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Effect of weed control methods on growth, flowering and flower yield in African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda

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Abstract
An experiment was conducted to find out the effect of different weed control methods on growth, flowering and flower yield in African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda at the Department of Floriculture and Landscape Architecture, College of Agriculture, Indira Gandhi Agricultural University, Raipur, Chhattisgarh during the *kharif* season 2016-17. The experiment consisted of twelve treatments combination of different weed control methods. The results indicated that application of pendimethalin @ 1.0 kg/ha followed by one hand weeding at 30 DAT resulted in the maximum plant height (45.33 cm, 80.63 cm and 101.53 cm at 25,50 and 75 DAT, respectively), number of primary and secondary branches plant^{-1} (3.27, 6.87 and 10.67 primary branches and 8.60, 20.13 and 36.50 secondary branches at 25, 50 and 75 DAT, respectively), maximum plant spread (68.17 cm), earliest 50 per cent flowering (47.00 days), significantly biggest flower (6.97 cm), maximum weight of flowers plant^{-1} (126.73 g.), flowers yield ha^{-1} (136.85 q). Similar treatment *i.e.* Pendimethalin 30% EC @ 1.0 kg ha^{-1} (PE) followed by one Hand Weeding at 30 DAT resulted the highest B:C ratio (3.98) followed by Pendimethalin 30% EC @ 1.0 kg ha^{-1} (PE) + Fenoxaprop - p-ethyl 9.3% EC @ 0.10 kg ha^{-1} at 30 DAT (PoE) with B: C Ratio (1:3.60) as compared to other treatments. The minimum values for these parameters were recorded in unweeded treatment.

Keywords: *Pendimethalin, Oxyfluorfen, Quizalofop ethyl, Fenoxaprop-p-ethyl, unweeded*

Introduction
Marigold (*Tagetes erecta* L.) is one of the most important annual flower crops cultivated commercially in India and Chhattisgarh state for making garlands, religious offering and cut flower purposes. Reduction in crop yield has direct correlation with weed competition. Weed infestation hampers the growth of marigold in early stages and ultimately affect the yield of crop. Weeds have been a great nuisance in production of flower yield of marigold which compete heavily with crop plants for light, space, nutrient and moisture and thus caused heavy reduction in their yield. Reduction in crop yield has direct correlation with weed competition. Severity of growth reduction and survival of crops mainly depend on weed density and weed species. The removal of weeds either by mechanical means or herbicides during the critical period of crop-weed competition will certainly help in increasing the crop growth and flower yield in marigold. Keeping the above fact in view, the present investigation was carried-out to find out the appropriate method of weed management and ascertain a good flower yield in marigold crop.

Material and Methods
The study was carried out at Research Farm, Borsi, Dau Kalyan Singh Agriculture College and Research Station, Bhatapara, Indira Gandhi Krishi Vishwavidyalaya, Raipur during *kharif* season 2016-17. There were twelve treatments *viz.* T_1 (Pendimethalin 30% EC @ 1.0 kg ha^{-1} (PE) + Hand Weeding at 30 DAT), T_2 (Oxyfluorfen 23.5% EC @ 0.20 kg ha^{-1} (PE) + Hand Weeding at 30 DAT), T_3 (Quizalofop ethyl 5% EC @ 0.05 kg ha^{-1} at 25 DAT PoE), T_4 (Pendimethalin 30% EC @ 1.0 kg ha^{-1} (PE) + Quizalofop ethyl 5% EC @ 0.05 kg ha^{-1} at 30 DAT PoE), T_5 (Oxyfluorfen 23.5% EC @ 0.20 kg ha^{-1} (PE) + Quizalofop ethyl 5% EC @ 0.05 kg ha^{-1} (PoE) at 30 DAT), T_6 (Fenoxaprop- p-ethyl 9.3% EC @ 0.10 kg ha^{-1} at 25 DAT PoE),

