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RESEARCH ARTICLE

Integrated approach to manage the complex weed flora in garlic

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ABSTRACT

A field experiment was conducted during *Rabi* seasons (2014-15 and 2015-16) at AICRP-Weed Management, GBPUA&T, Pantnagar, to evaluate the effect of integration of different herbicides and mulching on weeds, yield and economics of garlic. The experiment involved the integration of two mulch treatments in the main plot (with and without rice straw mulch) and four weed management treatments replicated thrice in a split-plot design. The weed density and biomass, weed control efficiency, plant growth parameters and garlic bulb yield varied significantly amongst tested weed management treatments. During both the years, grassy and non-grassy weed density was significantly reduced with rice straw mulch 5 t/ha integration with different herbicides compared to without mulch. The pre-emergence application (PE) of oxyflurofen 0.223 kg/ha recorded lowest density and biomass of all the weeds. The rice straw mulch 5 t/ha resulted in significantly the highest garlic yield (2.95 and 4.25 t/ha); net returns (₹ 1,75850 and 2,80250/ha and B:C (2.9 and 4.7), during both the years, respectively. Among herbicides, oxyflurofen 0.223 kg/ha PE recorded the highest net returns (₹ 1,31700 and 2,04100/ha) and B:C (2.4 and 3.7) during both the year, respectively.

Keywords: Garlic, Herbicides, Integrated weed management, oxyfluorfen, Mulchng

INTRODUCTION

Garlic (*Allium sativum* L.) is cultivated commercially throughout the tropical and subtropical region of the world. It is one of the oldest cultivated spices and is next to onion in production. Although India stands second in area and production of garlic but its productivity (5.69 t/ha) is strikingly far below China and Egypt (National Horticulture Board advanced Estimates for 2015). India produced 2,916,970 tonnes of garlic from 362,950 hectares cultivated area with 8,037 kg/hectare yield during 2019-20 (Spices Board India, Ministry of Commerce and Industry, Government of India). Garlic grows best in well drained fertile soils that are high in organic matter. Incorporating compost or well-rotted manure into heavy soils will result in the soil being friable and suitable for production. Like onion, garlic is sensitive to highly acidic, alkali and saline soils and water logging conditions (Khade *et al.* 2017). It requires cooler weather during the early stages of growth and dry atmosphere with moderately high temperature for maturation.

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Garlic is highly vulnerable to weed infestation, due to its slow emergence. Weed infestation is the major factor responsible for reduction in bulb yield upto 30-60% (Lawande *et al.* 2009). Garlic is a closely planted crop with very small canopy, non-branching habit, sparse foliage and shallow root system with requirement for frequent irrigation and high fertilizer application, which aid to weed species occurrence with variation and abundance which hamper the growth and yield of crop (Sahoo *et al.* 2018). A single hand weeding is not sufficient to control weeds in garlic due to its longer crop duration. These factors necessitate the reliance on herbicides for an effective and timely control of weeds in garlic (Kumar *et al.* 2013). Often, due to shortage of labour, high wages and unexpected rains, hand weeding and mechanical operations are either delayed or not implemented at all. The herbicidal weed management in garlic becomes much more important under such situations (Sampat *et al.* 2014, Chaudhary *et al.* 2019) as herbicides are most practical, effective and economical method to control weed and increasing bulb yield of garlic crop (Siddhu *et al.* 2018). However, continuous and intensive use of herbicide over a period of time leads to development of resistant biotypes within the weed community (Shibayama 2001). To overcome these problems, there is need to reduce the reliance on synthetic herbicides and shift to low-input sustainable means of weed management, which are eco-friendly (Farooq *et al.* 2011). In this respect, mulching is an agricultural and horticultural technique, not only increase bulb yield but also improve some quality indices such that ash percent, TSS and vitamin C in garlic bulb and create congenial condition for crop growth by regulating soil moisture and temperature, reducing salinity and controlling the weeds (Slam *et al.* 2007; Najafabadia *et al.* 2012). Among organic mulching materials, straw makes good mulch as straw suppresses weeds conserves moisture and retain in soil for longer period (Close 2017; Slam *et al.* 2007).

Thus, this study was conducted to quantify the efficacy of new herbicides and paddy straw mulch used either alone or in combination at different times to manage weeds and improve garlic yield.

