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Assessment of bioefficacy of novel pyroxasulfone for controlling weeds in summer maize

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ABSTRACT

An experiment was conducted during summer 2020 at Zonal Agricultural Research Station, UAS, GKVK, Bangalore to study the bio-efficacy of pyroxasulfone for controlling weeds in summer maize. Treatment consisted of pre-emergence application of pyroxasulfone 85% WG at 125, 150, 175 and 300 g/ha and was compared with atrazine 50% WP at 2000 g/ha along with unweeded control and weed-free treatment. Treatments were arranged under randomised complete block design with 3 replications. Weeds caused yield reduction to the tune of 32% in summer maize. Results revealed that application of pyroxasulfone reduced weed-crop interference effectively which was significantly superior over atrazine. The per cent increase in maize yield due to pyroxasulfone treatment in its corresponding doses of 125, 150, 175 and 300 g/ha was 21, 18, 14 and 7%, respectively over unweeded control treatment. Increasing the dose of pyroxasulfone beyond 125 kg/ha reduced the yield of maize.

Maize (*Zea mays* L.) is an important cereal crop cultivated in India. Although maize was an untouched part of Indian green revolution, due to its unbeatable performance in both rainfed and irrigated ecosystem tempts the growers and therefore, area under maize is picking up steadily (Joshi *et al.* 2005, Kumar *et al.* 2015 and Hiremath *et al.* 2016). Presently, in India maize occupied 9.18 million hectares area with the average productivity of 2.96 t/ha and the country produces about 27.23 million tonnes of maize kernels (DES-GOI 2020). Responding to its multiple uses, the demand for maize is constantly increasing. In spite of evolution of elite cultivars, herbicide and drought-tolerance technology offered by bio-technological innovations imparted great promise in maize productivity (Joshi *et al.* 2005). The contemporary cultural and chemical weed management strategies have been evolved and advocated to growers, but unattainability and higher cost results in unsatisfactory management with manual and cultural methods. In-spite of good number of chemicals no single chemical found effective in full season weed control. However, since long time, pre-emergent herbicide like atrazine is said to be the most popular chemical for management of weeds in maize. However, repeated application of atrazine over the years developed the herbicide resistance in many weeds. In this backdrop identification of novel herbicide molecule which could offers full season weed control is need of the hour. Study conducted by earlier scholar in USA, Canada, Australia, and South Africa opined that pre-emergent herbicide pyroxasulfone resulted in satisfactory weed control in corn (Odero and Wright 2013), soybeans (Soltani *et al.* 2019), cotton (Cahoon *et al.* 2015) and wheat (Kaur *et al.* 2019) in recent past. Further, from their study it was observed that pyroxasulfone 127.5 g/ha has been even found effective against the weeds reported to be resistant. This led to the need to investigate bio-efficacy and phytotoxicity of pyroxasulfone 85% WG at various dosages in comparison with atrazine 50% WP 1000 g/ha in summer maize during summer season of 2020.

A field experiment was conducted to investigate bioefficasy of pyroxasulfone against weed complexes in during summer season of 2020 at Zonal Agricultural Research Station, University of Agricultural Sciences, Bangalore (UASB), (12° 58' 17.7564 N, 77° 35' 40.4268 E,924 m above sea level), Karnataka, India. The soil of the experimental site was sandy loam in texture, moderately acidic (5.93) and electrical conductivity (0.11dS/m), medium in organic carbon (0.56 %), available nitrogen (386.56 kg/ha) and available phosphorus (29.67 kg/ha) and high in available potassium (428.40 kg/ha). The secondary and micro nutrient status of the experimental site was in the range of medium for magnesium and sulphur and sufficient for iron, manganese, zinc and copper.

