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Effect of Irrigation Regimes and Herbicides on *Phalaris Minor* in Wheat (*Triticum aestivum* L.)

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ABSTRACT: For sustainable wheat production management of *Phalaris minor* are the major challenge. An experiment was carried out at Kanpur in *rabi* season of 2017-18 and 2018-19 in split-plot design with four replication having four irrigation regimes in main plot *viz*. irrigation at CRI and active tillering (I_1), irrigation at CRI + jointing + booting (I_2), CRI + active tillering + booting + flowering stage (I_3) and irrigation at CRI + jointing + booting + flowering + milking stage (I_4), and eight herbicidal treatments (W_1- weedy check, W_2- hand weeding at 20 and 40 days after sowing, W_3-sulfosulfuron 25 gha^{-1} at 35 DAS, W_4- pendimethalin (pre-em) *fb* WCPL-15, 400 gha^{-1}at 35 DAS, W_5- broadway (carfentrazone ethyl 20% + sulfosulfuron 25%WG) 100 gha^{-1} at 35 DAS, W_6- halauxafen + penxasulam 23.5%, 75 gha^{-1} at 35 DAS, W_7- halauxafen - methyl 1.21% w/w + fluroxypyr at 35 DAS and W_8- clodinafop- propargyl 15% + metsulfuron 1%, 400 gha^{-1} 35 DAS) were allocated to sub plots for assessing their effects on *P. minor*. Results revealed that application of irrigation at CRI and active tillering stage (I_1) significantly reduces the density of *P. minor* and their fresh and dry weight, weed effectiveness (WE), weed persistence index (WPI) with highest weed control efficiency (WCE) and crop resistance index (CRI). However, maximum yield was achieved with five irrigation at CRI+ jointing+ booting+ flowering+ milking stage (I_4). Lowest count and biomass of *P. minor,* WPI, and (WE); and the highest WCE, CRI, grain and biological yield was recorded with the application of broadway @ 100 g/ha at 35 DAS as compared to other treatments. Decreasing irrigation number and the post emergence application of broadway are the best option for controlling *P. minor* in wheat, but for higher yield more number of irrigations required.

Keywords: CRI, Irrigation, Herbicides, *P. minor,* WCE, Yield.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the major staple food crop of India, contributed 31.5% in food grain production and its demand increased day by day as rapid increase in our population. Many factors affecting wheat production globally of which pests are on the top. Infestation of weeds are the major biotic hindrance for higher wheat yield in all wheat growing tracks of world (Abbas *et al*., 2016, Lie *et al*., 2016, Singh *et al*., 2019). Unchecked weeds growth lower down the wheat yield up to 62 per cent or more as per the density, weed types and infestation duration (Mukherjee, 2018). Diverse weed flora infesting wheat crop, as it is grown in different growing environment, cropping sequence, irrigation and crop establishment methods (Mansoori, 2019, Singh *et al*., 2020). In India under rice-wheat cropping system particularly in Northern Indo-Gangetic plains *P. minor* is the major grassy weed of wheat crop (Punia *et al*., 2017, Kaur *et al*., 2019) and some time it cause almost 100 per cent crop loss (Singh and Singh, 2004) and control of *P. minor* has become a serious challenge nowadays (Nanher *et al*., 2015). *P. minor* infests many crop cultivate during winter but due to its simultaneous germination, mimics nature and similar requirements for growth and development causes strong competition with wheat ultimately reduces yield.