MATERIALS AND METHODS

A field experiment was conducted during *Rabi* seasons of 2014-15 and 2015-16, at Norman E. Borlaugh Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The experimental site was situated at 29^0N latitude, 27.3^0E longitude and at an altitude of 243.8 MSL in subtropical climatic condition of Himalaya foot hill of Uttarakhand. The soil of the experiment was loamy, medium in organic carbon (0.67%), available nitrogen (210 kg/ha), phosphorus (17.5 kg/ha) and potassium (181.2 kg/ha) with a pH value of 7.5. During the growing period, the temperature ranged 11.6-25.0 ^{0}C and total rainfall was 206.9 mm in *Rabi* season of 2014-15 and the temperature range was 12.7-28.3 ^{0}C and the total rainfall 33.2 mm in *Rabi* season of 2015-16.

Garlic variety white "*Nashik*" was planted on Nov. 8th and Oct. 26th, during *Rabi* season of 2014-15 and 2015-16, respectively. The experiment was laid out in split-plot design with three replications. There were eight treatments consisting of two mulch treatments in main plots (with and without rice straw mulch) and four weed control treatments in sub-plot *viz*. recommended herbicides (pre-emergence application (PE) of pendimethalin 1.0 kg/ha, oxyfluorfen 0.223 kg/ha), hand weeding twice at 25 and 45 days after seeding (DAS) and unweeded (control). Pre-emergence application of herbicides was done on Nov. 10th, 2014 and Oct. 28th, 2015 by using knap-sac sprayer fitted with boom along with flat-fan nozzle and the crop was harvested on April 15th 2014 and 20th 2015 during *Rabi* season of 2014-15 and 2015-16, respectively.

Density and biomass of dominated weed species was recorded at 75 DAS. For recording both, density and biomass of the weeds a quadrat of 0.25 m^2 was placed randomly at two places in each of the plots and weeds were counted and biomass was estimated using standard procedure. The data are presented on per m^2 basis. The relative weed density and weed control efficiency was calculated according to the method given by Moinuddin *et al.* (2018). The yield and yield attributes were recorded at harvest and converted to per hectare.

Relative weed density (%)

The relative weed density in weedy check plots was estimated at 75 DAS during both the years (**Table 1**) by following formula:

$$\text{Relative weed density (\%)} = \frac{\text{Total number of individual weed species}}{\text{Total number of all weed species}} \times 100$$

RESULTS AND DISCUSSION

Effect on weeds

The dominant weed species in the experimental plot were. *Phalaris minor*, *Avena ludoviciana*, *Polypogon monspeliensis* among grasses, *Medicago denticulata*, *Melilotus alba*, *Coronopus didymus*, *Polygonum plebeium*, *Chenopodium album*, *Anagallis arvensis*, *Rumex acetosella*, *Fumaria parviflora* among BLWs and *Cyperus rotundus* as sedge. The *Coronopus didymus* and *Phalaris minor* had the highest relative density during both the years, respectively (**Table 1)**.

Table 1. Relative density of weeds at 75 days after seeding in weedy plot

Weed Species	Relative weed density (%)	
	2014-15	2015-16
Grasses		
Phalaris minor	18.6	56.2
Avena ludoviciana	3.0	1.4
Polypogon monspeliensis	14.7	6.0
Broad-leaved weeds		
Medicago denticulata	6.6	4.6
Melilotus alba	6.3	2.6
Coronopus didymus	25.6	10.8
Polygonum plebeium	12.5	7.7
Chenopodium album	3.4	5.2
Anagallis arvensis	1.7	1.2
Rumex acetosella	2.0	0.9
Fumaria parviflora	1.3	1.3
Sedge		
Cyperus rotundus	4.4	2.1

Among grasses, the lowest density of *P. minor*, *A. ludoviciana* and *P. monspeliensis* was recorded with straw mulch 5 t/ha during *Rabi* 2014-15 at 75 DAS. However, during 2015-16, the density of *P. minor* and *P. monspeliensis* was not significantly affected due to mulch treatments. *P. monspeliensis* was completely controlled with pendimethalin 1.0.kg/ha PE during both the *Rabi* seasons. The lowest density of *P. minor* and *A. ludoviciana* was recorded with pendimethalin 1.0 kg/ha PE during *Rabi* 2014-15 and with oxyfluorfen 0.223 kg/ha PE during *Rabi* 2015-16 and both treatments were found at par to each other with respect to reducing the density of grasses **(Table 2)**.

