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Influence of herbicides on weed control efficiency and economics of Garlic (*Allium sativum* L.) production

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Abstract
A field experiment was conducted during *Rabi* season of (2017-18) to study the impact of herbicides on weed control efficiency and yield attributes in Garlic (*Allium sativu*m L.) at Fruit Research Station Intkhedi Bhopal, RAK College of Agriculture, Sehore (M.P.) The investigation was carried out to study the relative impact of cultural practices and herbicides on weed control in garlic production. The result of the present investigation indicated that, the population of monocot and dicot weeds recorded the least weed density (2.0, 3.0) in treatment two hand weeding at 30 and 60 days after sowing followed by application of Quizalofop ethyl 5% EC 40 g a.i. /ha+ one hand weeding (15.20) after 30 DAS and Oxyfluorfen 23.5% EC 250 g a.i. /ha + one hand weeding (18.12, 8.00) after 30 DAS at 30, 60 and 90 days after sowing. While the highest weed population density found in control plot (132, 125). The treatment two hand weeding at 30 and 60 DAS found maximum bulb yield (86.45) and thereafter it were received from Oxyfluorfen 23.5% EC 250 g a.i. ha^{-1} + one hand weeding after 30 days after sowing (84.33) as compre to control (25.62). The B:C ratio in treatment Oxyfluorfen 23.5% EC 250 g a.i. ha^{-1} + one hand weeding after 30 days after sowing (1:60) was recorded the highest net return of 469385 ₹ ha^{-1} as compare to two hand weeding at 30 and 60 DAS which has net return of ₹ 447963 ha^{-1}. However, Control plot (without hand weeding and without use of herbicides) recorded significantly lesser B: C ratio (1.20).

Keywords: Treatments, weed density, weed control efficiency, bulb yield, DAS, B: C ratio

Introduction
Garlic (*Allium sativum* L.) an herbaceous annual vegetable crop of family Alliaceae, is the second most valuable bulb crop after Onion crop an important spice crop cultivated in India since ancient time. China is the leading garlic producing country accounting for over 75% of world output followed by India, Egypt, Russia, Myanmar, Ethiopia and USA (FAO, 2010) [2]. The bulb comprises many pungent cloves. In India, Madhya Pradesh is the leading producer of garlic followed by Gujarat (Area, production and productivity of garlic in Jammu and Kashmir, 2011) [1]. Madhya Pradesh ranks second in garlic production grown in an area of 92.50 thousand hectares with production of 405.00 thousand MT and productivity of 4.38 tones $hectare^{-1}$. Indore, Ratlam, Neemuch, Shajapur, Ujjain and Sehore are the major garlic producing districts of Madhya Pradesh. 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 (Rahman *et al.*, 2012) [8]. The garlic is closely planted crop with very small canopy. Weeds are mostly managed by human labour, which is tedious time taking and expensive operation and often damages the crop (Sampat *et al.*, 2014) [9]. The weeds compete for the nutrients, moisture, space and light and finally affect growth and development. Weed reduces the bulb yield to the extent of 40-80% (Verma and Singh, 1996) [11] therefore, it is essential to keep the field weed free during the critical period of crop growth. As garlic is commercial crop, farmers invest more money through costly inputs like seed material, fertilizers, plant protection schedule and irrigation for achieving higher yield. Hence, the present investigation was carried out to test the efficacy of herbicides either as pre-emergence spray and post emergence 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 for obtaining better garlic bulb yield.