P. minor is the most important grassy weed of wheat crop develop multiple herbicide resistance. Due to alone use of isoproturon for weed control in wheat led to the evolution of herbicide resistance in *P. minor* in the early 1990s (Malik and Singh, 1993). Therefore, in herbicide resistance affected area of rice- wheat cropping system some new herbicides like clodinafop, sulfosulfuron, fenoxaprop and tralkoxydim were suggested to cultivators. Use of these herbicide effectively controlled the resistant biotype of *P. minor* and also delayed the development of multiple resistance. Sequential use of pendimethalin *fb* the application of clodinafop/pinoxaden and sulfosulfuron effectively control the *P. minor* and significantly increase wheat yield (Kaur *et al.*, 2019, Raseed *et al.*, 2020). Unfortunately, the farmers forgot rotation of herbicides and it promotes development of resistance against these new herbicides molecules. In many wheat growing regions of the country *P. minor* showing resistance to a number of herbicides. This show the multiple herbicide resistance in *P. minor* across the PS-II site, AC Case, and ALS inhibitors (Heap, 2019). For the effective control of resistant *P. minor* some post-emergence herbicide mixtures were also suggested to the farmer such as mesosulfuron + iodosulfuron and clodinafop+ metsulfuron (Singh *et al.*, 2017, Singh *et al.*, 2020). Presently only few research reports are available on the efficacy of WCPL-15, broadway (carfentrazone ethyl 20% + sulfosulfuron 25%WG), halauxafen + penxasulam and halauxafen - methyl 1.21% w/w + fluroxypyr on weeds across the diverse environments. These new combination of herbicides provide the alternative option over existing herbicides and ideal chemical for the management of resistant biotype of *P. minor*. In future, the sustainability of wheat production may affect significantly due to increase in the development of resistance in *P. minor*. Keeping above facts in mind the present experiment was planned for management of *P. minor* using herbicides along with the application of irrigation water at critical stages in wheat under field conditions.

MATERIALS AND METHODS

To assess the effect of irrigation regimes and herbicides on existence of *P. minor* and yield of wheat crop, this experiment was conducted at CSAUAT, Kanpur (U.P) during *Rabi* season 2017-18 and 2018-19.

A. Experimental Site

The experimental farm is situated between Latitudes 26º 20′′ and 26º 35′ N and Longitudes 80º 18′ and 80º 35′ E and altitude of 125.9 m above mean sea level. Kanpur's climate is classified as warm and semi-arid. Soil of the study site was sandy loam (Inceptisols) shallow, flat, good internal drainage and moderately fertile, being low in available OC (0.35%), available N (172.4 kgha^{-1}), sulphur (15.7 kgha^{-1}) and zinc (1.02 kgha^{-1}, and medium in available P (12.8 kgha^{-1}) and K (156.5 kgha^{-1}). A composite sample from each plot, 0-30 cm of soil depth, was collected and analyzed before sowing.

B. Experimental Treatments Details

The treatments replicated four time using Split Plot Design having 32 treatment combinations. Treatments consisted of four irrigation schedule *viz.* irrigation at CRI and active tillering stage (I_1), irrigation at CRI + jointing + booting (I_2), CRI + active tillering + booting + flowering stage (I_3) and irrigation at CRI + jointing + booting + flowering + milking stage (I_4) were assigned to main plots and herbicidal treatments *viz.* W_1-weedy check, W_2-two hand weeding at 20 and 40 DAS, W_3-sulfosulfuron 25 gha^{-1}at 35 DAS, W_4- pendimethalin (pre-em) *fb* WCPL-15, 400 gha^{-1} at 35 DAS, W_5-broadway (carfentrazone ethyl 20% + sulfosulfuron 25%WG) 100 gha^{-1} at 35 DAS, W_6- halauxafen + penxasulam 23.5%, 75 gha^{-1} at 35 DAS, W_7- halauxafen - methyl 1.21% w/w + fluroxypyr at 35 DAS and W_8-clodinafop- propargyl 15% + metsulfuron 1%, 400 gha^{-1} 35 DAS were allocated to sub plots.

C. Agronomic Practices

The sowing of crop was carried out by seed-drill at 22.5 cm row spacing and adjusting the 100 kg seed ha^{-1}. Foot sprayer having flat fan nozzle was use for the application herbicides as per the treatment using 500 litres of water ha^{-1}. Recommended quantity of nutrients (150+75+75+20+25 kg NPKSZn ha^{-1}) was applied to fulfil the nutritional requirement of wheat. All the agronomic practices were done for the success of crop.

D. Observations Recorded

(a) *P. minor* Density

An area of 0.25 m^2 was selected randomly at three places in each plot. Population of *P. minor* (No. m^{-2}) was taken at 60 and 90 DAS.

