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Weed Flora and Yield of Sunflower (*Helianthus annuus* L.) as Influenced by Pre- and Post-emergence Application of Herbicides

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Sunflower (*Helianthus annuus* L.) is an important oil seed crop of India. Presently, in India, sunflower is cultivated on an area of 1.81 million hectares and the total production of 1.16 million tonnes with an average productivity of 639 kg/ha during 2008-09. 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 in irrigated conditions due to following wider spacing and application of higher dose of fertilizers. Uncontrolled weed growth reduced the seed yield of sunflower upto an extent of 55% (Wanjari *et al.,* 2000). Further, non-availability of labour and high rate of wages during peak periods of agricultural operations increased hiring charges of bullock-drawn intercultural implements, pre- and post-emergence herbicides may be viable option to control the weeds right from the sowing to harvesting of sunflower crop. In order to increase the productivity of sunflower and reduce the cost of cultivation, the use of tank-mix combinations or sequential application of pre- and post-emergence herbicides may be the useful option rather than pre or post-emergence herbicide application alone. The sequential application of pre- and post-emergence herbicides in sunflower has not been investigated adequately. Keeping this in view, the present study was undertaken to evaluate the relative efficiency of sequential application of pre-emergence herbicides *viz*., pendimethalin and oxadiargyl in combination with post-emergence herbicides *viz*., fenoxaprop, propaquizafop and quizalofop for their influence on weed growth and productivity of sunflower.

A field experiment was conducted at Dryland Farm, Tirupati Campus of Acharya N. G. Ranga Agricultural University, Andhra Pradesh during **rabi** season of 2010-11. The soil of experimental plot was sandy loam in texture with a pH of 6.0. It was low in organic carbon (0.23%) and available nitrogen (230 kg/ha); medium in available phosphorus (23.7 kg/ha) and potassium (204 kg/ha). The experiment consisted of 10 treatments laid-out in a randomized block design with three replications consisting of pre-emergence application of pendimethalin and oxadiargyl alone and sequential application of these two pre-emergence herbicides with post-emergence herbicides *viz*., fenoxaprop, propaquizafop and quizalofop along with two hand weedings and unweeded check (Table 1). Pre- and post-emergence herbicides were applied uniformly at 2 and 20 DAS, respectively, by using spray fluid @ 600 l/ha with the help of knap sack sprayer as per the treatments. Sunflower hybrid NDSH-1 was sown on 17 December 2010 at a spacing of 45 x 20 cm. Recommended dose of fertilizers i. e. 75 kg of N, 90 kg of P_2O_5 and 30 kg of K_2O/ha was applied in each plot to raise the crop. Half of the nitrogen and full amount of phosphorus and potassium were applied as basal. Rest of the nitrogen was top dressed in two equal splits at button stage and at flowering. Need-based irrigation was given to the crop. All the recommended package of practices, except weed management as adapted to sunflower were adopted as per recommendations of Acharya N. G. Ranga Agricultural University. The crop was harvested on 18 March 2011. Data on weed density were recorded at harvest by randomly placing a quadrate of 0.5 x 0.5 m, at two places in each plot. The dry weight of weeds was recorded after drying the weeds in oven at 70±1°C upto 48 h. The data on weed density and dry weight were subjected to square root transformation before statistical analysis. Nutrient uptake by weeds was estimated as per the standard procedures.

The major weeds recorded from the experimental field were *Cyperus rotundus* L. and *Cyperus difformis* L. among sedges, *Trichoderma indicum*, *Euphorbia thymifolia* L., *Commelina benghalensis* L., *Euphorbia hirta* L., *Digera arvensis* L., *Phyllanthus niruri* L., *Celosia argentea* L., *Cleome monophylla* L. and *Boerhaavia erecta* L. among broad-leaved weeds, and *Chloris barbata* Sw., *Cynodon dactylon* L. Pers., *Dactyloctenium aegyptium* (L.) Willd, *Digitaria bicornis* L., *Echinochloa colona* L. Link., *Digitaria sanguinalis* L. and *Brachiaria reptans* L. among grasses. The relative density of grasses, sedges and broad-leaved weeds was