The study included seven treatments namely pyroxasulfone 85% WG applied the commercial dose at the rate of 125 g/ha, 150 g/ha, 175 g/ha and 300 g/ha and atrazine 50% WP 2000 g/ha in comparison with weed-free treatment and unweeded control (**Table 1**). The treatments were imposed in randomized complete block design (RCBD) with three replications. The herbicides were applied immediately after sowing in moist soil with a knapsack sprayer fitted with a flat fan nozzle using a spray volume of 500 L/ha. Well decomposed farmyard manure at the rate of 10 t/ha was incorporated two weeks before sowing. The recommended doses of fertilizers *i.e.* nitrogen 150 kg/ha, phosphorus 75 kg/ha, potassium 37.5 kg/ha and 25 kg zinc sulphate were applied uniformly to seed rows. The sources of NPK were used as urea, single super phosphate (SSP) and muriate of potash (MoP), respectively.

The singe cross maize hybrid *'Hema (NAH-1137)'* was sown in first fortnight of April 2020 by using the seed rate of 15 kg/ha. The seeds were treated with phosphate solubilizing bacteria and *Azospirillum* with the dose of 750 g/ha each prior to sowing. Two seeds per hill were dibbled manually at an interval of 30 cm in seed rows opened at 60 cm apart in 4.5 x 4.8 m plot. At the time of sowing 50 kg nitrogen and entire dose of phosphorus and potassium were applied and remaining quantity of nitrogen was applied in two equal splits at 30 and 50 days after sowing. Irrigation was given at every 5 days interval so as to avoid possible water stress. All the recommended plant protection measures were carried out as per the local recommendations of the state. The data on weed density was recorded from five randomly selected spots in each plot at 15, 30 and 45 days after herbicide treatment (DAHT) using 0.5 × 0.5 m quadrat. The weeds of different species of weeds were uprooted at 15, 30 and 45 days after herbicide treatment. The weeds were placed in paper bag and were dried in an oven at 65 degree until the weeds attained a constant weight. Dried biomass was recorded as dry weight of weeds. Observations on growth, yield attributes, kernel and stover yields were recorded as per the standard procedure. The data collected on weeds were subjected to square root transformation ($\sqrt{x+0.5}$) to meet assumption of variance for statistical analysis. Weed control efficiency (WCE) was calculated on the basis of data recorded at 15, 30 and 45 days after herbicide treatment as per the formula suggested by Mani *et al.* (1976). The data were subjected to ANOVA and means were separated at p=0.05 with Fishers' LSD test.

Weed floristic composition

A total of 23 weed species were observed from 15 quadrats belonging to 18 genera and 8 families indicated infestation of divers category of weeds in *summer* maize. The Poaceae was the leading families having 6 weeds species in grassy category. In broad leaved weeds, member of Amaranthaceae family found abundant. The *Cyperus rotundus, Cyperus tenuispica* and *Cyperus compressus* were also abundant in the experimental site (**Table 2**).

Effect of pyroxasulfone on weed density and weed dry weight

Pyroxasulfone at its different dosages significantly influenced the weed density and weed dry weight of BLW, grasses and sedges at 15, 30 and 45 DAHT in *summer* maize (**Table 3**). Excellent control of BLW was recorded with pyroxasulfone treatments. Pre-emergent herbicide pyroxasulfone reduced the infestation of BLW - and there were no weeds with 150 and 300 g/ha at 15 DAHT Similar trends were observed at 30 and 45 DAHT. Irrespective of dosage, the reduction in BLW and grasses population with pyroxasulfone application was significantly superior over pre-emergent herbicide atrazine (**Table 3**). The values of weed density with pyroxasulfone treatment especially at 175 and 300 g/ha was numerically comparable with that of weed free treatment (**Table 3**). Similarly, data on density of grassy weeds indicated that pyroxasulfone at its different dosages significantly influenced the grassy weed density at 15, 30 and 45 DAHT (**Table 3**). The results indicated that pyroxasulfone controlled the grasses effectively up to 30 DAHT with the dose of 175 and 300 g/ha**.** On account of significantly lower density of both broad-