(b) Absolute density of *P. minor*

Absolute density was calculated using formula:

Absolute density (AD)

$$= \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats employed}} \tag{1}$$

Total number of *P. minor* present in quadrate was counted and the average value was taken. The *P. minor* present within the quadrate were taken per plot for fresh and their dry weight. Collected weed samples were sun dried for two days at 22.4-23.3^{o}C and 22.9-23.1^{o}C temperature during 2017-18 and 2018-19, respectively and then kept in oven at 70±5^{o}C to achieve the constant dry weight as gm^{-2} by Gravimetric method and expressed. To normalize the variation, recorded weeds data was square root transformed $\sqrt{(\mathbf{x+1})}$ as suggested by Fisher and Yates (1947).

(c) Weed Control Efficiency

WCE denote the efficiency of particular set of treatments and it were calculated by the following formula:

$$\text{WCE (\%)} = \frac{\text{DMC-DMT}}{\text{DMC}} \times 100 \tag{2}$$

Where, D.M.C. =Dry matter of *P. minor* (m^2) in weedy check. D.M.T. = Dry matter of *P. minor* (m^2) in treated plot to be compared.

(d) Crop Resistance Index (CRI)

CRI of *P. minor* are calculated using following formula:

$$\text{CRI} = \frac{\text{Dry matter production by the crop in treated plot}}{\text{dry matter production by the crop in control plot}} \times \frac{\text{Dry matter production of weed in control plot}}{\text{Dry matter production of weed in treated plot .}} \tag{3}$$

(e) Weed Persistence Index

Weed persistence index of *P. minor* are calculated by using formula:

$$WMI = \frac{\text{Dry weight of weeds in treated plot}}{\text{Dry weight of weeds in control plot}} \times \frac{\text{Weed density in control plot}}{\text{Weed density in treated plot}} \quad (4)$$

(f) Weed Effectiveness (%)

It refers to the population of weeds in treated plot to the same as in untreated plot and it can be calculated by the following formula:

$$\text{Weed effectiveness (\%)} = \frac{\text{Number of } P. \textit{ minor} \text{ in treatment plot}}{\text{Number of } P. \textit{ minor} \text{ in weedy plot}} \times 100 \quad (5)$$

(g) Yield (kg ha^{-1})

At full maturity the crop was harvested on 18 April 2018 and 21 April 2019, respectively. After complete sun drying, harvested produce of each net plot were weighed for yield (kgha^{-1}).

E. Statistical Analysis Applied

Critical differences (CD) at 5% level of probability were worked out for comparing the treatments means, method suggested by Fisher and Yates (1947).

RESULTS AND DISCUSSION

A. Effect on P. minor

The total and absolute density, fresh and dry weight of *P. minor* was increased and reaches apex at 60 DAS and decreased thereafter due to completion of its life cycle resulted in reduction of density and their weight, irrespective of irrigation and the herbicides application (Table 1). Significant reduction in population and weight of *P. minor* were observed due to variation in irrigation number as compare to weedy check. Decrease in number of irrigation significantly decreased the population and weight of *P. minor*. Five irrigation at CRI + jointing + booting + flowering + milking stage (I_4) was recorded highest density, fresh and dry biomass of *P. minor* followed by irrigation at irrigation at CRI + active tillering + booting + flowering stage (I_3), which facilitates an adequate growing environment to *P. minor*. Irrigation at CRI and active tillering stage (I_1) was recorded minimum density, fresh and dry biomass of *P. minor* over other irrigations. Greater moisture availability under frequent irrigation treatments gives the congenial growing condition to weeds, which poses the positive effect on weed counts and their biomass (Verma *et al*., 2008, Verma *et al*., 2017) and the reduction in weed counts and their biomass under lower number of irrigation is due to inadequate supply of moisture (Verma *et al*., 2015).

Table 1: Effect of irrigation and herbicides on density, fresh and dry weight of *P. minor* (pooled data of two years).

