E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; 7(3): 80-83
Received: 13-12-2023
Accepted: 17-01-2024

Jyoti Sharma
Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology, Jammu & Kashmir, India

Anil Kumar
Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology, Jammu & Kashmir, India

Neetu Sharma
Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology, Jammu & Kashmir, India

Corresponding Author:
Jyoti Sharma
Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology, Jammu & Kashmir, India

Effect of normal sowing time and herbicides on yield attributes and yield of ACCase resistant *Phalaris minor* in wheat under irrigated conditions

Jyoti Sharma, Anil Kumar and Neetu Sharma

DOI: https://doi.org/10.33545/2618060X.2024.v7.i3b.384

Abstract
A field experiment was conducted in the *Rabi* season of 2021-22 at Division of Agronomy, SKUAST-Jammu, to evaluate the effect of normal sowing time and herbicides on yield attributes and yield of ACCase resistant *Phalaris minor* in wheat under irrigated conditions. The experiment was laid out in laid out in split plot design with three replications. The treatments comprised of two factors including 3 sowing window i.e. 5th November, 15th November and 25th November) and nine weed management treatments. The early post emergence herbicide were applied at 25 DAS and post emergence herbicide were applied at 35 DAS to control *Phalaris minor*. The crop was sown with full dose of P and K along with half N was applied as basal at time of sowing through inorganic sources of nutrient *viz.* Urea, DAP and MOP, respectively and remaining nitrogen in two split doses. Further, the crop was managed as per regional recommendations of the crop. The results revealed that among normal sowing crop ecologies, wheat crop sown on 5th November sowing window recorded significantly higher yield attributes, grain and straw yield which was statistically at par with 15th November sown wheat crop. Among the various herbicidal treatments, pre-emergence application of Pyroxasulfone @127.5 g ha^{-1} recorded significantly yield attributes and yield which was statistically at par with the early post emergence application of Pyroxasulfone 127.5 g ha^{-1}, post-emergence application of Pinoxaden 40 g ha^{-1} and pre-emergence application of Flumioxazin 125 g ha^{-1}. Hence, on the basis of one year study it can be concluded that 5th November sown crop along with pre-emergence application of Pyroxasulfone @127.5 g ha^{-1} improve the yield of wheat under irrigated conditions.

Keywords: Wheat, herbicides, sowing window, ACCase, pyroxasulfone

1. Introduction
Wheat (*Triticum aestivum* L.) is one of the most important staple food crops of India which provides food security to about 77% of the country's population. In India, it occupies an area of about 30.54 million hectares with a production and productivity of about 106.41 million tonnes and 3484 kg ha^{-1}, respectively (Anonymous, 2022) [1]. However, in Jammu region, wheat crop is cultivated on an area of about 242.48 thousand hectares with production and productivity of about 4811thousand quintals and 2357 kg ha^{-1}, respectively which are substantially way below as compared to national average yield. In order to fulfill the demand of the burgeoning Indian population, it is estimated that by 2051, wheat production needs to increased by 110-120 million tonnes. (Sharma *et al.*, 2013) [17]. The low productivity of wheat can easily be attributed to several limiting factors and amongst them sowing time and weed management can be taken as two of the most important limiting factors. Sowing of wheat at an appropriate time leads to a healthy crop stand that can smother weed growth (Hussain *et al.*, 2015) [11]. Besides the sowing time, weeds impose competition for nutrients, solar radiation and water. Weeds flourish at the early crop growth stages and their relative density plays a significant role in reducing the yield of crop. In wheat about 10-82% losses are caused by weeds in the grain yield depending upon the type of weed species, the extent of severity and duration of weed infestation (Chhokar and Sharma, 2008) [6]. Among the grassy weeds, *Phalaris minor* accounts for 20-25% infestation which may be even as high as 90% in certain pockets of different states (Om *et al.*, 2004; Yadav and Malik, 2007) [14, 13].

