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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(10): 11-15

www.thepharmajournal.com
Received: 14-07-2022
Accepted: 18-08-2022

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Efficacy of herbicides against diverse weed flora of wheat (*Triticum aestivum* L.)

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Abstract
The present experiment was conducted at Barrister Thakur Chhedilal College of Agriculture and research station, Bilaspur, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during *Rabi* season 2021-22. With a view to study the "Efficacy of herbicides against diverse weed flora of wheat (*Triticum aestivum* L.)" in wheat. The wheat variety gw322 was used for the research and the treatments were replicated three times in a randomized block design and the treatments was consisted of twelve treatments. Results revealed that among herbicidal treatment T_7 where application of Pyroxasulfone + Metsulfuron (EPOST tank mix) 127.5 + 4 g a.i ha^{-1} at tillering and jointing stages resulted the highest plant height, number of effective tillers at harvest, number of tillers (m^{-2}) length at harvest, grain yield (qha^{-1}), straw yield (q ha-1). Which was closely followed by the treatment T_5 Pyroxasulfone + Metsulfuron (pre-em) 127.5 + 4 g a.i ha^{-1}.

Keywords: Pyroxasulfone, metsulfuron, wheat, growth, yield

Introduction
Wheat (*Triticum aestivum* L.) is India's second most important food grain after rice. Wheat is known as the "King of Cereals". Wheat is a self-pollinated crop in the Graminae (Poaceae) family with chromosome no. 42. On a global scale, India is the second largest producer of wheat, accounting for approximately 12% of global wheat production. It is also the second largest consumer of wheat after China, with a rapidly growing demand. Wheat has occupied an area of 224.49 m ha, with a total production of 792. 40 m t and a productivity of 3.52 t ha^{-1} in the world. Wheat is grown on 33.61 million ha in India, producing 106.21 m t with a national average yield of 3.16 t ha^{-1} in 2019-20. (Anonymous, 2020) [1].Wheat is an important *rabi* crop in Chhattisgarh, and the state's cropping system is primarily rain fed. Wheat covers approximately 227 (000 ha) in Chhattisgarh, with an average productivity of 1.6 t ha^{-1} (Anonymous, 2021) [2].

Weeds are a major barrier to maintaining wheat production and productivity levels. Weeds caused an estimated yield loss of 7.7 to 23.9% worldwide, depending on the region (Kosina *et al*., 2007) [4].

In such a crisis, herbicides with different modes of action, such as pendimethalin (pre-emergence) and metribuzin (pre-emergence or post-emergence) alone and in sequential or tank mix combination with post-emergence herbicides sulfosulfuron and clodinofop, pin oxaden, could be viable options (Yadav *et al*., 2016) [15]. It may also be beneficial not only to broaden the scope of weed management and control, but also to reduce selection pressure on resistant biotypes in order to avoid or postpone the development of multiple herbicide resistance and maintain wheat production.

Pyroxasulfone is a relatively new herbicide (pre-emergence or post-emergence). It has been approved for use in corn, soya bean, cotton, and wheat in a number of countries. Pyroxasulfone's herbicidal efficacy was evaluated using growth inhibition tests, greenhouse tests, and a field trial. Pyroxasulfone herbicide demonstrated excellent herbicidal activity at lower application rates than S-metolachlor and has sufficient residual activity, making it an effective tool for chemical weed management programmes.

Material and Methods
A field experiment was carried out during *rabi* season of 2021-22 at Agricultural Research

Farm of Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur (Chhattisgarh). The test variety was gw 322 sown in second week of November and harvest in first week of April. The soil of the experimental field was neutral in reaction 6.2 and clay loam soil in texture The experiment was laid out in Randomized Block Design with twelve treatments and three replications. The treatment are Pendimethalin (pre-em) 1000 g a.i. ha^{-1} (T_1), Pendimethalin (pre-em) 1500 g a.i. ha^{-1} (T_2), Pyroxasulfone (pre-em) 85% WG 127.5 g a. i. ha^{-1} (T_3), Pendimethalin + Pyroxasulfone (Pre-em tank mix) 1250 + 127.5 g a.i. ha^{-1} (T_4), Pyroxasulfone + Metsulfuron (pre-em) 127.5 + 4 g a.i. ha^{-1} (T_5), Pyroxasulfone (EPOST) 127.5 g a.i. ha^{-1} (T_6), Pyroxasulfone + Metsulfuron (EPOST tank mix) 127.5 + 4 g a.i. ha^{-1} (T_7), Metribuzin (pre-em) 300g a.i. ha^{-1} (T_8), Pendimethalin + Metribuzin (pre-emtank mix) 1250 + 280 g a.i. ha^{-1} (T_9), Pyroxasulfone + Metribuzin (pre em tank mix) 127.5 + 280 gha^{-1} (T_{10}) Weedy check (T_{11}), Weed free (T_{12}).
The recommended dose of fertilizers for wheat are 120:60:40 kg of N, P_2O_5, K_2O ha^{-1}, respectively. Full dose of P2O5, K2O and 50% of Nitrogen were applied at the time of sowing. Growth parameters were recorded just before harvesting of crop. Harvesting was done when the panicle matured and plant was dried up. The threshing of the crop was done by manually by plot wise and grain and straw where conducted separately. The grain yield was recorded as kg $plot^{-1}$ and then conducted into qha^{-1}.

