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GROWTH, YIELD AND ECONOMICS OF SUNFLOWER AS INFLUENCED BY DIFFERENT WEED MANAGEMENT PRACTICES

*Rohini N. Meti[1], K. N. Geetha[1], A.G. Shankar[2], A.S. Prathima[1], & Jagadish[1]
[1]Department of Agronomy, UAS, GKVK, Bangalore – 560065, Karnataka, India.
[3]Department of Crop Physiology, UAS, GKVK, Bangalore – 560065, Karnataka, India.
* Corresponding Author email: rohinimeti5080@gmail.com

ABSTRACT
A field experiment was conducted during *Kharif* 2014 in red sandy loam soil to evolve "Integration of pre and post-emergence herbicides and cultural practices for weed management in sunflower (*Helianthus annuus* L.)". The experiment was laid out in RCBD with 9 treatments replicated thrice. The treatments were pre and post emergence herbicides, their combinations and farmer's practice (two IC at 20 and 40 DAS + one HW at 30 DAS) compared with weed free (Three hand weedings at 15, 30 and 45 DAS) as well as unweeded check. The study revealed that significantly higher seed yield (1795 kg ha^{-1}) and oil yield (675.4 kg ha^{-1}) 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 and farmers practice (1888 and 726.4 kg ha^{-1}, respectively) when compared to weed free (1824 and 697.4 kg ha^{-1}, respectively). Though the highest net returns and marginal return were recorded in farmers practice (35,099 and 26,003 ha^{-1}, respectively), higher B: C ratio and marginal return to marginal cost were recorded in the 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 (2.73 and 10.75, respectively) which was found most economically feasible weed management practice for sunflower.

KEY WORDS: Seed yield, Oil yield, Economics and Sunflower.

INTRODUCTION
Sunflower (*Helianthus annuus* L.) is one of the most important oilseed crop of India. Since it has been introduced into India during 1969. Sunflower is known for its wider adaptability to different agro climatic zones and soil types, easy crop management, photo insensitivity, short duration, high seed multiplication ratio (1:50). Among the several factors responsible for the lower yields of sunflower, most dominant factor is weeds which compete with crop for nutrients, water, sunlight and space. Wider spacing in sunflower favours the growth of weeds even before crop emergence hence gets infested with variety of weeds and subjected to heavy weed competition, which often inflicts huge losses ranging from 18.6 to 36.3% in sunflower (Saudy and Ei-Metwally, 2009). Presence of weeds reduces the photosynthetic efficiency, dry matter production and distribution to economic parts and there by reduces sink capacity of crop resulting in poor seed yield. The conventional method of weed control is laborious, inefficient and costly. Hence, neither herbicide nor cultivations are adequate for consistent and acceptable weed control. Therefore integrated weed management is the best for higher productivity and profitability, using pre and post emergence herbicides in combination with hand weeding or inter-cultivation with implements.

MATERIALS & METHODS
An experiment was conducted during *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. Experiment included nine treatments consisting of 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 source of micronutrients and applied to soil before sowing. Pre-emergence herbicides were applied by using knapsack sprayer fitted with 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 volume ha^{-1}. The post-emergence herbicides were sprayed when they were in active stage without being wilted to ensure good action by the herbicides.

Then the experimental data 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 oil yield and B: C ratio are detailed below.

Oil yield

$$\text{Oil yield (kg ha}^{-1}\text{)} = \frac{\text{Oil per cent in seed} \times \text{seed yield (kg ha}^{-1}\text{)}}{100}$$

Benefit cost ratio (B: C)

$$\text{Benefit cost ratio} = \frac{\text{Gross returns (` ha}^{-1}\text{)}}{\text{Cost of cultivation (` ha}^{-1}\text{)}}$$

RESULTS & DISCUSSION

Growth and yield parameters

The obtained data revealed that 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 (675.4 kg ha^{-1}) and farmers practice (Two IC at 20 and 40 DAS + one HW at 30 DAS) (726.4 kg ha^{-1}) recorded significantly higher plant height (176.7 and 182.9 cm, respectively) and increased stem girth (2.81 and 2.84 cm, respectively) which were on par with weed free check (Three HW at 15, 30 and 45 DAS) (180.5 and 2.83 cm, respectively) than the unweeded control plot (157.4 and 2.03 cm, respectively). As a result of effective control and suppression of weeds as compared to other treatments and unweeded control (Table 2). The difference in plant height in the present study was attributed to weed competition in sunflower plant as reported by Smita Prachand *et al*. (2014).

Among different treatments, farmers practice (Two IC at 20 and 40 DAS +one HW at 30DAS) recorded significantly higher seed yield (1888 kg ha^{-1}). 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}).

The higher seed yield obtained 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 (Table 1) was mainly attributed to improved yield components such as capitulum diameter (17.40 cm), test weight (4.42 g /100 seeds) which were on par with weed free (Three HW at 15, 30 and 45 DAS) (18.00 cm and 4.56 g/100 seeds, respectively). The reason for increased yield components might be due to efficient and broad spectrum weed management achieved by the above treatments resulted in increased availability of plant nutrients and moisture to crop throughout the cropping period. The favourable 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 capitulum diameter and test weight were increased. This is evident from the significant positive relation of growth and yield attributes of sunflower with seed yield. 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 seed weight is due to availability of more amounts of photosynthates and better partitioning of dry weight. Whereas, significantly lower seed yield was recorded with unweeded control (1021 kg ha^{-1}) owing to more competition by weeds resulted to less amount of photosynthates. Comparable reports were observed by Hafeez Ullah *et al*. (2001) and Young *et al*. (2003).

