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Effect of Chemical Herbicides on Weed Management in *Allium sativum L.* (Garlic) and Its Yield

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Authors' contributions

This work was carried out in collaboration among all authors. Author TG designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors MRR and GRR managed the analyses of the study. Author GRR managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during 2015-16, 2016-17 and 2017-18 at Agricultural Research Station, Hanumanamatti, Ranebennur (Tq), Haveri (Dist.) Karnataka, to study the effect of chemical herbicides on weed management in garlic. The treatments consisted of pre emergent application of Pendimethalin, Oxyfluorfen, Quizalofop ethyl and Butachlor. The pooled mean results indicated that, pre-emergent application of Butachlor 50 EC @ 1.0 kg ai/ha + one hand weeding + second spray at 30 days after planting (B1HW2S:T7) recorded the least weed density (82.83, 89.67 monocot weeds and 8.15, 6.34 dicot weeds), weed bio-mass (80.99g, 93.33g fresh weight of monocot weeds and 8.48g, 1.82g fresh weight of dicot weeds, 32.40g, 37.33g dry weight of monocot weeds and 3.39g, 0.73g dry weight of dicot weeds), the highest garlic plant height (4.34cm, 16.17 cm), number of leaves (3.55, 6.57) at 30 and 60 days after planting respectively. Treatment with Butachlor 50 EC @ 1.0 kg ai/ha + one hand weeding + second spray at 30 days after planting (B1HW2S:T7) also recorded the highest hundred bulb weight (912.98 g), yield per plot

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(2056.63g) and yield/ha (41.13 Q) followed by Oxyflurofen 23.5 EC @ 0.15 kg ai /ha + one hand weeding + second spray at 30 Days after planting (O1HW2S:T4) compared to farmer's practice (2HW:T8) and untreated control (WC:T9).

Keywords: Garlic; herbicides; weed density; weed bio-mass; Bulb weight.

1. INTRODUCTION

Allium sativum L. (Garlic) is an important spice crop cultivated in India since ancient time. China is the leading garlic producing country accounting for over 75% of world out put followed by India, Egypt, Russia, Myanmar, Ethiopia and USA [1]. The bulb comprises of many pungent cloves. In India, Madhya Pradesh is the leading producer of garlic followed by Gujarat [2]. In Karnataka, it is grown in several districts since many years where soil is friable and loose during kharif and rabi. Garlic productivity in the state is quite less as compared to national average due to number of factors but the main limiting factor is the weed infestation. Garlic grows to a height of one foot, competition of weeds start at the early growth stage of seedlings. Garlic is highly vulnerable to weed infestation due to its slow initial growth and shallow root system [3,4]. The garlic is closely planted crop with very small canopy. Due to smaller leaf size it cannot compete with the weeds. Under Jammu and Kashmir conditions, weeds are mostly managed by human a labour, which is tedious and expensive operation and often damages the crop [5]. Weeds compete for nutrients and soil moisture, considerably reducing the yield, quality and value through increased harvesting costs [6]. Farmers now-a-days opt for chemicals as an effective weed control measure and replace the conventional method of weed control in crops like garlic to improve its productivity and quality. Application of a single herbicide, even though may provide good control of certain weeds [7].

Due to non availability of labour and excessive rainfall, hand weeding and mechanical operations are limited. Under these conditions, the weed management by weedicides becomes much more important. Wide ranges of chemical herbicides have been listed for weed management in bulb crops. Hence, the present investigation was carried out to test the efficacy of herbicides either as pre-emergent spray with one hand weeding at 30 days after planting or with one more additional spray at 30 days after planting of cloves for weed management and better garlic yield.

2. MATERIALS AND METHODS

The Field experiment was conducted during 2015-16, 2016-17 and 2017-18 at Agricultural Research Station, Hanumanamatti, Ranebennur (Tq), Haveri (Dist.), Karnataka to study the effect of chemical herbicides on weed management in garlic. The land was prepared to a fine tilth and individual treatment plots of 3 m x 5 m size (15 m^2) were prepared during kharif. The nine treatments were imposed in randomized block design and was carried out in triplicate. Pre-emergent application of Pendimethalin, Oxyflurofen, Quizalofop ethyl and Butachlor with one hand weeding plus an additional spray of herbicide at 30 days after planting of garlic along with the farmer's practice (2HW: T8) and un-weeded control (WC:T9) was conducted . After planting of ginger cloves, spraying of weedicides was taken up on the same day or very next day with sufficient moisture in the soil at specified concentrations with the following treatment details.

