Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(6): 403-406
Received: 05-09-2020
Accepted: 09-10-2020

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Efficacy of pyroxasulfone 5% + pendimethalin 40% ready mixture on associated weed flora, growth and yield of soybean (*CV* JS 20-29)

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Abstract
The field experiment entitled "Efficacy of pyroxasulfone 5% + pendimethalin 40% ready mixture on associated weed flora, growth and yield of soybean (*CV* JS 20-29)" was conducted at Research Farm, Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (Madhya Pradesh) during growing season's *Kharif* 2017. The eight treatments comprising of four doses of pyroxasulfone + pendimethalin mixture (450, 675, 900 and 1125 g ha^{-1}), alone application of pyroxasulfone (100 g ha^{-1}) & pendimethalin (750 g ha^{-1}) as pre-emergence and hand weeding twice at 20 and 40 DAS including weedy check, were laid out in randomized block design with three replications. Hand weeding twice at 20 and 40 DAS recorded the lowest weeds intensity and weeds biomass followed by pyroxasulfone + pendimethalin at 900 g $ha^{-1}$and these treatments significantly reduced the weeds intensity and weeds biomass (3.29 g m^{-2}) over rest of the herbicidal treatments and weedy check. Among the herbicidal treatments, application of pyroxasulfone + pendimethalin mixture at 900 and 1125 g ha^{-1} as pre emergence arrested the weed biomass production remarkably and proved superior to its lower dose (450 g ha^{-1}), alone application of pyroxasulfone (100g ha^{-1}) and pendimethalin (750 g ha^{-1}). The seed yield and gross monetary returns were maximum in hand weeding treatment among all the treatments, but net monetary return and B:C ratiowere the highest (Rs 15182 ha^{-1} and 1.53, respectively) under combined application of pyroxasulfone + pendimethalin at 900 g ha^{-1}closely followed by pyroxasulfone + pendimethalin at 1125 g ha^{-1} as pre emergence to soybean.

Keywords: Pyroxasulfone, pendimethalin, ready mixture

Introduction
Soybean is a native of North-eastern China belongs to family Fabaceae. It is legume crop mainly grown in *kharif* season. It is known as "Golden bean" and miracle crop of 20th century. Soybean contains 35-40% protein, 19% oil, 35% carbohydrate, 5% minerals and several other components including vitamins (Meena and Kumhar, 2017a) [9]. In India it is grown in 10.50 million hectares with the production of 9.50 million tonnes (SOPA, 2017) [16]. Madhya Pradesh is a leading state in India for cultivation of soybean, where it is grown in 5.01 million hectares with the total production of 4.20 million tonnes. But the productivity is 838 kg/ha which is far below than its yield potential *i.e.* 2500 kg ha^{-1} (SOPA, 2017) [16].

There are various factors which are responsible for lower productivity of soybean, green gram and other legume crpos in the state but weeds are the major culprit which causes more yield reduction (Vollmann *et al*., 2010 and Meena *et al.*, 2017b) [17, 10]. If weeds are not controlled during critical period of crop-weed competition, there is appreciable loss in the yield of soybean from 58-85%, depending upon type and weed intensity (Kewat *et al*., 2000) [6]. Earlier the farmers were using pre-plant incorporated and pre-emergence herbicides *viz*., flucloralin, trifluralin, metalaclore, and alaclore etc. for controlling weeds in soybean. But now these herbicides are not available in market. Therefore, farmers are switching towards pre emergence herbicides *viz*., imazethapyr, bentazone, propaquizafop, quizalofop-p-ethyl, clorimuron *etc*., but their weed control spectrum is narrow. Hence forth the ready mixture herbicides are being used by the majority of farmers for wide spectrum weed control in soybean. Presently different ready mixture herbicides *viz*., pyroxasulfone + pendimethalin *etc.* are being extensively used. Pyroxasulfone, pendimethalin are a new herbicide of pyrazole herbicide family. It has pre emergence activity and inhibits shoot elongation of susceptible seedling plants by inhibiting the biosynthesis of very-long-chain fatty acids (Sahu *et al.*,2019) [13]. Application of pyroxasulfone at 209 g ha^{-1} controled broadleaf *signalgrass (Urochloa platyphylla)* and velvetlea*f* (Abutilon theophrasti Medik). Pyroxasulfone is currently labeled in the United States for controlling corn, soybean and wheat. (Olson *et al*., 2011) [11].

