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Comparative studies on herbicide spray through drone, knapsack and boom sprayer for weed control on growth of safflower (*Carthamus tinctorius* L.)

AB Thombre, BV Asewar and SU Pawar

Abstract
A field experiment was conducted during the *rabi* season of 2022-23 at Post Graduate Experimental Farm, Department of Agronomy, College of Agriculture, VNMKV, Parbhani. The experiment was laid out in Restricted Randomized Block Design with eight treatments in three replications each, which are T_1 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} at 1.0 m height by drone, T_2 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} at 1.5 m height by drone, T_3 - PE herbicide application of Pendimethalin 30% EC @ 0.05 kg a.i. ha^{-1} at 1.0 m height by drone, T_4 - PE herbicide application of Pendimethalin 30% EC @ 0.05 kg a.i. ha^{-1} at 1.5 m height by drone, T_5 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by knapsack sprayer, T_6 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by boom sprayer, T_7 - Weed free, T_8 - Weedy check. On the basis of present studies results revealed that, among the weed management practices, weed free (T_7) can satisfactorily manage the weeds in safflower and produce the higher growth attributing characters *viz.*, plant height, number of branches plant $^{-1}$, number of functional leaves plant^{-1}, total dry matter accumulation plant^{-1} which was significantly superior over rest of treatments and it was found to be at par with the PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by boom sprayer (T_6) and the PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by knapsack sprayer (T_5). Whereas, lowest values were recorded with weedy check (T_8). The lowest weed count of both monocot and dicot weeds were found in weed free (T_7).

Keywords: Safflower, drone, knapsack sprayer, boom sprayer, pendimethalin, weeds

Introduction
Weeds are unwanted plants that can reduce crop yields by competing for water, nutrients, light, space, and carbon dioxide. As long as there have been weeds, farmer have known that presence of unplanted species hinders the growth of the crops they are trying to raise. Among various constraints in crop production, weeds are the major problems which are generally neglected. Losses due to weed ranged from 10% to as much as 88% in oil seed crops. Thus, weed competition is serious problem in safflower cultivation. Safflower which is heavily infested with weeds resulting in poor yield (Blackshaw, 1993) [3]. Safflower is a poor competitor with weeds and weed control is one of the major production challenges for successful adoption of this crop (Anderson, 1987, Blackshaw *et al.*, 1990) [1, 4]. Several methods for controlling weed problems include manual weeding, conventional herbicides, mechanical and machines, sustainable strategies, and artificial intelligence. Tractor or bullock mounted boom sprayer is the most common type of device for applying herbicides in broad scale farming. It has increased not only area coverage but also reduced the time and energy required for the herbicide application. It provides better wind resistance, better coverage and minimizes excessive overlap. Knapsack sprayers are extremely useful agricultural equipment. It is utilised for applying herbicides in small farm operations where patches of invasive species must be controlled. An agricultural drone is an unmanned aerial vehicle (UAV) used in agriculture operations, mostly in yield optimization, for spraying purpose and in monitoring crop growth and crop production. Drones are used to spray herbicides to avoid the health problems of humans when they spray manually. This could also be lowers the wasting of chemical and water. It is also help to spray easier and saves the time.

Materials and Methods
A field experiment entitled "Comparative studies on herbicide spray through drone, knapsack and boom sprayer for weed control in Safflower (*Carthamus tinctorius* L.)" was conducted

during the *rabi* season of 2022-23 at PG Experimental Farm, Department of Agronomy, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The experimental field was levelled and well drained, with a clayey texture that was medium in available nitrogen, phosphorus, and potassium. The experiment was laid out in Restricted Randomized Block Design with eight treatments in three replications each, which are T_1 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} at 1.0 m height by drone, T_2 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} at 1.5 m height by drone, T_3 - PE herbicide application of Pendimethalin 30% EC @ 0.05 kg a.i. ha^{-1} at 1.0 m height by drone, T_4 - PE herbicide application of Pendimethalin 30% EC @ 0.05 kg a.i. ha^{-1} at 1.5 m height by drone, T_5 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by knapsack sprayer, T_6 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by boom sprayer, T_7 - Weed free, T_8 - Weedy check. Each experimental unit had a net plot size of 6.3 m × 5.4 m and was repeated three times, with a gross plot size of 7.2 m x 6.0 m. The pre-emergence herbicide application was done on first day after sowing. The water requirement for drone sprayer was 25 L ha^{-1}. The applied dose of Pendimethalin 30% EC was 0.33 kg ha^{-1} in T_1 and T_2 respectively and dose of Pendimethalin 30% EC was 0.16 kg ha^{-1} in T_3 and T_4 respectively. The applied dose of Pendimethalin 30% EC was 0.33 kg ha^{-1} in T_5 and T_6. The number of weeds m^{-2} was recorded by using one m^2 quadrant. This frame was kept in net plot and number of weeds observed inside the frame were recorded at 20 and 40 DAS. The weed count counted separately as monocot and dicot.