Table 1. Treatments of the experiment

Treatment	Concentration of active ingredient (g/ha)	Dose of commercial product (g/ha)	Date of application/execution
Pyroxasulfone 85% WG	106.25	125	16 April 2020
Pyroxasulfone 85% WG	127.50	150	16 April 2020
Pyroxasulfone 85% WG	148.75	175	16 April 2020
Pyroxasulfone 85% WG	225.00	300	16 April 2020
Atrazine 50% WP	1000.0	2000	16 April 2020
Weed-free	-	-	April 23, May 3, May 20, June 3and June 17
Unweeded control	-	-	-

leaf and grassy weeds, weed dry weight was also significantly lower with pyroxasulfone -300 g/ha **(Table 4)** and was statistically comparable with that of pyroxasulfone 175 g/ha. These results are in accordance with the earlier reports of Knezevic *et al.* (2009), Geier *et al.* (2006) and Gregory *et al.*(2005) where pyroxasulfone treated at 200 to 300 g/ha provided excellent control of green foxtail (*Setaria viridis*), field sandbur (*Cenchrus spinifex* Cav.), large crabgrass (*Digitaria sanguinalis*), palmer amaranth (*Amaranthus palmeri*), puncturevine (*Tribulus terrestris* L.), Texas panicum (*Panicum texanum*) and velvetleaf (*Abutilon theophrasti* Medik.).

Effective and persistent control of sedges was not observed with herbicide treatments, however, density of sedges decreased gradually with successive increase in pyroxasulfone dose. Slight reduction in growth of sedges with higher doses of pyroxasulfone (175 and 300 g/ha) at early phase of its application could be due to higher absorption rates of herbicidal solution by infant sedge seedlings. Similar observations are also reported by Tanetani *et al.* (2009) and Jha *et al.* (2015).

Weed control efficiency of pyroxasulfone

Data of the experiment revealed that pre-emergent herbicide pyroxasulfone exhibited excellent control of broad-leaf and grassy weeds over atrazine (**Table 3**). The maximum weed control efficiency recorded with pyroxasulfone at 300 g/ha (100, 100 and 97%, respectively at 15, 30 and 45 DAHT in broadleaf weeds and 100, 100 and 94.72%, respectively at 15, 30 and 45 DAHT in grasses) and the values were closely followed by pyroxasulfone at 175 g/ha (100, 98 and 97%, respectively at 15, 30 and 45 DAHT in broad-leaf weeds and 98, 100 and 94.98%, respectively at 15, 30 and 45 DAHT in grasses) **(Table 5)**. These results are in harmony of the findings of Mahoney *et al.* (2014) who found 100% control of most of broad-leaf and grassy weeds in soybean with application of pyroxasulfone at 89 g/ha.

Table 2. Floristic composition of weed flora in experimental site

Common name	Scientific name	Category	Family	Relative density (%)
Cock's comb	*Celosia argentea L*	BLW	Amaranthaceae	3.51
Tick weed	*Cleome viscosa L.;*	BLW	Capparidaceae	3.72
Tropical spiderwort	*Commelina benghalensis L*	BLW	Commelinaceae	3.51
Climbing dayflower	*Commelina diffusa*	BLW	Commelinaceae	4.13
Wild poinsettia	*Euphorbia geniculata*	BLW	Euphorbiaceae	2.68
Goat weed	*Ageratum conyzoides*	BLW	Asteraceae	3.92
Sessile joyweed	*Alternanthera sessilis;*	BLW	Amaranthaceae	5.26
Bristly starbur	*Acanthospermum hispidum*	BLW	Asteraceae	3.51
Khaki weed	*Alternanthera pungens*	BLW	Amaranthaceae	2.68
Spiny pigweed	*Amaranthus spinosus*	BLW	Amaranthaceae	2.79
Spanish needles	*Bidens pilosa*	BLW	Asteraceae	4.33
Asthma herb	*Euphorbia hirta*	BLW	Euphorbiaceae	2.99
Five leaved carpetweeds	*Mollugo pentaphylla*	BLW	Molluginaceae	4.13
Congress grass	*Parthenium hysterophorus*	BLW	Asteraceae	4.33
Bermuda grass	*Cynodon dactylon*	Grass	Poaceae	5.26
Goose grass	*Eleusine indica*	Grass	Poaceae	7.12
Jungle rice	*Echinochloa colona*	Grass	Poaceae	3.92
Crowfoot grass	*Dactyloctenium aegyptium*	Grass	Poaceae	5.37
Browntop millet	*Brachiaria ramose*	Grass	Poaceae	4.44
Large crabgrass	*Digitaria sanguinalis*	Grass	Poaceae	5.99
Purple nutsedge	*Cyperus rotundus*	Sedge	Cyperaceae	7.22
Slender spiked sedge	*Cyperus tenuispica*	Sedge	Cyperaceae	5.57
Poorland flatsedge	*Cyperus compressus*	Sedge	Cyperaceae	3.61