Among different weed management practices higher oil yield was observed in the 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 (675.4 kg ha^{-1}) as well as with farmers practice (Two IC at 20 and 40 DAS + one HW at 30 DAS) (726.4 kg ha^{-1}) which were on par with weed free check (Three HW at 15, 30 and 45 DAS) (697.4 kg ha^{-1}). The increase in oil yield was due to higher seed yield.

ECONOMICS

The successful adoption of any technology depends on the economic superiority of that technology over the existing ones in terms of higher net returns and B: C ratio realized. Among different weed management practices, highest net returns was obtained with farmers practice (Two IC at 20 and 40 DAS + one HW at 30 DAS) (35099 ha^{-1}), 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 (34157 ha^{-1}) and weed free check (Three HW at 15, 30 and 45 DAS) (32178 ha^{-1}). This might be due to higher gross returns realized in respective treatments which are mainly governed by higher seed yield and better market price (Table 3).

TABLE 1: Seed yield (Kg ha^{-1}), oil content (%) and oil yield (kg ha^{-1}) in sunflower as influenced by different weed management practices

Treatments	Oil content	Oil yield	Seed yield
T_1: Pendimethalin 38.7 CS at 0.75 kg a.i. ha^{-1} as PE	37.40	522.4	1396
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	37.62	621.7	1653
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	37.62	675.4	1795
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	37.51	590.6	1573
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	37.39	551.4	1475
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	37.38	471.0	1260
T_7: Farmers practice (Two IC at 20 and 40 DAS + one HW at 30 DAS)	38.49	726.4	1888
T_8: Weed free (Three HW at 15, 30 and 45 DAS)	38.27	697.4	1824
T_9: Unweeded control	37.28	380.0	1021
S.Em±	0.05	29.15	76.64
CD (p=0.05)	NS	87.40	229.7

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

TABLE 2: Plant height at harvest (cm), stem girth at harvest (cm), capitulum diameter (cm) and test weight (100 seeds) in sunflower as influenced by different weed management practices.

Treatments	Plant height at harvest	Stem girth at harvest	Capitulum diameter	Test weight
T_1: Pendimethalin 38.7 CS at 0.75 kg a.i. ha^{-1} as PE	164.4	2.37	16.60	3.69
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	169.2	2.40	17.13	4.07
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	176.7	2.81	17.40	4.42
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	167.1	2.38	16.83	4.00
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	166.0	2.37	16.73	3.73
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	164.2	2.15	16.55	3.22
T_7: Farmers practice (Two IC at 20 and 40 DAS + one HW at 30 DAS)	182.9	2.84	18.60	4.78
T_8: Weed free (Three HW at 15, 30 and 45 DAS)	180.5	2.83	18.00	4.56
T_9: Unweeded control	157.4	2.03	16.20	3.21
S.Em±	4.29	0.13	0.47	0.13
CD (p=0.05)	12.86	0.38	1.41	0.4

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

TABLE 3: Economics (ha^{-1}) of sunflower as influenced by different weed management practices

Treatments	Gross returns	Net returns	B:C ratio	Marginal return	Marginal cost	MR/MC
T_1: Pendimethalin 38.7 CS at 0.75 kg a.i. ha^{-1} as PE	41,880	23,139	2.23	11,258	1,200	9.38
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	49,580	28,839	2.39	18,943	7,200	2.63
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	53,860	34,157	2.73	23,233	2,162	10.75
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	47,190	27,059	2.34	16,550	2,590	6.39
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	44,250	24,529	2.24	13,625	2,280	5.98
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	3,7785.7	18,658	1.98	7,170	1,587	4.52
T_7: Farmers practice (Two IC at 20 and 40 DAS + one HW at 30 DAS)	56,640	35,099	2.63	26,003	6,000	4.33
T_8: Weed free (Three HW at 15, 30 and 45 DAS)	54,720	32,178	2.43	24,094	8,000	3.01
T_9: Unweeded control	30,620	13,079	1.75	-	-	-

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

Due to broad spectrum and efficient weed control in these treatments resulted in higher gross returns. While, unweeded control (13079 ha^{-1}) recorded lowest net returns due to lower economic yields. The results obtained are in accordance with Basanagouda *et al*. (2007) and Siva Sankar and Subramanyam (2011).

The B:C ratio was higher 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 (2.73), farmers practice (Two IC at 20 and 40 DAS + one HW at 30 DAS) (2.63) and weed free (Three HW at 15, 30 and 45 DAS) (2.43). This was mainly due to higher economic yield, net returns and lower cost of cultivation and also due to lesser cost of pre and post-emergence herbicides and increased seed yield in these weed management practices. Whereas, lowest B:C ratio was recorded in unweeded control (1.75) as compared to all other treatments (Table 2) The results obtained are in accordance with Madhu *et al*. (2006) and Siva Sankar and Subramanyam (2011).

The ratio of marginal return to marginal cost was higher 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 (10.75), pendimethalin 38.7 CS at 0.75 kg a.i ha^{-1} as PE (9.38) and 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 (6.39) (Table 3).

CONCLUSION

Pendimethalin 38.7CS at 1.0kg a.i ha^{-1} as PE + quizalofop-ethyl 10EC at 37.5g a.i. ha^{-1}at 17 DAS as directed POE on weeds proved practically best feasible weed management practice for sunflower. Considering the present condition of scarcity and high cost of labours, quality of weed control, yield, B:C ratio and marginal return to marginal cost ratio of cultivation of sunflower.

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