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Impact of integrated weed management on growth and yield of cauliflower (*Brassica oleracea* var. *botrytis*)

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Abstract
A field experiment was conducted to study the impact of integrated weed management practices on growth and yield of cauliflower. The treatments namely, T_1 (Hand weeding),T_2 (Rice straw mulch), T_3 (Mulching with eucalyptus leaves), T_4 (Black plastic mulch), T_5 (Pendimethalin @1.5 Kg/ha + black plastic mulch), T_6 (Oxyfluorfen @1.5 kg/ha + black plastic mulch), T_7 (Pendimethalin @1.5 Kg/ha + hand weeding), T_8 (Oxyfluorfen @1.5 Kg/ha + hand weeding), T_9 (Fluchloralin @1.5 Kg/ ha + hand weeding) and T_{10} (Control) were evaluated. Results indicated that T_6 recorded the maximum value of plant height, number of leaves, plant spread, earliest curd initiation, curd maturity duration, diameter of curd, curd size, quality trait and yield attribute. The application of T_6 was most effective in reducing the weed density and dry matter of weeds at all stages of observation. Therefore, T_6 was observed to be the best weed management treatment having highest weed control efficiency.

Keywords: Oxyflourfen, pendimethalin, mulch, weed control efficiency

Introduction
Cauliflower (*Brassica oleracea* var. *botrytis* L.) is one of the most popular vegetable crops among the cole crops. It belongs to the family Brassicaceae and is mainly grown for its white tender curd, which is widely used as vegetable, curry, soup and pickle preparation. Beside, being a good source of proteins and carbohydrates, it is a rich source of vitamins and minerals. The curd extract is used as a traditional medicine in the treatment of scurvy, as a blood purifier and as an antacid. Its seed also have contraceptive properties [1].

India ranks second in area and production of cauliflower in the world after China. Major cauliflower growing states in India are West Bengal, Bihar, Maharashtra, Madhya Pradesh, Orissa, Gujarat, Haryana etc. State of Punjab cultivates cauliflower in an area of about 19.59 hectares producing 363.31 tonnes [2].

Cauliflower fresh curds are highly nutritive and contains moisture 90.8 g, protein 2.6 g, fat 0.4 g, minerals 1.0 g, fibre 1.2 g, carbohydrates 4.0 g, calcium 33 mg, phosphorous 57 mg, iron 1.5 mg, carotene 30 mg, thiamine 0,04 mg, riboflavin 0.10 mg, niacin 1.0 mg, vitamin C 56 mg per 100g of edible portion [3]. The immense importance of cauliflower makes it imperative for the horticulturists to overcome major constraints in its cultivation. Every year, there are considerable number of losses due to various stresses of agriculture and among these weeds top the list by contributing 33 per cent towards the total loss [4]. During its growth period, weeds provide tough competition to main crop and adversely affect its growth, yield and quality [5]. Besides direct losses, weeds also attract pathogens, nematodes, insects etc. that may later attack the crop and may also serve as disease reservoirs. Thus, for profitable cultivation of cauliflower, the control of weeds is necessary. Traditionally, weeds were controlled by manual hand weeding. But presently labour has become very costly. The second alternative can be the use of herbicides but the use of herbicides like fluchloralin, pendimethalin and oxyfluorfen alone may not be an appropriate answer to the problem because environmentalists claim their usage dangerous for sustainable agriculture. Even, no single herbicide is effective in controlling the wide range of weed flora and even continuous use of same herbicide develops resistance in escaping the weed flora. Besides, hand weeding and herbicidal control, mulching (particularly plastic and rice straw mulch) has been advocated by many researchers as an effective mean for reducing the weed population under control. Among the mulches, plastic mulch and rice straw mulch are found effective [6].Thus, the appropriate choice for weed control in cauliflower would be an integration of cultural and herbicidal control for boosting the cauliflower production. Therefore, present investigation was planned to access the impact of integrated weed management practices on weed dynamics and growth, yield and quality of cauliflower.