Table 3. Effect of treatments on weed density of broad-leaf, grasses and sedges (no./m^2)

Treatment	Broad-leaf weeds			Grasses			Sedges		
	15 DAHT	30 DAHT	45 DAHT	15 DAHT	30 DAHT	45 DAHT	15 DAHT	30 DAHT	45 DAHT
Pyroxasulfone 85% WG 125 g/ha	(2.0)1.6*	(12.0)3.5	(27.3)5.3	(8.0)2.9	(12.0)3.5	(24.7)5.0	(3.67)2.0	(17.67)4.3	(22.7)4.8
Pyroxasulfone 85% WG 150 g/ha	(3.3)2.0	(14.3)3.8	(16.7)4.1	(7.0)2.7	(7.3)2.8	(22.3)4.8	(6.3)2.6	(14.7)3.9	(30.7)5.6
Pyroxasulfone 85% WG 175 g/ha	(5.3)2.4	(15.3)4.0	(18.3)4.3	(7.0)2.7	(5.7)2.5	(21.7)4.7	(6.7)2.7	(12.7)3.6	(23.3)4.9
Pyroxasulfone 85% WG 300 g/ha	(0.0)0.7	(3.0)1.9	(6.3)2.6	(1.3)1.3	(0.0)0.7	(5.3)2.4	(0.0)0.7	(10.7)3.3	(19.3)4.4
Atrazine 50% WP 2000 g/ha	(5.7)2.5	(16.0)4.1	(32.3)5.7	(9.3)3.1	(32.3)5.7	(43.7)6.6	(15.7)4.0	(35.7)6.0	(40.7)6.4
Weed free	(0.0)0.7	(0.0)0.7	(0.0)0.7	(2.7)1.8	(0.0)0.7	(0.0)0.7	(7.0)2.7	(11.3)3.4	(2.3)1.67
Unweeded control	(113.3)10.7	(166.3)12.9	(197.3)14.0	(77.0)8.8	(103.7)10.2	(127.3)11.3	(22.3)4.8	(52.7)7.3	(71.0)8.4
LSD (p=0.05)	0.29	0.53	0.60	0.47	0.53	0.80	0.25	0.49	0.64

Data in the parentheses indicates original values; *indicates transformed values ($\sqrt{x+0.5}$) DAHT-Days after herbicide treatment

Effect of pyroxasulfone on growth and yield of maize

In this experiment, different doses of pyroxasulfone did not register significant variation in germination of maize **(Table 6).** However, different doses of the herbicide recorded significant variation in growth, yield attributes and yields of maize **(Table 6 and 7)** and this variation was mainly due to the variation on weed control**.** Weed-free condition produced taller plants at harvest (170.0 cm) as compared to all herbicide treatments except atrazine 2000 g/ha (161.0 cm). Significant reduction in plant height was noticed with pyroxasulfone applied at 300 g/ha (137.8 cm) and was comparable with that of plant height obtained with weedy check. These results were similar with the findings of Khalil *et al.* (2018) who found significant shoot-length inhibition of Italian ryegrass with pyroxasulfone application. The reduction in growth of leaf was also observed by recording significantly lower leaf area index of maize with application of pyroxasulfone over weed-free treatment and atrazine 2000 g/ha (**Table 6**). Further it was also observed that quality of chlorophyll pigmentation was badly affected with application of pyroxasulfone. Significantly lower SPAD chlorophyll meter reading was registered with the plots treated with pyroxasulfone at the dose of 300 g/ha and was remain comparable with other doses of pyroxasulfone. Plots treated with pyroxasulfone taken significantly higher time to attain 50% tasselling and silking than weed-free, atrazine and unweeded control treatments. So far, no published paper has highlighted the effect of pre-emergent herbicide pyroxasulfone on the developmental stages of maize. Further, as per as yield attributes are concern, generally yield attributes are the manifestation of growth attributing character in maize (Kumar *et al.* 2015a). Due to