Materials and Methods

A field experiment was conducted at Fruit Research Station Intkhedi Bhopal, RAK College of Agriculture, Sehore (M.P.) during the *Rabi* season, 2017-18 on medium black (Vertisol) soil. The experiment was laid out using ten different treatments in randomized block design, *viz.*, $Treatment_1$ - Control plot (without hand weeding and without use of herbicides), $Treatment_2$ – Twice hand weeding at 30 and 60 days after sowing, $Treatment_3$ - Pendimethalin 30% EC 1.5 kg a.i.ha^{-1} (pre-emergence), $Treatment_4$ - Pendimethalin 30% EC 1.5 kg a.i. ha^{-1} + one hand weeding after 30 days after sowing, $Treatment_5$ - Quizalofop ethyl 5% EC 40 g a.i. ha^{-1} 25 days after sowing (post- emergence), $Treatment_6$ - Quizalofop ethyl 5% EC 40 g a.i. ha^{-1} + one hand weeding after 30 days after sowing, $Treatment_7$ - Oxadiargyl 80% WP 100 g a.i. ha^{-1} (pre-emergence), $Treatment_8$ - Oxadiargyl 80% WP 100 g a.i. ha^{-1} + one hand weeding after 30 days after sowing, $Treatment_9$ - Oxyfluorfen 23.5% EC 250 g a.i. ha^{-1} (pre-emergence), $Treatment_{10}$ - Oxyfluorfen 23.5% EC 250 g a.i. ha^{-1} + one hand weeding after 30 days after sowing with three replications. All other crop production practices was adopted during growing season. The observations were recorded on number of monocot, dicot and population of total weeds (m^{-2}) at 60 and 90 DAS and weed control efficiency of different treatments. At maturity, the garlic bulbs were harvested and the weight of 20 cloves (g), bulb yield (g $plant^{-1}$) and bulb Yield (q ha^{-1}) was recorded. The benefit cost ratio was worked out by considering the cost of cultivation and gross monetary returns. The mean data obtained on various treatments were statistically analyzed for all characters as per standard procedure given by (Panse and Sukhtme, 1989) [7].

Results and Discussion

Influence of herbicides on weed density (m^{-2})

The influence of different treatments with pre and post herbicides on the weed density was noticed significant at 60 and 90 DAS is presented in (Table 1, Fig. 1, 2). Result revealed that the density of monocot weeds was found cheapest in treatment 2 hand weeding at 60 and 90 days after sowing (2.01and 2.20) and thereafter results were received from application of Quizalofop ethyl 5% EC 40 g a.i. ha^{-1} days after sowing (post-emergence) + One hand weeding after 30 days after sowing (2.16 and 2.28)and Oxyfluorfen 23.5% EC 250 g a.i. ha^{-1} (pre-emergence) + One hand weeding after 30 days after sowing (2.38 and 2.51) at 60 and 90 days after sowing. While it had maximum value for control plot(12.80, 13.49). Similarly the influence of different treatments with pre and post herbicides on the density of dicot weeds was show significant at 60 and 90 DAS is presented in (Table 1, Fig 2). The lowest density of dicot weed was found in treatment with twice hand weeding at 30 and 60 days after sowing (2.06, 1.81) followed by treatment Oxyfluorfen 23.5% EC 250 g a.i. /ha + one hand weeding after 30 DAS (2.35, 1.88) and treatment Oxadiargyl 80% WP 100 g a.i. /ha + one hand weeding after 30 DAS (2.59, 2.15) as compare to control (11.74, 13.07). After two hand weeding treatments at 30 and 60 DAS, the crop became almost weed-free, and provided a good environment for the growth and development of crop plants. Due to the effect of this treatment, weeds have to compete with plants again for sunlight, soil moisture; nutrients and suitable space and they did not regenerate. Such results were also obtained by Farag *et al.* (1994) [3], and Naresh *et al.* (2002) [5].

