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EFFECT OF WEED MANAGEMENT PRACTICES ON WEED GROWTH AND YIELD OF SUNFLOWER (*HELIANTHUS ANNUUS* L.)

ROHINI N. METI[1]*, K. N. GEETHA[1], A. G. SHANKAR[2], K. N. KALYANAMURTHY[1] AND PRATHIMA, A. S[1]
[1]Department of Agronomy, UAS, GKVK, Bangalore - 560 065, Karnataka, INDIA
[2]Department of Crop Physiology, UAS, GKVK, Bangalore - 560 065, Karnataka, INDIA
e-mail: rohinimeti5080@gmail.com

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***Corresponding author**

ABSTRACT
A field experiment was conducted during *Kharif*2014 at AICRP on sunflower, ZARS, UAS, GKVK, Bengaluru to evaluate the "Integration of pre and post-emergence herbicides and cultural practices for weed management in sunflower (*Helianthus annuus*L.)"in red sandy loam soil. The experiment was laid out inRCBD with thirteen treatments replicated thrice. Thetreatments were pre and post-emergence herbicides(pendimethalin and quizalofop-ethyl, propaquizafop, fenoxoprop-ethyl, chlorimuron-ethyl, respectively) andtheir combinations (pendimethalin + quizalofop-ethyl,pendimethalin + propaquizafop, pendimethalin + fenoxoprop-ethyl andquizalofop-ethyl + chlorimuron-ethyl) compared with farmer's practice and weed free as well as unweeded control.The study revealed that significantly higher seed yield and lower weed index were observed in pendimethalin 38.7 CS at 1.0 kg a.i.ha^{-1} as PE + quizalofop-ethyl 10 EC at 37.5 g a.i.ha^{-1} at 17 DAS as directed POE on weeds (1795 kg ha^{-1} and 4.89) and farmers practice (1888 kg ha^{-1} and 0) when compared to weed free (1824 kg ha^{-1} and 3.43).

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 contain about 36-42 % oil in the seed. Sunflower oil is generally considered as premium oil because of its light color, higher levels of unsaturated fatty acids which is good for cardiac patients. Oilcake is rich in high quality protein (40-44 %) and used as cattle and poultry feed. Being a short duration crop and sunflower can be fit into different types of cropping systems.

Productivity in India is very low (791 kg ha^{-1}) as compared to the world average (1495 kg ha^{-1}) indicating wider scope for improving the yield potential. Among the causes for low productivity of sunflower crop-weed competition is one of the important factors. Weeds are considered as serious problem because they compete for water, nutrients, light and space, reducing crop growth and yield (Lehoczky and Reisinger, 2003). The reduction in sunflower yield due to weed competition ranges from 18.6 to 36.3% (Saudy and Ei-Metwally, 2009). Weed management is an important component of successful sunflower production. Sunflower is usually planted at low densities and grows slowly during the first several weeks. Therefore, maintaining a weed-free condition for 20 to 49 DAS will minimize weed competition and maximize yields (Wanjari *et al*., 2001).

The conventional method of weed control is labour intensive, inefficient and costly. Sometimes wet conditions due to frequent raining during *kharif* do not permit weeding when the crop requires weed free conditions. Moreover, these methods are employed only after the crop has attained a certain stage of growth, by which time, the weeds would have also attained sufficient growth, depleting the available and applied nutrients and moisture (Basavarajappa, 1992).

Application of pre-emergent herbicides provides a weed free environment especially during the early stages of crop growth but later stage of the crop will suffer from the weeds. Use of both pre and post-emergence herbicides may be viable option to control the weeds right from the sowing to harvesting of 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 (Siva Sankar and Subramanyam, 2011). 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 in combination with post-emergence herbicides *viz*., fenoxaprop, propaquizafop, chlrimuron ethyl and quizalofop for their influence on weedgrowth and productivity of sunflower.