T_7 (Pendimethalin 30% EC @ 1.0 kg ha^{-1} (PE) + Fenoxaprop - p-ethyl 9.3% EC @ 0.10 kg ha^{-1} at 30 DAT PoE), T_8 (Oxyfluorfen 23.5% EC @ 0.20 kg ha^{-1} (PE) + Fenoxaprop-p-ethyl 9.3% EC @ 0.10 kg ha^{-1} at 30 DAT PoE), T_9 (One Hand Weeding at 25 DAT), T_{10} (Two Hand Weeding at 25 and 50 DAT), T_{11} (Two Hand Weeding at 25, 50 and 75 DAT) and T_{12} Unweeded (Control).The experiment was laid out in Randomized Block Design (RBD) with three replications having plot size of 2.25 m x 2.40 m. All recommended cultural practices were followed when and where required. The transplanting of the seedlings was done after three days of herbicidal application at the spacing of 45x30 cm.

Result and Discussion

The predominant weed species which were highly active during the growth period of marigold were *Echinochloa colonum* followed by *Parthenium hysterophorus, Condon dactylon, Cyperus rotundus,* Phyllanthus niruri, *Amaranthus viridis, Portulaca quadrifolia, Phylsalis minima, Comelina bengalensis, Alternanthras eselis.* The minimum weed count was noted for *Casia tora*.

The vegetative growth of plant is an important parameter to assess the vigour of the plant. In the present study, marigold crop responded positively to weed control treatments. Plant height, number of primary and secondary branches during throughout period of crop growth and plant spread at 90 DAT varied significantly due to different weed control treatments. The plot treated with Pendimethalin 30% EC @ 1 kg ha^{-1} followed by one Hand weeding at 30 DAT recorded maximum plant height at 25, 50 and 75 DAT (45.33, 80.63 and 101.53 cm, respectively) while it was on par with treatments received pre emergence application of pendimethalin and oxyflourfen at 25 DAT *i.e.* T_2 (43.8 cm), T_4 (44.67 cm), T_5 (43.16 cm), T_7 (43.0 cm) and T_8 (43.1 cm). The same treatments recorded *at par* with T_2 (77.77 cm) and T_7 at 50 DAT (75.90 cm) and at 75 DAT (98.27 cm). This may attributed to that the pre-emergence herbicidal application act as barrier for weed emergences which ultimately reduces the weed flora and also help the crop to grow better, right from the early stages up to the end of cropping period. Reduced weed competition also offers the crop to grow better with appropriate environment for growth like more availability of nutrients, moisture and sunlight. Our findings are in conformity with the findings of Rao *et al.* (2014) in gladiolus who reported that pendimethalin at both concentrations (Pendimethalin@ 0.75 kg a.i./ha and Pendimethalin@ 1 kg a.i./ha) has resulted in significantly maximum plant height (91.20cm and 87.35cm, respectively) over weedy check (77.34cm) and at par with weed free check (88.67cm). Similar results had also been reported by Bhat and Sheikh (2013) [4] in gladiolus Ravneet Kaur and Madhubala (2016) [7] in chrysanthemum. Further, the result of this experiment also reveals that an early occupant of the field tends to discourage the later ones. The weeds germinate either before or along with the crop offer stronger competition to it than the later germinating ones. This might be the reason of decreased plant height in the treatments where application of pre emergence herbicides had not been done at early stages of crops. The minimum plant height (39.00 cm) at 25 DAT was recorded in Quizalofop ethyl 5% EC @ 0.05 kg ha^{-1} at 25 DAT (PoE) where it was maximum in unweeded treatment *i.e.* control (58.03 cm at 50 DAT and 76.27 cm at 75 DAT). The fact may be that weed count was more in weedy control which might have resulted in severe competition by weeds with the crop for nutrients, moisture, physical space and light (Bond and Oliver 2006) [5] as a result; crop growth is often reduced and ultimately reduced the plant height. (Acharya *et al*., 2003. Shalini and Patil, 2006) [1, 13].