2.1 Treatment details

The observations were recorded on number of monocot and dicot weeds (per m^2) at 30 and 60 days after imposition of treatments. After the count, the weeds were uprooted and the fresh weight (g) was recorded. The dry weight (g) was recorded after drying the weeds at 65^o C in an oven. The height (cm) and number of leaves of garlic was recorded on five plants in each replication. At maturity, the garlic bulbs were harvested and the hundred bulb weight (g) and plot yield (g) was recorded. The bulb yield per ha was worked out and expressed in q/ha. The statistical analysis was conducted for comparing the treatments. During subsequent years (2016-17 and 2017-18), the same plots were used for imposition of treatments. The pooled mean data was generated and statistical analysis was carried out.

The phytotoxicity effect of herbicides on garlic crop was studied for leaf tips, surface injury, wilting, necrosis, epinasty and hyponasty were observed. Ten plants were selected at random from each treatment and the total number of leaves and those showing phyto-toxicty were

counted. The extent of phyto-toxicty is recorded based on 0-10 scale core.

After three years of experimentation, the best treatment was compared with the recommended package of practices (B1HW:T6) through farm trial and large scale demonstration (LSD) which were conducted in farmer's field in ten gunta and one acre area respectively and the results were compared.

3. RESULTS AND DISCUSSION

The results of 2015-16, 2016-17 and 2017-18 are pooled and presented in Tables 3 and 4 whereas, the results of farm trial and large scale demonstration (LSD) are presented in Table 5. The pooled means are discussed under the following headings.

3.1 Effect of Pre-Emergent Herbicides on Weed Density and Weed Bio-Mass in Garlic

Application of weedicides as pre emergent plus one hand weeding plus second spray at 30 days after planting has drastically reduced the weed density and weed bio mass in garlic plot. The pooled mean data (Table 3) indicated that, at 30 days after planting the least monocot weed density (82.83 no./m^2) was recorded with Butachlor 50 EC @ 1.0 kg ai/ha + one hand weeding + second spray at 30 days after planting (B1HW2S:T7) followed by O1HW2S (100.04 no/m^2:T4). Treatment B1HW2S (T7) was on par with P1HW (T1), P1HW2S (T2), O1HW (T3), O1HW2S (T4), QE1HW2S (T5) and B1HW (T6) and significantly superior over 2HW (T8) and WC (T9). The least dicot weed density (8.15 no./m^2)was recorded with Butachlor 50 EC @ 1.0 kg ai/ha + one hand weeding + second spray at 30 days after planting (B1HW2S:T7) followed by B1HW (T6). Treatment B1HW2S (T7) was on par with O1HW (T3), O1HW2S (T4) and significantly superior over rest of the treatments. Whereas, at 60 days after planting the least monocot weed density (89.67 no./m^2) was also recorded with Butachlor 50 EC @ 1.0 kg ai/ha + one hand weeding + second spray at 30 days after planting (B1HW2S :T7) followed by B1HW(100.27no./m^2: T6). The least dicot weed density (6.34 no./m^2) was recorded with Butachlor 50 EC @ 1.0 kg ai/ha + one hand weeding + second spray at 30 days after planting (B1HW2S:T7) followed by B1HW (9.46 g/m^2:T6) it was on par with O1HW2S (T4) and B1HW (T6) and significantly superior over rest of the treatments.

Table 1. Chemical herbicides and their quantity used in the experiment

T1	Pendimethalin (Stomp) 30EC @ 1.0 kg ai/ha + One hand weeding (P1HW)
T2	Pendimethalin (Stomp) 30EC @ 1.0 kg ai/ha + One hand weeding + Second spray @ 30 Days after planting (P1HW2S)
T3	Oxyflurofen (Goal) 23.5 EC @ 0.15 kg ai /ha + One hand weeding (O1HW)
T4	Oxyflurofen (Goal) 23.5 EC @ 0.15 kg ai /ha + One hand weeding + Second spray @ 30 Days after planting (O1HW2S)
T5	Quizalofop ethyl 5 EC @ 0.05 kg ai/ha + One hand weeding + Second spray @ 30 Days after planting (QE1HW2S)
T6	Butachlor 50 EC @ 1.0 kg ai/ha (B1HW) (RPP)
T7	Butachlor 50 EC @ 1.0 kg ai/ha + One hand weeding + Second spray @ 30 Days after planting (B1HW2S)
T8	Two hand weeding @ 30 and 60 Days after planting (2HW)(Farmer's practice)
T9	Weedy check (WC)