Materials and Methods

The field experiment was conducted during *kharif* season of 2017, at Research Farm, Department of Agronomy, JNKVV, Jabalpur, Madhya Pradesh to study the "Efficacy of pyroxasulfone 5% + pendimethalin 40% ready mixture on associated weed flora, growth and yield of soybean (*CV* JS 20-29)". The soil of experiment area was sandy clay loam soil which was medium in organic carbon (0.62%), available nitrogen (365kg ha^{-1}) and phosphorus (16.34kg ha^{-1}) but high in potassium (317.16kg ha^{-1}) and neutral in reaction (pH 7.2). The eight treatments comprising of four doses of pyroxasulfone + pendimethalin mixture (450, 675, 900 and 1125 g ha^{-1}), alone application of pyroxasulfone (100 g ha^{-1}) & pendimethalin (750 g ha^{-1}) as pre-emergence and hand weeding twice at 20 and 40 DAS including weedy check, were laid out in randomized block design with three replications.

Soybean variety 'JS 20-29' sown (17th July) in rows 45 cm apart at the depth of 3-4 cm and then seeds were covered with fine soil, using 70 kg ha^{-1} seeds. Recommended nutrient dose of 20 kg N + 60 kg P_20_5 + 20 kg K_20 ha^{-1} were applied as basal dose through urea, single super phosphate and muriate of potash, respectively. The whole quantities of all the nutrients were applied manually at the time of sowing as basal dressing in the rows about 3 cm below the seed. All the herbicidal treatments were applied one day after sowing (18thJuly). Observations were recorded on weeds (*viz*., weed flora, weed density and weed biomass), growth parameters (*viz.*, plant height, effective nodules $plant^{-1}$, branches $plant^{-1}$andcrop biomass) and yield attributes (*viz.*, pods $plant^{-1}$, seeds pod^{-1} and seed index) were recorded at maturity on five randomly selected plants in each treatment. All data were subjected to analysis of variance according to the experimental design used in this study and critical difference (CD) was utilized to compare the different means of treatment.

Results and Discussion

Weed flora: The dominant weeds associated with soybean in the experimental field were mainly comprised of monocot weeds like *Echinochloa colona*, *Cyperus rotundus*, *Commelina communis* and dicot weeds like *Phyllanthus niruri* and *Euphorbia hirta*(Table1). Species wise weeds were recorded in weedy check plots indicated that there was pre-dominance of monocot weeds (63.26%) as compared to dicot weeds (36.74%) in the experimental field.

Among the monocot weed, the *Commelina communis* was the most dominant as they contributed 33.87 m^{-2} and 28.88% to the weed density m^{-2} and relative density of weeds followed by dicot weed *Phyllanthus niruri* (25.53 m^{-2} and 21.78%, respectively) due to continuous germination of these weed seeds from soil. However, other monocot weeds like *Cyperus rotundus*, dicot weeds *Euphorbia hirta* also present in less numbers in soybean.

Table 1: Associated weed flora of soybean in weedy check plots during crop season

Weed flora	Density /m^2		Mean	Relative Density (%)
	30DAA	60DAA		
Monocot weeds				
Echinochloa colona	16.70	21.73	19.21	16.38
Cyperus rotundus	18.33	23.93	21.13	18.02
Commalina communis	31.00	36.73	33.89	28.88
Dicot weeds				
Phyllanthus niruri	20.33	30.79	25.53	21.78
Euphorbia hirta	13.33	21.73	17.53	14.95
Total			117.27	100.00

Effect on weeds

Results revealed (Table 2) that twice hand weeding at 20 and 40 DAS recorded the lowest weed biomass followed by pre-emergence pyroxasulfone + pendimethalin mixture at 1125 gha^{-1} and pyroxasulfone + pendimethalin mixture at 900 g ha^{-1} (3.29 and 3.44g m^{-2}, respectively) and these treatments significantly reduced the weed biomass over rest of the herbicidal treatments and weedy check, these finding were in strictly agreement with results of Jha and Soni, 2013 [4].

