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RESEARCH ARTICLE

Effect of irrigation levels and weed management practices on weeds, water productivity and yield of cauliflower

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ABSTRACT

Water shortage and weed infestation are major constraints in vegetable production. Micro-irrigation integrated with weed management practices is one way to maximize the yield and water productivity in crops. A field trial was conducted during *Rabi* seasons of 2018-19, 2019-20 and 2020-21 at the Water Management Farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur to study the effect of irrigation levels and weed management practices on weeds, crop and water productivity in cauliflower. The experiment was laid out in split plot design with three irrigation levels (0.9 PE, 0.7 PE and 0.5 PE) in main plots and four weed management practices (black polythene mulch, pre-plant incorporation (PPI) of pendimethalin 1.5 kg/ha followed by (*fb*) hand weeding, pendimethalin 1.5 kg/ha PPI *fb* straw mulching and weedy check) in sub plots. The treatments were replicated thrice. The irrigation given to crop at 0.9 PE level proved to be better in terms of yield and net returns in cauliflower. Black polythene mulch resulted in efficient weed control and improving crop developmental parameters and yield attributes. There was progressive increase in weed density and biomass with increase in irrigation level, with least in lower irrigation level of 0.5PE. It is concluded that higher crop productivity and returns in cauliflower can be obtained by using black polythene mulch and irrigation applied at 0.9PE level. However, under limited water availability, the best alternative will be applying irrigation at 0.7 PE level and using black polythene mulch.

Keywords: Cauliflower, Irrigation levels, Mulching, Water productivity, Weed management

INTRODUCTION

Cauliflower (*Brassica oleracea* L. var. *botrytis*), one of the most important vegetable crop in world, belongs to family Brassicaceae. In India, it covers an area of 473 thousand hectares with production and productivity of 9225 thousand tonnes and 19.5 t/ha, respectively (Anonymous 2020-21). It is usually grown for its white edible curd, which is used in number of preparations like vegetable, curry, pickle, and soup. Cauliflower is highly nutritive containing protein, minerals (potassium, calcium, and sodium), fibre, fat, carbohydrates and vitamins. The crop grows well in range of 15-21°C and prefers soil rich in organic matter with pH range of 5.5-6.5 (Savita *et al*. 2014). It is medium rooted crop and requires enough moisture in root zone.

Cauliflower being a sensitive crop, requires frequent irrigation to keep the crop vigorous. Both irrigation and weed management are important agronomic practices for successful production of crop (Sen *et al.* 2018, Kumari and Devi 2020). The management of these factors not only improves the efficiency of the system, but also reduces cost and environmental problems. Water table is depleting day by day at an alarming rate. This is due to traditional irrigation methods of flooding, which results in reducing water use efficiency and overexploitation of groundwater (Sandhu *et al.* 2019). The demand for water is expected to rise in future because of increasing world population, increase in irrigated area and climate change. The only key to mitigate the water shortage in agriculture is to increase agricultural water productivity. Micro-irrigation has emerged as one of the best alternatives to conventional irrigation which applies water directly in the root zone of plants, improves water productivity under low water retention soils, saves more than 60% water and increases the yield by 30-40% over traditional methods (Magar and Nandgude 2005). Drip irrigation was proved beneficial in fruit and vegetable crops to attain high economic return. Along with irrigation method, scheduling of irrigation based on consumptive use of crop can also be helpful in improving water use efficiency.

Weeds are important cause of reduced cauliflower productivity (Qasem 2007). Frequent irrigations are required in cauliflower due to high evapotranspiration demand, which support weed growth and reduces crop yield. Weeds remove the

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available nutrients in large quantity from soil and reduce crop growth, reduce the yield, and impair the quality of produce. Thus, weed management needs special attention. Weeds are controlled effectively by hand weeding traditionally. But shortage and high cost of labour makes weed control more challenging making farmers to opt for use of herbicides, which poses threat to environment and natural resources. Use of organic mulches for weed management was experimented (Agarwal *et al.* 2022), but their high volume and transportation cost make their use limited. The use of polyethylene mulch is an effective mean for controlling weed population (Sen *et al.* 2018). Moreover, it is more efficient as compared to organic mulches (Sathiyamurthy *et al.* 2017).

In many parts of North-western Himalayas, water and weed management are the major constraints faced in cultivation of cauliflower due to reasons like erratic rain and high evaporative demand. However, research efforts on integration of micro-irrigation with proper weed management practices to improve water and cauliflower and productivity are limited. Hence, this study was carried out to evaluate and identify optimal irrigation levels and weed management treatments to effectively manage weeds and attain economically optimal water productivity, net returns, and yield of cauliflower.