Results and Discussion

Plant height (cm)

The data on mean plant height of safflower as influenced by various treatments was recorded periodically during the crop growth period at various intervals and presented in Table 1. The mean plant height was 13.12, 33.02, 54.37, 66.28, 74.29, 80.03 and 80.03 cm at 30, 45, 60, 75, 90, 105 DAS and at harvest, respectively. The mean plant height was influenced significantly at different growth period of the crop. At 30 DAS taller plants of safflower was recorded with weed free (T_7) which was statistically at par with the PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by boom sprayer (T_6) and the PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by knapsack sprayer (T_5) and found significantly superior over rest of the treatments. Lowest plant height was recorded in weedy check (T_8) at all growth period. Similar trend of plant height was observed at 45, 60, 75, 90, 105 DAS and at harvest. At harvest there was no increase in plant height was seen.The increase in plant height might be due to greater availability of nutrient and lowest crop weed competition for light, moisture, temperature and water. The lowest crop weed competition leads to high nutrient flow that is diverted for promoting plant growth, especially in plant height. The results were in conformity with the findings of Sivakumar (1997) [6].

Table 1: Mean plant height (cm) of safflower as influenced by different treatments at different crop growth period

Sr. No.	Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	At harvest
1	T_1 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} at 1.0 m height by drone	11.56	30.76	50.93	61.82	69.03	74.53	74.53
2	T_2 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} at 1.5 m height by drone	12.17	31.50	52.29	63.24	70.73	76.49	76.49
3	T_3 - PE herbicide application of Pendimethalin 30% EC @ 0.05 kg a.i. ha^{-1} at 1.0 m height by drone	13.14	33.09	54.11	66.16	74.06	80.15	80.15
4	T_4 - PE herbicide application of Pendimethalin 30% EC @ 0.05 kg a.i. ha^{-1} at 1.5 m height by drone	12.83	32.20	53.08	64.82	72.61	78.48	78.48
5	T_5 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by knapsack sprayer	14.06	35.19	57.12	70.14	78.92	85.12	85.12
6	T_6 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by boom sprayer	14.87	36.18	58.79	72.05	80.94	87.42	87.42
7	T_7 - Weed free	15.64	37.55	61.04	74.89	83.95	90.53	90.53
8	T_8 - Weedy check	10.71	27.73	47.60	57.12	64.07	67.56	67.56
	S.E. m±	0.54	1.39	2.20	2.78	3.17	3.27	3.27
	C.D. @ 5%	1.63	4.20	6.64	8.40	9.58	9.88	9.88
	General mean	13.12	33.02	54.37	66.28	74.29	80.03	80.03

Number of functional leaves plant^{-1}

The data on mean number of functional leaves of safflower as influenced by various treatments was recorded periodically during the crop growth period at various intervals and presented in Table 2. It was observed from the Table 2 mean number of functional leaves plant^{-1} recorded at 30, 45, 60, 75, 90 and 105 DAS were 15.91, 41.04, 86.38, 143.06, 179.01 and 137.30, respectively. At 30 DAS, the maximum number of functional leaves plant^{-1} was observed in weed free (T_7) which was statistically at par with the PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by boom sprayer (T_6) and the PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by knapsack sprayer (T_5) and found significantly superior over rest of the treatments. Lowest number of functional leaves plant^{-1} was recorded in weedy check (T_8) at all growth period. Similar trend of number of functional leaves plant^{-1} was observed at 45, 60, 75, 90 and 105 DAS. There were no functional leaves at harvest due to senescence.

This may be due to low weed infestation, which provide aeration, light, nutrients, water and space available to the plants, resulting in better leaf development. The results were in agreement with findings of Jalali *et al*. (2002) [5].

Number of branches plant^{-1}

The data on mean number of branches plant^{-1} of safflower recorded periodically as influenced by different treatments at various growth period and presented in Table 3. Mean number of branches plant^{-1} of safflower at 45, 60, 75, 90, 105 DAS and at harvest were 2.98, 6.60, 10.04, 12.35, 13.62 and 13.62, respectively. At 45 DAS the highest mean number of branches plant^{-1} was recorded in weed free (T_7) which was statistically at par with the PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by boom sprayer (T_6) and the PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by knapsack sprayer (T_5) and found significantly superior over rest of the treatments. Lowest branches plant^{-1} was recorded in weedy check (T_8) at all growth period. Similar trend of observation was observed at 60, 75, 90, 105 and at harvest. At harvest there was no increase in number of branches plant^{-1} was seen.