Among the different weed control treatments data given in Table 2.The higher weed control efficiency (92.00%) was recorded under pre-emergence application of pyroxasulfone + pendimethalin (1125 g ha^{-1})closely followed by pyroxasulfone + pendimethalin (900 g ha^{-1}) because both treatments curbed the growth of the both type of weeds effectively and resulted in the lowest weed biomass which may be the main reason for higher weed control efficiency and confirming the views of Girothia and Thakur (2006) [2]. The poor weed control efficiency (85.93% and 65.31%) was noticed in case of pyroxasulfone + pendimethalin (450 g ha^{-1}) and alone application of pendimethalin (750 g ha^{-1}), respectively due to poor activity against weed flora.

Effect on crop

The growth parameters (*viz.*, plant height, effective nodules $plant^{-1}$, branches $plant^{-1}$and crop biomass) and yield attributing traits (*viz.*, pods $plant^{-1}$, seeds pod^{-1} and seed index-100 seeds weight) were significantly due to different weed control treatments (Table 2).

The plant height differed significantly due to herbicidal treatments given in Table 2. Plant height was minimum (36.38 cm) under weedy check plots. It was further increased due the application of herbicides. The maximum plant height was (48.00 cm) fetched with application of pyroxasulfone + pendimethalin mixture at 900 g ha^{-1}. It was significantly superior to the pyroxasulfone + pendimethalin mixture at 450 g $ha^{-1}$and pyroxasulfone + pendimethalin mixture at 675g ha^{-1} (43.10 cm and 43.68 cm, respectively).Similar results were reported by Kushwah and Vyas 2008 [7], who reported that plant height of soybean was significantly increased by the pre emergence application of 1 kg ha^{-1} pendimethalin + 1 HW as compared to alone 1 kg ha^{-1} pendimethalin (PE) and weedy check.

The non-significantly variation was recorded in number of effective nodules $plant^{-1}$ at 45 DAS (Table 2). Among the different herbicidal treatments, the minimum number of effective nodules $plant^{-1}$ (40.73) were recorded under application of pendimethalin 750 g ha^{-1}. The nodulation activity was significantly higher when no weed control measures were adopted in soybean. So that the highest nodule

plant^{-1} (41.60) in hand weeded plot closely followed by weedy check plots (41.57 nodules plant^{-1}). Number of nodules plant^{-1} decreased slightly with pre emergence combine application of pyroxasulfone + pendimethalin (450 g ha^{-1}) found at par with increase in application of pyroxasulfone + pendimethalin applied at (675, 900 and 1125 g ha^{-1}), other alone herbicides pyroxasulfone (100 g ha^{-1}).

The significantly variation was recorded in branches plant^{-1} and minimum number of branches plant^{-1} (3.34) was recorded under weedy check plots, which increased appreciably in plots receiving weed control treatments (Table 2). The pre emergence combine application of pyroxasulfone + pendimethalin (900 gha^{-1}) registered maximum number of branchesplant^{-1} (3.94) followed by application of pyroxasulfone + pendimethalin 1125 gha^{-1} and 675 g ha^{-1}(3.83 and 3.71, respectively) being the minimum (3.67 and 3.42) were recorded with other alone application of pyroxasulfone 100 g ha^{-1} and pendimethalin 750 g ha^{-1} whereas at par to the application of pyroxasulfone + pendimethalin (450 g ha^{-1}) and (675 g ha^{-1}) treatments. However two hand weeding at 20 and 40 DAS had the maximum branches plant^{-1} (4.01). Similarly, Patel *et al.*, (2016) found that the maximum branches plant^{-1}pre emergence application of 677.25 g ha^{-1} pendimethalin + 1 HW at 30 DAS of soybean as compared to other combine herbicidal treatments and weedy check.