Materials and Methods

The field experiment was conducted during Rabi, 2019-2020 at Student's Research Farm Department of Agriculture, Khalsa College, Amritsar,(at 31°S–38'N latitude and 74°–52'E longitudes with an elevation of 236 m MSL).The soil of experimental field was sandy loam in texture with available nitrogen (294.6 kg/ha), phosphorus (22.0 kg/ha) and potassium (278.0 kg/ha). The experiment was laid out in a Randomized block design with 3 replications. The weed control treatments include Hand weeding, Rice straw mulch, Mulching with eucalyptus leaves, Black plastic mulch, Pendimethalin @1.5 Kg/ha + black plastic mulch, Oxyfluorfen @1.5 kg/ha + black plastic mulch, Pendimethalin @1.5 Kg/ha + hand weeding, Oxyfluorfen @1.5 Kg/ha + hand weeding, Fluchloralin @1.5+ hand weeding Kg/ and Control (Table 1).

The land was prepared by deep ploughing, harrowing and levelling and thereafter plots of size 3m x3m were prepared. Pure and healthy seedlings of about 5 weeks old of hybrid bishop were transplanted on last week of October, 2019 at a spacing of 60 cm x 45 cm and the number of plants per plot was 33. The crop was irrigated immediately after transplanting. The pre-emergence herbicides pendimethalin, oxyfluorfen and fluchloralin were applied as spray uniformly 2 days before transplanting of cauliflower seedlings. To calculate different readings five plants were selected randomly from each plot and tagged permanently. The growth parameters recorded were plant height, number of leaves per plant, days taken to curd initiation, curd maturity and plant spread (each at 30, 60 and 90 DAT). Among the quality parameters diameter of curd, curd size (product of curd length and width), Average curd weight (by weighing balance) and compactness of curd (thumb pressing) were examined. To calculate the weed density (weed /m^2) total weed species were counted from 1m^2 randomly in each plot. Dry matter of weeds was calculated at harvest by uprooted the weeds from 1m^2 area of each plot and then oven drying the sample at 65° C to a constant weight. Weed control efficiency (WCE%) was calculated at harvest by using the formula:

WCE (%) = (DMC-DMT)/DMCX100

Where, DMC = dry weight of weeds in weedy check plot; DMT= dry weight of weeds in treated plot.

Table 1: Details of Treatments used in present study

Treatment Symbol	Treatment Combination
T1	Hand weeding
T2	Rice straw mulch
T3	Mulching with eucalyptus leaves
T4	Black plastic mulch
T5	Pendimenthalin @ 1.5 kg/ha + black plastic mulch
T6	Oxyfluorfen @ 1.5 kg/ha + black plastic mulch
T7	Pendimenthalin @ 1.5 kg/ha + 1 hand weeding,
T8	Oxyfluorfen @ 1.5 kg/ha + 1 hand weeding
T9	Fluchloralin @ 1.5 kg/ ha + 1 hand weeding
T10	Control (weedy check)

Results and Discussion

Growth parameters

There was significant effect of weed management practices on all the growth parameters (Table 2). Among the various weed management practices, treatment T_6 (Oxyfluorfen @ 1.5 kg/ha + black plastic mulch) recorded the maximum plant height, number of leaves, plant spread followed by treatment T_5 (Pendimethalin @ 1.5 kg/ha + black plastic mulch) while the minimum value of all the growth parameters were recorded under treatment T_{10} (Control).This might be due the reason that the number of weeds were low in above best performing treatments because of herbicidal action of oxyfluorfen and suppression of weed growth by application of black plastic mulch, resulting into lesser crop weed completion for light, nutrients moisture and space resulting into increasing availability of assimilates for growth and developments of plants [5]. The probable reason for lowest number of leaves in weedy check is that it has highest weed intensity which might have altered the spectral photon distribution within the canopy [5] thus affected the plant development. Bhayan *et al*., reported that weed control treatments increases availability of nutrients, moisture and space to crop which results into more biomass accumulation ultimately increased number of leaves [7]. Similarly, treatment T_6 (Oxyfluorfen @ 1.5 kg/ha + black plastic mulch) recorded least number of days taken to curd initiation and curd maturity followed by pendimethalin @ 1.5 kg/ha + black pastic mulch. This might be due to the control of weed infestation at early stage and less crop weed competition during the critical growth stage of the crop. These findings are in agreement with the earlier reports obtained in cauliflower [6] and cabbage [8]. However, treatment T_{10} (Control) recorded the maximum number of days taken to curd initiation and maturity.