Table 1. Effect of pre- and post-emergence herbicides on weed density, dry weight , WCE and nutrient uptake by weeds in **rabi** sunflower

Treatment	Dose (g/ha)	Time of application (DAS)	Weed density* (No./m^2)			Weed dry weight* (g/m^2)			Weed control efficiency	Nutrient uptake by weeds (kg/ha)		
			Grasses	Sedges	BLWs	Grasses	Sedges	BLWs	(%)	N	P	K
Pendimethalin	1000	2	5.56 (30.4)	16.31 (265.4)	8.5 (71.8)	5.86 (33.8)	8.49 (71.7)	8.92 (79.0)	20.9	28.0	8.0	29.0
Oxadiargyl	250	2	5.93 (34.7)	15.81 (249.5)	9.01 (80.6)	6.24 (38.5)	8.24 (67.4)	9.44 (88.7)	16.5	34.0	12.4	39.1
Pendimethalin *fb* fenoxaprop	1000 & 60	2 & 20	2.92 (8.0)	15.47 (238.9)	6.88 (46.9)	3.07 (8.9)	8.06 (64.5)	7.22 (51.6)	46.4	21.8	5.6	23.6
Oxadiargyl *fb* fenoxaprop	250 & 60	2 & 20	5.45 (29.3)	14.81 (218.8)	8.14 (65.8)	5.74 (32.5)	7.72 (59.0)	8.54 (72.4)	29.6	32.6	9.6	35.5
Pendimethalin *fb* propaquizafop	1000 & 60	2 & 20	2.37 (5.1)	15.15) (228.9)	6.58 (42.8)	2.49 (5.7)	7.89 (61.8)	6.90 (47.1)	50.8	19.5	3.4	18.2
Oxadiargyl *fb* propaquizafop	250 & 60	2 & 20	4.91 (23.6)	14.71 (215.8)	7.75 (59.6)	5.17 (26.2)	7.67 (58.3)	8.13 (65.6)	35.6	26.5	9.0	32.1
Pendimethalin *fb* quizalofop	1000 & 50	2 & 20	2.45 (5.5)	15.22 (231.2)	6.74 (44.9)	2.59 (6.2)	7.93 (62.4)	7.06 (49.4)	49.3	20.5	4.5	19.5
Oxadiargyl *fb* quizalofop	250 & 50	2 & 20	5.26 (27.2)	14.59 (212.5)	7.87 (61.5)	5.54 (30.2)	7.61 (57.4)	8.26 (67.7)	33.4	31.7	9.3	34.3
Two hand weedings	-	20 & 40	2.81 (7.4)	9.33 (86.6)	3.29 (10.3)	2.95 (8.2)	3.58 (12.3)	3.44 (11.3)	86.3	7.2	1.9	6.2
Unweeded check	-	-	6.60 (43.1)	17.24 (296.6)	9.85 (96.5)	6.88 (46.8)	8.98 (80.1)	10.33 (106.2)	-	44.2	16.6	42.6
LSD (P=0.05)			0.33	0.55	0.70	0.27	0.35	0.33	-	3.0	1.0	2.8

Figures in parentheses are original values. *Square root transformed ($\sqrt{X+0.5}$) values.

20, 40 and 38%, respectively, in unweeded check (control) plots at harvest.

