J. Farm Sci., 35(2): (214-218) 2022

RESEARCH PAPER

Effect of pre and post emergence application of herbicides on weed control efficiency, performance of sunflower *(Helianthus annuus* L.) and succeeding chickpea crop(*Cicer arietinum* L.)

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(Received: February, 2022 ; Accepted: June, 2022)

Abstract: A field experiment was conducted during *kharif*, 2017 on medium black soil at the Main Agricultural Research Station, UAS Raichur. The experiment consisted of eleven treatments laid out in Randomized Block Design. Among the different weed management practices, pre-emergent application of pendimethalin 38.7 CS @ 0.75 kg a.i ha^{-1} followed by post emergent application of propaquizafop 10 EC @ 62 g a.i ha^{-1}at 15 - 20 DAS was found effective to manage weeds and grain yield comparable with weed free condition. It also recorded lower grasses, sedges, broad leaf weeds and total weeds count, dry weight of weeds (2.25 g m^{-2}) lower weed index (4.50) and higher weeds control efficiency (95.65 %) at 30 DAS when compared to weedy check. Extent of yield reduction due to weed infestation was 52.8% over weed free. There were no phyto-toxicity symptoms was not observed both on sunflower and succeeding chickpea crop.

Key words: Chickpea, Pendimethalin, Propaquizafop, Sunflower, Weed index

Introduction

Sunflower (*Helianthus annuus* L.) is one of the important oilseed crops of India. It is known for its wider adaptability to varied agro-climatic conditions and soil types, easy crop management, photo-insensitivity, high seed multiplication ratio (1:50) and commercially available varieties/hybrids contains about 36 to 42 % oil ,15 g of total fat, 1g of saturated fat, 6 g of protein, 6 g of carbohydrate and 3 g of fiber in seed. It is a rich source of linoleic acid (55-65%) and oleic acid (20-30%). Sunflower oil is generally considered as premium oil because of its light colour, higher levels of unsaturated fatty acids which is good for cardiac patients. Oil cake is rich in high quality protein (40-44 %) and used as cattle and poultry feed. The productivity of sunflower has been often deflated due to an array of biotic and abiotic factors. Weed competition is one of the major biotic constraints in realizing higher sunflower productivity due to wider spacing and application of higher dose of fertilizers. Uncontrolled weed growth reduced the seed yield of sunflower to an extent of 55 % (Wanjari *et al.,* 2001). In sunflower, the first 4-weeks period after germination is most critical in determining damage from weed competition. Competition of weeds decreases the sunflower yield to an extent of 58 % (Daugovish *et al.,* 2003). In recent years, due to labour shortage and increased cost of production an alternate methods is vital for successful weed management (Shwetha *et al.,* 2016). In view of growing labour scarcity and increasing cost of manual weeding, herbicides are now becoming increasingly popular because of their cost effectiveness and better weed control. The use of both pre and post-emergence herbicides may be a viable option to control the weeds right from the sowing to critical period of crop weed competition in sunflower. Keeping this in view, the present study was undertaken to evaluate the relative efficacy of sequential application of pre-emergence herbicides *viz.,* pendimethalin followed by post-emergence herbicides *viz.,* fenoxaprop ethyl, propaquizafop and quizalofop ethyl in combination with cultural practice for their influence on weed growth and productivity of sunflower.