Influence of herbicides on total weed density (m^{-2})

All different treatments with pre and post herbicides significantly influenced the total weed density recorded at 60 and 90 days after sowing of crop is presented in (Table 1, Fig. 3). Two hand weeding after 30 and 60 days of sowing, the total density of weed was found to be significantly lowest at 60 and 90 days after sowing (2.88, 2.85) and thereafter results were received from Oxyfluorfen 23.5% EC 250 g a.i. ha^{-1} (pre-emergence) + one hand weeding after 30 days of sowing at 60 and 90 days after sowing (3.34, 3.14) and treatment Pendimethalin 30% EC 1.5 kg a.i. /ha + one hand weeding after 30 DAS (3.54, 3.58). While it maximum value recorded for control (17.37, 18.78). Significant reduction in the number of weeds at all stages of the crop has been observed treatment one hand weeding treatment at 30 and 60 days after sowing as compared to control plot. Treatments Oxyfluorfen 23.5% EC 250 g a.i. ha^{-1} (pre emergence) + one-hand weeding after 30 day of sowing and Pendimethalin 30% EC 1.5 kg a.i. /ha (pre-emergence) + one hand weeding after 30 DAS successfully controlled the second plus of weeds that to be emerged in the later stage of crop development. These finding are similar with Porwal and Singh (1993) [6] in onion and Vora and Mehta (1999) [12] in garlic.

Table 1: Influence of herbicides on weed density, total weed density and WCE (%) in Garlic (*Allium sativum* L.)

Treatments	Weed density (m^{-2})				Total weed density (m^{-2})		WCE (%) At harvest
	Monocot		Dicot				
	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS	
T_1	164 (12.80)	182 (13.49)	138 (11.74)	171 (13.07)	102 (17.37)	153 (18.78)	0.00
T_2	4.05 (2.01)	4.85 (2.20)	4.25 (2.06)	3.30 (1.81)	8.30 (2.88)	8.15 (2.85)	94.67
T_3	24.67 (4.96)	15.34 (3.91)	33.10 (5.75)	28.67 (5.35)	57.77 (7.60)	44.01 (6.63)	71.23
T_4	6.21 (2.49)	7.36 (2.71)	7.25 (2.69)	5.50 (2.34)	12.55 (3.54)	12.86 (3.58)	91.59
T_5	16.15 (4.01)	11.85 (3.44)	35.40 (5.94)	31.10 (5.57)	51.55 (7.17)	62.95 (7.93)	58.85
T_6	4.70 (2.16)	5.22 (2.28)	7.85 (2.80)	5.10 (2.25)	13.46 (3.66)	26.32 (5.13)	82.79
T_7	38.65 (6.21)	32.37 (5.68)	27.30 (5.22)	24.14 (4.91)	65.95 (8.12)	56.51 (7.51)	63.06
T_8	9.35 (3.05)	10.31 (3.21)	6.75 (2.59)	4.63 (2.15)	16.10 (4.01)	14.94 (3.86)	90.23

T_9	19.65 (4.43)	13.45 (3.66)	11.30 (3.36)	8.15 (2.85)	30.95 (5.56)	21.60 (4.64)	85.88
T_{10}	5.67 (2.38)	6.35 (2.51)	5.53 (2.35)	3.54 (1.88)	11.20 (3.34)	9.89 (3.14)	93.53
S.Em±	2.66	1.74	2.8	1.46	2.3	0.8	-
CD 5%	4.866	3.920	4.984	3.636	4.571	2.658	-

T_1: Control plot (without hand weeding and without use of herbicides).
T_2: Two hand weeding at 30 and 60 days after sowing.
T_3: Pendimethalin 30% EC 1.5 kg a.i. /ha (PE).
T_4: Pendimethalin 30% EC 1.5 kg a.i. /ha + one hand weeding after 30 DAS.
T_5: Quizalofop ethyl 5% EC 40 g a.i. /ha 25 DAS (PoE).
T_6: Quizalofop ethyl 5s% EC 40 g a.i. /ha + one hand weeding after 30 DAS.
T_7: Oxadiargyl 80% WP 100 g a.i. /ha (PE).
T_8: Oxadiargyl 80% WP 100 g a.i. /ha + one hand weeding after 30 DAS.
T_9: Oxyfluorfen 23.5% EC 250 g a.i. /ha (PE).
T_{10}: Oxyfluorfen 23.5% EC 250 g a.i. /ha + one hand weeding after 30 DAS