MATERIALS AND METHODS

An experiment was conducted during the *kharif* season of

2014, at AICRP on sunflower, ZARS, UAS, GKVK, Bengaluru. The soil was red sandy loam in texture and slightly acidic in reaction (6.70) with available nitrogen 250 kg ha^{-1}, available phosphorus 58 kg ha^{-1} and available potassium 218 kg ha^{-1} and organic carbon content of 0.43%. KBSH-53 sunflower hybrid was directly sown on 11th August with a spacing of 60 cm X 30 cm. The experiment included nine treatments T_1: Pendimethalin 38.7 CS at 0.75 kg a.i.ha^{-1} as PE, T_2: Pendimethalin 38.7 CS at 0.75 kg a.i. ha^{-1} as PE + one IC at 30 DAS + HW at 40 DAS, T_3: Pendimethalin 38.7 CS at 1.0 kg a.i.ha^{-1} as PE + quizalofop-ethyl 10 EC at 37.5 g a. i. ha^{-1} at 17 DAS as directed POE on weeds, T_4: Pendimethalin 38.7 CS at 1.0 kg a.i. ha^{-1} as PE + propaquizafop 62 EC at 62 g a.i. ha^{-1} at 17 DAS as directed POE on weeds, T_5:Pendimethalin 38.7 CS at 1.0 kg a.i. ha^{-1} as PE + fenoxoprop-ethyl 9 EC at 37.5 g a.i. ha^{-1} at 17 DAS as directed POE on weeds, T_6: Quizalofop-ethyl 10 EC at 37.5 g a.i. ha^{-1} + chlorimuron-ethyl 25 WP at 9 g a.i. ha^{-1} at 17 DAS as directed POE on weeds, T_7: Farmers practice (Two IC at 20 and 40 DAS + one HW at 30 DAS), T_8: Weed free (Three HW at 15, 30 and 45 DAS), T_9: Unweeded control. Farm yard manure at 7.5 t ha^{-1} was applied two weeks before planting. The fertilizer nitrogen, phosphorus and potassium were applied as per recommended dose 90:90:60 N, P_2O_5 and K_2O kg ha^{-1} through urea, SSP and MOP. 50 % of fertilizer nitrogen and entire dose of P and K were applied at the time of planting. Remaining 50 % nitrogen was top-dressed at the time of earthing up and $ZnSO_4$ (36 % Zn) and borax (11 % B) as sources of micronutrients were applied to the soil before sowing. Pre-emergence herbicides were applied by using a knapsack sprayer fitted with an Aspee WFN 78 nozzle with a spray volume of 750 liters ha^{-1}. Post-emergence herbicides were applied by using knapsack sprayer fitted with Aspee WFN 40 nozzle by using 375 liters of spray volumeha^{-1}. The post-emergence herbicides were sprayedwhen they were in the active stage without being wilted to ensure good action by the herbicides.

The data on weed density and weed dry weight were subjected to log (x + 2) transformation. Then the experimental data on weed growth and yield were subjected to analysis by using Fisher's method of Analysis of Variance (ANOVA) (Gomez and Gomez 1984). The levels of significance used in *F* and *t* test was at $p = 0.05$. The formulae for calculating weed control efficiency and weed index are detailed below.

Weed control efficiency

$$WCE\,(\%) = \frac{DMC - DMT}{DMC} X\,100$$

Where,

WCE = Weed control efficiency expressed in percentage

DMC = Total weed dry weight in unweeded control plot

DMT = Total weed dry weight in the treated plot

Weed index

$$WI\,(\%) = \frac{X - Y}{X} X\,100$$

Where,

WI = Weed index expressed in percentage

X = Yield from weed free plot or best treatment plot

Y = Yield from treatment for which weed index has to be worked out.

RESULTS AND DISCUSSION

Weed flora

During the crop growth period, weed flora of the experimental field predominantly consisted of thirteen weed species that included nine species of broad leaved weeds, *viz., Argemone mexicana*, *Commelina benghalensis*, *Parthenium hysterophorus*, *Borreri ahispida*, *Alternanthera sessilis*, *Datura stramonium*, *Sida acuta*, *Amaranthus viridis* and *Portulacaoleracea,* three spicies of grassy weeds *viz.*, *Cynodon dactylon, Digitaria marginata* and *Eleusine indica, Cyperus rotundus* was the only sedge weed found. With regard to the relative densities, broad leaved weeds accounted for 69 % and grasses accounted for 23 %

Weed density

At 60 DAS and at harvest significantly lower sedge, grass,

Table 1: Ctegory wise weed density at 60 DAS and at harvest in sunflower as influenced by different weed management practices