Among the broad-leaved weeds, the density of *F. parviflora* and *R. acetosella* during *Rabi* 2014-15 and of *M. denticulata*, *M. alba*, *C. didymus* and *C. album* during *Rabi* 2015-16 was not significantly influenced with mulching. However, the lowest weed density of *M. denticulata*, *M. alba*, *C. didymus*, *P. plebeium*, *F. parviflora*, *R. acetosella*, *C. album* and *A. arvensis* was recorded with straw mulch 5 t/ha during both the *Rabi* seasons. Among sub plot treatments, pendimethalin 1.0 kg/ha PE and oxyfluorfen at 0.223 kg/ha PE had completely controlled *P. plebeium*, *C. album*, *A. arvensis* and *R. acetosella* during both the seasons. The lowest density of *M. denticulata* and *C. didymus* was recorded with oxyfluorfen 0.223 kg/ha PE and of *M. alba* with pendimethalin 1.0 kg/ha PE during both the seasons **(Table 3)**.

The density of sedge; *C. rotundus* was not significantly influenced by straw mulch 5 t/ha during *Rabi* 2014-15 but it recorded the lowest density with straw mulch 5 t/ha during *Rabi* 2015-16. Among the herbicidal treatments the lowest density of *C. rotundus* was recorded with oxyfluorfen 0.223 kg/ha PE during both the seasons **(Table 4)**. Effective control of all the weeds with mulching indicates the weed suppression effectiveness of rice straw (Chaudhary *et al.* 2019). Mulch controls the weeds by smothering seedlings, prevent day light which

Table 2. Effect of treatments on weed density of grasses at 75 DAS

Treatment	Weed density (no./m^2)					
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
	P. minor		*A. ludoviciana*		*P. monspeliensis*	
Mulching						
Without straw mulch	4.1 (21.3)	6.5(69.7)	3.0(9.7)	2.3(5.2)	3.1(20.7)	2.4(9.6)
Rice straw mulch (5 t/ha)	2.9(14.0)	4.6(51.8)	2.2(4.5)	1.7(2.2)	1.8(3.0)	1.9(3.3)
LSD (p=0.05)	0.4	NS	0.2	0.67	0.7	NS
Weed management						
Pendimethalin 1.0 kg/ha	2.4(6.0)	3.2(10.3)	3.4 (10.7)	2.4(5.0)	1.0(0.0)	1.0(0.0)
Oxyfluorfen 0.223 kg/ha	2.8(8.0)	3.3(14.7)	3.1(8.7)	2.3(4.3)	1.2(0.7)	1.2(0.6)
Manual weeding (25 and 45 DAS)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.6(2.0)	1.6(2.0)
Weedy check	7.6(56.7)	14.8(218.0)	3.1(9.0)	2.5(5.3)	6.0(44.7)	4.7(23.3)
LSD (p=0.05)	0.4	0.59	0.3	0.35	0.5	0.61

*DAS: Days after sowing; NS: Non-significant; Values in parentheses were original and transformed to $(\sqrt{x+1})$ for analysis