Result and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads:

Plant height

Wheat plant height was observed at 30, 60, 90 DAS and harvest. None of the treatments showed significant variation in plant height at 30, 60, 90 DAS and harvest weed free (T_{12}) recorded tallest plant height generally grew as crop age advanced up to 90 DAS, however, at harvest little height decline was observed. Under weedy check (T_{11}), the lowest plant height was recorded during the study. Possibly as a result of less weed competition for water, more sunlight, and more nutrients being available, which led to a plant growing frugally. The reason for the lowest plant height in a weedy check (T_{11}) may be related to weeds' constant fight with plants for nutrients, water, air, and space. This competition inhibited plant growth. These findings agreed with those of Rajpar *et al*., (2010) [11] and Pandey and Verma (2002) [8].

Number of total tillers (m^{-2}) at harvest

At 30, 60, 90 DAS and at harvest stage of observation, the weed-free (T_{12}) treatment was recorded highest number of tillers per square metre (197.25, 443.82, 437.00 and 418.56), were recorded which was at par with the treatment Pyroxasulfone + Metsulfuron (pre-em) 127.5 + 4 g a.i. ha^{-1} (T_5), and Pyroxasulfone + Metsulfuron (EPOST tank mix) 127.5 + 4 g a.i. ha^{-1} (T_7). This may be due to these treatments successful suppression of both grassy and broad-leaved weeds as well as their reduced competition for nutrients, sunlight, and free space for tiller growth, all of which contributed to the increase in the number of tillers per plant. Weedy check (T_{11}) had the statistically lowest number of tillers per (m^{-2}). Similar result have been reported by Pandey and Verma (2002) [8], and Sharma (2009) [13].

Table 1: Effect of herbicides on plant height (cm) at harvest, no. of tillers per meter length at harvest

Treatments	Plant height (cm)at harvest	Number of total tillers (m^{-2}) at harvest
T_1	70.90	330.88
T_2	72.14	331.99
T_3	80.42	375.84
T_4	79.22	371.87
T_5	85.77	398.65
T_6	81.22	383.17
T_7	86.30	407.44
T_8	70.29	315.89
T_9	70.67	321.88
T_{10}	78.76	368.45
T_{11}	62.85	271.69
T_{12}	89.77	418.56
SE m ±	2.09	9.34
CD (P=0.05)	6.14	27.40

Weed population (m^{-2})

At 60 DAS, all of the herbicides examined in this study were applied. Weed management method had a significant impact on weed population at90 DAS and harvest. The best results were obtained under application of Pyroxasulfone + Metsulfuron (EPOST tank mix) 127.5 + 4 g a.i. ha^{-1} (T_7) treatment. At 60, 90 DAS, and At harvest, respectively, this treatment found weed population of 12.26, 13.42 and 16.24 m^{-2}. The next- 2nd best method for reducing the weed population was the application of Pyroxasulfone + Metsulfuron (pre-em) 127.5 + 4 g a.i. ha^{-1} (T_5), in this treatment at 60, 90 DAS and harvest found weed populations of 16.53, 17.26 and 18.89 m^{-2}, respectively. Maximum weed population of 108.11, 209.95, 293.37 and 296.08 m^{-2} at 30, 60, 90 DAS and harvest respectively were recorded weedy check (T_{11}) treatment.