Weed management practices	60 DAS (number m^{-2})				At harvest (number m^{-2})			
	Sedges#	Grasses#	BLW#	Total#	Sedges#	Grasses#	BLW#	Total#
T_1	1.40(23.00)	1.30(19.89)	1.76(57.12)	2.00(100.0)	1.41(24.67)	1.27(18.00)	1.62(42.27)	1.94(84.94)
T_2	1.30(18.11)	1.01(8.32)	1.42(25.27)	1.72(51.7)	1.20(16.00)	1.08(10.00)	1.42(25.13)	1.72(51.13)
T_3	1.01(8.44)	0.80(4.76)	1.04(9.03)	1.37(22.2)	0.85(5.33)	0.49(1.11)	0.83(4.69)	1.11(11.13)
T_4	1.32(18.99)	1.05(9.65)	1.49(30.63)	1.78(59.3)	1.29(19.00)	1.13(12.23)	1.39(24.89)	1.75(56.13)
T_5	1.31(19.78)	1.17(12.88)	1.50(29.56)	1.80(62.2)	1.35(21.99)	1.21(14.33)	1.44(27.72)	1.81(64.04)
T_6	1.59(38.00)	1.53(33.53)	1.63(51.42)	2.09(122.9)	1.52(31.67)	1.55(35.33)	1.62(40.77)	2.03(107.7)
T_7	0.94(6.77)	0.55(1.64)	0.91(7.24)	1.23(15.6)	0.82(4.77)	0.49(1.30)	0.72(3.50)	1.06(9.57)
T_8	1.00(8.44)	0.64(2.53)	1.02(8.63)	1.33(19.6)	0.70(3.00)	0.53(1.39)	0.71(3.17)	0.98(7.56)
T_9	1.60(40.77)	1.78(62.21)	2.40(251.4)	2.55(354.4)	1.64(42.33)	1.82(66.22)	2.10(126.2)	2.37(234.7)
S.Em ±	0.07	0.09	0.11	0.06	0.10	0.07	0.09	0.05
CD (p = 0.05)	0.20	0.26	0.32	0.18	0.29	0.20	0.28	0.14

T_1: Pendimethalin 38.7 CS at 0.75 kg a.i. ha^{-1} as PE, T_2: Pendimethalin 38.7 CS at 0.75 kg a.i. ha^{-1} as PE + one IC at 30 DAS + HW at 40 DAS, T_3: Pendimethalin 38.7 CS at 1.0 kg a.i. ha^{-1} as PE + quizalofop-ethyl 10 EC at 37.5 g a. i. ha^{-1} at 17DAS as directed POE on weeds, T_4: Pendimethalin 38.7 CS at 1.0 kg a.i. ha^{-1} as PE + propaquizafop 62 EC at 62 g a.i. ha^{-1} at 17 DAS as directed POE on weeds, T_5: Pendimethalin 38.7 CS at 1.0 kg a.i. ha^{-1} as PE + fenoxoprop-ethyl 9 EC at 37.5 g a.i.ha^{-1} at 17DAS as directed POE on weeds, T_6: Quizalofop-ethyl 10 EC at 37.5 g a.i. ha^{-1} + chlorimuron-ethyl 25 WP at 9 g a.i. ha^{-1} at 17 DAS as directed POE on weeds, T_7: Farmers practice (Two IC at 20 and 40 DAS + one HW at 30 DAS), T_8: Weed free (Three HW at 15, 30 and 45 DAS); T_9: Unweeded control.; CS: Aqueous capsule suspension, PE: Pre-emergence spray, POE: Post-emergence spray, DAS: Days after sowing, fb: followed by, HW: Hand weeding, IC: Inter cultivation, BLW: Broad leaf weeds, Dates within parentheses are original values, # - data analyzed using log (x + 2) transformation.

Table 2: Dry weight of sedges, grasses, broad leaved weeds and total dry weight of weeds at harvest (g m^{-2}) WCE, seed yield and weed indices of sunflower as influenced by different weed management practices

Treatments	Sedges	Grasses	BLW	Total	WCE (%)	Seed yield (kg ha^{-1})	Weed indices (%)
T_1	1.14 (11.93)	1.34 (20.67)	1.40 (23.85)	1.76 (56.45)	62	1396	25.92
T_2	0.74 (3.51)	0.82 (4.67)	0.75 (3.64)	1.14 (11.81)	92.12	1653	12.47
T_3	0.67 (2.67)	0.76 (4.00)	0.73 (3.33)	1.07 (10.00)	93.51	1795	4.89
T_4	0.77 (3.87)	1.01 (8.93)	1.29 (17.85)	1.51 (30.65)	85.87	1573	16.53
T_5	0.99 (8.04)	1.32 (19.33)	0.99 (8.37)	1.57 (35.75)	70.01	1475	21.75
T_6	1.16 (12.80)	1.42 (24.40)	1.40 (25.08)	1.80 (62.28)	59.67	1260	33.18
T_7	0.56 (1.73)	0.64 (2.40)	0.53 (1.37)	0.88 (5.51)	96.43	1888	0
T_8	0.61 (2.13)	0.72 (3.33)	0.59 (1.92)	0.97 (7.39)	95.24	1824	3.43
T_9	1.26 (16.67)	1.87 (72.53)	1.82 (64.55)	2.19 (153.7)	0	1021	46.01
S.Em ±	0.05	0.05	0.07	0.06	NA	76.64	NA
CD (p = 0.05)	0.16	0.17	0.21	0.20	NA	229.7	NA