Table 3. Effect of treatments on weed density of broad-leaved weeds at 75 DAS

Treatment	Weed density (no./m^2)															
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
	M. denticulata		*M. alba*		*C. didymus*		*P. plebeium*		*C. album*		*A. arvensis*		*R. acetosella*		*F. parviflora*	
Mulching																
Without straw mulch	5.0 (25.0)	3.8 (16.0)	3.9 (16.7)	6.5 (64.6)	6.3 (44.3)	4.8 (24.6)	3.3 (19.7)	2.7 (12.5)	1.8 (4.3)	2.1 (7.3)	1.5 (2.0)	1.4 (1.7)	1.6 (2.3)	1.4 (1.3)	1.3 (1.0)	1.5 (1.7)
Rice Straw mulch (5 t/ha)	2.7 (7.3)	2.2 (5.0)	3.1 (9.7)	2.6 (11.3)	4.5 (25.7)	3.2 (11.3)	1.9(4.0)	2.2 (5.5)	1.3 (0.8)	1.6 (2.7)	1.2 (0.7)	1.2 (0.7)	1.5 (1.3)	1.0 (0.0)	1.4 (1.3)	1.6 (2.0)
LSD (P=0.05)	0.7	NS	0.7	NS	1.4	NS	0.4	0.35	0.2	NS	0.2	0.26	NS	0.22	NS	0.18
Weed management																
Pendimethalin 1.0 kg/ha	4.8 (24.0)	3.7 (13.7)	2.4 (4.7)	2.0 (3.7)	4.2 (18.7)	3.5 (12.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
Oxyfluorfen 0.223 kg/ha	3.1 (12.0)	2.9 (10.3)	5.1 (26.0)	5.6 (46.3)	2.9 (10.0)	2.6 (7.3)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.2 (0.7)	1.8 (2.3)
Hand weeding (25 and 45 DAS)	3.0 (8.7)	1.0 (0.0)	1.9 (2.7)	1.0 (0.0)	5.8 (33.3)	3.4 (10.7)	3.2 (9.3)	2.6 (6.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.5 (1.3)	1.1 (0.3)	1.0 (0.0)	1.0 (0.0)
Weedy check	4.5 (20.0)	4.3 (18.0)	4.4 (19.3)	9.6 (100.2)	8.8 (78.0)	6.5 (42.0)	5.4 (38.0)	5.4 (30.0)	3.2 (10.3)	4.5 (20.0)	2.5 (5.3)	2.3 (4.7)	2.6 (6.0)	2.1 (3.7)	2.2 (4.0)	2.4 (5.0)
LSD(p=0.05)	0.5	0.28	0.5	1.3	0.7	0.51	0.2	0.34	0.8	0.25	0.1	0.16	0.2	0.22	0.2	0.13

*DAS: Days after sowing; NS: Non-significant; Values in parentheses were original and transformed to $(\sqrt{x+1})$ for analysis

Table 4. Effect of treatments on density of sedges at 75 DAS

Treatment	Weed density (no./m^2)	
	2014-15	2015-16
	C. rotundus	
Mulching		
Without straw mulch	3.7(17.3)	3.3(12.3)
Rice Straw mulch (5 t/ha)	3.6(13.0)	2.3(4.8)
LSD (p=0.05)	NS	0.6
Weed management		
Pendimethalin 1.0 kg/ha	6.0(36.0)	4.2(18.3)
Oxyfluorfen 0.223 kg/ha	3.1(8.7)	3.0(8.0)
Hand weeding (25 and 45 DAS)	1.8(2.7)	1.0(0.0)
Weedy check	3.7(13.3)	3.0(8.0)
LSD(p=0.05)	0.5	0.31

*DAS: Days after sowing; NS: Non-significant; Values in parentheses were original and transformed to $(\sqrt{x+1})$ for analysis

helps faster germination from reaching weed seeds and prevents airborne seeds from taking hold on the soil surface (Amoroso *et al*. 2009). Better control of weeds with oxyfluorfen and pendimethalin in garlic was reported earlier (Shashidhar *et al*. 2013).

Weed biomass and weed control efficiency

The straw mulch 5 t/ha could not significantly reduce the grassy weed biomass during *Rabi* 2014-15 and of BLW's during *Rabi* 2015-16. However, the sedges biomass was significantly reduced by mulching (5 t/ha) during both the years. Sub plot treatments had significant effect on grasses and non-grasses weeds. Among herbicidal treatments, oxyfluorfen 0.223 kg/ha PE caused lowest biomass of all weed categories during both the seasons except of broad-leaved weeds during *Rabi* 2015-16 whereas pendimethalin 1.0 kg/ha PE recorded lowest weed biomass at 75 DAS **(Table 5).** The dry biomass of total weeds was recorded significantly lower under straw mulch 5.0 t/ha spread after planting as mulch smothered weed seedlings, prevented day light from reaching weed seeds and prevented airborne seeds from taking hold on the soil surface. Further, significantly the lowest density and biomass of total weeds was recorded with hand weeding at 25 and 45 DAS due to removal of weeds manually at 25 and 45 DAS. Further, oxyfluorfen 0.223 kg/ha PE proved superior over pendimethalin 1.0 kg/ha PE with respect to reducing density and biomass of weeds at 75 DAS confirming findings of Sampat *et al.* (2014) and Malik *et al*. (2017). The highest weed density and biomass was observed under weedy check due to absence of weed control practices.