MATERIALS AND METHODS

The study was conducted in *Rabi* season 2018-19, 2019-20 and 2020-21 at the Water Management Research Farm of Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. It is located at 32° 06 ´ 39.1´´ N latitude and 76° 32´ 10.5´´ E longitude and at an elevation of 1290 m above mean sea level. The location represents the sub temperate mid-hill zone of Himachal Pradesh. Analysis of physical and chemical properties of soil of the experimental site was done before execution of the experiment. The soil of experimental area was silty clay loam in texture with 17.5% sand, 50.0% silt and 32.5% clay and slightly acidic (pH=5.3) in nature. It was medium in available N (273.48 kg/ha), high in phosphorus (33.08kg/ha) and low in available K (121.44 kg/ha).

Cauliflower variety used in the experiment was *Palam Uphaar*. The recommended package of practices for planting, nutrients and disease pest and other management were followed, whereas the weed and irrigation treatments were applied as per experimental treatments. There were twelve treatment combinations comprising of three irrigation levels in main plots (irrigation at 0.9 PE, 0.7 PE and 0.5 PE and four weed management treatments in sub plots (black polythene mulch; pre-plant incorporation (PPI) of pendimethalin 1.5 kg/ha followed by (*fb*) 1 hand weeding at 40-45 days after transplanting (DAT); pendimethalin 1.5 kg/ha PPI *fb* straw mulching and weedy check) in split-plot design with three replications.

Irrigation scheduling

The irrigation schedule as per different irrigation levels tested was developed using the daily climatic data of the meteorological observatory of Department of Agronomy (CSKHPKV Palampur). The Pan Evaporation method was used to determine reference evapotranspiration (ETO). To relate pan evaporation to ETO, USWB class A open pan data on evaporation and empirically derived pan coefficient was used. The following formula was used to calculate crop evapotranspiration:

ETO= Kpan X Epan {Kpan=pan coefficient Epan= evaporation (mm/day)}

ETC= ETo X Kc {ETc= crop evapotranspiration (mm/day) KC= crop coefficient}

The net depth of water applied for each irrigation as per level was worked out using the equation:

Dn=ETo X KC X % Wetted area

The gross depth of water to be applied was computed using the equation

Dg=Dn/EU (Dg = gross depth of irrigation (mm/day) D n = Net depth of water (mm/day) EU = Average emission uniformity (fraction)

The volume of water to be applied per treatment plot was worked out using the equation

V= Dg X A (A= Area of bed m^2)

The time of operation (TO) of the drip irrigation system for each plot was calculated as follow:

TO= V/Q Where (TO= time of operation V= Volume of water applied litre day^{-1} Q= water applied per bed lph)

Q= q X n (q= average emitter discharge lph, N = number of emitters in the bed)

The irrigation was scheduled at an interval of 3 days. The average discharge per emitter was 2 lph and the numbers of emitters were 36.

Weed management practices

The herbicide pendimethalin was applied as pre-plant incorporation 24 hours before transplanting. After cleaning the plots, the plastic mulch (black polythene sheet: 25 micron) was laid before 7 days of transplanting and holes were made at desired spacing for transplanting. In straw mulch treatment, 5 t/ha mulching material from farm wastes was used and applied after herbicide application.

Observations

In each plot, data on weed density and biomass was recorded at monthly intervals from 50 cm × 50 cm quadrat placed randomly at two places in each of the plot. The data obtained was converted to number and grams per square meter, respectively by multiplying the average count and dry weight of the weeds with factor 4.

At the time of curd maturity, only fully grown leaves per plant were recorded, while the small leaves in the inner whorl were not counted to obtain number of leaves per plant. The length of the stalk was noted by measuring the length from the ground level to the position of the first leaf with the help of measuring scale. Days taken to curd initiation was recorded by counting the number of days from the date of transplanting to the day when 50% initiation of curds was achieved. Days taken to marketable curd maturity was recorded by counting the number of days from the date of transplanting to the day when 50% of curds attained a marketable size and at this stage; the younger inner leaves covering the curd just began to separate. The diameter of the curd (cm) was measured with the help of a thread followed by scale. Gross weight (g/plant) was recorded at the time of marketable maturity which included the weight of the curd along with leaves and stalk. After harvesting, fresh weight of curd (g) was recorded. Marketable curd (%) was calculated as the ratio of marketable curd to the number of curds and multiplied by 100. The pooled marketable curd yield obtained from each plot was converted into kg/ha. Water productivity (kg/m^3) was calculated by dividing the yield (kg/ha) obtained by total water use (m^3/ha).