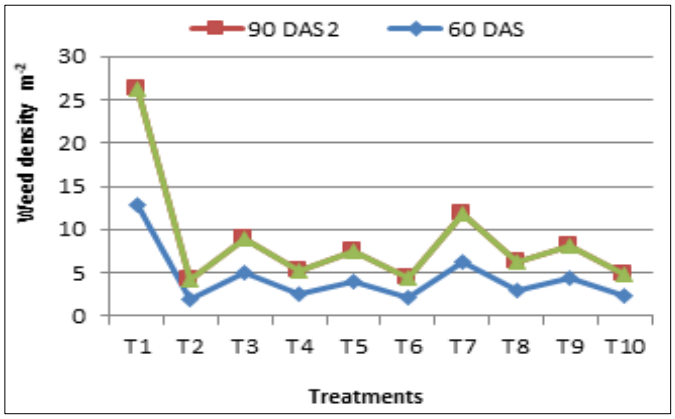

Fig 1: Influence of herbicides on weed density (m^{-2}) of monocot weed

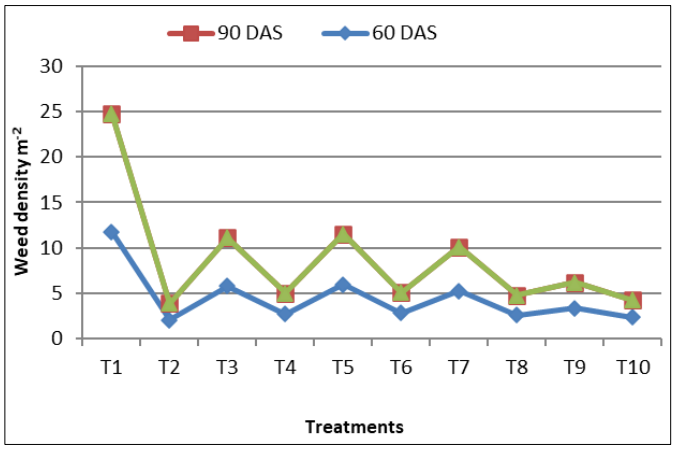

Fig 2: Influence of herbicides on weed density (m^{-2}) of dicot weed

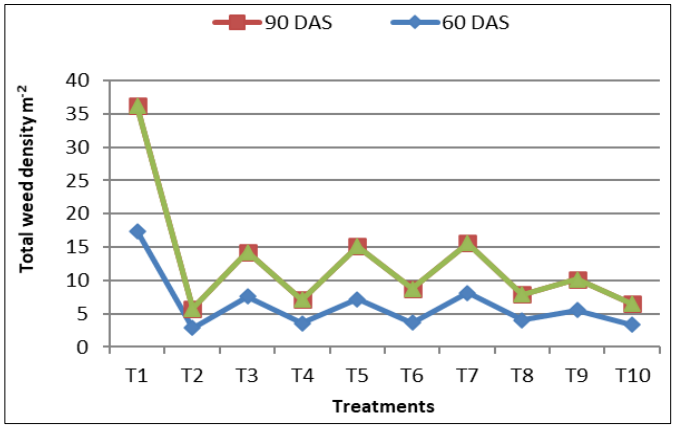

Fig 3: Influence of herbicides on total weed density (m^{-2})