It has similar morphology to wheat, but grows slightly taller than the crop at maturity. It produces 300-450 oblong, greyish-green or black seeds per earhead that mature almost 15-18 days ahead of wheat. This weed causes 30-50% yield loss in wheat depending upon crop conditions, cultural practices, and duration of competition (Chhokar and Sharma, 2008) [6]. With an increased density of *Phalaris minor* (0 to 200 plants m^{-2}), wheat yield loss increased by 33% and may result in crop failure (Duary and Yaduraju, 2005; Chhokar *et al.*, 2006) [21, 7] and have rendered it difficult to control manually. Therefore, keeping weeds below threshold level, herbicides provide the cheapest and most effective tool through which excessive weed population can be controlled before the critical crop-weed competition sets in. For controlling dicot weeds in wheat in Jammu region, a number of pre and post emergence herbicides have already found their place in cultivation package of wheat, however continuous use of some of the herbicides may result in development of herbicidal resistance in weeds over a period of time. The first case of herbicide resistance in *Phalaris minor* was reported in India during 1991 (Malik and Singh, 2017) [13]. Currently, resistance in *Phalaris minor* against several commonly used ACCase inhibitors and acetolactate synthase (ALS) inhibitors has been reported in different parts of the world including India (Heap, 2016) [22]. Different acetyl-CoA carboxylase (ACCase) inhibitors, including fenoxaprop-P-ethyl, clodinafop-propargyl and pinoxaden have been applied to control *Phalaris minor* in wheat (Yadav *et at*., 2016) [20]. *Phalaris minor* biotypes have developed resistance to ACCase-inhibiting herbicides (clodinafop, fenoxaprop and tralkoxydim) (Chhokar and Malik, 2002; Chhokar and Sharma, 2008; Gherekhloo *et al*., 2011) [5, 6, 10]. There is ever growing consensus that *Phalaris minor* has evolved resistance to different herbicides including ACCase inhibitors in many countries including Australia, India, Iran, Israel, Mexico, South Africa, and the United States (California) (Heap, 2016) [22]. Multiple herbicide resistance in *Phalaris minor* against ACCase inhibitors has been confirmed in India and South Africa (Pieterse and Kellerman, 2002; Chhokar and Sharma, 2008) [23, 6]. Farming community in Jammu already applies the herbicides isoproturon, clodinofop, sulfosulfuron, fenoxaprop and pinoxaden etc. but of late in past four- five years has confronted with poor control of grassy weeds especially *Phalaris minor* by herbicides in wheat growing areas. This raises a suspicion that herbicide resistance might have developed with usually recommended herbicides thus leading to poor or no control of *Phalaris minor* in wheat crop. However, keeping the above points in view, experiment entitled Effect of Normal Sowing time and Herbicides on Yield Attributes and Yield of ACCase Resistant *Phalaris minor* in Wheat under Irrigated Conditions was conducted.

2. Materials and Method

The experimental site, in general is bestowed with sub-tropical in nature endowed with hot and dry early summers followed by hot and humid monsoon seasons and cold and dry winters. The mean annual rainfall of the location varies from 1050-1115 mm of which 70% is received from June to September, whereas the remaining 30% of rainfall is received in few scanty showers of cyclonic winter rains from December to March due to western disturbances. An investigation was conducted in the *Rabi* season of 2021-22 at the Division of Agronomy, SKUAST-Jammu. Geographically, the experimental site is located at of 32° 39' North latitude and 74° 53' East longitude at an elevation of 332 meters above the mean sea level falling in the sub-tropical areas of Jammu and Kashmir. The field experiment comprised of twenty-seven treatment combinations, which were laid out in split plot design with three replications. The treatments comprised of two factors including 3 sowing window i.e. 5th November, 15th November and 25th November) and nine weed management treatments. The crop was sown with full dose of P and K along with half N was applied as basal at time of sowing through inorganic sources of nutrient *viz*. Urea, DAP and MOP, respectively and remaining nitrogen in two split doses. Further, the crop was managed as per regional recommendations of the crop.