Table 2. Phyto-toxicity scale

Score	Phytotoxicity (percent)	Score	Phytotoxicity (percent)
0	No Phyto-toxicity	6	51-60
1	1-10	7	61-70
2	11-20	8	71-80
3	21-30	9	81-90
4	31-40	10	91-100
5	41-50	-	-

Table 3. Effect of pre-emergent weedicides on weed density and weed bio-mass in *Allium sativum* L. (Garlic) (Pooled mean of 2015-16, 2016-17 and 2017-18)

Treatments	Weed density (No/m^2)				Weed Biomass (g/m^2)							
	Monocot		Dicot		Fresh weight (Monocot)		Fresh weight (Dicot)		Dry weight (Monocot)		Dry weight (Dicot)	
	30 DAS*	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
T1	106.02	124.43	10.76	12.37	106.02	131.89	11.72	8.45	42.41	52.76	4.69	3.38
T2	121.31	136.23	10.77	11.62	103.67	129.89	10.96	7.53	41.47	51.96	4.38	3.01
T3	127.17	128.92	8.81	10.61	93.02	114.33	9.82	6.30	37.21	45.73	3.93	2.52
T4	100.04	100.27	9.41	9.65	82.66	103.00	9.80	2.94	33.06	41.20	3.92	1.18
T5	133.46	201.21	19.02	15.17	116.76	139.33	22.47	8.62	46.70	55.73	8.99	3.45
T6	124.65	159.49	8.44	9.46	89.39	108.67	8.76	2.38	35.76	43.47	3.50	0.95
T7	82.83	89.67	8.15	6.34	80.99	93.33	8.48	1.82	32.40	37.33	3.39	0.73
T8	253.75	348.85	24.28	16.48	196.28	184.89	27.02	11.75	78.51	73.96	10.81	4.70
T9	257.68	352.62	29.38	32.54	240.20	372.85	30.96	43.53	96.08	149.14	12.38	17.41
SEm±	19.00	61.18	0.74	1.22	3.39	2.91	1.60	1.29	3.82	6.67	0.82	0.73
CD@ 5%	57.64	NS	2.26	3.69	10.30	8.81	4.85	3.92	11.02	19.78	2.48	2.22

**DAS: Days after sowing*

Table 4. Influence of pre-emergent weedicides on growth and yield of *Allium sativum* L. (Garlic) (Pooled mean of 2015-16, 2016-17 and 2017-18)

Treatments	Growth parameters				Yield parameters			
	Plant height (cm)		No. of leaves					
	30 DAS*	60 DAS	30 DAS	60 DAS	100 Clove weight (g)	100 Bulb weight (g)	Yield per plot (g)	Yield (Q/ha)
T1	3.28	13.01	2.36	4.69	87.43	676.21	1365.08	27.31
T2	3.30	13.13	2.37	5.06	88.22	690.93	1410.05	28.21
T3	3.42	13.67	2.62	5.13	89.87	696.73	1425.76	28.51
T4	3.96	14.81	3.17	5.80	99.95	806.72	1767.11	35.33
T5	2.93	12.44	1.97	4.55	84.33	666.63	1198.85	23.98
T6	3.80	14.41	3.00	5.68	97.02	756.22	1616.33	32.33
T7	4.34	16.17	3.55	6.57	116.64	912.98	2056.63	41.13
T8	2.02	11.38	1.90	4.30	78.10	595.12	1052.46	21.04
T9	1.98	9.97	1.74	3.74	39.69	302.42	547.52	10.66
SEm±	0.16	0.15	2.59	0.20	2.45	28.84	69.57	1.39
CD @ 5%	0.50	0.44	2.50	0.60	7.43	87.48	211.03	4.21

**DAP: Days after sowing*

Table 5. Farm trial data on weed management in garlic as influenced by Butachlor 50 EC (two sprays) plus one hand weeding over a spray of Butachlor 50 EC (2018-19)