Material and methods

A field experiment was conducted under rainfed condition during *kharif* 2017 at the Main Agricultural Research Station, UAS, Raichur. The centre is situated between 16^0 12' N latitude and 77^0 20' E longitude with an altitude of 389 m above the mean sea level and it belongs to north eastern dry zone of Karnataka. The soil type was medium deep black soil. Experiment was conducted in randomized complete block design with three replications. The treatments tested are pendimethalin 38.7 CS @ 0.75 kg a.i ha^{-1} as PE fb IC at 35 DAS (T_1), quizalofop ethyl 5 EC @ 37.5 g a.i. ha^{-1} at 15-20 DAS as POE fb IC at 35 DAS (T_2), propaquizafop 10 EC @ 62 g a.i. ha^{-1} at 15-20 DAS as POE fb IC at 35 DAS (T_3), fenoxoprop ethyl @ 37.5 g a.i. ha^{-1} at 15-20 DAS as POE fb IC at 35 DAS (T_4), pendimethalin 38.7 CS @ 0.75 kg a.i ha^{-1} as PE fb quizalofop ethyl 5 EC @ 37.5g a.i ha^{-1} at 15-20 DAS as POE (T_5), pendimethalin 38.7 CS @ 0.75 kg a.i ha^{-1} as PE fb propaquizafop 10 EC @ 62 g a.i ha^{-1} at 15 - 20 DAS as POE (T_6), pendimethalin @ 38.7 CS @ 0.75 kg a.i ha^{-1} as PE fb fenoxoprop ethyl 9.3 EC @ 37.5 g a.i ha^{-1} at 15-20 DAS as POE (T_7), IC at 30-35 DAS (T_8), Farmer's practice (HW at 20 DAS + IC at 30-35 DAS) (T_9), Weed free (T_{10}), Unweeded control (T_{11}). The variety used was RSFH-1887 planted at a spacing of 60 cm x 30 cm. The recommended dose of fertilizer was applied 90:90:60 kg N, P_2O_5, K_2O per ha. The crop was hand dibbled on ridges on 12th August 2017 and harvested on 10th November 2017. The gross and net plot sizes were 30 m^2 and 20.25 m^2, respectively. The data on weed density in a quadrant of 0.5 m x 0.5 m was taken at 30 DAS. From this, the density and dry weight of the weeds at 30 DAS was worked out. Chickpea cv. JG-11 was sown in undisturbed plots after harvest of the sunflower to test the phytotoxicity effect of herbicides. Production practices for

chickpea were followed as per the zonal recommendations of the University. The data on weeds density and dry weight were analyzed using transformation of square root of ($\sqrt{x} + 0.5$). At harvest, the data on seed yield, head diameter, 100 seed weight and seed volume weight were recorded.

Weed index was worked out by using the formula given by Gill and Kumar (1984).

$$\text{Weed index (\%)} = \frac{\text{Yield from weed free plot or best treatment plot (kg ha}^{-1}\text{)} \quad \text{Yield from treated plot for which weed index to be worked out (kg ha}^{-1}\text{)}}{\text{Yield from weed free plot or best treatment plot (kg ha}^{-1}\text{)}} \times 100$$

Weed control efficiency was calculated by using the following formula as suggested by Mari *et al*. (1973).

$$\text{Weed control efficiency (\%)} = \frac{\text{Total weed dry weight in unweeded plot (g)} \quad \text{Total weed dry weight in treated plot (g)}}{\text{Total weed dry weight in unweeded control plot (g)}} \times 100$$

Results and discussion

Weed flora of the experimental field

The major grassy weeds observed in the experiment plot were *Cynodon dactylon, Dactyloctenium aegyptium, Eleusine indica, Echinochloa colona,* while common broad-leaved weeds observed were *Abutilon indicum, Amaranthus viridis*, *Commelina benghalensis*, *Celosia argentea, Cyanotis cristata, Malvastrum coramandelianum, Portulaca oleracea* and sedges weed like *Cyperus rotundus.*

Effect on weeds

At 30 DAS, lower weed dry weight of 2.25 g per sq m was recorded with application of pendimethalin 38.7 CS @ 0.75 kg a.i ha^{-1} PE fb propaquizafop 10 EC @ 62 g a.i ha^{-1} at 15 - 20 DAS as POE compared to unweeded control. Weed free check recorded lower weed density throughout the crop season and pendimethalin 38.7 CS @ 0.75 kg a.i ha^{-1} PE fb propaquizafop 10 EC @ 62 g a.i ha^{-1} at 15 - 20 DAS as POE recorded significantly lower density of grasses, sedges, broad leaf weeds and total weeds (1.58, 2.26, 2.39 6.23 per sq m, respectively) This might be due to effect of treatments in remarkable reduction in weed population and ultimately low dry weight of weeds observed under these treatments. Tadavi *et al*. (2017) also confirmed that growth and yield attributes of sunflower were improved under weed free treatment (3 HW at 15, 30 and 45 DAS) and in pre-emergence application of pendimethalin @1 kg a.i ha^{-1} as PE followed by fenoxoprop ethyl @ 37.5 g a.i ha^{-1} as post emergent application. Similar results were also reported by Rohini *et al.* (2017) and Sujith *et al*. (2017) wherein application of pendimethalin 38.7 CS at 1.0 kg a.i ha^{-1} as pre emergent fb quizalofop-ethyl 10 EC at 37.5 g a.i ha^{-1} at 17 DAS as post emergent herbicide on weeds recorded higher seed yield over weed free check.