Table 4. Effect of treatments on weed dry weight of broad-leaf, grasses and sedges (gm/m^2)

Treatment	Broad-leaf weeds			Grasses			Sedges		
	15 DAHT	30 DAHT	45 DAHT	15 DAHT	30 DAHT	45 DAHT	15 DAHT	30 DAHT	45 DAHT
Pyroxasulfone 85% WG 125 g/ha	(1.1)1.3*	(7.3)2.8	(18.3)4.3	(3.7)2.0	(5.8)2.5	(12.6)3.6	(1.1)1.3	(6.9)2.7	(9.5)3.2
Pyroxasulfone 85% WG 150 g/ha	(1.8)1.5	(8.7)3.0	(11.2)3.4	(3.2)1.9	(3.5)2.0	(11.4)3.4	(2.0)1.6	(5.7)2.5	(12.9)3.7
Pyroxasulfone 85% WG 175 g/ha	(2.9)1.8	(9.3)3.1	(12.3)3.6	(3.2)1.9	(2.7)1.8	(11.0)3.4	(2.1)1.6	(4.9)2.3	(9.8)3.2
Pyroxasulfone 85% WG 300 g/ha	(0.0)0.7	(1.8)1.5	(4.2)2.2	(0.6)1.0	(0.0)0.7	(2.7)1.8	(0.0)0.7	(4.2)2.2	(8.1)2.9
Atrazine 50% WP 2000 g/ha	(3.1)1.9	(9.8)3.2	(21.7)4.7	(4.3)2.2	(15.5)4.0	(22.3)4.8	(7.0)2.7	(13.9)3.8	(17.1)4.2
Weed free	(0.0)0.7	(0.0)0.7	(0.0)0.7	(1.2)1.3	(0.0)0.7	(0.0)0.7	(2.2)1.6	(4.4)2.2	(1.0)1.2
Unweeded control	(61.2)7.8	(101.5)10.1	(132.2)11.5	(35.4)6.0	(49.8)7.1	(64.9)8.1	(12.5)3.6	(20.5)4.6	(29.8)5.5
LSD (p=0.05)	0.09	0.52	0.52	0.26	0.29	0.51	0.26	0.51	0.50

Data in the parentheses indicates original values; *indicates transformed values ($\sqrt{x+0.5}$) DAHT-Days after herbicide treatment

Table 5. Effect of treatments on weed control efficiency (%)

Treatment	Broad-leaf weeds			Grasses			Sedges		
	15 DAHT	30 DAHT	45 DAHT	15 DAHT	30 DAHT	45 DAHT	15 DAHT	30 DAHT	45 DAHT
Pyroxasulfone 85% WG 125 g/ha	98.24	92.79	86.15	89.61	88.42	79.80	90.91	66.46	68.08
Pyroxasulfone 85% WG 150 g/ha	97.06	91.38	91.55	90.91	92.93	81.63	84.29	72.15	56.81
Pyroxasulfone 85% WG 175 g/ha	95.29	90.78	90.71	90.91	94.53	82.15	83.47	75.95	67.14
Pyroxasulfone 85% WG 300 g/ha	100.00	98.20	96.79	98.27	100.00	94.98	100.00	78.48	72.77
Atrazine 50% WP 2000 g/ha	95.00	90.38	83.61	87.88	68.81	64.88	43.79	32.28	42.72
Weed free	100.00	100.00	100.00	96.54	100.00	99.17	82.64	79.75	96.71
Unweeded control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DAT-Days after herbicide treatment