The data presented in Table 1 clearly shows that primary and secondary number of branches $plant^{-1}$ were maximum (3.27 and 8.60) in the treatment Pendimethaline 30% EC @ 1 kg ha^{-1} + 1 Hand weeding at 30 DAT (T_1) which was closely followed by Pendimethalin 30% EC @ 1.0 kg ha^{-1} (PE) + Quizalofop ethyl 5% EC @ 0.05 kg ha^{-1} at 30 DAT (PoE), Oxyfluorfen 23.5% EC @ 0.20 kg ha^{-1} (PE) + Hand Weeding at 30 DAT, Oxyfluorfen 23.5% EC @ 0.20 kg ha^{-1} (PE) + Fenoxaprop- p-ethyl 9.3% EC @ 0.10 kg ha^{-1} at 30 DAT (PoE) and Oxyfluorfen 23.5% EC @ 0.20 kg ha^{-1} (PE) + Quizalofop ethyl 5% EC @ 0.05 kg ha^{-1} (PoE) at 30 DAT (PoE) and Pendimethalin 30% EC @ 1.0 kg ha^{-1} (PE) + Fenoxaprop - p-ethyl 9.3% EC @ 0.10 kg ha^{-1} at 30 DAT (PoE) at 25 DAT. Such improvement in number of branches in early stage of crop growth might be because of reduction in weed population due to application of pendimethaline and oxyfluorfen which reduced the weed population and allowing more absorption of nutrients and water for better growth of crop plants during initial period. At 50 and 75 DAT, all the weed control treatment resulted significant more number of primary and secondary branches $plant^{-1}$ as compare to unweeded treatment and it was highest in Pendimethaline 30% EC @ 1 kg ha^{-1} + 1 Hand weeding at 30 DAT (6.87 and 10.67 primary branches at 50 and 75 DAT; 20.13 and 36.50 secondary branches at 50 and 75 DAT) followed by oxyfluorfen 23.5% EC @ 0.20 kg ha^{-1} (PE) + Hand Weeding at 30 DAT. However, treatment two hand weeding at 25 and 50 DAT and three hand weeding at 25, 50 and 75 DAT were also recorded at par with pendimethalin 30% EC @ 1.0 kg ha^{-1} (PE) + hand weeding at 30 DATat 75 DAT for this trait. This might be due to the fact that these treatments reduced the weed competition with the crop and as a result the competition for nutrients, moisture and sunlight reduced which ultimately resulted into improvement of crop growth in terms of number of branches per plant. The result of present investigation are in conformity with findings of Kumar and Gowda (2011) [9] who also obtained increased number of branches $plant^{-1}$ (14.0) with application of Pendimethaline 30 EC 0.75 kg a.i./ ha @ 30 DAT + earthing up at 35 DAT as compared to unweeded control (14.6) in china aster. The increased number of branches with pre emergence application of Pendimethaline 30% EC and Oxyfluorfen 23.5% EC than weedy check in marigold cv. Pusa Narangi Gainda grown in all the three season *i.e.* rainy, winter and summer also noticed by Bhat *et al.* (2012) [3].On the other hand, due to severe competition of weeds with crop for water, nutrients and sunlight in unweeded treatment (T_{12}) the growth of crop was suppressed and as a consequence the minimum number of primary branches per plant (1.48 at 25 DAT,2.38 at 50 DAT and 4.53 at 75 DAT) and secondary branches per plant (4.29 at 25 DAT,7.30 at 50 DAT and 13.70 at 75 DAT) were obtained.

All the weed control treatments resulted significant increased plant spread than unweeded control treatment. It was maximum (68.17 cm) in Pendimethalin 30% EC @ 1 kg ha-1 + 1 Hand weeding at 30 DAT which closely followed by Three hand weeding at 25, 50 and 75 DAT (65.27 cm), Two Hand Weeding at 25 and 50 DAT (64.97 cm) and Oxyfluorfen 23.5% EC @ 0.20 kg ha-1 (PE) + Hand Weeding at 30 DAT(64.73cm). These four treatments showed non-significant difference with each other. The proportionally

suppressed weed population under these treatments which further encourages the flower plants to grow profusely and have better plant spread with increased number of branches might be the reason of increased plant spread under this treatments. Sharma *et al.* (2014) [14] also noticed significant increased plant spread with application of Pendimethalin @ 0.64 kg ai / ha + one hand weeding at 40 DAT in chrysanthemum however, they observed maximum plant spread in treatment in Pendimethalin (extra) @ 0.64 kg ai / ha + one hand weeding at 40 DAT + Pendimethalin (extra) @ 0.64 kg a.i. / ha.