The straw mulch 5 t/ha did not reduce the total biomass significantly at 75 DAS during both the seasons. However, oxyfluorfen 0.223 kg/ha PE recorded the lowest total weed biomass. The highest weed control efficiency was recorded with straw

Table 6. Effect of treatments on total weed biomass and weed control efficiency (%) at 75 DAS

Treatment	Total weed biomass (g/m^2)		Weed control efficiency (%)	
	2014-15	2015-16	2014-15	2015-16
Mulching				
Without straw mulch	13.4 (205.8)	13.1 (229.5)	24.7	40.2
Rice straw mulch (5 t/ha)	12.0 (160.5)	10.5 (146.4)	32.6	52.1
LSD (p=0.05)	NS	NS	-	-
Weed management				
Pendimethalin 1.0 kg/ha	15.2 (230.7)	11.5 (134.3)	14.6	47.5
Oxyfluorfen 0.223 kg/ha	11.8 (148.3)	10.7 (125.4)	34.5	51.1
Hand weeding (twice)	5.9 (35.1)	3.1 (9.6)	66.9	85.8
Weedy check	17.8 (318.5)	21.9 (482.6)	-	-
LSD (p=0.05)	1.0	0.9		-

*DAS: Days after sowing; NS: Non-significant; Values in parentheses were original and transformed to $(\sqrt{x+1})$ for analysis

Table 5. Effect of treatments on weed biomass of grasses, broad-leaved weeds (BLW's) and sedges at 75 DAS

Treatment	Grasses weed biomass (g/m^2)		BLWs weed biomass (g/m^2)		Sedges weed biomass(g/m^2)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Mulching						
Without straw mulch	10.3(136.4)	10.8(165.0)	7.3(57.7)	7.0(57.8)	3.5(11.7)	2.6(6.6)
Rice straw mulch (5 t/ha)	9.8(120.5)	9.3(120.0)	5.7(13.0)	4.3(24.1)	2.7(6.6)	1.8(2.4)
LSD (p=0.05)	NS	0.78	0.7	NS	0.3	0.49
Weed management						
Pendimethalin 1.0 kg/ha	12.8(164.9)	10.0(100.0)	6.9(50.4)	4.8(25.4)	4.0(15.4)	3.0(8.5)
Oxyfluorfen 0.223 kg/ha	9.9(100.3)	8.6(76.1)	6.3(44.3)	5.8(45.6)	2.2(3.7)	2.1(3.7)
Hand weeding (twice)	1.7(2.6)	1.7(2.5)	4.9(25.5)	2.7(7.1)	2.7(6.9)	1.0(0.0)
Weedy check	15.7(245.8)	19.8(391.2)	7.9(62.3)	9.2(85.6)	3.3(10.4)	2.5(5.8)
LSD (p=0.05)	1.0	0.73	0.6	0.75	0.3	0.22

*DAS: Days after sowing; NS: Non-significant; Values in parentheses were original and transformed to $(\sqrt{x+1})$ for analysis

Table 7. Effect of treatments on yield and yield attributing characters of garlic

Treatment	Bulb/m^2		Bulb diameter (cm)		No. of cloves/bulb		Bulb weight(g)		Bulb yield (t/ha)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Mulching										
Without straw mulch	11.9	14.7	6.9	7.8	11.5	15.0	8.8	9.6	1.25	1.78
Rice Straw mulch (5 t/ha)	19.5	30.7	8.4	8.6	13.5	18.4	13.4	12.4	2.95	4.25
LSD (p=0.05)	7.3	8.8	0.2	1.1	NS	2.3	0.6	NS	0.79	1.21
Weed management										
Pendimethalin 1.0 kg/ha	15.7	24.0	8.3	8.2	13.1	16.6	12.7	11.5	2.26	3.07
Oxyfluorfen 0.223 kg/ha	16.6	24.2	8.8	8.9	13.7	18.9	12.8	12.1	2.33	3.23
Hand weeding (25 and 45 DAS)	27.7	39.3	8.6	9.6	12.9	20.6	13.4	14.1	3.65	5.55
Weedy check	2.9	3.3	4.9	6.1	10.5	10.7	5.5	6.2	0.17	0.21
LSD (p=0.05)	3.1	3.9	0.7	0.8	NS	3.0	1.2	0.7	0.29	0.59