Centre	No. of farmers	Treat ments	No. of weeds/ m^2				Yield/ plot (Q/ 5 gunta)	Yield (Q/ha)	% increase in yield over T2
			30 DAS*		60 DAS				
			Monocot (No)	Dicot (No)	Monocot (No)	Dicot (No)			
KVK	1	T1**	7.12	4.20	6.42	5.10	1.27	25.40	14.41
Hanumana		T2***	6.03	5.01	13.30	11.12	1.11	22.20	
matti	2	T1	6.13	3.12	7.20	4.15	1.37	27.40	17.09
		T2	6.12	4.10	13.23	11.72	1.17	23.40	
	3	T1	5.21	4.10	6.25	5.09	1.26	25.20	15.59
		T2	4.23	5.13	14.74	12.06	1.09	21.80	
	4	T1	7.23	5.12	6.41	4.10	1.21	24.20	13.08
		T2	8.42	7.54	17.22	13.23	1.07	21.40	
AEEC, Dwd	1	T1	4.26	3.63	5.39	7.02	1.60	32.00	13.89
		T2	5.31	5.02	12.03	11.40	1.44	28.80	
	2	T1	6.10	4.14	6.43	5.72	1.65	33.00	13.79
		T2	7.12	5.63	14.0	11.00	1.45	29.00	
ICAR-KVK,	1	T1	8.10	6.05	7.12	5.40	1.76	35.20	9.85
Dwd		T2	9.06	6.43	16.03	15.10	1.52	30.45	
	2	T1	9.04	8.36	9.02	6.46	1.75	35.10	9.01
		T2	9.70	10.06	18.0	16.06	1.61	32.20	
DOH	1	T1	11.02	8.46	9.33	7.84	1.47	29.40	14.84
Ranebennur	2	T2	12.12	10.36	17.64	19.09	1.28	25.60	
LSD	1	T1	10.14	8.7	12.06	8.04	1.67	33.40	7.05
	2	T2	11.04	11.36	18.0	21.0	1.56	31.20	

**DAS: Days after sowing*

***T1: Butachlor 50 EC @ 1.0 kg ai/ha + One hand weeding + Second spray @ 30 Days after sowing (B1HW2S)*

****T2: Butachlor 50 EC @ 1.0 kg ai/ha (B1HW) (RPP)*

The pooled mean data also indicated that, at 30 days after sowing the least fresh weight of monocot weeds (89.49 g/m^2) was recorded with Butachlor 50 EC @ 1.0 kg ai/ha + one hand weeding + second spray at 30 days after planting (B1HW2S :T7) followed by O1HW2S (82.66 g/m^2: T4). It was on par with B1HW (100.27 no/m^2:T6) and significantly superior over rest of the treatments. The least fresh weight of dicot weeds (8.48 g/m^2) was recorded with Butachlor 50 EC @ 1.0 kg ai/ha + one hand weeding + second spray at 30 days after planting (B1HW2S :T7) followed by B1HW (8.76 g/m^2 :T6), it was on par with P1HW(T1), P1HW2S (T2), O1HW(T3), O1HW2S(T4) and significantly superior over rest of the treatments. Whereas, at 60 days after planting the least fresh weight of monocot weeds (93.33 g/m^2) was recorded with Butachlor 50 EC @ 1.0 kg ai/ha + one hand weeding + second spray at 30 days after planting (B1HW2S:T7) followed by O1HW2S (103.00g/m^2:T4), it was on par with O1HW (T3), B1HW (T6) and significantly superior over rest of the treatments. The least fresh weight of dicot weeds (1.82g/m^2)was recorded with Butachlor 50 EC @ 1.0 kg ai/ha + one hand weeding + second spray at 30 days after planting (B1HW2S:T7) followed by B1HW (2.38g/m^2:T6). Treatment B1HW2S (T7) was onpar with O1HW2S (T4) and significantly superior over rest of the treatments.