Among the different weed control treatments, the treatment Pendimethaline 30% EC @ 1 kg ha-$^{-1}$ + 1 Hand weeding at 30 DAT (T_1) resulted the earliest 50 per cent flowering (47.00 days) followed by Pendimethalin 30% EC @ 1.0 kg ha^{-1} (PE) + Fenoxaprop - p-ethyl 9.3% EC @ 0.10 kg ha^{-1} at 30 DAT (PoE) and oxyfluorfen 23.5% EC @ 0.20 kg ha^{-1} (PE) + hand weeding at 30 DATwhich recorded on par with each other (Table 2). On Other hand all remaining treatments were delayed the 50 per cent flowering as compared to aforesaid treatments but resulted significantly earlier 50 per cent flowering than control. However, unweeded treatment took the longest period (56.33 cm) for 50 per cent flowering. Rao *et al.* (2014) also observed earlier 50 per cent flowering with pendimethaline @ 0.75 kg a.i. and 1.0 kg a.i. per ha followed by hand weeding after one month of planting of gladiolus corms. Earlier flowering with application of pendimethaline were also reported by Shalini and Patil (2006) [13] in gerbera and Bhat *et al.* (2013) [4] in gladiolus.

The improvement in flower diameter in various weed control treatments might be due to suppressed weed growth which resulted into better availability of nutrients in the soil leading to more vegetative and eventually resulting into better sized flower. These results are in accordance with the findings of Murthy and Gowda (1993) in tuberose and Basavaraju *et al.* (1992) in china aster. The maximum flower diameter (6.97 cm) was recorded in Pendimethaline 30% EC @ 1.0 kg ha^{-1} (PE) + Hand Weeding at 30 DAT (T_1) which was quite closely followed by oxyfluorfen 23.5% EC @ 0.20 kg ha^{-1} (PE) + hand weeding at 30 DAT, three hand weeding at 25, 50 and 75 DAT and two hand weeding at 25 and 50 DAT. These results are in line with Rao *et al.* (2014) [11] who reported significantly biggest flower in pendimethalin @1.0 kg a.i. ha-1 followed by one hand weeding after one month of corm planting in gladiolus. However, minimum flower diameter (3.33) was noticed in unweeded treatment.

Among the different weed control treatments tried, significantly maximum weight of flowers plant^{-1}(126.73 g.) and flower yield ha^{-1}(136.85 q)was recorded in Pendimethalin 30% EC @ 1.0 kg ha^{-1} (PE) + Hand Weeding at 30 DAT (T_1) and showed its significant superiority over rest of the treatments as regard weight of flowers plant^{-1}. Our findings are in close conformity with Acharya *et.al.*, (2003) [1] who recorded maximum flower yield (393.98 g plant^{-1}) with pre emergence application of pendimethalin followed by two hands weeding in marigold var. Pusa Basanti Gainda. Increase in flower yield per plantmay be attributed to better control of weed population right from seedling transplanting to throughout growing stages of crop which ultimately resulted in better vegetative growth coupled with better production of photosynthates in source and accumulation of food materials in sink caused an increase in flower yield plant^{-1} under these treatments. This treatment was followed by Three Hand Weeding at 25, 50 and 75 DAT (117.89), Oxyfluorfen 23.5% EC @ 0.20 kg ha^{-1}(PE) + 1Hand Weeding at 30 DAT (116.13 g.) and Two Hand Weeding at 25 and 50 DAT (112.56 gms) were on par to each other. The findings of present study is more closer to report of Salini and Patil (2006) in gerbera, Sharma *et al.* (2014) [14] in chrysanthemum and Rathore and Venugopal (2017) [12] in tuberose.