At 30 DAS, the higher weed control efficiency of 100 per cent was recorded in weed free check. Among herbicide treatments, significantly higher weed control efficiency (95.65 %) was recorded with application of pendimethalin 38.7 CS @ 0.75 kg a.i ha^{-1} as PE fb propaquizafop 10 EC @ 62 g a.i ha^{-1} at 15 - 20 DAS as POE. This may be due to significant reduction in the weed dry weight as a result of broad spectrum weed control by pendimethalin as well as specific control of annual and perennial grassy weeds by propaquizafop during critical period of crop weed competition (Siva Sankar and Subramanyam, 2011; Rohini *et al.*, 2017).

Weed index indicated yield reduction due to weed competition and it was higher in unweeded control (52.68 %). This was due to less sunflower seed yield associated with unchecked weed growth throughout the crop growth period. However, the lower weed index (4.50 %) was noticed in plot treated with pendimethalin 38.7 CS @ 0.75 kg a.i ha^{-1} as PE fb propaquizafop 10 EC @ 62 g a.i ha^{-1} at 15 - 20 DAS as POE. This may be due to the satisfactory control of weeds and reduction in the crop weed competition. The effective use of herbicides at optimum dosage and time of application might have enabled the crop to utilize available resources like light, nutrients, moisture and space resulting in higher yield. Rohini *et al*. (2017) also observed higher weed control efficiency and lower weed index in sunflower due to sequential application of pendimethalin as pre emergence fb quizalofop ethyl as post emergence.

Effect on yield

Yield and yield attributes were significantly influenced by different weed management practices in sunflower (Table 1). Weed free check recorded significantly higher seed yield. Among herbicide treatments, significantly higher seed yield was recorded with application of pendimethalin 38.7 CS @ 0.75 kg a.i ha^{-1} as PE fb propaquizafop 10 EC @ 62 g a.i ha^{-1} at 15 - 20 DAS as POE (1632 kg ha^{-1}).The reason for increased seed yield in this treatment was due to higher yield components which might be due to efficient and broad spectrum weed control achieved by the above treatments resulted in increased availability of plant nutrients and moisture to crop throughout the cropping period. The favorable condition created by efficient weed management resulted in competition free environment. This has increased the capacity of source (LAI) and sink and in turn the head diameter, 100-seed weight and seed volume weight were increased. This is evident from the significant positive relation of growth and yield attributes of sunflower with seed yield. Results were in line with Tadavi *et al* (2017). All these yield attributing characters were adversely affected in unweeded control treatment due to severe weed competition exerted by weeds for space, light, moisture and nutrients throughout the crop growth period. The increase of 100 seed weight is due to more availability of nutrients and moisture as there was less competition between weeds and crops thereby the seed weight increased. Tadavi *et al* (2017) also observed similar results wherein pre-emergence application of pendimethalin @ 1 kg a.i ha^{-1} as PE followed by fenoxoprop ethyl @ 37.5 g a.i ha^{-1} as POE in sunflower resulted in higher growth parameters and yield attributes of sunflower.

Table1. Seed yield and yield parameters of sunflower as influenced by different weed management practices

