tested farmers practice (hand weeding twice 20 and 40 DAS) registered highest spike length and no. of grains/spike 9.21 and 38.00 respectively, over untreated weedy check (Table 4). These results are corroborated by the research findings of Kironmay *et al.* (2006) and Surin *et al.* (2013). Whereas, among the different herbicidal treatments aclonifen 600 SC @ 1.2 kg *a.i.*/ha applied as pre-emergence as well as early post-emergence recorded maximum spike length (8.89 and 8.56) and no.of grains per spike (37 and 36) and which is at par with pre and early post-emergence application of aclonifen 600 SC @ 1.05 kg *a.i.*/ha. These results are in line with Kilinc [20] and Pala *et al.* [21].

Effect of treatments on yield: It is clear from Table 5 that, the farmer's practice treatment recorded significantly highest grain yield, straw yield and biological yield of 4.3 t/ha, 6.50 t/ha and 10.80 t/ha and 15% respectively. Whereas, minimum crop yields were recorded in untreated control, which is mainly due to uncontrolled weed growth and poor performance of crop yield attributing characters. Amongst the different chemical treatment's application of aclonifen 600 SC @ 1.2 kg *a.i.*/ha both pre and early post-emergence recorded higher grain yields (4.27 and 4.08 t/ha) straw yields (6.35 and 6.23 t/ha) and biological yield (10.62 and 10.36 t/ha) by wheat crop and which is at par with pre and early post-emergence application of aclonifen 600SC @1.05 kg *a.i.*/ha. Pala *et al.* [21] have been reported that herbicidal treated plots significantly reduced the crop-weed competition and resulted in increased vegetative growth and yield attributing characteristics of wheat which ultimately leads to the highest grain yield and harvest index.

Economics of the treatments: The primary consideration for the adoption of any technology or practice is economic feasibility of the proposed technique by the farmers. Certainly, the use of herbicides will help us to cut the extra expenditure as compare to manual weeding which ultimately results in higher net profits. From the Table 5 it is clear that, the herbicidal option involved with the application of aclonifen 600 SC @ 1.2 kg *a.i.*/ha both as pre (Rs 79108.70/-) and early post emergence (Rs 70370.30/-) given highest net returns. The same treatments registered the highest per day returns (Table 5). These economic findings are in line with the reports of Narayan *et al.* [23] and Nekhat *et al.* [22][24].

4. CONCLUSION

Based on the results obtained from the trial it is concluded that the application of aclonifen 600 SC @ 1.2 kg *a.i./*ha as pre and early post emergence may be used for effective control of weed flora of wheat to obtain higher wheat yields and profitability under changing global climate.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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