2.1 Yield attributes and Yield: Data on yield attributes and yield were recorded for studied treatments. For data pertaining to yield and yield attributes was obtained at harvest. Yield attributes *viz.* number of effective tillers per m^2, number of grains per earheads and 1000 grain weight (gm) were counted from randomly selected plants from the net plot whereas, a sizeable sample of grains was taken randomly for counting 1000 grain from the bulk produce of each net plot and thereafter, 1000 grain weight was recorded in g (grams). From the individual plot, net plot was harvested and subsequently, the grain, stover yield thus obtained were weighed and expressed in kg ha^{-1}. Statistical analysis of yield and yield attributes was performed to examine the effect of different treatments. The analysis of variance was conducted using OP-Stat developed by CCSHAU, Hisar for all observations recorded during the years. Fisher's test of significance was used to compare the difference between means at 5% probability level. Standard errors along with critical difference at 5% of significance were computed for discriminating the treatment effects for chance effects.

3. Results and Discussion

3.1 Yield attributes and yield

The data presented in Table 1 revealed that normal sowing window crop ecologies and herbicides on ACCase resistant *Phalaris minor* recorded significant effect on number of effective tillers m^{-2}, number of grains spike^{-1} and 1000-grain weight at harvest during the crop growing seasons of *Rabi* 2021-22. Among normal sowing crop ecologies, wheat crop sown on 5th November recorded significantly higher number of effective tillers m^{-2}, number of grains spike^{-1} and 1000-grain weight which was found to be statistically at par with 15th November sown wheat crop. This increase in yield attributes in 5th November sown crop can be attributed to favourable climatic conditions that prolonged the vegetative period, leading to increased interception of solar radiation. This, in turn, positively affected the number of effective tillers m^{-2}, number of grains spike^{-1} and 1000 grain weight. Similar findings have been reported by Kalwar *et al.* (2018) [12], Singh *et al.* (2017) [13], Bachhao *et al.* (2018) [3].

Among the various weed management practices, weed free recorded significantly higher number of effective tillers m^{-2}, number of grains spike^{-1} and 1000-grain weight while the lowest number of effective tillers m^{-2}, number of grains spike^{-1} and 1000-grain weight were recorded in weedy check. However, among the various herbicidal treatments, pre-emergence application of Pyroxasulfone @127.5 g ha^{-1} recorded significantly higher number of effective tillers m^{-2}, number of grains spike^{-1} and 1000-grain weight which was statistically at par with the early post emergence application of Pyroxasulfone 127.5 g ha^{-1}, post-emergence application of Pinoxaden 40 g ha^{-1} and pre- emergence application of Flumioxazin 125 g ha^{-1}. It might be due to pre-emergence application of Pyroxasulfone 127.5 g ha^{-1} which provided excellent control of ACCase resistant biotypes and resulted in higher yield attributes which were converted into higher grain yield (and Singh, 1997) [24]. These results are in close conformity with those of Chhokar and Malik (2002) [5], Dhawan *et al.* (2012) [25] and Chhokar *et al.* (2008) [6].

Table 1: Effect of Normal Sowing time and Herbicides on Yield attributes of Wheat under Irrigated Conditions during *Rabi* 2021-22

Treatments	No. of effective tillers m^{-2}	No. of grains $spike^{-1}$	1000 grain weight (g)
Sowing window			
D_1- 5th November	360.81	39.53	40.63
D_2- 15th November	345.45	38.67	40.03
D_3- 25th November	317.64	37.82	39.19
SEm (±)	5.07	0.23	0.16
CD (5%)	19.90	0.89	0.61
Weed management			
W_1 - Flumioxazin 125 g ha^{-1} as pre-emergence	348.94	38.78	40.16
W_2 - Pyroxasulfone 127.5 g ha^{-1} as pre-emergence	362.33	39.40	40.68
W_3 - Pyroxasulfone 127.5 g ha^{-1} as early post-emergence	358.62	39.06	40.46
W_4 - Metribuzin 280 g ha^{-1} as pre-emergence	337.59	38.28	39.67
W_5 - Clodinofop propargyl 60 g ha^{-1} as post-emergence	314.01	37.99	38.99
W_6 - Fenoxaprop-p-ethyl 100 g ha^{-1} as post-emergence	330.34	38.20	39.51
W_7 - Pinoxaden 40 g ha^{-1} as post-emergence	354.16	38.94	40.31
W_8 - Weedy check	299.44	37.75	38.69
W_9 - Weed free	366.29	39.66	41.08
Sem (±)	7.96	0.39	0.35
CD (5%)	22.64	1.10	0.99
Normal Sowing Window × Herbicides			
CD (5%)	NS	NS	NS