The lowest density and dry weight of grasses and broad-leaved weeds were recorded with pre-emergence application of pendimethalin 1000 g/ha *fb* propaquizafop 60 g/ha applied at 20 DAS and it was closely followed by pre-emergence application of pendimethalin 1000 g/ha *fb* quizalofop 50 g/ha applied at 20 DAS (Table 1). This might be due to reduced germination and emergence of weeds due to pre-emergence application of pendimethalin as it controls the weeds by inhibiting cell division and cell elongation of the emerging shoots of weeds more effectively than oxadiargyl. Further, application of post-emergence herbicide, propaquizafop or quizalofop was found to be more effective in controlling the late coming grassy weeds due to inhibition of Acetyl Co-enzyme A Corboxylase, a key enzyme responsible for synthesis of fatty acids in plants. These results are in agreement with those of Kironmay *et al*. (2006) and Pannacci *et al*. (2007). The reduction in density and dry weight of grasses was 88.10 and 93.27%, respectively, with pre-emergence application of pendimethalin 1 kg/ha *fb* propaquizafop 60 g/ha applied at 20 DAS compared to unweeded check (Table 1). Pre-emergence application of oxadiargyl 250 g/ha alone or in combination with any of the post-emergence herbicides applied at 20 DAS was not effective as that of pendimethalin alone or in combination with post-emergence herbicides applied at 20 DAS in suppressing the growth and development of grassy weeds (Ahmad *et al*., 2000). However oxadiargyl @ 250 g/ha was not effective in controlling the dominant broad-leaved weed *T. indicum* as that of pendimethalin.

Among the sequential applications of herbicides applied, pre-emergence application of oxadiargyl 250 g/ha *fb* quizalofop 50 g/ha or propaquizafop 60 g/ha applied at 20 DAS recorded significantly lesser density and dry weight of sedges. The reduction in dry weight of sedges at harvest was 28.35% with pre-emergence application of oxadiargyl 250 g/ha *fb* quizalofop 50 g/ha applied at 20 DAS compared to unweeded check. The oxadiargyl 250 g/ha was reported effective in controlling the annual sedges (Dickmann *et al*., 1997). The highest WCE was noticed with hand weeding twice at 20 and 40 DAS followed by pre-emergence application of pendimethalin 1000 g/ha *fb* propaquizafop 60 g/ha. Pre-emergence application of oxadiargyl 250 g/ha alone or in combination with post-emergence herbicides registered the lowest WCE due to increased density and dry weight of weeds in general and *T. indicum* in particular.

The lowest uptake of nitrogen, phosphorus and potassium by weeds was recorded with two hand weedings at 20 and 40 DAS followed by pre-emergence application of pendimethalin 1000 g/ha *fb* propaquizafop 60 g/ha applied at 20 DAS. This can be attributed to lesser dry matter production of weeds due to effective control of all the categories of weeds due to these weed management practices. These findings are in accordance with those of Sumathi *et al*. (2009). The uptake of nitrogen, phosphorus and potassium by weeds was 44.2, 16.6 and 42.6 kg/ha, respectively, in unweeded check due to heavy weed infestation (Table 1). These results are in conformity with the findings of Wanjari *et al.* (2000).

All the weed management practices significantly improved the growth, yield components and yield of sunflower over unweeded check. Growth parameters *viz.,* plant height and dry matter production and yield components *viz.,* number of seeds/head, filled seeds/head and 100-seed weight were significantly higher with pre-emergence application of pendimethalin 1000 g/ha *fb* propaquizafop 60 g/ha applied at 20 DAS and these growth and yield parameters were at par with hand weeding twice at 20 and 40 DAS (Table 2). This might be due to weed free environment, especially at critical period of crop-weed competition growth, which might have resulted in increased production and translocation of photosynthates sufficient to supply the sink needs (El-Hamid, 2004). Pre-emergence application of oxadiargyl alone and sequential application of oxadiargyl *fb* any of the post-emergence herbicides were not effective in promoting growth and yield components due to poor weed control efficiency of these treatments.

The highest seed yield of sunflower was obtained with pre-emergence application of pendimethalin *fb* propaquizafop 60 g/ha applied 20 DAS, which was significantly higher than with rest of the weed management practices due to increased stature of yield components as result of lesser competition offered by weeds. These results are in conformity with those of Bedmar (1997) and Poienaru *et al*. (2005). The reduction in seed yield of sunflower due to unchecked weed growth was 50.03 and 42.02%, respectively, compared to pre-emergence application of pendimethalin 1 kg/ha *fb* propaquizafop 60 g/ha applied at 20 DAS and hand weeding twice at 20 and 40 DAS (Table 2). Among the sequential application of herbicides, the lowest seed yield was recorded with oxadiargyl *fb* quizalofop or