Quality parameters

In the present investigation, the oxyfluorfen resulted into better quality parameters *viz.* diameter, curd size and compactness of curd (Table 3). Whereas, curds from the weedy check plot were poor in quality. Similar results were observed by Moniruzzaman *et al*. [9]. This is due to balanced and adequate availability of nutrients and simultaneously better use of natural resources such as solar radiation to the crop.

Yield parameters

All the weed management treatments significantly increased the yield of cauliflower over weedy check. The pre-emergence application of Oxyfluorfen @ 1.5 kg/ha + black plastic mulch was effective and significantly superior to rest of the treatments, by recording the higher values for different yield attributes namely average weight of curds, yield per plot and total yield per hectare. This might be due to the excellent control of weed infestation at early stage and less crop weed completion during the critical growth stage of the crop. Moreover, black plastic mulch provide better moisture utilization, by checking evaporation loss and fall of soil temperature during winter and lesser compaction of weeds. These finding are in agreement with earlier report **[10, 11]**.

Contrary to this, poor value of these yield parameters recorded in weedy check plot may be due to more crop weed competition.

Weed parameters

Table 4 displays that weed density and dry matter of weeds were minimum in treatment T_6 (Oxyfluorfen @ 1.5 kg/ha + black plastic mulch) followed by treatment T_5 (Pendimethalin@ 1.5 kg/ha + black plastic mulch). It is because of better control of weeds under these treatments by combined effect of herbicides and black plastic mulch. However, maximum weed density and weed dry matter were observed in weedy check because weeds were allowed to grow throughout the growing season and removed appreciable amount of nutrients from the soil. Moreover, superiority of weed control treatments was estimated in terms of weed control efficiency. Table 4 shows that highest weed control efficiency was found in treatment T_6 (Oxyfluorfen @ 1.5 kg/ha + black plastic mulch) which might be due to the suppression in weed density and slowed dry matter build-up in weeds. Singh and Mir also obtained the highest weed control efficiency with black polythene mulch in cabbage pride of India [12].

Conclusion

It can be concluded from the present investigation that the impact of integrated weed management practices on the growth, curd yield and quality traits of cauliflower was significant. The application of Oxyfluorfen @1.5 Kg/ha + black plastic mulch proved to be most effective in reducing the weed density, dry matter of weeds and thereby having the maximum weed control efficiency, which increase the plant height, number of leaves, plant spread, curd size, average weight of curd and yield. Moreover, better quality curds were produced from the plots which were treated with herbicide oxyfluorfen @ 1.5 Kg/ha + black plastic mulch. Therefore, from the present investigation, it was concluded that the integration of Oxyfluorfen @1.5Kg/ha + black plastic mulch was witnessed to be the best integrated weed management approach for cultivation of cauliflower under Punjab conditions.