Treatment	Dry matter at harvest (g/plant)	Seed yield (kg/ha)	Head diameter (cm)	100 seed weight (g)	Seed volume weight (g)	Weed Index (%)
Pendimethalin 38.7 CS @ 0.75 kg a.i/ha (PE) fb IC at 35 DAS	131.6	1602	16.2	4.2	41.1	6.23
Quizalofop ethyl 5 EC @ 37.5 g a.i/ha at 15 – 20 DAS (POE) fb IC at 35 DAS	102.7	1032	13.5	3.7	32.5	39.41
Propaquizofop 10 EC @ 62 g a.i/ha at 15 – 20 DAS (POE) fb IC at 35 DAS	112.9	1216	14.1	3.8	36.4	28.51
Fenoxoprop ethyl 9.3 EC @ 37.5 kg a.i ha^{-1} at 15-20 DAS (POE) fb IC at 35 DAS	110.0	1107	13.8	3.8	34.4	35.00
Pendimethalin 38.7 CS @ 0.75 kg a.i/ha (PE) fb Quizalofop ethyl 5 EC @ 37.5 g a.i/ha at 15-20 DAS (POE)	121.9	1396	14.7	4.0	37.9	18.35
Pendimethalin 38.7 CS @ 0.75kga.i/ha (PE) fb Propaquizofop 10 EC @ 62 g a.i/ha at 15-20 DAS (POE)	134.3	1632	16.4	4.4	41.4	4.50
Pendimethalin 38.7 CS @ 0.75 kga.i/ha (PE) fb Fenoxoprop ethyl 9.3 EC @ 37.5 g a.i/ha at 15-20 DAS (POE)	129.3	1586	16.1	4.2	40.8	7.08
Intercultivation at 35 DAS	98.5	1000	11.2	3.2	30.4	41.20
Farmer's practice (Hand weeding @ 20 DAS fb intercultivation @ 35 DAS)	119.5	1326	14.6	3.9	37.5	22.12
Weed free	136.4	1704	16.5	4.4	43.3	0.00
Unweeded control	93.1	805	10.4	3.2	28.4	52.68
S.Em.±	2.72	92.68	0.56	0.14	1.37	5.37
C.D. (p=0.05)	8.01	273.42	1.66	0.41	4.06	15.84

IC-Intercultivation; CS- Capsule Suspension; EC- Emulsifiable concentrates; HW- Hand Weeding; PE- Pre Emergence; POE- Post Emergence; DAS- Days After Sowing

Table 2. Weed dynamics and weed control efficiency as influenced by different weed management practices

Treatment	Weed density (number / sq m)				Weed dry weight at 30 DAS (g)	Weed control efficiency (%)
	Grasses	Sedges	Broad leaf weeds	Total		
Pendimethalin 38.7 CS @ 0.75 kg a.i/ha (PE) fb IC at 35 DAS	1.76 (7.3)	2.41 (5.3)	2.64 (6.7)	6.81 (19.3)	2.75 (7.2)	93.09
Quizalofop ethyl 5 EC @ 37.5 g a.i/ha at 15 – 20 DAS (POE) fb IC at 35 DAS	2.67	3.53 (4)	4.30 (12)	10.50 (18)	3.28 (34)	90.05 (10.4)
Propaquizofop 10 EC @ 62 g a.i/ha at 15 – 20 DAS (POE) fb IC at 35 DAS	2.53 (3.3)	3.44 (11.3)	3.89 (14.7)	9.85 (29.3)	3.18 (9.7)	90.70
Fenoxoprop ethyl 9.3 EC @ 37.5 kg a.i ha^{-1} at 15-20 DAS (POE) fb IC at 35 DAS	2.67 (4)	3.53 (12)	4.14 (16.7)	10.34 (32.7)	3.25 (10.1)	90.29
Pendimethalin 38.7 CS @ 0.75 kg a.i/ha (PE) fb Quizalofop ethyl 5 EC @ 37.5 g a.i/ha at 15-20 DAS (POE)	2.26 (2.7)	2.90 (8)	3.00 (8.7)	8.17 (19.3)	2.41 (5.4)	94.88
Pendimethalin 38.7 CS @ 0.75kga.i/ha (PE) fb Propaquizofop 10 EC @ 62 g a.i/ha at 15-20 DAS (POE)	1.58 (2)	2.26 (4.7)	2.39 (5.3)	6.23 (12)	2.25 (4.6)	95.65
Pendimethalin 38.7 CS @ 0.75 kga.i/ha (PE) fb Fenoxoprop ethyl 9.3 EC @ 37.5 g a.i/ha at 15-20 DAS (POE)	1.94 (2)	2.55 (6)	2.67 (6.7)	7.16 (14.7)	2.27 (4.7)	95.53
Intercultivation at 35 DAS	4.44 (19.3)	3.97 (15.3)	4.79 (22.7)	13.21 (57.3)	9.68 (93.2)	10.75
Farmer's practice (Hand weeding @ 20 DAS fb intercultivation @ 35 DAS)	2.41 (2.7)	1.34 (1.3)	1.46 (1.7)	5.21 (5.7)	2.29 (4.8)	95.46
Weed free	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	100.00
Unweeded control	4.59 (20.7)	4.13 (16.7)	5.15 (26)	13.87 (63.3)	10.26 (104.8)	0.00
S.Em.±	0.16	0.15	0.21	0.36	0.14	1.49
CD (p=0.05)	0.46	0.45	0.61	1.06	0.42	4.40