This might be because of effective weed control by the treatment. There is more free space available for growth of branches due to weed free condition as well as competition for sunlight and nutrients were less which helped in increasing number of branches plant^{-1}. Zain *et al.* (2020) [8] also reported a greater number of branches plant^{-1}.

Total dry matter accumulation plant^{-1} (g)

The data concerned with periodical accumulation of mean total dry matter plant^{-1} at various growth period of crop as influenced by different treatments and presented in Table 4. The mean dry matter accumulation at 30, 45, 60, 75, 90, 105 DAS and at harvest were 4.28, 8.49, 14.85, 36.60, 46.55, 54.20 and 61.08 g plant^{-1}, respectively. At 30 DAS the highest mean total dry matter accumulation plant^{-1} was observed in weed free (T_7) which was statistically at par with the PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by boom sprayer (T_6) and the PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by knapsack sprayer (T_5) and found significantly superior over rest of the treatments. Lowest value was recorded in weedy check (T_8) at all growth period. Similar trend of observation was observed at 45, 60, 75, 90, 105 DAS and at harvest.

This might be due to the effective control of weeds, so it resulted in minimum crop-weed competition. The dry matter accumulation is largely a function of photosynthetic surface which has also more under these treatments resulting in increased biological productivity and finally dry matter accumulation. These results were similar to Vijay *et al.* (2018) [7].

Table 2: Mean number of functional leaves plant^{-1} of safflower as influenced by different treatments at different crop growth period

Sr. No.	Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS
1	T_1 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} at 1.0 m height by drone	14.22	37.49	81.79	136.20	174.10	132.59
2	T_2 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} at 1.5 m height by drone	14.84	38.61	83.79	137.53	175.45	133.26
3	T_3 - PE herbicide application of Pendimethalin 30% EC @ 0.05 kg a.i. ha^{-1} at 1.0 m height by drone	16.00	41.66	85.12	141.09	178.91	136.20
4	T_4 - PE herbicide application of Pendimethalin 30% EC @ 0.05 kg a.i. ha^{-1} at 1.5 m height by drone	15.46	40.53	84.45	140.53	177.76	135.22
5	T_5 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by knapsack sprayer	17.24	43.77	91.88	151.67	191.48	146.42
6	T_6 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by boom sprayer	17.81	44.62	92.76	152.45	192.67	147.06
7	T_7 - Weed free	18.32	46.91	97.36	159.45	201.52	153.81
8	T_8 - Weedy check	13.35	34.72	73.89	125.52	140.22	113.84
	S.E. m±	0.68	1.67	3.50	5.79	7.27	5.66
	C.D. @ 5%	2.04	5.05	10.56	17.49	21.94	17.10
	General mean	15.91	41.04	86.38	143.06	179.01	137.30

Table 3: Mean number of branches plant^{-1} of safflower as influenced by different treatments at different crop growth period

Sr. No.	Treatments	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	At harvest
1	T_1 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} at 1.0 m height by drone	2.13	5.78	8.27	10.02	11.35	11.35
2	T_2 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} at 1.5 m height by drone	2.49	5.90	9.21	11.06	12.46	12.46
3	T_3 - PE herbicide application of Pendimethalin 30% EC @ 0.05 kg a.i. ha^{-1} at 1.0 m height by drone	3.06	6.82	10.67	13.23	14.27	14.27
4	T_4 - PE herbicide application of Pendimethalin 30% EC @ 0.05 kg a.i. ha^{-1} at 1.5 m height by drone	2.75	6.24	10.12	12.17	13.32	13.32
5	T_5 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by knapsack sprayer	3.59	7.42	11.25	14.18	15.18	15.18
6	T_6 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by boom sprayer	3.84	7.98	11.86	14.69	15.79	15.79
7	T_7 - Weed free	4.18	8.45	12.06	15.13	16.76	16.76
8	T_8 - Weedy check	1.81	4.23	6.88	8.36	9.84	9.84
	S.E. m±	0.20	0.40	0.43	0.52	0.58	0.58
	C.D. @ 5%	0.61	1.20	1.29	1.57	1.75	1.75
	General mean	2.98	6.60	10.04	12.35	13.62	13.62

Table 4: Mean dry matter accumulation (g) of safflower as influenced by different treatments at different crop growth period