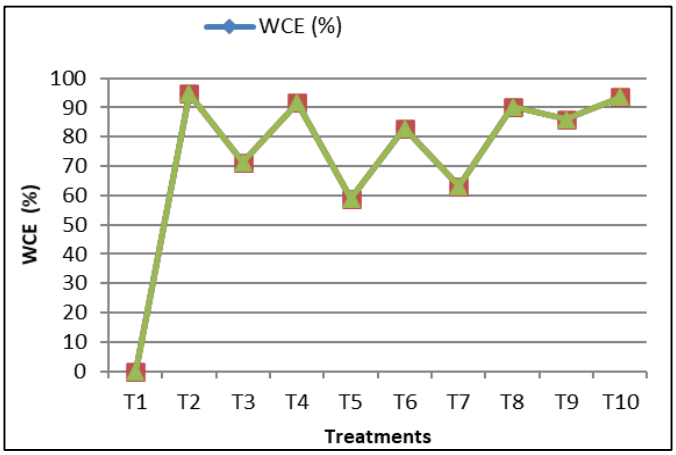

Fig 4: Influence of herbicides on WCE (%)

Influence of herbicides on weed control efficiency (%)

The data pertaining to weed control efficiency of all treatments are given in (Table 1, Fig. 4) The highest weed control efficiency (94.67%) was found under the treatment of two hands weeding at 30 and 60 DAS and thereafter it was received from Oxyfluorfen 23.5% EC 250 g a.i. ha^{-1} (pre-emergence) + single hand weeding after 30 DAS (93.53%) and treatment Pendimethalin 30% EC 1.5 kg a.i. ha^{-1} (pre-emergence) + single hand weeding after 30 DAS (91.59%).

Influence of herbicides on bulb yield

The bulb yield (g $plant^{-1}$) and bulb yield (q ha^{-1}) at harvest of the crop is presented in (Table 2) which revealed that harvested bulb yield (g $plant^{-1}$) and bulb yield (q ha^{-1}) of garlic was significantly affected by treatments. The treatment two hand weeding at 30 and 60 DAS found maximum bulb yield (g $plant^{-1}$) and bulb yield (q ha^{-1}) (45.78, 86.45) and thereafter it was received from Oxyfluorfen 23.5% EC 250 g a.i. ha^{-1} + one hand weeding after 30 days after sowing (45.40, 84.33). The lowest bulb yield (g $plant^{-1}$) and bulb yield (q ha^{-1}) (28.10, 25.62) was found in control plot treatment. Similar finding have been reported by Sandhu *et al.* (1997) [10] in Garlic (*Allium sativum* L.)

Influence of herbicides on benefit: cost ratio

Benefit cost ratio was worked out by considering the cost of cultivation and gross monetary returns. The data concerned to cost of cultivation of garlic crop, net income, and benefit cost ratio for the influence of herbicides benefit: cost ratio has been presented in (Table 2 Fig. 5). The B:C ratio was recorded higher in the treatment of Oxyfluorfen 23.5% EC 250 g a.i. ha^{-1} + one hand weeding after 30 days after sowing

(1:60) with the highest net return of 469385 ₹ ha^{-1}. This could be attributed to lower cost of cultivation in this herbicide as compare to two hand weeding at 30 and 60 DAS which has given of net return ₹ 447963 ha^{-1}. Moreover, Control plot (without hand weeding and without use of herbicides) recorded significantly lesser B:C ratio (1.20) due to lower bulb yield owing to more crop weed competition. This could be due to more cost of cultivation increased remarkably due to frequent weeding operations followed by clean cultivation. Similar findings were recorded by Varmani *et al.* (2002) [13], Sampat *et al.* (2014) [9] in garlic and Kalhapure and Shete (2013) [4] in onion crop.