Treatments	Density (No. m^{-2})		Absolute density (No. m^{-2})		Fresh weight (g/m^2)		Dry weight (g/m^2)	
	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS
Irrigation schedule								
I_1-Two irrigation (CRI+ active tillering)	15.38 (4.05)	13.43 (3.80)	5.13 (2.47)	4.48 (2.34)	18.42 (4.41)	14.58 (3.95)	3.65 (2.16)	2.84 (1.96)
I_2-Three irrigation(CRI+ jointing+ booting)	15.54 (4.07)	13.60 (3.82)	5.18 (2.49)	4.53 (2.35)	21.63 (4.76)	17.80 (4.34)	4.84 (2.42)	4.03 (2.24)
I_3- Four irrigation (CRI+ Active tillering+ booting+ flowering)	19.33 (4.51)	17.38 (4.29)	6.45 (2.73)	5.79 (2.61)	24.85 (5.08)	21.01 (4.69)	5.23 (2.50)	4.52 (2.35)
I_4-Five irrigation (CRI+ jointing+ booting+ flowering+ milking)	20.94 (4.68)	19.00 (4.47)	6.98 (2.82)	6.33 (2.71)	26.13 (5.21)	22.30 (4.83)	5.51 (2.55)	4.89 (2.43)
CD (P=0.05)	0.26	0.28	0.07	0.06	0.36	0.41	0.27	0.29
Weed management practices								
W_1-Weedy check	37.43 (6.20)	35.20 (6.02)	12.48 (3.67)	11.74 (3.57)	37.25 (6.18)	32.59 (5.80)	13.54 (3.81)	12.75 (3.71)
W_2- Two hand weeding (20 and 40 DAS)	0.00 (0.67)	0.00 (0.67)	0.00 (0.67)	0.00 (0.67)	0.00 (0.67)	0.00 (0.67)	0.00 (0.67)	0.00 (0.67)
W_3-Sulfosulfuron @25 g ha^{-1} at 35 DAS	20.82 (4.67)	18.59 (4.43)	6.94 (2.82)	6.20 (2.68)	26.37 (5.23)	22.03 (4.80)	5.40 (2.53)	4.47 (2.34)
W_4- Pendimethalin (pre-em) *fb* WCPL-15@400 g ha^{-1} at 35 DAS	17.38 (4.29)	15.15 (4.02)	5.79 (2.61)	5.05 (2.46)	24.00 (5.00)	19.66 (4.55)	4.53 (2.35)	3.60 (2.14)
W_5-Broadway (carfentrazone ethyl 20%+ sulfosulfuron 25%WG) @ 100 g *a.i.* ha^{-1}at 35 DAS	12.81 (3.72)	10.58 (3.40)	4.27 (2.30)	3.53 (2.13)	21.20 (4.71)	16.86 (4.23)	3.49 (2.12)	2.56 (1.89)
W_6- Halauxafen + penxasulam 23.5% @ 75 g *a.i.* ha^{-1} at 35 DAS	15.58 (4.07)	13.35 (3.79)	5.76 (2.60)	5.02 (2.45)	23.94 (4.99)	19.60 (4.54)	4.50 (2.35)	3.57 (2.14)
W_7- Halauxafen - methyl 1.21% w/w + fluroxypyr @ at 35 DAS	21.10 (4.70)	18.87 (4.46)	7.03 (2.83)	6.29 (2.70)	26.56 (5.25)	22.22 (4.82)	5.47 (2.54)	4.54 (2.35)
W_8- Clodinafop- propargyl 15% + metsulfuron 1% @ 400 g *a.i.* ha^{-1} 35 DAS	17.29 (4.28)	15.06 (4.01)	5.19 (2.49)	4.45 (2.33)	22.76 (4.87)	18.42 (4.41)	4.17 (2.27)	3.14 (2.03)
CD (P=0.05)	0.21	0.19	0.06	0.05	0.22	0.29	0.18	0.16

Table 2: Effect of irrigation and herbicides on *P. minor* indices and yield of wheat (pooled data of two years).