*DAS: Days after sowing; NS: Non-significant

Table 8. Economics of garlic crop as influenced by mulching and weed management practices

Treatment	Cost of cultivation (x10^3 `/ha)		Gross returns (x10^3 `/ha)		Net returns (x10^3 `/ha)		B:C	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Mulching								
Without straw mulch	53.75	53.75	100.00	142.20	46.25	89.55	0.9	1.7
Rice Straw mulch (5 t/ha)	60.15	60.15	236.00	340.40	175.85	280.25	2.9	4.7
Weed management								
Pendimethalin 1.0 kg/ha	55.40	55.40	180.80	246.00	125.40	190.60	2.3	3.4
Oxyfluorfen 0.223 kg/ha	54.70	54.70	186.40	258.80	131.70	204.10	2.4	3.7
Hand weeding (25 and 45 DAS)	61.75	61.75	292.00	444.00	230.25	382.25	3.7	6.2
Weedy check	52.65	52.65	13.60	16.56	-39.05	-37.35	0.7	0.7

DAS: Days after sowing; Pendimethalin: ₹ 500/lit; Oxyfluorfen: ₹ 3000/lit; Straw- ₹ 150/quintal; one hand weeding: ₹ 4000/ha; Garlic- ₹ 8000/quintal

mulch (5 t/ha) and oxyfluorfen 0.223 kg/ha PE and hand weeding twice during both years at 75 DAS **(Table 6)**. The lowest WCE was recorded in weedy check as reported by Rahman *et al.* (2012) in garlic and Hussain *et al.* (2008) in onion.

Effect on garlic yield and yield attributes

The highest number of bulb (19.5/m^2 and 30.7/m^2) and diameter of bulb (8.4 and 8.6 cm) were recorded with rice straw mulch 5 t/ha during both the seasons. Among herbicidal treatments oxyfluorfen 0.233 kg/ha PE recorded highest yield attributing characters which was comparable to pendimethalin 1.0 kg/ha PE.

Similarly, significantly higher bulb yield of 2.95 t/ha and 4.25 t/ha was achieved with straw mulch material (5 t/ha) during both the seasons. The positive response of mulching on increased bulb yield of garlic was also reported by Mia *et al.* (1996) and Rahman *et al.* (2005). Among herbicide treatments, the highest yield (2.33 t/ha and 3.23 t/ha) was recorded with application oxyfluorfen 0.233 kg/ha PE which was at par with pendimethalin 1.0 kg/ha PE during *Rabi* 2014-15 and 2015-16, respectively **(Table 7)** due to effective reduction of the density and biomass of monocot (grasses), dicot (broad-leaved) and total weeds which resulted in better availability of nutrient for better growth and development of plant and thereby bulb yield. Further, better management of weeds is turn to increased plant height and produced more assimilates synthesized, translocated and accumulated in plants organs which positively reflected on bulb yield.

Economics

The highest net returns (₹/ha 175850 and 280250) and B:C (2.9 and 4.7) was achieved with straw mulch application (5 t/ha). Oxyfluorfen 0.233 kg/ha PE recorded the highest net returns (₹ /ha 131700 and 204100) and B:C (2.4 and 3.7) during both the seasons, respectively **(Table 8)** due to remarkable increase in gross returns due to higher crop yield (bulb yield) with comparatively low cost of cultivation of garlic in this treatment. Higher B:C with herbicide use was also reported by Kumar *et al.* (2013) in garlic. In hand weeding plots the cost of cultivation increased remarkably due to higher cost involved in manual weeding operations. Moreover, weedy check (control) recorded significantly lesser B:C due to lower bulb yield as recorded by Prakash *et al.* (2000) and Vermani *et al.* (2001).

Conclusion

It is concluded that the use of straw mulch 5 t/ha and oxyfluorfen at 0.223 kg/ha as pre-emergence herbicide may be recommended for effective weed management and to achieve higher garlic bulb yield.

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