T_1:Pendimethalin 38.7 CS at 0.75 kg a.i.ha^{-1} as PE, T_2:Pendimethalin 38.7 CS at 0.75 kg a.i.ha^{-1} as PE + one IC at 30 DAS + HW at 40 DAS, T_3:Pendimethalin 38.7 CS at 1.0 kg a.i.ha^{-1} as PE + quizalofop-ethyl 10 EC at 37.5 g a. i. ha^{-1} at 17DAS as directed POE on weeds, T_4:Pendimethalin 38.7 CS at 1.0 kg a.i.ha^{-1} as PE + propaquizafop 62 EC at 62 g a.i.ha^{-1} at 17 DAS as directed POE on weeds, T_5:Pendimethalin 38.7 CS at 1.0 kg a.i.ha^{-1} as PE + fenoxoprop-ethyl 9 EC at 37.5 g a.i.ha^{-1} at 17DAS as directed POE on weeds, T_6:Quizalofop-ethyl 10 EC at 37.5 g a.i.ha^{-1} + chlorimuron-ethyl 25 WP at 9 g a.i.ha^{-1} at 17 DAS as directed POE on weeds,; T_7: Farmers practice (Two IC at 20 and 40 DAS + one HW at 30 DAS), T_8: Weed free (Three HW at 15, 30 and 45 DAS), T_9:Unweeded control; CS: Aqueous capsule suspension, PE: Pre-emergence spray, POE: Post-emergence spray, DAS: Days after sowing, fb: followed by, HW: Hand weeding, IC: Inter cultivation, BLW: Broad leaf weeds, Dates within parentheses are original values, # - data analyzed using log (x + 2) transformation.

Table 3: Visual phytotoxicity symptoms score of herbicides on crop and scale of weed control ratings due to different weed management practices in sunflower

Treatments	Phytotoxicity rating on crop (0-10 scale)	Rating on weeds (0-10 scale)
T_1: Pendimethalin 38.7 CS at 0.75 kg a.i.ha^{-1} as PE	0 (No injury normal)	4 (Deficient control)
T_2: Pendimethalin 38.7 CS at 0.75 kg a.i.ha^{-1} as PE + one IC at 30 DAS + HW at 40 DAS	0	8 (Good control)
T_3: Pendimethalin 38.7 CS at 1.0 kg a.i.ha^{-1} as PE + quizalofop-ethyl 10 EC at 37.5 g a. i. ha^{-1} at 17DAS as directed POE on weeds	0	9 (Good to excellent)
T_4: Pendimethalin 38.7 CS at 1.0 kg a.i.ha^{-1} as PE + propaquizafop 62 EC at 62 g a.i.ha^{-1} at 15-20 DAS asdirected POE on weeds	0	7 (Satisfactory control)
T_5: Pendimethalin 38.7 CS at 1.0 kg a.i.ha^{-1} as PE + fenoxoprop-ethyl 9 EC at 37.5 g a.i.ha^{-1} at 17DAS as directed POE on weeds	0	4
T_6: Quizalofop-ethyl 10 EC at 37.5 g a.i.ha^{-1} + chlorimuron-ethyl 25 WP at 9 g a.i.ha^{-1} at 17 DAS asdirected POE on weeds	7 (Stunting injury, discolouration and stand loss)	4
T_7: Farmers practice (Two IC at 20 and 40 DAS + one HW at 30 DAS)	0	9
T_8: Weed free (Three HW at 15, 30 and 45 DAS)	0	10 (Complete control)
T_9: Unweeded control	0	0