Treatments	*P. minor* CE (%)		Crop resistance index		*P. minor* persistence index		*P. minor* effectiveness (%)		Grain yield (kg/ha)	Biological yield (kg/ha)
	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS		
Irrigation schedule										
I_1-Two irrigation (CRI+ active tillering)	73.0	77.7	3.87	5.03	0.66	0.58	41.10	38.15	2737	6233
I_2-Three irrigation(CRI+ jointing+ booting)	64.3	68.4	3.10	3.66	0.86	0.82	41.52	38.62	2900	6529
I_3- Four irrigation (CRI+ Active tillering+ booting+ flowering)	61.4	64.5	2.98	3.33	0.75	0.72	51.65	49.38	3037	6722
I_4-Five irrigation (CRI+ jointing+ booting+ flowering+ milking)	59.3	61.6	2.90	3.17	0.73	0.71	55.95	53.96	3151	6899
CD (P=0.05)	-	-	-	-	-	-	-	-	146	231
Weed management practices										
W_1-Weedy check	-	-	-	-	-	-	-	-	2506	5766
W_2- Two hand weeding (20 and 40 DAS)	100.0	100.0	-	-	-	-	-	-	3402	7532
W_3-Sulfosulfuron @25 g ha^{-1} at 35 DAS	60.1	64.9	2.72	3.23	0.72	0.66	55.62	52.81	2856	6400
W_4- Pendimethalin (pre-em) *fb* WCPL-15@400 g ha^{-1} at 35 DAS	66.5	71.8	3.18	4.23	0.72	0.66	46.43	43.04	2911	6503
W_5- Broadway (carfentrazone ethyl 20% + sulfosulfuron 25%WG) @ 100 g *a.i.* ha^{-1}at 35 DAS	74.2	79.9	4.62	6.18	0.75	0.67	34.22	30.06	3193	7007
W_6- Halauxafen + penxasulam 23.5% @ 75 g *a.i.* ha^{-1} at 35 DAS	66.8	72.0	3.28	4.26	0.80	0.74	41.62	37.93	2946	6581
W_7- Halauxafen - methyl 1.21% w/w + fluroxypyr @ at 35 DAS	59.6	64.4	2.65	3.02	0.72	0.66	56.37	53.61	2749	6181
W_8- Clodinafop- propargyl 15% + metsulfuron 1% @ 400 g *a.i.* ha^{-1} 35 DAS	69.2	75.4	3.75	4.88	0.67	0.58	46.19	42.78	3093	6798
CD (P=0.05)	-	-	-	-	-	-	-	-	102	196

Weedy check recorded significantly the highest population, fresh and dry biomass of *P. minor* over herbicidal treatments. Combined application of post-emergence herbicides was significantly reduced the infestation of *P. minor* over to the single use of post-emergence herbicide and sequential herbicide application. Application of broadway 100 gha^{-1} at 35 DAS significantly reduced the population, fresh and dry biomass of *P. minor* compared to other herbicidal treatments and it was statistically at par with the application of clodinafop- propagyl 15% + metsulfuron 1% 400 gha^{-1} at 35 DAS (Table 2). Similar results was reported by (Punia *et al*., 2017) he illustrated that the application of single herbicides (pre or post-em) for the control of *P. minor* were not good, because single herbicides are failed to check the second flush of weeds. Significantly lowest density of *P. minor* was recorded with the mixed use of 25 gha^{-1} sulfosulfuron at + 4 gha^{-1} metsulfuron methyl and clodinafop + metsulfuron-methyl 64 gha^{-1} reported by (Singh *et al*., 2017). Hand weeding at 20 and 40 DAS proved superiority over herbicidal treatments. Similar results was also confirmed by (Yadav *et al*., 2020) and Singh *et al.,* (2020) he was stated the excellent results of manual weeding over herbicidal treatments.

Relative efficiency of weed control treatments are judge by calculating the WCE compared to untreated check (Table 2). Irrigation at CRI and active tillering stage (I_1) was recorded highest weed control efficiency as compare to I_4, I_3 and I_2, respectively. Reduction in the number of irrigation increases the weed control efficiency was confirmed by (Verma *et al*., 2008 and Verma *et al.,* 2017).