3.2 Grain Yield and Straw Yield

Yield in wheat is influenced by a combination of genetic and environmental factors. A perusal of data presented in Table 2 revealed that the grain and straw yield of wheat was significantly influenced with normal sowing ecologies and herbicide application on ACCase resistant *Phalaris minor*. Among normal sowing crop ecologies, wheat crop sown on 5th November sowing window recorded significantly higher grain and straw yield which was statistically at par with 15th November sown wheat crop. This increased yield with the 5th November sowing might be attributed to favourable temperatures during the reproductive phase, leading to prolonged grain-filling period, maximum light interception, and efficient translocation of photosynthates to the sink (grain) due to higher leaf area index, higher test weight, and a greater number of effective tillers. These results align with the findings Patel *et al.* (2019) [26], also observed that early-sown wheat tends to produce higher grain and straw yields. The increased straw yield in 5th November sowing can be attributed to taller plants, a higher number of tillers, and increased dry matter accumulation. These observations were in consistent with the findings of Baloch *et al.* (2010) [27], Prabhakar *et al.* (2002) [15].

Among the weed management practices the weed free treatment recorded highest grain and straw yield. However, among the various herbicidal treatments, pre-emergence application of Pyroxasulfone @127.5 g ha^{-1} recorded significantly higher grain and straw yield which was statistically at par with the early post emergence application of Pyroxasulfone 127.5 g ha^{-1}, post-emergence application of Pinoxaden 40 g ha^{-1} and pre-emergence application of Flumioxazin 125 g ha^{-1}. It might be due to effective weed control by pre-emergence application of Pyroxasulfone 127.5 g ha^{-1} so resources were easily available to crop which resulted into higher number of effective tiller and grain and straw yield of wheat. These results are in close conformity with those of Chhokar and Sharma (2008) [6], Punia and Yadav (2010) [16], and Yadav *et al.* (2016) [20].

Table 2: Effect of normal sowing time and herbicides on yield of wheat under irrigated conditions during *Rabi* 2021-22

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest Index (%)
Normal Sowing window			
D_1 - 5th November	4921	6147	44.42
D_2 - 15th November	4692	5918	44.18
D_3 - 25th November	4238	5457	43.57
Sem (±)	61	65	28
CD (5%)	239	256	NS
Weed management			
W_1 - Flumioxazin 125 g ha^{-1} as pre-emergence	4738	5964	44.24
W_2 - Pyroxasulfone 127.5 g ha^{-1} as pre-emergence	4933	6159	44.44
W_3 - Pyroxasulfone 127.5 g ha^{-1} as early post-emergence	4862	6088	44.37
W_4 - Metribuzin 280 g ha^{-1} as pre-emergence	4587	5791	44.15
W_5 - Clodinofop propargyl 60 g ha^{-1} as post-emergence	4272	5498	43.70
W_6 - Fenoxaprop-p-ethyl 100 g ha^{-1} as post-emergence	4490	5716	43.97
W_7 - Pinoxaden 40 g ha^{-1} as post-emergence	4809	6035	44.30
W_8 - Weedy check	3746	4972	42.66
W_9 - Weed free	5116	6342	44.67
SEm (±)	120	125	0.45
CD (5%)	341	355	NS
Normal Sowing Window × Herbicides			
CD (5%)	NS	NS	NS

4. Conclusion

It can be concluded that among normal sowing crop ecologies, wheat crop sown on 5th November sowing window recorded significantly higher yield attributes, grain and straw yield which was statistically at par with 15th November sown wheat crop. Among the various herbicidal treatments, pre-emergence application of Pyroxasulfone @127.5 g ha^{-1} recorded significantly yield attributes and yield which was statistically at par with the early post emergence application of Pyroxasulfone 127.5 g ha^{-1}, post-emergence application of Pinoxaden 40 g ha^{-1} and pre- emergence application of Flumioxazin 125 g ha^{-1}. Hence, on the basis of one year study it can be concluded that 5th November sown crop along with pre-emergence application of Pyroxasulfone @127.5 g ha^{-1} improve the yield of wheat under irrigated conditions.

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