CS: Aqueous capsule suspension, PE: Pre-emergence spray, POE: Post-emergence spray, DAS: Days after sowing, fb: followed by, HW: Hand weeding, IC: Inter cultivation

broad leaf weeds and total weeds density was observed in pendimethalin 38.7 CS at 1.0 kg a.i.ha^{-1} as PE + quizalofop-ethyl 10 EC at 37.5 g a. i. ha^{-1} at 17 DAS as directed POE on weeds (8.44, 4.76, 9.03 & 22.2 and 5.33, 1.11, 4.69 & 11.13 m^{-2}, respectively) and farmers practice (6.77, 1.64, 7.24 & 15.6 and 4.77, 1.30, 3.50 & 9.57 m^{-2}, respectively) which was on par with weed free treatment (8.44, 2.53, 8.63 & 19.6 and 3.00, 1.39, 3.17 &7.56 m^{-2}, respectively) due to better control of sedge, grass and broad leaf weeds by the combined action of both pre (Pendimethalin) and post emergence herbicides (Quizalofop-ethyl) because pendimethalin was effective against broad leaf weeds like *Argemone mexicana*, *Commelina benghalensis*, *Parthenium hysterophorus*, *Borreria hispida*, *Alternanthera sessilis*, *Datura stramonium*, *Sida acuta*, *Amaranthus viridis* and *Portula caoleracea*. Application of quizalofop-ethyl waseffective for controlling annual and perennial grassy weeds like *Cynodon dactylon, Digitaria marginata* and *Eleusine indica* Goud *et al.*(2013)(Table 1). Whereas, significantly higher sedge, grass, broad leaf weeds and total weed density was observed in unweeded control due to uncontrolled weed growth due to no management practices.

Weed dry weight at harvest

Significantly lower dry weight of sedge, grass, broad leaf weeds and total weed dry weight was observed in pendimethalin 38.7 CS at 1.0 kg a.i.ha^{-1} as PE + quizalofop-ethyl 10 EC at 37.5 g a. i. ha^{-1} at 17DAS as directed POE on weeds (2.67, 4.00, 3.33 and 10.00 g m^{-2}, respectively) (Table 2) and farmers practice (1.73, 2.40, 1.37 and 5.51 g m^{-2}, respectively) due to lower density of sedge, grass, broad leaf weeds and total weeds which was found on par with weed free (2.13, 3.33, 1.92 and 7.39 g m^{-2}, respectively), similar trend has also observed in case of weed control efficiency. The higher weed control efficiency at harvest may be due to significant reduction in the weed dry weight as a result of broad spectrum weed control of pendimethalin on broad leaved weeds as well as specificaction of quizalopof-ethyl on annual and perennial grassy weeds leaded toreduction of competition from weeds during critical period of crop weed competition Siva Sankar and Subramanyam (2011).

Seed yield

Among different treatments, farmers practice (two IC at 20 and 40 DAS + one HW at 30 DAS) recorded significantly higher seed yield (1888 kg ha^{-1}). Mechanical weeding improved the soil aeration and increased nutrient availability to the crop through active mineralization and decomposition. It was also accordance with Aradhana Bali *et al*. (2016).

Among herbicides treatments, significantly higher seed yield was recorded with pendimethalin 38.7 CS at 1.0 kg a.i ha^{-1} as PE + quizalofop-ethyl 10 EC at 37.5 g a.i. ha^{-1} at 17 DAS as directed POE on weeds (1795 kg ha^{-1}) which was on par with weed free check (three HW at 15, 30 and 45 DAS) (1824 kg ha^{-1}), whereas, significantly lower seed yield was observed in unweeded control (1021 kg ha^{-1}) (Table 2) compared to all other treatments, owing to more competition by weeds resulting in less photosynthates. Comparable reports were observed by HafeezUllah *et al*. (2001) and Young *et al*. (2003).

Weed index

The lowest weed index (0.00 %) was noticed in farmers practice (Two IC at 20 and 40 DAS + one HW at 30 DAS) which was followed by weed free check (Three HW at 15, 30 and 45 DAS) (3.43 %). Among the herbicide treatments pendimethalin 38.7 CS at 1.0 kg a.i. ha^{-1} as PE + quizalofop-ethyl 10 EC at 37.5 g a.i. ha^{-1} at 17 DAS as directed POE on weeds (4.89 %) (Table 2) recorded lowest weed index. 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. Similar results were obtained by Saudy and Ei-Metwally (2009) and Rajanand Hiremath *et al*. (2013).

Visual phytotoxic symptoms in crop and scale of weed control ratings

Application of pre and post-emergence spray of herbicides was assessed on phytotoxicity of sunflower and it was found that post-emergence spray of chlorimuron-ethyl 25 WP at 9 g a.i.ha^{-1} at 17 DAS as directed POE on weeds resulted in phytotoxicity causing stunting injury and discolouration resulting in stand loss.

Phytotoxicity rating of different herbicides on the crop was '0' in case of all the herbicide treatments except quizalofop-ethyl 10 EC at 37.5 g a.i.ha^{-1} + chlorimuron-ethyl 25 WP at 9 g a.i.ha^{-1} at 17 DAS as directed POE on weeds (Table 3).

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