At 30 days after planting, the least dry weight of monocot weeds (32.40 g/m^2) was recorded with Butachlor 50 EC @ 1.0 kg ai/ha + one hand weeding + second spray at 30 days after planting (B1HW2S:T7) followed by O1HW2S (T4) and on par with P1HW (T1), P1HW2S (T2), O1HW (T3) B1HW (T6) and significantly superior over QE1HW2S (T5), 2HW (T8) and WC (T9). The least dry weight of dicot weeds (3.39g/m^2) was recorded with B1HW2S (T7) followed by B1HW (3.50 g/m^2:T6) and it was on par with P1HW(T1), P1HW2S (T2), O1HW (T3), O1HW2S(T4) and significantly superior over rest of the treatments. Whereas, at 60 days after planting the least dry weight of monocots (37.33 g/m^2) was recorded with Butachlor 50 EC @ 1.0 kg ai/ha + one hand weeding + second spray at 30 days after planting (B1HW2S :T7) followed by O1HW2S (41.20:T4), it was on par with P1HW(T1), P1HW2S (T2), O1HW (T3), QE1HW2S (T5), B1HW (T6) and significantly superior over rest of the treatments. The least dry weight of dicots (0.73g/m^2) was also recorded with B1HW2S (T7) followed by B1HW (0.73 g/m^2:T6). It was on par with O1HW (T3), O1HW2S (T4), and significantly superior over rest of the treatments. The reduction in total weed density and weed bio mass in herbicide treated plots might be due to the effect of herbicides, which have controlled most of the monocot (Grassy) and dicot (Broad leaf) weeds. Similar results were also reported in garlic [8,9,5] and in onion crop [10,11,12,13,14]. The treatment of the un-weeded control (WC) recorded the maximum number of monocotyledonous and dicotyledonous weeds and weed bio-mass.

3.2 Influence of Pre-Emergent Weedicides on Growth and Yield of Garlic

Spraying of herbicides helped the garlic plant growth, development and the yield. The pooled mean data indicated that, the growth (plant height and number of leaves) and yield of garlic plant was significantly influenced by weedicides (Table 4).

At 30 days after planting, the highest plant height (4.34cm) was recorded with Butachlor 50 EC @ 1.0 kg ai/ha + one hand weeding + second spray at 30 days after planting (B1HW2S :T7) followed by O1HW2S (T4) and significantly superior over rest of the treatments. Whereas, at 60 days after planting the highest plant height (16.17 cm) was recorded with B1HW2S (T7) followed by O1HW2S (14.81cm: T4) and significantly superior over rest of the treatments.

The highest number of leaves per plant (3.55, 6.57) was recorded with Butachlor 50 EC @ 1.0 kg ai/ha + one hand weeding + second spray at 30 after sowing (B1HW2S :T7) at 30 and 60 days after sowing respectively followed by O1HW2S (3.17, 6.58:T4) and significantly superior over rest of the treatments. The highest hundred clove weight (116.64 g), hundred bulb weight (912.98g), yield per plot (2056.63g) and yield per hectare (41.13 q) was recorded with Butachlor 50 EC @ 1.0 kg ai/ha + one hand weeding + second spray at 30 after sowing (B1HW2S:T7) followed by O1HW2S(T4){99.95g, 806.72g, 1767.11 g and 35.33 q/ha respectively}. It was significantly superior over rest of the treatments. These similar results are also obtained in garlic [15,8,16,17,5] and in onion crop [14,18].

The lowest yield (10.66 q/ha) was obtained in un-weeded control (WC: T9) followed by T8 (2HW: two hand weeding). This might be due to low chlorophyll content and photosynthetic rates of garlic pant due to unchecked weed growth there by reducing the availability of soil moisture, light and nutrients to the garlic crop. The effect different chemicals have been identified and listed on four bulb crops which support the present work were by use of various weedicides [19].

The phyto-toxicity effect of herbicides on garlic crop was observed and no effect was seen.

3.3 Performance of Chemical Herbicides under Farm Trails and Large Scale Demonstration

The results of farm trials conducted by four institutions at replicated locations indicated that, application of weedicide Butachlor 50 EC @ 1.0 kg ai/ha plus one hand weeding plus second spray at 30 days after sowing recorded 9 to 17 percent higher bulb yield as compared to recommended package of practices (2HW). The large scale demonstration conducted by the scientist also recorded 15 percent higher yield in the same treatment as compared to recommended package of practices (2HW) and farmers practice (Table 5).

4. CONCLUSION

Based on the results of present investigation, treatment with Butachlor 50 EC @ 1.0 kg ai/ha + second spray at 30 days after sowing + one hand weeding (B1HW2S:T7) recorded the least weed density and weed bio-mass, the highest plant height, bulb yield, gross and net returns followed by Oxyflurofen 23.5 EC @ 0.15 kg ai /ha + one hand weeding + second spray at 30 days after sowing (O1HW2S:T4). Due to non availability of labours and excessive rainfall weed growth may be more in garlic fields. Under such circumstances, pre emergent spray and an additional spray of Butachlor at 30 days after sowing + one hand weeding can be a promising alternative to effective.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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