On the basis of economic assessment of various treatments for assessment of different Weed Control Methods in African marigold cv. 'Pusa Narangi Gainda' under Chhattisgarh Plain agro-c1imatic conditions, it may be inferred that application of Pendimethalin 30% EC @ 1.0 kg ha^{-1} (PE) followed by one Hand Weeding at 30 DAT gave the highest additional profit of Rs. 164076.6 per hectare as well as the highest B:C ratio (3.98) followed by Pendimethalin 30% EC @ 1.0 kg ha^{-1} (PE) + Fenoxaprop - p-ethyl 9.3% EC @ 0.10 kg ha^{-1} at 30 DAT (PoE) with profit Rs. and B: C Ratio 1:3.60 as compared to other treatments. The minimum B:C ratio of 1.01 was recorded at control (Table 2). Acharya *et.al.*, (2003) [1] in marigold and Channappagourdar and Biradar (2007) [6] in onion also found that application of pendimethalin @ 1.0 kg per hectare as a pre-emergence herbicide followed one hoeing & weeding at the stage of 30 days after transplanting to be the most economic treatment.

Table 1: Effect of different weed control methods on plant height, number of branches and plant spread of Marigold var. Pusa Narangi Gainda.

Treatments		Plant height(cm)			Number of Primary Branches Plant^{-1}			Number of Secondary Branch Plant^{-1}			Plant Spread(cm)
		25 DAT	50 DAT	75 DAT	25 DAT	50 DAT	75 DAT	25 DAT	50 DAT	75 DAT	90 DAT
T_1	Pendimethalin 30% EC @ 1.0 kg ha^{-1} (PE) +1 Hand Weeding at 30 DAT	45.33	80.63	101.53	3.27	6.87	10.67	8.60	20.13	36.50	68.17
T_2	Oxyfluorfen 23.5% EC @ 0.20 kg ha^{-1} (PE) +1 Hand Weeding at 30 DAT	43.8	77.77	98.27	2.77	5.60	8.49	7.64	18.37	33.72	64.73
T_3	Quizalofop ethyl 5% EC @ 0.05 kg ha^{-1} at 25 DAT (PoE).	39.0	65.37	83.3	1.50	3.90	5.62	4.37	10.77	22.5	50.03
T_4	Pendimethalin 30% EC @ 1.0 kg ha^{-1} (PE) + Quizalofop ethyl 5% EC @ 0.05 kg ha^{-1} at 30 DAT (PoE).	44.67	68.8	87.93	2.93	4.07	7.33	7.97	16.87	30.67	53.47
T_5	Oxyfluorfen 23.5% EC @ 0.20 kg ha^{-1} (PE) + Quizalofop ethyl 5% EC @ 0.05 kg ha^{-1} (PoE) at 30 DAT (PoE).	43.16	66.27	86.07	2.60	4.67	7.90	7.17	15.2	28.31	53.2
T_6	Fenoxaprop- p-ethyl 9.3% EC @ 0.10 kg ha^{-1} at 25 DAT (PoE)	40.37	71.45	90.27	1.93	4.29	6.47	4.52	12.49	22.5	58.37
T_7	Pendimethalin 30% EC @ 1.0 kg ha^{-1} (PE) +	43.0	75.90	93.82	3.00	5.13	7.33	8.23	17.66	32.76	63.33

	Fenoxaprop - p-ethyl 9.3% EC @ 0.10 kg ha^{-1} at 30 DAT (PoE).										
T_8	Oxyfluorfen 23.5% EC @ 0.20 kg ha^{-1} (PE) + Fenoxaprop- p-ethyl 9.3% EC @ 0.10 kg ha^{-1} at 30 AT (PoE).	43.1	75.60	92.53	2.48	4.93	7.07	7.40	15.34	31.32	62.97
T_9	One Hand Weeding at 25 DAT.	40.67	74.41	83.60	1.70	4.58	7.30	4.70	17.53	30.13	52.16
T_{10}	Two Hand Weeding at 25 and 50 DAT.	39.67	75.62	97.47	1.77	4.89	8.37	4.57	17.38	34.13	64.97
T_{11}	Three Hand Weeding at 25, 50 and 75 DAT.	40.02	76.53	97.60	1.83	4.97	8.58	4.82	17.62	34.66	65.27
T_{12}	Unweeded (Control).	39.56	58.03	76.27	1.46	2.38	4.53	4.29	7.3	13.7	37.23
SEm ±		0.81	1.66	1.45	0.31	0.48	0.76	0.83	0.77	1.26	1.47
CD $_{0.05\%}$		2.38	4.78	4.26	0.89	1.39	2.22	2.24	2.26	3.70	4.31