The data generated from field was subjected to statistical analysis using the technique of analysis of variance for split-plot design for the interpretation of results. The treatment differences were compared at 5 per cent level of significance (p=0.05).

RESULTS AND DISCUSSION

Weed density

The pooled data of three years on effect of irrigation levels and weed management treatments on weed density in cauliflower (**Table 1**) indicated that at all stages (30, 60 and 90 DAT) significantly higher weed density with 0.9 PE irrigation level was observed as compared to other levels. At 30 DAT, when irrigation level was reduced to 0.7 PE and 0.5 PE, weed density was reduced with both levels at par with each other. Whereas, at 60 and 90 DAT, significantly lower weed density was recorded in 0.5 PE irrigation level over other two levels, which could be attributed to the weed seed bank to germinate and grow vigorously when there was enough moisture in soil as reported by Kishore *et al.* (2018).

Weed density at all observed stages revealed that use of black polythene mulch resulted in significantly lower weed density when compared to other treatments. The highest weed density was found in weedy check treatment at all the stages. Amongst the other treatments, pendimethalin 1.5 kg/ha PPI *fb* straw mulching resulted in lower weed density at 30 and 90 DAT as compared to pendimethalin 1.5 kg/ha PPI *fb* hand weeding. Both the treatments were at par with each other at 60 DAT due to reduction in germination of weed seeds with mulching as reported by Ferdous *et al.* (2017) with plastic mulching in cauliflower.

Weed biomass

It was found that weed dry matter decreased with decrease in irrigation level. At 30 DAT, significantly higher weed dry matter was noted in 0.9 PE irrigation level which was statistically at par with 0.7 PE (**Table 1**). Whereas, at 60 and 90 DAT, 0.9 PE resulted in significantly higher weed biomass over other levels. In all the stages of crop, weed dry matter was lowest with 0.5 PE irrigation level.

Effect of weed management was similar as reflected in weed count. Use of black polythene mulch resulted in significantly lower weed biomass. While the highest weed biomass was recorded in weedy check at all stages. The results agree with Suresh *et al.* (2014) who reported the beneficial effect of black polythene mulch on weed suppression in cauliflower.

Effect on cauliflower

Significantly higher number of leaves, higher stalk length, higher curd diameter, individual curd weight, marketable curd and gross weight per plant were recorded at 0.9 PE as compared to 0.7 and 0.5 PE (**Table 2** and **3**). Whereas, lowest number was seen in 0.5 PE as observed by Bozkurt *et al.* (2011), Yu *et al.* (2006), Abdelkhalik *et al.* (2019) pertaining to number of leaves, stalk length, yield attributes, respectively. Lesser number of days were taken in curd initiation and marketable curd maturity at 0.9 PE level (**Table 2**). Sohail *et al.* (2018) and Salman *et al.* (2018) reported similar results in cauliflower.

In case of weed management practices, significantly higher number of leaves, stalk length, lesser number of days taken for curd initiation and to marketable curd maturity were observed with black polythene mulch which was statistically at par with pendimethalin 1.5 kg/ha followed by straw mulching and pendimethalin 1.5 kg/ha followed by hand weeding (**Table 2**). Significantly higher curd diameter (11.71 cm), gross weight per plant (680.22 g), individual curd weight (516 g) and marketable curd (88%) were also noted with black polythene mulch when compared to other treatments (**Table 3**). Weedy check resulted in lowest yield attributes. These results are in line with those reported by Sen *et al.* (2018), Qasem (2009), Kumar *et al.* (2019) pertaining to leaves, stalk length, days to curd initiation, days to marketable curd maturity, yield attributes, respectively.

Cauliflower yield

The increase in irrigation level from 0.5 PE to 0.7 PE and 0.9 PE significantly increased the marketable yield of cauliflower (**Table 3**). The percent increase at 0.7 PE and 0.9 PE over 0.5 PE was 72.2 and 88.8, respectively. The highest yield recorded was with 0.9 PE (12801 kg/ha). Micro irrigation at 0.9 PE provides sufficient moisture in crop root zone and increase the availability of nutrients resulting in increased yield of crop as reported by Bozkurt *et al.* (2011).

Significantly higher cauliflower yield was obtained under black polythene mulch (14464 kg/ha) which was followed by weed management practice of pendimethalin 1.5 kg/ha PPI *fb* straw mulching (11808 kg/ha). The use of black polythene mulch and pendimethalin 1.5 kg/ha *fb* straw mulch as weed management practice increased the curd yield by 191 and 132%, respectively over weedy check. This could be attributed to optimum moisture and temperature conditions maintained by mulching that suppressed the weed density and improved crop yield as reported by Ahmed *et al.* (2020).