Among herbicidal treatments, an application of broadway 100 gha^{-1} at 35 DAS was observed the highest WCE of *P. minor fb* the WCE with clodinafop-propagyl 15% + metsulfuron 1% 400 gha^{-1} at 35 DAS and the same were lowest with the post-emergence application of sulfosulfuron 25 gha^{-1} and sequential application of pendimethalin (pre-em) *fb* WCPL-15 400 gha^{-1}, respectively. Relative killing potential of weeds under particular set of treatment has significant positive effect on WCE (Verma *et al.,* 2017). However, hand weeding twice (weed free) proved superiority over herbicidal treatments, which will be the better control of *P. minor*. These findings established support from (Singh *et al*., 2017; Singh *et al*., 2020 ; Yadav *et al.,* 2020).

The maximum crop resistance index was recorded with irrigation at CRI+ active tillering stage over other irrigation schedule. Whereas, *P. minor* persistence index and weed effectiveness index was the highest with the application of irrigation at CRI + jointing + booting + flowering + milking stage (I_4) and these were reduced with decreased in the number of irrigations.

Among herbicidal treatments, post-emergence application of 100 gha^{-1} carfentrazone- ethyl 20% + sulfosulfuron 25% WG was recorded maximum crop resistance index and the lowest *P. minor* persistence index and weed effectiveness percentage as compared to clodinafop- propagyl 15% + metsulfuron 1% 400 gha^{-1} at 35 DAS, pendimethalin (pre-em) *fb* WCPL-15 400 gha^{-1} at 35 DAS, halauxafen + penxasulam 23.5 % 75 gha^{-1} at 35 DAS, sulfosulfuron 25 gha^{-1} at 35 DAS and halauxafen 1.21% w/w + fluroxpyr at 35 DA, respectively.

B. Effect on Yield

Significant influence of irrigation schedule on wheat yield was observed (Table 2). An application of five irrigation at CRI + jointing + booting + flowering + milking stage (I_4) was significantly improved the grain and biological yield than irrigation at CRI and active tillering stage (I_1) and irrigation at CRI + jointing + booting stage (I_2) and it was statistically at par with irrigation at CRI + active tillering + booting + flowering stage (I_3). This was attributed to maximum crop growth and yield attributing characters than other irrigation schedule. The results are corroborated with the research results of (Singh *et al*., 2010; Verma *et al*., 2017).

Significantly lowest yield was recorded under weedy check over herbicides application due to heavy weed infestation and poor performance of yield attributes. Post-emergence application of broadway 100 gha^{-1} was observed maximum yield *fb* clodinafop- propagyl 15% + metsulfuron 1% 400 g/ha at 35 DAS, pendimethalin (pre-em) *fb* WCPL-15 400 g/ha at 35 DAS, halauxafen + penxasulam 23.5 % 75 g/ha at 35 DAS, sulfosulfuron 25 g/ha at 35 DAS and halauxafen 1.21% w/w + fluroxpyr at 35 DAS, respectively. These results are corroborated with the research results of (Verma *et al*., 2015; Singh *et al*., and Singh *et al*., 2019). Herbicidal treatments gives the relatively weed free growing environment, which reduces crop weed competition and thus leads to better crop growth and wheat yield (Verma *et al*., 2017, Mansoori, 2019, Yada *et al*., 2020).

CONCLUSION

The field experiment was conducted at Kanpur during 2017-18 and 2018-19 under SPD having four replication with four irrigation regimes in main plot and eight factors of weed management were allocated to sub plots. Based on the above results it can conclude that irrigation at CRI and active tillering stage (I_1) significantly reduced the density and weight of *P. minor* with highest WCE and CRI however, maximum WE, grain and biological yield was achieved with I_4 irrigation. Among weed management treatments, application of broadway (carfentrazone- ethyl 20% + sulfosulfuron 25% WG) 100 gha^{-1}at 35 DAS (W_5) was recorded lowest density and weight of *P. minor*, WE and the highest WCE, CRI, WPI and yield of wheat followed by W_8.

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Conflict of Interest. The authors declare no conflict of interest.

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