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Table 2: Impact of integrated weed management on growth parameters of cauliflower

Treatments	Plant height (cm)			Number of leaves / plant			Plant spread (cm^2)			Days taken to curd initiation	Days taken to curd maturity
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT		
T_1	26.02	45.38	55.92	6.21	14.53	20.53	509.95	1324.64	1899.04	58.41	77.30
T_2	25.76	42.33	54.36	6.04	13.06	19.69	440.01	1222.06	1813.99	59.20	78.04
T_3	22.28	41.63	53.55	5.64	12.56	18.94	411.73	1192.28	1782.67	59.53	78.23
T_4	28.68	47.72	57.67	7.26	16.25	21.46	569.29	1413.94	1967.70	56.35	75.86
T_5	29.47	48.35	58.11	7.32	16.74	22.12	589.40	1440.83	1987.94	54.46	73.25
T_6	31.80	50.39	60.62	8.78	17.73	23.73	636.86	1509.18	2082.29	52.32	71.80
T_7	26.45	44.52	55.56	6.42	14.32	20.11	495.68	1293.30	1889.18	58.65	77.14
T_8	27.15	46.37	56.03	7.13	14.95	20.36	532.14	1361.42	1907.26	57.97	76.98
T_9	23.53	43.80	54.79	5.78	13.34	19.86	485.57	1269.32	1839.84	58.86	77.66
T_{10}	20.04	41.06	52.09	5.14	12.21	17.81	364.92	1166.92	1727.82	60.67	80.56
C.D at 5%	3.52	3.16	2.86	1.56	2.43	2.25	4.53	4.42	3.55	3.26	3.46

Table 3: Impact of integrated weed management practices on quality and yield parameters of cauliflower

Treatments	Diameter of curd (cm)	Curd size (cm^2)	Compactness of curd (points out of ten)	Average curd weight (g)	Yield per plot (kg)	Yield per hectare (q/ha)
T_1	15.64	178.76	8.14	739.17	24.39	271.03
T_2	14.34	146.69	7.35	702.35	23.17	257.53
T_3	14.11	138.27	6.87	692.53	22.85	253.93
T_4	16.76	206.14	8.92	769.74	25.40	282.24
T_5	17.50	219.80	9.32	785.45	25.55	288.62
T_6	18.65	238.72	9.78	815.01	26.89	298.84
T_7	15.12	165.71	7.99	721.93	23.82	264.71
T_8	16.18	191.73	8.53	754.77	24.90	276.75
T_9	14.75	155.17	7.66	711.92	23.49	261.04
T_{10}	13.83	128.28	6.28	678.40	21.39	250.42
C.D at 5%	1.26	7.05	0.84	7.75	1.33	9.23

Table 4: Impact of integrated weed management practices on weed parameters of cauliflower

Treatments	Weed density (weed/m^2)			Dry weight of weeds (g/m^2)	Weed control efficiency
	30 DAT	60 DAT	90 DAT	(at harvest)	(%)
T_1	49.10 (7.07)	148.10 (12.21)	174.33 (13.24)	21.55 (4.74)	51.24
T_2	62.70 (7.98)	193.27 (13.93)	219.62 (14.85)	27.35 (5.32)	38.12
T_3	68.40 (8.33)	201.07 (14.21)	221.83 (14.92)	31.2 (5.67)	29.41
T_4	36.10 (6.09)	115.30 (10.78)	138.31 (11.80)	14.05 (3.87)	68.21
T_5	33.60 (5.62)	104.02 (10.24)	129.40 (11.41)	12.8 (3.71)	71.04
T_6	32.10 (5.75)	92.16 (9.65)	107.02 (10.39)	11.05 (3.47)	75.24
T_7	47.20 (6.94)	153.23 (12.41)	176.55 (13.32)	20.6 (4.64)	53.39
T_8	38.20 (6.26)	122.03 (11.09)	148.92 (12.24)	16.1 (4.13)	63.57
T_9	52.30 (7.30)	162.58 (12.78)	189.74 (13.81)	23.15 (4.91)	47.62

T_{10}	76.40 (8.79)	245.82 (15.71)	278.95 (16.73)	44.2 (6.72)	-----
C.D at 5%	1.86	2.69	2.87	1.83	-----

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