Table 1. Effect of irrigation levels and weed management treatments on weed density and biomass (pooled data of 3 years)

Treatment	Weed density(no./m^2)			Weed biomass (g/m^2)		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
Irrigation level						
0.9PE	(42)5.90	(41)5.81	(58)6.93	(26)4.56	(25)4.83	(49)6.34
0.7PE	(32)5.07	(34)5.26	(40)5.77	(22)4.37	(22)4.42	(43)6.00
0.5PE	(25)4.47	(26)4.62	(34)5.17	(17)3.76	(15)3.71	(36)5.38
LSD (p=0.05%)	0.72	0.44	0.40	0.47	0.34	0.31
Weed management						
Black polythene mulch	(1)1.25	(4)2.00	(3)1.88	(0)0.92	(5)2.30	(4)2.04
Pendimethalin 1.5 kg/ha PPI *fb* 1 HW at 40-45 DAT	(36)5.95	(25)4.47	(47)6.79	(22)4.69	(14)3.78	(43)6.54
Pendimethalin at 1.5 kg/ha PPI *fb* straw mulching	(26)5.12	(23)4.82	(29)5.40	(25)5.02	(26)5.10	(27)5.21
Weedy check	(68)8.27	(84)9.24	(96)9.76	(40)6.29	(37)6.11	(97)9.85
LSD (p=0.05%)	0.37	0.55	0.51	0.50	0.40	0.48

Data subjected to $\sqrt{x+0.5}$ transformation and figures in parentheses are original values; PPI: pre-plant incorporation; HW: hand weeding; DAT: days after transplanting

Table 2. Effect of irrigation levels and weed management treatments on developmental stages of cauliflower (pooled data of 3 years)

Treatment	No. of leaves at maturity	Stalk length (cm)	Days to curd initiation	Days to marketable curd maturity
Irrigation level				
0.9PE	22	7.20	75	87
0.7PE	20	4.71	76	87
0.5PE	15	4.06	79	93
LSD (p=0.05)	1.79	0.25	1.15	1.92
Weed management				
Black polythene mulch	20	5.44	75	87
Pendimethalin 1.5 kg/ha PPI fb 1 HW at 40-45 DAT	19	3.91	77	91
Pendimethalin at 1.5 kg/ha PPI fb straw mulching	20	5.10	75	87
Weedy check	17	3.76	79	91
LSD (p=0.05)	1.53	0.55	1.72	3.08

Interaction effect of irrigation levels and weed management practices on yield

Significantly higher curd yield was obtained when black polythene mulch was used as weed management practice with an irrigation level of 0.9 PE over all other combinations (**Table 4**). Black polythene mulch resulted in better moisture utilization and suppressed weed growth, thus increasing crop yield.

Net returns

The net returns increased by 34 and 38% with irrigation application level of 0.7 PE and 0.9 PE, respectively over 0.5PE (**Table 3**). Higher net returns in these treatments could be due to higher yield obtained because of optimum moisture in root zone.

Among weed management practices, pendimethalin 1.5 kg/ha with straw mulching gave significantly higher net returns (80625 ₹/ha) which was at par with pendimethalin *fb* hand weeding (80336 ₹/ha) and black polythene mulch (75974 ₹/ha). This might be due to higher cost of black polythene mulch. The results are in close conformity with those reported by Vazquez *et al.* (2010).

Interaction effect of irrigation levels and weed management practices on net returns

At 0.9 PE irrigation level, black polythene mulch gave significantly higher net returns over other weed management practices (**Table 4**) due to less weed competition and optimum soil, air, water ratio in these treatments which is also supported by Salim *et al.* (2008).

Significantly higher net returns were obtained with black polythene mulch at 0.7 PE level, which was at par with both, pendimethalin followed by straw mulching and pendimethalin followed by hand weeding. Whereas, at 0.5 PE, pendimethalin followed by straw mulching proved to be better which was at par with pendimethalin followed by hand weeding.

Water productivity

The highest water productivity of 2.59 kg curd yield /m^3 water used was obtained when crop was given irrigation of 0.7PE level (**Table 3**). It was further observed that the increase in irrigation level from 0.5PE to 0.7PE significantly increased the water productivity. Further increase in irrigation level to 0.9PE significantly decreased the water productivity as compared to the productivity obtained with 0.7 PE irrigation although it was higher than the water productivity from 0.5PE level. Highest water productivity at a level lower than highest irrigation may be attributed to optimum level for maximum incremental yield. Similar results were reported by Harris *et al.* (2014) in cabbage.