At 60 and 90 DAS application, Pyroxasulfone + Metsulfuron (EPOST tank mix) 127.5 + 4 g a.i. ha^{-1} (T_7) treatment had the significantly reduced weed population (12.26 and 13.42 m^{-2}) while Pyroxasulfone + Metsulfuron (pre-em) 127.5 + 4 g a.i. ha^{-1} (T_5) had the second-lowest weed population, followed by Pyroxasulfone (EPOST) 127.5 g a.i. ha^{-1} (T_6), Pyroxasulfone (pre-em) 85% WG 127.5 g a.i. ha^{-1} (T_3), and Pendimethalin + Pyroxasulfone (pre-em tank mix) (T_4), Pyroxasulfone + Metribuzin (pre em tank mix) 127.5 + 280 g a.i. ha^{-1} (T_{10}). Almost similar trend followed at harvest state. Significantly lowest weed population was observed under weed free (T_{12}) treatment (0.00 m-2) than the rest of the treatment, which might be due to effective control of both grassy and broad leaved weeds. These results are similar to those reported by Kurchania *et al*., (1996) [6].

Weed dry weight (g m^{-2})

Application of Pyroxasulfone + Metsulfuron (EPOST tank mix) 127.5 + 4 g a.i. ha^{-1} (T_7) treatment resulted in significantly decreased weed dry matter accumulation of 7.98, 4.33, and 3.31 g m^{-2} at 60, 90 DAS and harvest respectively. However, the combination of Pyroxasulfone + Metsulfuron (pre-em) 127.5 + 4 g a.i. ha^{-1} (T_5) was applied, weed dry weight were observed 10.09, 7.16 and 4.14 g m^{-2} at 60, 90 DAS, and harvest respectively. In comparison to the application of Pyroxasulfone + Metsulfuron (EPOST tank mix) 127.5 + 4 g a.i. ha^{-1} (T_7), the weedy check (T_{11}) treatment recorded 95.63, 26.81 g m^{-2} and higher weed dry weight at 60, 90 DAS, and harvest. Different weed control treatment had a considerable impact on the dry matter of weeds during harvest. These findings agreed with findings of Pisal and Sagarka (2013) [9] and Kumar *et al*., (2013) [5]. All herbicide applications recorded noticeably lower weed counts, weed dry matter, and consequently weed dry weight. The findings of Singh *et al*., (2005) [14].

Table 2: Effect of herbicides on Weed population (m^{-2}) at harvest, Weed dry weight (gm^{-2}) at harvest

Treatments	Weed population (m^{-2}) at harvest	Weed dry weight (g m^{-2}) at harvest
T_1	29.22	7.47
T_2	25.96	7.09
T_3	20.58	5.67
T_4	22.54	6.14
T_5	18.89	4.14
T_6	20.13	4.47
T_7	16.24	3.31
T_8	31.85	8.28
T_9	29.32	7.88
T_{10}	24.60	6.82
T_{11}	296.08	20.61
T_{12}	0.00	0.00
SE m ±	1.32	0.41
CD (P=0.05)	3.89	1.21

Weed control efficiency (%)

The post emergence integrated application of Pyroxasulfone + Metsulfuron (EPOST tank mix) 127.5 + 4 g a.i. ha^{-1} (T_7) recorded maximum weed control efficiency (%) at 60, 90 DAS, and harvest, (94.14, 96.90 and 94.51) Although effect of Pyroxasulfone + Metsulfuron (pre-em) 127.5 + 4 g a.i. ha^{-1} (T_5) was found the next best treatment with WCE of 92.12, 94.79 and 93.62 at 60, 90, and harvest. Metribuzin (pre-em) 300 g a.i. ha^{-1} (T_8) was the least effective treatment for WCE at 60, 90 DAS, and harvest. The lowest weed population seen may have been caused by the herbicides from the sulfonyl urea group, which synthesise ACT (aceto lactase compound), which causes weeds to die quickly and results in the highest weed control efficiency of this treatment. These findings agree with those of Mishra *et al*., (2010) [7].

Weed index (%)

The observation of the weed index as modified by various herbicides was presented in Table 4.11. Application of Pyroxasulfone + Metsulfuron (EPOST tank mix) 127.5 + 4 g a.i. ha^{-1} (T_7) treatment resulted in the lowest weed index (4.75), followed by application of Pyroxasulfone + Metsulfuron (pre-em) 127.5 + 4 g a.i. ha^{-1} (T_5) (6.62%). Among herbicidal treatment, the application of Metribuzin (pre-em) 300 g a.i. ha^{-1} (T_8) reported the highest weed index (25.61%). Sharma (2009) [13], Kumar *et al.* (2013) [5], Pisal and Sagarka (2013) [9], and Singh *et al.* (2013) [16] made similar observations.