Table 2. Effect of pre- and post-emergence herbicides on growth and yield components, seed yield and economics of **rabi** sunflower

Treatments	Dose (g/ha)	Time of application (DAS)	Plant height (cm)	Dry matter production (kg/ha)	Nutrient uptake by crop (kg/ha)			Total number of seeds/head	Filled seeds/ head	100-seed weight (g)	Seed yield (kg/ha)	Net returns (Rs./ha)	Benefit : cost ratio
					N	P	K						
Pendimethalin	1000	2	137	4110	44	10	61	540	478	5.22	1545	39,804	3.10
Oxadiargyl	250	2	130	3291	34	8	51	463	378	4.60	1296	28,642	2.38
Pendimethalin *fb* fenoxaprop	1000 & 60	2 & 20	139	4238	48	17	70	622	554	5.34	1663	43,108	3.14
Oxadiargyl *fb* fenoxaprop	250 & 60	2 & 20	132	3546	36	10	52	480	416	4.88	1372	30,350	2.39
Pendimethalin *fb* propaquizafop	1000 & 60	2 & 20	148	4994	67	28	83	650	591	5.87	2105	59,812	3.96
Oxadiargyl *fb* propaquizafop	250 & 60	2 & 20	133	3855	38	13	65	512	427	5.17	1452	33,298	2.52
Pendimethalin *fb* quizalofop	1000 & 50	2 & 20	140	4434	57	22	77	637	574	5.64	1800	47,814	3.32
Oxadiargyl *fb* quizalofop	250 & 50	2 & 20	133	3523	37	11	55	497	413	5.08	1367	29,660	2.33
Two hand weedings	-	20 & 40	142	4779	60	24	77	640	578	5.83	1815	46,310	3.04
Unweeded check	-	-	126	3072	25	7	47	427	340	4.39	1052	22,716	2.31
LSD (P=0.05)			8	229	3	3	5	41	37	0.37	163	4386	0.62

fenoxaprop applied at 20 DAS and these weed management practices produced comparable yields as that of pre-emergence application of oxadiagyl alone. This might be due to severe competition offered by weeds for growth resources, which in turn, reduced the yield components and yield of sunflower.

Pre-emergence application of pendimethalin 1000 g/ha *fb* propaquizafop 60 g/ha resulted in the highest uptake of nutrients *viz.,* nitrogen, phosphorus and potassium and it was closely followed by two hand weedings at 20 and 40 DAS, owing to higher dry matter production of crop and corresponding nutrient contents of the tissues in these treatments due to elimination of competition offered by weeds for nutrient uptake (Table 2). Crop and weeds growing together in a community, nutrient uptake by crop and weeds follow an inverse relationship and it was an evident in the present investigation also. These results are in conformity with those of Sumathi *et al*. (2009).

The maximum net returns and benefit : cost ratio were realized with pre-emergence application of pendimethalin 1 kg/ha *fb* propaquizafop 60 g/ha or quizalofop 60 g/ha applied at 20 DAS. This might be due to lesser cost of pre- and post-emergence herbicides and increased seed yield in these weed management practices than the hand weeding twice at 20 and 40 DAS. Among the sequential application of herbicides, the lowest net returns and benefit : cost ratio were obtained with pre-emergence application of oxadiargyl *fb* quizalofop or fenoxaprop applied at 20 DAS, which were, however, comparable with pre-emergence application of oxadiargyl @ 250 g/ha alone. It clearly indicated that there was no monitory advantage due to sequential application of oxadiargyl *fb* any of the post emergence herbicide tried as these weed management practices recorded lowest weed control efficiency and reduced seed yield.

It can be cocluded that the highest seed yield and maximum economic returns in **rabi** sunflower were obtained with pre-emergence application of pendimethalin 1 kg/ha *fb* propaquizafop 60 g/ha applied at 20 DAS, besides obtaining broad spectrum weed control throughout the crop growth period.

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