Sr. No.	Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	At harvest
1	T_1 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} at 1.0 m height by drone	3.38	7.26	12.66	34.12	42.66	49.87	56.19
2	T_2 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} at 1.5 m height by drone	3.51	7.65	13.78	35.53	45.25	52.61	59.24
3	T_3 - PE herbicide application of Pendimethalin 30% EC @ 0.05 kg a.i. ha^{-1} at 1.0 m height by drone	4.36	8.77	15.12	37.65	47.58	55.29	62.27
4	T_4 - PE herbicide application of Pendimethalin 30% EC @ 0.05 kg a.i. ha^{-1} at 1.5 m height by drone	4.02	8.26	14.51	36.65	46.51	54.09	60.89
5	T_5 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by knapsack sprayer	4.87	9.37	16.62	40.42	51.36	59.16	66.19
6	T_6 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by boom sprayer	5.23	9.83	17.41	41.40	52.44	60.42	67.80
7	T_7 - Weed free	5.75	10.52	18.32	42.41	53.71	62.27	69.98
8	T_8 - Weedy check	3.11	6.25	10.40	24.61	32.87	39.90	46.05
	S.E. m±	0.31	0.48	0.66	1.54	1.93	2.25	2.48
	C.D. @ 5%	0.95	1.44	1.98	4.63	5.84	6.79	7.50
	General mean	4.28	8.49	14.85	36.60	46.55	54.20	61.08

Weed count (m^{-2})

Data on mean number of monocot and dicot weeds (m^{-2}) at various stages as influenced by different treatments is presented in Table 6.

Monocot weeds

The data presented in Table 5 indicated that mean number of monocot weeds at 20 and 40 DAS were 2.71 and 3.47. Mean number of monocot weeds were influenced significantly by different treatments at 20 and 40 DAS.

At 20 DAS the lowest monocot weeds were observed in weed free (T_7) and it was found at par with PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by boom sprayer (T_6) and PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by knapsack sprayer (T_5). Highest monocot weed count was observed in weedy check (T_8) due to unchecked weed growth at all stages of crop. At 40 DAS similar result was recorded. The most dominant monocot weed in safflower was *Cynodon doctylon* this was in conformity with Birajdar (1990) [2].

Dicot weeds

Mean number of dicot weeds were influenced significantly by different treatments at 20 and 40 DAS. The data presented in Table 5 indicated that mean number of dicot weeds at 20 and 40 DAS were 2.58 and 3.30.

At 20 and 40 DAS, lowest dicot weed intensity was observed with weed free (T_7) and it was found at par with PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by boom sprayer (T_6) and PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by knapsack sprayer (T_5). Highest dicot weed count was observed in weedy check (T_8) due to unchecked weed growth at all stages of crop.

The most dominant dicot weeds were *Digeria arvensis*, *Euphorbia geniculata*, *Parthenium hysterophorus*. These results were in conformity with Birajdar (1990) [2].

Table 5: Mean weed count (m^{-2}) as influenced by different treatments at 20 and 40 days after sowing

Sr. No.	Treatments	20 DAS		40 DAS	
		Monocot	Dicot	Monocot	Dicot
1	T_1 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} at 1.0 m height by drone	2.21 (2.90)	2.06 (2.43)	2.99 (6.21)	2.81 (5.34)
2	T_2 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} at 1.5 m height by drone	2.31 (3.28)	2.22 (2.97)	3.08 (6.70)	2.94 (5.95)
3	T_3 - PE herbicide application of Pendimethalin 30% EC @ 0.05 kg a.i. ha^{-1} at 1.0 m height by drone	2.78 (5.20)	2.72 (4.92)	3.61 (9.68)	3.49 (8.93)
4	T_4 - PE herbicide application of Pendimethalin 30% EC @ 0.05 kg a.i. ha^{-1} at 1.5 m height by drone	2.99 (6.18)	2.79 (5.25)	3.67 (10.06)	3.54 (9.26)
5	T_5 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by knapsack sprayer	2.49 (3.96)	2.45 (3.79)	3.30 (7.86)	3.16 (7.08)
6	T_6 - PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by boom sprayer	2.42 (3.69)	2.33 (3.34)	3.20 (7.32)	3.06 (6.57)
7	T_7 - Weed free	1.99 (2.23)	1.88 (1.91)	2.76 (5.12)	2.55 (4.22)
8	T_8 - Weedy check	4.52 (16.16)	4.22 (13.83)	5.09 (21.14)	4.88 (19.19)
	S.E. m±	0.18	0.20	0.19	0.21
	C.D. @ 5%	0.54	0.61	0.58	0.63
	General mean	2.71	2.58	3.47	3.30

*Values in parenthesis are means of original values; Data transformed to square root transformation ($\sqrt{x}$ + 0.5)

Conclusion

Among the different sprayers used for PE herbicide application, the higher growth and yield attributing characters were obtained with PE herbicide application of Pendimethalin 30% EC @ 1.0 kg a.i. ha^{-1} by boom sprayer which was proved to be effective for satisfactorily managing the weeds in safflower.

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