Crop biomass was influenced significantly due to the treatments at different intervals and harvest (Table 2). Weedy check plots had the minimum crop biomass (298.35g m^{-2}) which increased appreciably in plots receiving weed control treatments. Pre emergence combine application of pyroxasulfone + pendimethalin 900 gha^{-1} registered higher crop biomass (327.59g m^{-2}) followed by pyroxasulfone + pendimethalin at the rate of 1125 and 675 g ha^{-1} (324.57 and 321.54g m^{-2}, respectively). The minimum crop biomass (307.34g m^{-2}) was recorded with application of Pendimethalin 750 g ha^{-1}. However two hand weeding at 20 and 40 DAS had the maximum (331.38g m^{-2}) crop biomass which was at par to crop biomass attained in pyroxasulfone + pendimethalin 900 g ha^{-1} (327.59g m^{-2}).

The number of pods plant^{-1} and seeds pod^{-1} as believed to be closely associated with seed yield plant^{-1} resulting high productivity. The number of pods plant^{-1} varied significantly due to different weed control treatments (Table 2). Among all the treatments, the minimum number of pods plant^{-1} (30.83) was recorded under weedy check, which was increased significantly when weed control measures were adopted, the maximum number of pods plant^{-1} (35.47) was recorded under combine application pyroxasulfone + pendimethalin as pre emergence at 900 g ha^{-1}, which was found superior to pyroxasulfone + pendimethalin 450 g ha^{-1} and alone pendimethalin 750 g ha^{-1}(32.57 and 31.24 pods plant^{-1}, respectively).Similarly, Amaregouda *et al.*, (2013) [1] studied that the application of pendimethalin 1350.50 g ha^{-1} and imazethepyr 87.50 g ha^{-1} increased pods plant^{-1} over control.

The seed pod^{-1}and seed index did not show any significant variation among different weed control treatments (Table 2). The possible reason for a non-significant difference in seed pod^{-1} and seed index under the weed control treatments were due to genetic factor and varietal characters i.e. similarity in size and shape of individual grains. These results are in collaboration with the findings of singh and singh, 2000 [15].

Table 2: Influence of weed control treatments on weed biomass, weed control efficiency, plant height, branches plant^{-1}, crop biomass, Effective nodules plant^{-1}, pods plant^{-1}, seeds plant^{-1}and seed index of soybean

Treatment	Rate (g ha^{-1})	Weed biomass (g m^{-2})	WCE (%)	Plant height (cm)	Branches plant^{-1}	Effective nodules plant^{-1}at 45 DAS	Crop biomass (g m^{-2})	Pods plant^{-1}	Seeds Pod^{-1}	Seed index (g)
T_1- Pyroxasulfone + Pendimethalin	450	5.67	85.93	43.10	3.70	41.40	316.67	32.57	2.00	12.01
T_2-Pyroxasulfone + Pendimethalin	675	4.03	89.99	43.68	3.71	41.43	321.54	35.27	2.33	12.02
T_3- Pyroxasulfone + Pendimethalin	900	3.44	90.77	48.00	3.94	41.51	327.59	35.47	2.33	12.07
T_4- Pyroxasulfone + Pendimethalin	1125	3.29	92.00	44.42	3.83	41.44	324.57	35.40	2.33	12.03
T_5- Pyroxasulfone	100	5.10	87.34	41.39	3.67	41.20	318.81	31.37	2.00	11.99
T_6- Pendimethalin	750	13.97	65.31	39.91	3.42	40.73	307.34	31.24	2.00	11.97
T_7- Hand weeding	20 &40 DAS	0.00	100.00	47.10	4.01	41.60	331.38	39.10	2.33	12.09
T_8- Weedy check		40.28	0.00	36.38	3.34	41.57	298.35	30.83	2.00	11.94
SEm±		-	-	1.15	0.10	0.42	1.23	0.10	0.22	0.12
CD at 5%		-	-	3.62	0.29	NS	3.81	0.28	NS	NS