Pyroxasulfone + Metsulfuron (EPOST tank mix) 127.5 + 4 g a.i. ha^{-1} (T_7) recorded the lowest weed index of all the weed control methods over the course of the study, which may have been caused by a decrease in weed density compared to the other applied herbicides. Similar findings were previously reported by Meena and Singh (2013) [16].

Weed control index (%)

The post emergence integrated application of Pyroxasulfone + Metsulfuron (EPOST tank mix) 127.5 + 4 g a.i. ha^{-1} (T_7) treatment had the maximum weed control index (%)11.18, 91.70, 84.38 and 84.09 at 30, 60, 90 DAS, and harvest, the use of Pyroxasulfone + Metsulfuron (pre-em) 127.5 + 4 g a.i. ha^{-1} (T_5) was the 2nd best treatment with WCI of 46.82, 89.50,73.57 and 80.02 at 30, 60, 90, and harvest, respectively. However, Metribuzin (pre-em) 300 g a.i. ha^{-1} (T_8) had WCI of 37.49, 87.50, 66.82 and 59.91, making it the least effective treatment for weed control index at all growth stages.

Table 3: Effect of herbicides on Weed control efficiency (%), Weed index (%) and Weed Control index (%) at harvest

Treatments	Weed Control Efficiency (%)	Weed index (%)	Weed Control index (%)
T_1	90.13	17.89	63.78
T_2	91.22	16.26	65.62
T_3	93.05	11.35	72.62
T_4	92.38	13.51	70.30
T_5	93.62	6.62	80.02
T_6	93.20	10.51	78.36
T_7	94.51	4.75	84.09
T_8	89.24	25.61	59.91
T_9	90.09	23.51	61.72
T_{10}	91.69	14.70	67.16
T_{11}	0.00	49.18	0.00
T_{12}	100.00	0.00	100.00

Relative weed density (%)

The highest relative weed density (41.15%) of Phalaris *minor* was noticed under application of Pyroxasulfone (pre-em) 85% WG 127.5 g a.i. ha^{-1} (T_3) treatment. However the lowest relative weed density (21.46%) of *Physalis minima* was recorded under application of Pendimethalin (pre-em) 1500 g a.i. ha^{-1} (T_1). While, highest relative weed density (41.76%) of *Physalis minima* was observed under treatment Pendimethalin (pre-em) 1500 g a.i. ha^{-1} (T_2).other than this highest relative weed density of *Parthenium hysterophorus* (39.95%) was found under application of Pendimethalin (pre-em) 1500 g a.i. ha^{-1} (T_1) and lowest (0.79%) was found application of Metribuzin (pre-em) 300 g a.i. ha^{-1} (T_8) i.e. the higher relative weed density of *Cynodon dactylon* (25.34%) was under treatment Metribuzin (pre-em) 300 g a.i. ha^{-1} (T_8) and lowest (0.22%) Pyroxasulfone + Metsulfuron (EPOST tank mix) 127.5 + 4 g a.i. ha^{-1} (T_7) and the highest relative weed density of *Chenopodium album* (22.45%) was under treatment Pyroxasulfone (EPOST)127.5 g a.i. ha^{-1} (T_6) and lowest (4.99%) was under treatment Pyroxasulfone (pre-em) 85% WG 127.5 g a.i. ha^{-1} (T_3).

Test weight (g)

The treatment weed-free (T_{12}) recorded higher test weight (46.81), followed by Pyroxasulfone + Metsulfuron (EPOST tank mix) 127.5 + 4 g a.i. ha^{-1} (T_7) (44.16) and Pyroxasulfone + Metsulfuron (pre-em) 127.5 + 4 g a.i. ha^{-1} (T_5) (43.74). A considerably decreased test weight was obtained under the weedy check treatment (T_{11}) (37.28 g). This may be due to the better light of facts that increase in yield attributes might have been owing to better utilization of resources *viz*., nutrients, water, light and space as a result of less weed competition which ultimately resulted into significant improvement in all these yield attributing characters. Similar results were reported by Saini *et al*., (1998) [2], Punia *et al*., (2001) [10].