Table 2: Influence of herbicides on economics of Garlic

Treatments	Bulb yield (g plant^{-1})	Bulb yield (q ha^{-1})	Gross return (65 ₹/kg)	Cost of cultivation (₹/ha)	Net Income (₹/ha)	B:C Ratio
T_1	28.10	25.62	166530	82682	109468	1:2.0
T_2	45.78	86.45	548145	100182	447963	1:5.4
T_3	33.20	40.62	264030	85382	178648	1:3.0
T_4	35.55	53.54	348010	94132	253878	1:3.6
T_5	30.25	31.25	203125	84282	118843	1:2.4
T_6	35.40	46.87	304655	93032	211623	1:3.2
T_7	31.78	53.12	345280	85482	259798	1:4.0
T_8	39.51	73.95	480675	94232	386443	1:5.1
T_9	36.70	68.75	446875	83790	363085	1:5.3
T_{10}	45.40	84.33	561925	92540	469385	1:6.0
S.Em±	2.70	2.72	-	-	-	-
CD 5%	6.14	4.90	-	-	-	-

Price: Pendimethalin 30 EC ₹ 135 /250 ml, Quizalofop-p-ethyl 5 EC ₹ 200 /100 ml, Oxadiargyl 80% WP ₹ 195 /22 g, Oxyfluorfen 23.5% EC ₹ 140 /50 ml, labor charge ₹ 250 day^{1}, 35 labor ha^{-1} for hand weeding, 4 labor day^{-1} for spraying ha^{-1}.

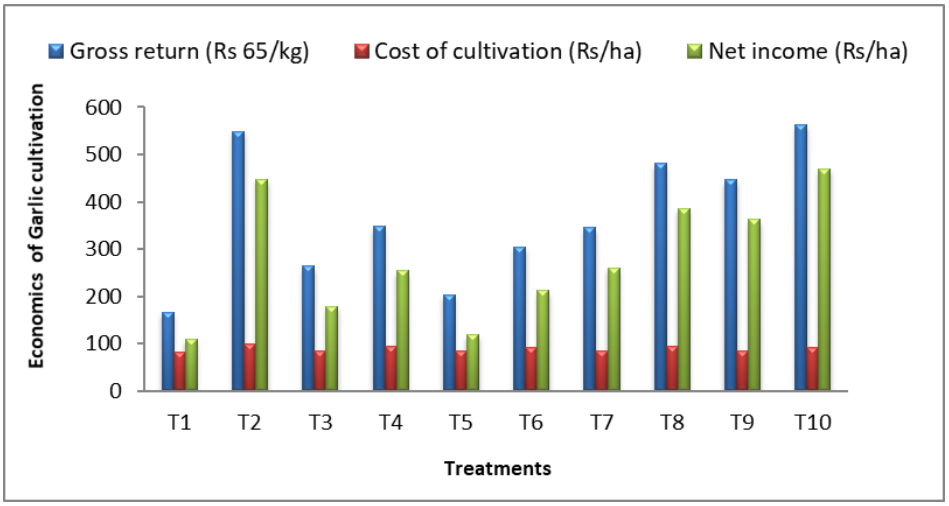

Fig 5: Influence of herbicides on economics of Garlic

Conclusion

As a result, in this study it has been found that to achieve good bulb yield and yield quality, it is found best to apply two hand weeding 30 and 60 DAS and the highest weed control efficiency was recorded under the treatment of two hand weeding at 30 and 60 DAS and thereafter results were received from Oxyfluorfen 23.5% EC 250 g a.i. ha^{-1} (pre-emergence) + single hand weeding after and treatment Pendimethalin 30% EC 1.5 kg a.i. ha^{-1} (pre-emergence) + single hand weeding after 30 DAS. The B:C ratio was exhibited higher in the treatment Oxyfluorfen 23.5% EC 250 g a.i. ha^{-1} + one hand weeding after 30 days after sowing (1:60) with the highest net return of 469385 ₹ ha^{-1}. This could be attributed to lower cost of cultivation in this herbicide as compare to two hands weeding at 30 and 60 DAS which has given net return of ₹ 447963 ha^{-1}. Moreover, Control plot (without hand weeding and without use of herbicides) recorded significantly lesser B: C ratio (1.20) due to lower bulb yield owing to more crop weed competition. Thus appropriate choice for weed control in Garlic would be an integration of cultural and herbicidal control combination for boosting the Garlic production.

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