Water productivity was significantly higher when black polyethylene mulch (2.98 kg/m^3) was used to suppress weeds which was followed by pendimethalin 1.5 kg/ha with straw mulching. The findings are in agreement with Kumari *et al.* (2020).

Interaction effect of irrigation levels and weed management practices on water productivity

Significantly higher water productivity was obtained when black polythene mulch was used and crop was given irrigation at 0.7 PE level when compared to all other combinations of irrigation levels and weed management practices (**Table 4**). This could be attributed to reduced evaporation and increased water harvesting and yield in this treatment resulting in higher water productivity.

It was concluded that significantly higher marketable cauliflower curd yield and net returns can be obtained with irrigation application at 0.9PE level

Table 3. Effect of irrigation levels and weed management practices on yield attributes in cauliflower (pooled data of three years)

Treatment	Curd diameter (cm)	Gross weight per plant(g)	Individual curd weight(g)	Marketable curd (%)	Marketable yield (kg/ha)	Net returns Rs/ha	Water productivity (kg/m^3)
Irrigation level							
0.9PE	11.30	608.67	453	77	12801	88128	2.31
0.7PE	10.76	600	432	75	12191	78979	2.59
0.5PE	8.50	471.33	343	64	7077	2256	1.82
LSD (p=0.05)	0.44	32.16	16.62	0.82	439	6599	0.07
Weed management							
Black polythene mulch	11.71	680.22	516	88	14464	75974	2.98
Pendimethalin 1.5 kg/ha PPI *fb* 1 HW at 40-45 DAT	10.06	598.56	388	72	11522	80336	2.39
Pendimethalin at 1.5 kg/ha PPI *fb* straw mulching	10.91	637.11	444	83	11808	80625	2.52
Weedy check	8.08	324.11	288	46	4965	-11117	1.07
LSD (p=0.05)	0.45	24.42	24.86	2.29	224	5836	0.04

Table 4. Interaction effect of irrigation level and weed management practices on yield, net returns and water productivity (pooled data of three years)

Weed management treatments	Yield (kg/ha)			
	Irrigation level			
	0.9PE	0.7PE	0.5PE	Mean
Black polythene mulch	17654	16717	9022	14464
Pendimethalin 1.5 kg/ha PPI *fb* 1 HW at 40-45 DAT	13883	13263	7421	11522
Pendimethalin at 1.5 kg/ha PPI *fb* straw mulching	13952	13679	7793	11808
Weedy check	5717	5107	4071	4965
Mean	12801	12191	7077	
LSD (p=0.05)	Irrigation level= 439		I×W=389	
	Weed management practice = 224		I×W*=550	
	Net returns (x10^3 `/ha)			
Weed management/irrigation	0.9PE	0.7PE	0.5PE	Mean
Black polythene mulch	123.82	109.77	-5.66	75.97
Pendimethalin 1.5 kg/ha PPI *fb* 1 HW at 40-45 DAT	115.75	106.45	18.82	80.34
Pendimethalin at 1.5 kg/ha PPI *fb* straw mulching	112.78	108.69	20.41	80.62
Weedy check	0.17	-8.99	-24.53	-11.12
Mean	88.3	78.98	2.26	
LSD (p=0.05)	Irrigation level= 6.60		I×W=5.84	
	Weed management practice = 3.37		I×W*=8.26	
	Water productivity(kg/m^3)			
Weed management/irrigation	0.9PE	0.7PE	0.5PE	Mean
Black polythene mulch	3.13	3.51	2.29	2.98
Pendimethalin 1.5 kg/ha PPI *fb* 1 HW at 40-45 DAT	2.48	2.80	1.91	2.39
Pendimethalin at 1.5 kg/ha PPI *fb* straw mulching	2.58	2.96	2.01	2.52
Weedy check	1.04	1.10	1.06	1.07
Mean	2.31	2.59	1.82	
LSD (p=0.05)	Irrigation level= 0.074		I×W=0.077	
	Weed management practice = 0.044		I×W*=0.104	

and using black polythene mulch to manage weeds. Among the tested weed management treatments, pendimethalin with straw mulching proved to be more economical as compared to polythene mulch. The highest water productivity was obtained with irrigation level of 0.7PE and black polythene mulch and hence drip irrigation at level of 0.7 PE along with use of black polythene mulch can be adopted for limited water available condition.

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