Table 2: Effect of different weed control methods on flower parameters and economics of Marigold var. Pusa Narangi Gainda

Treatments		Days to 50% Flowering	Flower Diameter (cm)	Flower Yield (gm. /plant)	Flower yield q/ha	NET Returns(Rs.)	B: C Ratio
T_1	Pendimethalin 30% EC @ 1.0 kg ha^{-1} (PE) + 1Hand Weeding at 30 DAT	47.00	6.97	126.73	136.85	164076.6	3.98
T_2	Oxyfluorfen 23.5% EC @ 0.20 kg ha^{-1} (PE) + 1Hand Weeding at 30 DAT	48.33	6.03	116.13	121.79	141772.4	3.47
T_3	Quizalofop ethyl 5% EC @ 0.05 kg ha^{-1} at 25 DAT (PoE).	53.26	4.38	91.1	84.26	93394.27	2.83
T_4	Pendimethalin 30% EC @ 1.0 kg ha^{-1} (PE) + Quizalofop ethyl 5% EC @ 0.05 kg ha^{-1} at 30 DAT (PoE).	51.33	4.81	101.9	89.81	99158.22	2.79
T_5	Oxyfluorfen 23.5% EC @ 0.20 kg ha^{-1} (PE) + Quizalofop ethyl 5% EC @ 0.05 kg ha^{-1} (PoE) at 30 DAT (PoE).	51.93	4.68	105.6	87.59	96093.89	2.72
T_6	Fenoxaprop- p-ethyl 9.3% EC @ 0.10 kg ha^{-1} at 25 DAT (PoE)	53.10	4.44	94.61	86.57	98986.11	3.21
T_7	Pendimethalin 30% EC @ 1.0 kg ha^{-1} (PE) + Fenoxaprop - p-ethyl 9.3% EC @ 0.10 kg ha^{-1} at 30 DAT (PoE).	47.33	5.87	110.6	108.52	127425.8	3.60
T_8	Oxyfluorfen 23.5% EC @ 0.20 kg ha^{-1} (PE) + Fenoxaprop- p-ethyl 9.3% EC @ 0.10 kg ha^{-1} at 30 DAT (PoE).	50.18	5.44	106.53	106.76	125055.9	3.56
T_9	One Hand Weeding at 25 DAT.	51.45	5.27	96.5	97.69	107914.8	2.79
T_{10}	Two Hand Weeding at 25 and 50 DAT.	50.33	5.96	112.56	113.89	124271.3	2.67
T_{11}	Three Hand Weeding at 25, 50 and 75 DAT.	50.33	6	117.89	121.36	127525.0	2.34
T_{12}	Unweeded (Control).	56.33	3.33	66.77	38.89	29406.33	1.02
SEm ±		0.93	0.35	2.65	5.34		
CD $_{0.05\%}$		2.71	1.03	7.78	15.01		

Conclusion

On the basis of the results of present investigation it may be concluded that removing of weeds at any time and by any means during the growth period is found good enough for obtaining full benefits of weed management in terms of increased crop yield. But, time of weeding in a crop is as important as the weeding itself. Highest flower yield and maximum profit of Rs. 164076.6 per hectare with the B; C per hectare followed by one weeding at 30 days after transplanting which provided an efficient control over weeds. In case of labour scarcity, application of pendimethalin 30% EC @ 1.0 kg ha (PE) + Fenoxapro-p-ethyl9.3% EC @ 0.10 kg ha^{-1} at 30 DAT could be a better alternative for fetching good flower yield with a B: C Ratio (1:3.60) as compared to other practices.

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