The seed yield is very complex trait, it is multiplicative end product of several basic components of yield such as pods plant^{-1}, seeds plant^{-1} and seed index etc. The seed and stover yield were found minimum (606.67 kg ha^{-1} and 1592.67 kg ha^{-1}, respectively) in weedy check plots where weeds were allowed to grow throughout crop season. But it was further increased with the application of different herbicides (Table 3). The maximum seed and stover yield (1606.00 kg ha^{-1} and 3156.33 kg ha^{-1}, respectively) were found under two hand weeding at 20 and 40 DAS. Whereas among the different herbicidal treatments maximum seed and stover yield (1335.92 kg ha^{-1} and 2884.33 kg ha^{-1}, respectively) were recorded with the application of 900 g ha^{-1} and it was superior to the other herbicidal treatments. Sharma and Shrivastava (2002) [14], Vyas and Jain (2003) [18] and Halvankar *et al.*, (2005) [3] also reported that hand weeding as an effective method of weed control for achieving the maximum yield of soybean.

Economic analysis of the treatments

The net monetary returns under each treatment was determined by subtracting the cost of cultivation from gross monetary returns of each treatment. The marginal loss of (Rs 5652 ha^{-1}) was obtained when crop was not weeded throughout the crop season.Whereas it was the Maximum gross monetary return (Rs 52139 ha^{-1}) was fetched with hand weeding twice at 20 and 40 DAS followed by combined application of pyroxasulfone + pendimethalin at 900 g ha^{-1} (Rs 43630 ha^{-1}) closely followed by 1125 g ha^{-1} (Rs 41000 ha^{-1}). Though the gross monetary returns was maximum in two hand weeding treatment among all the treatments, but net monetary return and B:C ratio were the highest (Rs 15182 ha^{-1} and 1.53, respectively) under combined application of

pyroxasulfone + pendimethalin at 900 g ha^{-1} closely followed by pyroxasulfone + pendimethalin at 1125 g ha^{-1} (Rs 11977 ha^{-1} and 1.41, respectively) as pre emergence herbicide to soybean. These results are in accord with Kamble *et al.*, 2017 [5], Manjunath & Hosmath, 2016 [8].

Table 3: Influence of weed control treatments on seed yield, stover yield and economic analysis of different weed control treatments in Soybean

Treatment	Rate (gha^{-1})	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Cost of cultivation (Rs ha^{-1})	Gross monetary returns (Rs ha^{-1})	Net monetary returns (Rs ha^{-1})	B:C Ratio
T_1- Pyroxasulfone + Pendimethalin	450	996.16	2402.33	27298	32785	5487	1.20
T_2- Pyroxasulfone + Pendimethalin	675	1181.40	2713.00	27873	38746	10873	1.39
T_3- Pyroxasulfone + Pendimethalin	900	1335.92	2884.33	28448	43630	15182	1.53
T_4- Pyroxasulfone + Pendimethalin	1125	1252.24	2807.00	29023	41000	11977	1.41
T_5- Pyroxasulfone	100	1101.76	2587.20	26326	36191	9864	1.37
T_6- Pendimethalin	750	656.92	1663.00	26767	29113	2345	1.09
T_7- Hand weeding	20 &40 DAS	1606.00	3156.33	37748	52139	14391	1.38
T_8- Weedy check		606.67	1592.67	25748	20096	-5652	0.78
SEm±		49.06	35.92	-	-	-	-
CD at 5%		147.08	107.68	-	-	-	-

Conclusions

From the present experiment it is concluded that the combined application of pyroxasulfone + pendimethalin at 900 g ha^{-1} attained higher values of growth parameters, yield attributes, both seed and stover yield, effective weed control in soybean and found more remunerative as it received highest value of net monetary return Rs. 15182 ha^{-1} and B:C ratio (1.53).

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