IC-Intercultivation; CS- Capsule Suspension; EC- Emulsifiable concentrates; HW- Hand Weeding; PE- Pre Emergence; POE- Post Emergence; DAS- Days After Sowing. Figures in parenthesis are transformed values

Table 3. Residual effect of herbicides on germination and seed yield of succeeding chickpea

Treatment	Crop phytotoxicity ratings	Germination percentage (%)		Seed yield (kg/ha)
		10 DAS	20 DAS	
Pendimethalin 38.7 CS @ 0.75 kg a.i/ha (PE) fb IC at 35 DAS	0.0	90.3	93.0	866
Quizalofop ethyl 5 EC @ 37.5 g a.i/ha at 15 – 20 DAS (POE) fb IC at 35 DAS	0.0	89.3	90.7	850
Propaquizofop 10 EC @ 62 g a.i/ha at 15 – 20 DAS (POE) fb IC at 35 DAS	0.0	90.0	91.7	856
Fenoxoprop ethyl 9.3 EC @ 37.5 kg a.i ha^{-1} at 15-20 DAS (POE) fb IC at 35 DAS	0.0	88.3	93.0	859
Pendimethalin 38.7 CS @ 0.75 kg a.i/ha (PE) fb Quizalofop ethyl 5 EC @ 37.5 g a.i/ha at 15-20 DAS (POE)	0.0	89.3	90.7	862
Pendimethalin 38.7 CS @ 0.75kga.i/ha (PE) fb Propaquizofop 10 EC @ 62 g a.i/ha at 15-20 DAS (POE)	0.0	89.3	91.0	870
Pendimethalin 38.7 CS @ 0.75 kga.i/ha (PE) fb Fenoxoprop ethyl 9.3 EC @ 37.5 g a.i/ha at 15-20 DAS (POE)	0.0	89.7	91.3	868
Intercultivation at 35 DAS	0.0	90.0	92.7	854
Farmer's practice (Hand weeding @ 20 DAS fb intercultivation @ 35 DAS)	0.0	90.0	91.3	849
Weed free	0.0	90.3	93.0	868
Unweeded control	0.0	89.7	91.7	859
S.Em.±	-	1.35	1.29	5.31
C.D. (p=0.05)	-	NS	NS	NS

IC-Intercultivation; CS- capsule Suspension; EC- Emulsifiable concentrates; HW- Hand Weeding; PE- Pre Emergence; POE- Post Emergence; DAS- Days After Sowing, NS: Non Significant

Table 4. Economics of sunflower production as influenced by different weed management practices

Treatment	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
Pendimethalin 38.7 CS @ 0.75 kg a.i/ha (PE) fb IC at 35 DAS	25106	54468	29362	2.17
Quizalofop ethyl 5 EC @ 37.5 g a.i/ha at 15 – 20 DAS (POE) fb IC at 35 DAS	24771	35088	10317	1.42
Propaquizofop 10 EC @ 62 g a.i/ha at 15 – 20 DAS (POE) fb IC at 35 DAS	24618	41344	16726	1.68
Fenoxoprop ethyl 9.3 EC @ 37.5 kg a.i ha^{-1} at 15-20 DAS (POE) fb IC at 35 DAS	24213	37638	13425	1.55
Pendimethalin 38.7 CS @ 0.75 kg a.i/ha (PE) fb Quizalofop ethyl 5 EC @ 37.5 g a.i/ha at 15-20 DAS (POE)	24437	47464	23027	1.94
Pendimethalin 38.7 CS @ 0.75kga.i/ha (PE) fb Propaquizofop 10 EC @ 62 g a.i/ha at 15-20 DAS (POE)	24284	55488	31204	2.28
Pendimethalin 38.7 CS @ 0.75 kga.i/ha (PE) fb Fenoxoprop ethyl 9.3 EC @ 37.5 g a.i/ha at 15-20 DAS (POE)	23879	53924	30045	2.26
Intercultivation at 35 DAS	23440	34000	10560	1.45
Farmer's practice (Hand weeding @ 20 DAS fb intercultivation @ 35 DAS)	25440	45084	19644	1.77
Weed free	27440	57936	30496	2.11
Unweeded control	21440	27370	5930	1.28
S.Em.±	-	2710.96	2710.96	0.11
C.D. (p=0.05)	-	7997.34	7997.34	0.33