Table 6. Effect of treatments on germination, plant height, leaf area index, chlorophyll content, days to 50% tasselling and silking

Treatment	Germination (%)	Plant height at harvest (cm)	Leaf area index at 90 DAS	SPAD at 90 DAS	TDMP at harvest (g/plant)	Days to 50% tasseling	Days to 50% silking
Pyroxasulfone 85% WG 125 g/ha	96.41	152.0	4.35	36.14	188.8	58.56	64.74
Pyroxasulfone 85% WG 150 g/ha	96.71	148.8	4.09	32.11	196.7	61.12	66.84
Pyroxasulfone 85% WG 175 g/ha	96.84	145.1	4.02	30.15	193.4	63.45	66.21
Pyroxasulfone 85% WG 300 g/ha	97.12	137.8	4.02	30.17	185.6	64.14	66.84
Atrazine 50% WP 2000 g/ha	96.42	161.0	4.74	41.12	193.4	54.14	58.15
Weed free	96.84	170.0	5.20	48.65	228.5	53.12	56.98
Unweeded control	94.41	154.2	4.44	37.45	181.3	55.74	59.47
LSD (p=0.05)	NS	22.5	0.58	4.06	19.12	2.60	2.89

Table 7. Effect of treatments on yield parameters, yield of summer maize

Treatment	Cob length (cm)	Cob girth (cm)	No. kernel rows/cob	No. of kernel /row	100 kernel weight(g)	Kernel yield per plant (g)	Kernel yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
Pyroxasulfone 85% WG 125 g/ha	17.5	16.1	14.4	33.6	27.3	131.6	5.54	6.94	44.43
Pyroxasulfone 85% WG 150 g/ha	17.1	16.0	14.8	33.3	26.7	129.6	5.40	6.88	43.92
Pyroxasulfone 85% WG 175 g/ha	16.8	15.9	14.0	33.7	26.2	126.1	5.20	6.96	42.77
Pyroxasulfone 85% WG 300 g/ha	13.14	13.19	14.0	26.41	25.6	109.3	4.87	6.54	42.68
Atrazine 50% WP 2000 g/ha	17.8	16.1	14.8	34.2	28.2	136.4	5.73	7.22	44.30
Weed-free	18.9	17.4	15.2	36.1	28.5	138.7	6.04	7.31	45.31
Unweeded control	15.5	14.3	13.5	27.8	27.2	120.3	4.57	6.35	41.81
LSD (p=0.05)	0.6	0.4	NS	1.6	NS	10.6	0.23	0.41	1.36

profound impact of pyroxasulfone application on growth of maize, yield attributing characters were greatly reduced (**Table 6** and **7**). Significantly lower kernel yield per plant was recorded with pyroxasulfone at 300 g/ha (109.3 g/plant) on account of significantly lower cob length and girth, number of kernels per row (**Table 7**) and these values were comparable with that of unweeded control treatment. However, yield attributing characters of maize with pyroxasulfone applied at 175, 150 and 125 g/ha were statistically comparable with atrazine at 2000 g/ha.

In summer maize, weed-crop interference caused 32% yield reduction in comparision to weed-free treatment (**Table 7**). there was per cent increase in maize yield due to pre-emergent herbicide pyroxasulfone at 125, 150, 175 and 300 g/ha was 21, 18, 14and 7%, respectively over unweeded control treatment. The data of the experiment clearly indicated the phytotoxic effect of pyroxasulfone at the dose more than 125 g/ha. Based on the findings of the present study, it can be concluded that pre-emergent herbicide pyroxasulfone provided satisfactory weed control and grain yield when it was applied at the dose of 125 and beyond this dose the performance of the crop in terms of lowering plant height, leaf growth, chlorophyll content and finally kernel yield got reduced significantly. This may be due to the phytotoxic effect of pyroxasulfone beyond the dose of 125 kg/ha. However, further investigation is required to confirm the findings.

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