Grain yield (q ha⁻¹)

The results showed that the treatment weed free (T_{12}) produced statically higher grain yield (45.78 q ha^{-1}) than weedy check (T_{11}) (23.21 q ha^{-1}), however, treatment Pyroxasulfone + Metsulfuron (EPOST tank mix) 127.5 + 4 g a.i. ha^{-1} (T_7) produced grain yield (43.67 q ha^{-1}) which was at par with weed free treatment (T_{12}). The treatment weedy check (T_{11}) recorded 49.30% lower grain yield than treatment weed free (T_{12}), whereas, under treatment Pyroxasulfone + Metsulfuron (EPOST tank mix) 127.5 + 4 g a.i. ha^{-1} (T_7) recorded only 4.60% less grain yield than best treatment. Among various herbicide treatment Pyroxasulfone + Metsulfuron (pre-em) 127.5 + 4 g a.i. ha^{-1} (T_5) produced grain yield (42.70q ha^{-1}) which was recorded next to Pyroxasulfone + Metsulfuron (EPOST tank mix) 127.5 + 4 g a.i. ha^{-1} (T_7). The accumulation of photosynthetic food material in various plant parts leads to tissue growth and expansion, which causes a gradual increase in dry matter and increases the number of effective tillers, spike length, grains per spike, and test weight, all of which lead to higher grain yield. Bhardwaj *et al*., (2004) [3] found comparable results.

Straw yield (q ha⁻¹)

The highest straw yield (49.77 q ha^{-1}) was observed under treatment weed-free (T_{12}) which was 21.19% higher than treatment weedy check (T_{11}) (39.22 q ha^{-1}). Among different herbicide treatments application of Pyroxasulfone + Metsulfuron (EPOST tank mix) 127.5 + 4 g a.i. ha^{-1} (T_7) produced 48.93 q ha^{-1} straw yield, which was statistically at par with treatment weed-free (T_{12}). Although the majority of photosynthetic ingested during the growth phase are likely to be transferred to the storage organs, the increased plant height and tiller count in wheat as a result of more effective weed management through integrated herbicide use may have contributed to the crop's growth and development and, consequently, the wheat crop's straw yield. The tendency may be confirmed by the findings of Kumar *et al*., (2008) [1] as straw production is a function of total plant dry matter per unit area.

Table 4: Effect of herbicides on Relative weed density (%)

	Relative weed density					
	Treatment	*Physalis minima*	*Phalaris minor*	*Parthenium hysterophorus*	*Cynodon dactylon*	*Chenopodium album*
T_1	Pendimethalin (pre-em) 1500 g a.i. ha^{-1}	21.46	27.05	39.95	3.79	7.75
T_2	Pendimethalin (pre-em) 1500 g a.i. ha^{-1}	41.76	20.13	25.50	4.37	8.24
T_3	Pyroxasulfone (pre-em) 85% WG 127.5 g a.i. ha^{-1}	23.18	41.15	10.73	19.96	4.99
T_4	Pendimethalin + Pyroxasulfone (pre-em tank mix) 1250 + 127.5 g a.i. ha^{-1}	39.40	24.89	20.13	4.75	10.83
T_5	Pyroxasulfone + Metsulfuron (pre-em) 127.5 + 4 g a.i. ha^{-1}	25.25	39.34	0.79	21.97	12.66
T_6	Pyroxasulfone (EPOST)127.5 g a.i. ha^{-1}	26.38	30.37	14.20	6.61	22.45
T_7	Pyroxasulfone + Metsulfuron (EPOST tank mix) 127.5 + 4 g a.i. ha^{-1}	27.06	21.23	33.11	0.22	18.37
T_8	Metribuzin (pre-em) 300 g a.i. ha^{-1}	32.78	20.96	7.72	25.34	13.20
T_9	Pendimethalin + Metribuzin (pre-em tank mix) 1250 + 280 g a.i. ha^{-1}	23.10	38.58	12.16	7.85	18.31
T_{10}	Pyroxasulfone + Metribuzin (pre em tank mix) 127.5 + 280 g a.i. ha^{-1}	32.68	19.79	28.85	4.37	14.31
T_{11}	Weedy check	33.81	20.69	29.81	3.81	11.88
T_{12}	Weed free	00	00	00	00	00

Table 5: Effect of herbicide on test weight (g), grain yield (q ha⁻¹), Straw yield (q ha⁻¹) at harvest

Treatment	Test weight (g)	Grain yield(q ha⁻¹)	Straw yield(q ha⁻¹)
T_1	40.93	37.43	44.33
T_2	41.49	38.39	44.50
T_3	42.47	40.62	44.82
T_4	42.01	39.63	45.12
T_5	43.74	42.70	47.59
T_6	42.83	41.00	45.32
T_7	44.16	43.67	48.93

T_8	39.77	34.05	42.03
T_9	40.20	35.00	44.25
T_{10}	41.98	39.06	45.12
T_{11}	37.28	23.21	39.22
T_{12}	46.81	45.78	49.77
SE m ±	1.27	1.56	1.41
CD (P=0.05)	3.75	4.58	4.14

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