IC-Intercultivation; CS- Capsule Suspension; EC- Emulsifiable concentrates; HW- Hand Weeding; PE- Pre Emergence; POE- Post Emergence; DAS- Days After Sowing

Economic returns

Relatively higher cost of cultivation was recorded in weed free treatment followed by farmer's practice. Involvement of more labours for weed free condition has resulted in higher cost of cultivation. Among different weed management practices, significantly higher gross returns was recorded in weed free (₹ 57,936) which was on par with application of pendimethalin 38.7 CS @ 0.75 kg a.i ha^{-1} as PE fb propaquizafop 10 EC @ 62 g a.i ha^{-1} at 15 - 20 DAS as POE (₹ 55,488), pendimethalin 38.7 CS @ 0.75 kg a.i ha^{-1} as PE fb IC at 35 DAS and pendimethalin @ 38.7 CS @ 0.75 kg a.i ha^{-1} as PE fb fenoxoprop ethyl @ 37.5 g a.i ha^{-1} at 15-20 DAS as POE. Weed management practices exerted significant difference on net returns. Significantly higher net returns was recorded with application of pendimethalin 38.7 CS @ 0.75 kg a.i ha^{-1} as PE fb propaquizafop 10 EC @ 62 g a.i ha^{-1} at 15 - 20 DAS as POE (₹ 31,204) which was on par with weed free check (₹ 30,496), pendimethalin @ 38.7 CS @ 0.75 kg a.i ha^{-1} as PE fb fenoxoprop ethyl @ 37.5 g a.i ha^{-1} at 15-20 DAS as POE (₹ 30,045) and pendimethalin 38.7 CS @ 0.75 kg a.i ha^{-1} as PE fb 1 IC at 35 DAS (₹ 29,362). Benefit: cost ratio was significantly higher with application of pendimethalin 38.7 CS @ 0.75 kg a.i ha^{-1} as PE fb propaquizafop 10 EC @ 62 g a.i ha^{-1} at 15 - 20 DAS as POE (2.28) and it was found on par with application of pendimethalin

@ 38.7 CS @ 0.75 kg a.i ha^{-1} as PE fb fenoxoprop ethyl @ 37.5 g a.i ha^{-1} at 15-20 DAS as POE (2.26), pendimethalin 38.7 CS @ 0.75 kg a.i ha^{-1} as PE fb 1 IC at 35 DAS (2.17) and weed free lower in unweeded control. The fundamental economic principal for weed management is simple, act only if benefits exceed the cost. Results in this study indicated that gross returns, net returns and BC ratio differed due to different weed management practices. Significantly higher net returns was obtained in treatments having combination of pre- and post-emergence herbicides. Application of pendimethalin 38.7 CS @ 0.75 kg a.i ha^{-1} as PE fb propaquizafop 10 EC @ 62 g a.i ha^{-1} at 15 - 20 DAS as POE recorded higher net returns and benefit : cost ratio. It's mainly due to higher gross returns realized in respective treatments governed by higher seed yield and better market price. Due to less crop weed competition weed free treatment and herbicidal treatments gave higher BC ratio. A lower net return (₹ 5,930) in unweeded treatment was due to lower yield as a consequence of higher weed competition. Results reported by Channappagoudar *et al.* (2008), Sumathi *et al*. (2010) and Tadavi *et al.* (2017) also showed that greater economic returns due to chemical weed management in various crops including sunflower.

Effect on succeeding crop chickpea

Germination count, crop phytotoxicity ratings and seed yield of chickpea did not differ significantly due to residual effect of herbicides imposed on sunflower during *kharif*. Mundra and Maliwal (2012) reported that quizalofop ethyl applied in blackgram did not show any kind of phytotoxicity on succeeding crops, *viz.,* wheat, mustard and chickpea.

Conclusion

The results indicated that application of pendimethalin 38.7 CS @ 0.75 kg a.i ha $^{-1}$ as pre-emergence *fb* propaquizafop 10 EC @ 62 g a.i ha^{-1} at 15 - 20 DAS as post emergence found to be effective for obtaining higher productivity and profitability in sunflower.

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